Great Cities Institute
University of Illinois at Chicago

From Waste to Water: A Framework for Sustainable Freshwater Supply in Northeastern Illinois

Prepared for -

Metropolitan Water Reclamation District of Greater Chicago (MWRD)

by

the Great Cities Institute
and the Freshwater Lab
University of Illinois Chicago

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THE FRESHWATER LAB

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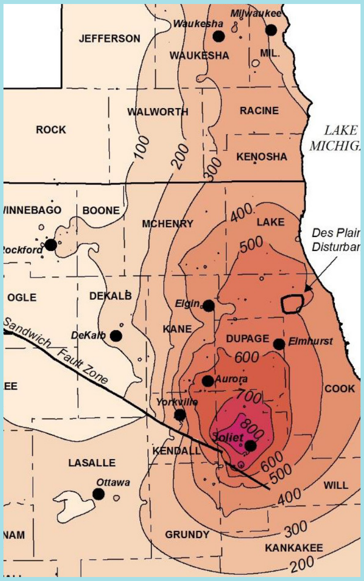
Project Overview

There is a looming water crisis in Northeastern Illinois:

- The Cambrian-Ordovician aquifer, which provides water to communities in Will, Kendall, Kane, and DuPage counties is collapsing.
- The largest aquifer drawdown from a single community has been in the city of Joliet (the third most populous city in Illinois), where the aquifer's water level has fallen by over 800 feet (Right).
- In order to avoid catastrophe, Joliet turned to the City of Chicago, which agreed to supply Joliet with treated Lake Michigan drinking water no later than January 1, 2030.
- Other communities on the collapsing aquifer will seek similar agreements for water supply from the city of Chicago.
- In the long run, providing Lake Michigan water to communities on the collapsing aquifer for all uses is not feasible or responsible because of diversionary limits.



Source: Illinois State Water Survey, 2015

If Chicago is going to provide water to communities reliant on the collapsing Cambrian-Ordovician aquifer, then it must do so sustainably.

A feasible water recycling solution exists to responsibly provide Lake Michigan water to communities relying on the collapsing aquifer:

- Chicago produces substantial treated wastewater that is currently not being used. This presents a missed opportunity for revenue.
- The Metropolitan Water Reclamation District of Greater Chicago (MWRD) and City of Chicago can make money in an environmentally responsible way through supplying industrial water users in Joliet and beyond with recycled water.
- This immediate water re-use strategy supplies recycled water for industrial uses – not for drinking.

This solution enables a more resilient future for Northeastern Illinois where:

- The quality and quantity of Lake Michigan water is preserved for human health and sanitation.
- Suburban and exurban Illinois communities are protected from the destabilization of water source loss.
- The costs of waste management are transformed into a revenue generating endeavor.

The University of Illinois Chicago Freshwater Lab and Great Cities Institute prepared a report for Metropolitan Water Reclamation District (MWRD) in April of 2023 that assesses the environmental, infrastructure, public health, and economic feasibility of implementing water recycling for industrial users in Northeastern Illinois. The report advances recommendations for a dual-pipeline system to provide drinking and recycled water to Joliet, which can serve as a model for communities throughout northeastern Illinois.

Table of Contents

Executive Summary

The present moment entails a new set of challenges to water management:

A formidable challenge to water management is the growing imbalance between flooding and water scarcity.

- Flooding and scarcity can wildly alternate in the same place or transpire in proximity to each other.
- This uneven water geography harms aquatic ecosystems and disrupts human health, economic stability, and social balance.

Current patterns of intensive water use and future anticipated demands, combined with the impacts of climate change, promise to further upend procurement of water.

- Developing adaptive infrastructure is the key to meeting these challenges.
- Water recycling that maximizes available water supply and supports commercial endeavors in situations of scarcity represents an essential piece of such adaptive infrastructure.

Because water recycling requires technical innovation and public health inquiry, as well as policy and urban planning considerations, we convened an interdisciplinary team to establish the research and development groundwork for water recycling.

This report:

- Addresses technical issues around treatment and delivery of recycled water as well as its public health and environmental implications.
- Provides a cost-benefit analysis that serves to overcome political and economic barriers to adoption.
- Suggests that large-scale water reuse can play a role in job creation and economic revitalization.
- Addresses scenarios and solutions for uneven water geography in northeastern Illinois, characterized by urban flooding along the Lake Michigan coast and impending collapse of the inland Cambrian-Ordovician aquifer.

Presently, these parallel problems are not addressed in tandem. Taking them together points to the ways in which water recycling can balance extremes of flooding and drought in our region and beyond.

Our research leads us to conclude that the Metropolitan Water Reclamation District of Greater Chicago (MWRD) can meet the industrial water needs of Illinois communities above the dwindling Cambrian-Ordovician aquifer by supplying treated storm and wastewater.

This manner of water sharing is a win-win for both regions that can benefit economically and environmentally from adaptive infrastructure.

- For municipalities facing groundwater collapse, the proposal offers crucial assistance in ensuring stability and growth.
- For the Chicago Metropolitan region, it introduces new streams of revenue and a model for sustainable industrial development in the 21st century and beyond.
- In addition, delivering water and its attendant prosperity forges productive bonds among a range of communities living in the same state.

This water recycling proposal establishes a dual-pipeline system that can be applied in each case where a new community requests water supply from Lake Michigan.

- The dual-pipeline system involves one pipe that conveys treated Lake Michigan water to communities in need and a second that carries recycled water to meet industrial needs.
- Based on the current capacity of MWRD water reclamation plants and allowances for Illinois to transfer Lake Michigan water out of the Great Lakes basin, the proposal can be implemented in the immediate term.
- This proposal is applicable to the full range of northeastern Illinois communities grappling with the question of how to obtain water following aquifer collapse.

Rather than a proposal for brand new infrastructure, this water recycling and dual-pipeline frameworks suggest modifications to existing plans.

- We model this approach on the existing Chicago-Joliet water transfer agreement, the most significant water infrastructure project in northeastern Illinois.
    - » Under the current agreement, the City of Joliet, the largest Illinois municipality dependent on the Cambrian-Ordovician aquifer, will receive treated Lake Michigan water via pipeline from the City of Chicago for all its water needs.
    - » Our discussion of the City of Joliet lays the foundation for an approach that can be used by many other impacted communities expected to file similar requests to receive treated Lake Michigan water.

Implementing this dual-pipeline system for treated waste water transfer has several important significant implications for water management in Northeastern Illinois:

- Access to Lake Michigan is not limitless; in fact, Illinois has a diversion limit set by the US Supreme Court.

    - Recycling and transferring Cook County's treated wastewater for industrial uses would enable Illinois to remain within its diversion limit while expanding overall water supply.

- While mitigating the worst impacts of groundwater depletion, such a transfer would support economic and population growth across the region.

- This proposal builds on the substantial storage capacity of Greater Chicago's Tunnel and Reservoir Plan (TARP or Deep Tunnel) and the Metropolitan Water Reclamation District of Greater Chicago's extensive wastewater treatment technology, thus closing the loop on waste and bringing it into productive use.

Our specific recommendation to satisfy industrial water needs in the Joliet region assumes a decentralized approach in which treated wastewater from a MWRD Water Reclamation Plant is supplied as is by pipeline.

- Based on the specific water quality needs of individual industries, additional treatment may or may not be required. Such treatment can occur on-site at industrial facilities to fit specific purposes.

- The primary advantage of a decentralized approach is that it can be achieved as part of the Chicago-Joliet water transfer at a minimal cost.

- The output from MWRD water reclamation plants meets regulatory standards for reuse and can supplement the water transferred to Joliet with a mere eight-mile transmission pipe.

In addition, as it meets acute water needs, water reuse in northeastern Illinois can generate several benefits:

- Advancing water security
- Reducing carbon footprint
- Enabling economic growth
- Curbing nutrient pollution
- Anchoring infrastructure that sustainably repurposes waste.

Significantly, our research shows that this plan is feasible and cost-effective. Furthermore, its implementation would mutually benefit lakefront and inland Illinois communities.

Key Findings:

- Illinois can meet current and future water demands through water recycling and a dual-pipeline system.
- The existing Chicago-Joliet water agreement is an opportunity to implement water recycling to serve northeastern Illinois on a large scale.
- Dual pipelines of drinking water and recycled water will grow overall drinking water availability by supplying industrial and commercial users with treated wastewater.
- The benefits of this dual pipeline outweigh the cost.
- A dual pipeline will help secure northeastern Illinois's role as a climate haven and will support MWRD's goals of upscaling resource recovery.

Introduction

Water reuse or water recycling –applying treated wastewater to a range of beneficial uses– is an established practice that mirrors the natural water cycle.[1] In the 21st century, research and implementation of water reuse techniques have gained momentum across the globe as well as in the United States. New technologies and applications along these lines can enable the expansion of water supply in ways that mitigate the effects of drought or other barriers to procurement. Recycling closes the loop on high water loss due to its designation as waste.[2] Water recycling transforms wastewater into a resource and confers multiple benefits, such as preventing pollution, preserving natural resources, addressing climate impacts, and supporting state and regional water goals and needs. Water recycling promotes sustainability by contributing to environmental, economic, and social benefits. It contributes to a region's resilience by providing a reliable, uninterrupted freshwater supply for a range of purposes, as well as adaptation to constraints, unforeseen circumstances, and emergency conditions.

Although large-scale water recycling has been established in drought-stricken countries with increasing implementation in arid regions of the United States,[3] it remains an under-examined and under-utilized approach in regions of relative water abundance. Our report seeks to fill this gap and make the Chicago Metropolitan region a center of water reuse. In current practice in many parts of the country, including northeastern Illinois, wastewater is collected, treated, and finally discharged into rivers. This practice of discharging treated wastewater into surface water bodies results in wastage of potentially usable water that could be repurposed for various non-potable water applications.

The central recommendation of this report is for treated wastewater from the Metropolitan Water Reclamation District of Greater Chicago (MWRD) to become available for industrial and commercial uses within Cook County and in Illinois counties experiencing groundwater collapse. It must be emphasized that the recommendation is not to supply recycled water for drinking but rather for industrial uses. This mode of increasing overall water supply will help to preserve the quality and quantity of Lake Michigan water for human health and

[1] Lee and Jepson differentiate between water recycling, which is when treated or untreated wastewater is used for the same purpose as the source water, and water reuse, which is the use of treated or untreated wastewater for other purposes. Kyungun Lee and Wendy Jepson, "Drivers and Barriers to Urban Water Reuse: A Systematic Review," Water Security 11 (2020): Art. 100073. Our project takes water reuse to mean application of effluent that meets current treatment standards and water recycling to mean extension of the treatment process in the name of widening possible uses. That said, the terms are at times used interchangeably.

[2] In this way, recycling relates to the One Water paradigm, which sees all forms of water as integrated. On that paradigm, see US Water Alliance, "One Water Roadmap: The Sustainable Management of Life's Most Essential Resource," 2016, https://uswateralliance.org/sites/uswateralliance.org/files/publications/Roadmap%20FINAL.pdf.

[3] On global efforts, see, e.g., MULTI-ReUse (Germany), NEWater (Singapore), Durban Water Recycling Project (South Africa), Centralized Water Reuse Project (Tianjin, China). See also Diego J. Rodriguez, Hector Alexander Serrano, Anna Delgado, Daniel Nolasco, and Gustavo Saltiel, "Wastewater? From Waste to Resource," in From Waste to Resource: Shifting Paradigms for Smarter Wastewater Interventions in Latin America and the Caribbean (Washington, DC: World Bank, 2020), https://www.worldbank.org/en/topic/water/publication/wastewater-initiative#casestudies. On the US context, and for information on the National Water Reuse Action Plan, see Environmental Protection Agency, "Water Reuse Action Plan," February 2020, www.epa.gov/waterreuse/water-reuse-action-plan.

sanitation. It will bring benefit to Chicago by transforming the cost of waste management into a revenue-generating endeavor and by supporting flood management strategies. At the same time, the framework has the capacity to spare suburban and exurban Illinois communities the destabilization of water source loss.

Due to the cost and disruption of establishing new water infrastructure, we recommend that supply systems largely remain as they are within the Lake Michigan basin and that recycled water transmission mains be built to serve industries in municipalities shifting to Lake Michigan for their domestic supply. When a community –like those above the dwindling Cambrian-Ordovician aquifer– applies to receive water from a lakefront municipality, their domestic and healthcare needs should be met so long as the diversion is viable. Industrial and some commercial needs, however, should be met with recycled water. In cases where water transmission mains are under construction to serve a new enterprise or supply a municipality, a dual-pipeline system of treated Lake Michigan water for domestic and healthcare purposes and treated wastewater for industrial processes should be established.

In order to meet current and projected water demand in northeastern Illinois, we recommend that every new community replacing or supplementing supply with Lake Michigan water build a dual pipeline system. The dual-pipeline system involves two lines: one for treated Lake Michigan drinking water and another for recycled water. Building two lines of supply at once saves on construction costs and, vitally, makes provision for the survival of a greater number of communities above a faltering aquifer. The dual-pipeline system joins the humanitarian project of supplying drinking water with innovative water reuse technologies that maximize production and secure growth in the state of Illinois. In addition, supporting industrial water needs with recycled water opens a new stream of revenue that can be reinvested in state-of-the-art treatment and conveyance infrastructure. Implementing the dual-pipeline system would allow industry to flourish, even to expand, at its current locations in cases where local groundwater can no longer support it.

Specifically, water recycling and the dual-pipeline system can be implemented immediately as part of the Chicago-Joliet water transfer agreement. A pipeline of treated Lake Michigan water from the Chicago Department of Water Management will run to Joliet by 2030. This momentous piece of cross-regional infrastructure provides the ideal occasion to actualize principles of sustainability and resilience. A parallel pipeline of recycled water can be established within the same timeframe along the same easement. As our sustainability assessment shows, recycling water will reduce MWRD’s carbon footprint. Although we model our approach on the Chicago-Joliet water transfer agreement, our proposal is meant to highlight the substantial opportunity to recycle water in the northeastern Illinois region by charting a strategy for MWRD to sell treated wastewater wherever there is need or desire within Illinois. In fact, a number of communities are expected to file requests to receive treated Lake Michigan water in the near future. These cumulative water needs can only be met through a combination of drinking and recycled water.

Our proposal advances MWRD's goals of becoming a full-scale resource reclamation agency and establishes Chicago as a leader in climate adaptation.

The report contains the following sections:

Why Recycle Chicago's Wastewater? illustrates how the metropolitan region can implement water-recycling infrastructure to adapt to the region's needs and become a leader in sustainability and resource recovery.

Promoting Water Security and Resilience in Illinois reviews the destabilization associated with water source loss and charts the course through which Illinois can avoid water crises while supporting strong cross-regional collaborative partnerships.

The Joliet Water Transfer details existing plans to pipe treated drinking water from the City of Chicago to Joliet and a consortium of nearby municipalities known as the Grand Prairie Water Commission. As it currently stands, the water transfer will provide a large number of heavy industries with high-quality drinking water that they do not need.

A Proposed Solution for Joliet—and Beyond specifies how the full suite of the Joliet region's water needs can be met by incorporating recycled water into supply from Chicago. In order to secure drinking water supply for the full range of communities above the faltering Cambrian-Ordovician aquifer, we recommend supplying industries in these communities with recycled water.

Economic, Environmental, and Social Considerations of a Decentralized Water Recycling Approach provides cost-benefit analysis of recycling water at MWRD and delivering it in a dual-pipeline system in collaboration with the Chicago Department of Water Management (CDWM). The short- and long-term benefits of the proposal outweigh the costs.

Topics for Future Exploration reaches beyond our immediate proposal to consider further innovation at MWRD water reclamation plants and the affordability challenges associated with necessary upgrades in water infrastructure.

Why Recycle Greater Chicago's Wastewater?

Our proposal to implement large-scale water recycling in the Chicago Metropolitan area may immediately raise the question, "why reuse a resource where it is plentiful?" For the most part, barring emergencies, a supply of treated wastewater is not needed within the Great Lakes basin. Many Great Lakes communities effectively recycle their water through practices of return use and by following the non-diversionary tenets of the Great Lakes Compact. Greater Chicago, with an over one-hundred-and-twenty-year wastewater diversion through the Sanitary and Ship Canal, has always presented an exception.

However, Illinois faces a rocky water future. With northeastern Illinois communities in four counties facing declining groundwater availability, the scenario in which heavy industries receive drinking water while Illinois households run dry must be anticipated and avoided. This can be done by supplying industrial and certain commercial users with recycled water, thereby preserving available Lake Michigan supply for domestic uses.

Recycling water in the Chicago Metropolitan area produces multiple wins: securing lives and livelihoods across northeastern Illinois, reallocating wastewater to productive uses, ensuring supply for industry, and transforming costs associated with wastewater diversion into revenue from a new source of water supply. In the face of extreme water scarcity across the globe and country, as well as within Illinois, valuable freshwater can no longer be dispensed with as waste. Rather than flushing billions of gallons of Great Lakes water through the canal, they can be reused to support out-of-basin industrial water needs in Illinois. Enlarging the water pie in this manner increases the overall availability of Lake Michigan drinking water and thereby accommodates population and economic growth.

Chicago possesses the ability to supply out-of-basin suburbs and cities with Lake Michigan water due to its status as an exception to the Great Lakes Compact, a pioneering piece of regional legislation that preserves the Great Lakes watershed and localizes its benefits. According to the terms of the Compact, out-of-basin diversions are limited to communities or counties that straddle the boundary of the watershed and receive approval from the Conference of Great Lakes and St. Lawrence Governors and Premiers that unites the chief executives from Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Ontario, Pennsylvania, Québec, and Wisconsin. Because the Compact was ratified in 2005, one hundred and five years after Chicago began directing its wastewater to the Mississippi River basin, Chicago's diversion of wastewater, as well as its out-of-basin supply to suburbs, were grandfathered into the regional withdrawal agreement. The city pumped treated drinking water to suburbs and partially treated wastewater to the Mississippi River basin prior to the Compact and continues to do so today. Although our proposal does not seek to change diversion status, it does transform patterns of water allocation by approaching wastewater as a viable source for industrial processes. By regarding both types of diversions as valuable water that can be put to use, Illinois's overall water pie increases and enables both resiliency and growth.

Even with climate fluctuation, the Great Lakes watershed remains a highly viable location. In fact, studies project that the region's water supply will enable it to assume the status of a climate haven.[4] Availability of water is key to sustaining food production and supporting growth in jobs, housing, and amenities. Therefore, increasing the total amount of water available through technologies such as water recycling correlates with both population and economic growth. Our water-recycling framework fits into a larger plan for sustainable economic development. Immediate gains for Chicago include turning a massive waste stream into rate-bearing water and anchoring resource-recovery hubs at existing water reclamation plants and industrial corridors. The immediate recommendation of this report pertains to water reuse. Our next phase of research will consider treatment technology advancement and how existing plants can grow into resource-recovery hubs. Our aspirational goal is to close the loop by always deriving use from waste and thereby reducing the need for extraction.

Adopting a closed-loop approach to wastewater can shift the considerable costs of gathering, storing, treating, and diverting stormwater and wastewater into revenue. It comports with MWRD's aspiration to become a resource-recovery agency.[5] We discuss the costs of recycled water below but state briefly that, like all municipal water, recycled water can net rates that can be reinvested in infrastructure. Extending water use to secondary and even tertiary phases can generate additional rates that can help recuperate capital costs and maintain an innovative technological edge. In no small measure, Chicago's ability to serve as a climate haven depends on adaptive infrastructure that protects Lake Michigan along with the built environment as it optimizes water usage.

The availability of freshwater combined with legislative initiatives to shift to renewable energy signal the potential for northeastern Illinois to grow both in population and economic activity while also becoming more resilient to climate change. Enacting this vision requires increasing water supply through infrastructural upgrades to the wastewater system. Currently, Greater Chicago's Tunnel and Reservoir Plan (TARP or Deep Tunnel) holds 10.95 billion gallons of combined storm and wastewater. By 2029, TARP's capacity will increase to 17.45 billion gallons. This vital infrastructure provides considerable flood protection in the region. TARP protects freshwater sources by impounding combined

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[4] Kyle Sullivan and Rachel Jacobson, Climate and Demographic Change in the Great Lakes Region: A Narrative Literature Review of Opportunities and Opportunity Barriers (Ypsilanti, MI: American Society of Adaptation Professionals, 2021): https://adaptationprofessionals.org/wp-content/uploads/2021/03/Literature-Review.pdf.

[5] In 2016, the MWRD adopted the Resource Recovery Ordinance (later amended in 2020). Raw resources are extracted from the wastewater treatment process and reused to produce renewable energy, reduce greenhouse gas emissions, and supplement the treatment process. The full text of the ordinance is available at the MWRD's website (https://mwrd.org/sites/default/files/documents/Resource%20Recovery%20Ordinance%20October%201%202020.pdf).

stormwater and wastewater, then staggering its arrival at MWRD wastewater treatment plants. Both TARP and the MWRD Stickney plant are the world's largest of their kind.

Laudable for significantly reducing flooding,[6] the intertwined infrastructures can confer additional benefits. In the current scenario, water held in TARP and treated at MWRD plants is largely diverted from the Great Lakes basin and the State of Illinois through the Chicago Sanitary and Ship Canal, itself a part of the Chicago Area Waterway System (CAWS).[7] The Sanitary and Ship Canal feeds the Des Plaines River, which connects to the Illinois and Mississippi Rivers (Figure 1). The Mississippi empties into the Gulf of Mexico, a saline terminus for high volumes of Great Lakes freshwater. Rather than transfer this water out of the basin as waste, our proposal charts a much shorter route of transfer to northeastern Illinois communities where it can be applied to productive uses.

Figure 1. Chicago Area Waterway System

Source: Illustration by David Wilson in Havrelock and Blackburn, 2020.[8]

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[6] To date, TARP presents cost savings of over $180 million in flood damages annually and has eliminated 85% of combined sewer overflows. "Tunnel and Reservoir Plan," MWRD, https://mwrd.org/tunnel-and-reservoir-plan-tarp.

[7] According to a 1991 study, MWRD reused some of its treated wastewater internally. The estimated volume is approximately 8.00 mgd at Stickney, 0.56 mgd at Calumet, 0.26 mgd at O'Brien, 0.31 at Kirie, 0.98 mgd at Egan, 0.95 at Hanover Park, and less than 0.01 mgd at Lemont. Earl W. Knight and Robert Sokol, "Reuse of Treated Wastewater in Metro Chicago," Water Science and Technology 24, no. 9 (1991): 143–52, https://doi.org/10.2166/wst.1991.0244. A 2005 study indicated that these findings are still valid. MWRD currently reuses approximately 17% of its treated wastewater. Paul R. Anderson and Yi Meng, Assessing Opportunities for Municipal Wastewater Reuse in the Metropolitan Chicago Area (Champaign: Illinois Sustainable Technology Center, 2011).

[8] Rachel Havrelock and Kathleen Blackburn, "What to Do with the Chicago River?," Belt Magazine, February 25, 2020, https://beltmag.com/chicago-river-future/.

El Segundo Case Study

Implementation of advanced water recycling has been achieved in El Segundo, California and provides a precedent for MWRD. The West Basin Water District in Southern California (West Basin) raised $600 million dollars from local, state, and federal funds to construct the state-of-the-art Edward C. Little Water Recycling Facility in El Segundo (ECLWRF) to meet water needs amid California's worst-in-1,200-years megadrought.[9] By producing 40 million gallons of recycled water each day, more drinking water becomes available for Southern California households.[10]

Drought conditions encouraged industrial users to adopt recycled water and contribute to the financing of its infrastructure to ensure a stable supply.[11] West Basin's approach models the process of recycling water for industrial use while improving water quality in Santa Monica Bay.[12] West Basin runs the first recycling operation in the world to create five varieties of "designer" water. The advancement of water reuse at West Basin is rooted in advanced technology, which includes the application of microfiltration as a pretreatment step for reverse osmosis and ozone as a pretreatment before microfiltration. West Basin has also effectively performed low-pressure, high-intensity UV disinfection and advanced oxidation for groundwater injection (Indirect Potable Reuse). This technical achievement paves the way for other agencies to pursue similar treatment processes for Indirect Potable Reuse (IPR). Over 52% of West Basin's recycled water is provided to refineries, 36% is used for groundwater-seawater barriers, and 12% is used for irrigation and other purposes. As shown by the success of West Basin's facilities, industry can successfully incorporate and rely on an uninterrupted supply of recycled water. Since 1995, the ECLWRF has produced over 225 billion gallons of recycled water.

West Basin's process of recycling water involves three types of facilities. Their Hyperion plant is one of five wastewater treatment plants operated by the water district. Ten percent of its treated wastewater is sent to the Little Water Recycling Facility, a multi-quality recycling plant that creates four types of water: non-potable irrigation water that meets California's title 22 standards, water that meets standards for a seawater barrier/groundwater recharge for Indirect Potable Reuse (IPR), and two grades of water for oil refineries (Low-Pressure Boiler Feedwater and High-Pressure Boiler Feedwater). The recycled water is then distributed through a 100-mile-long pipeline system. The Little Water Recycling Facility splits the flow between the Title 22 treatment process

[9] A. Park Williams, Benjamin I. Cook, and Jason E. Smerdon, "Rapid Intensification of the Emerging Southwestern North American Megadrought in 2020–2021," Nature Climate Change 12, no. 3 (2022): 232–34.

[10] Since 1995, the West Basin has produced over 225 billion gallons of recycled water. For more on this, see the "History" web page of the West Basin Municipal Water District, at https://dev.westbasin.org/about-us/what-we-do/history/.

[11] According to West Basin's 2021 Annual Comprehensive Financial Report, major recycled water customers pay a fixed rate based on contract terms that are used to cover the capital construction of recycling facilities. Since 2011, more than $76 million has been collected from these contracts. Finance Department and Margaret Moggia, 2021 Annual Comprehensive Financial Report (Carson, CA: West Basin Municipal Water District, 2021), https://www.westbasin.org/wp-content/uploads/2021/12/2021-Final-report.pdf.

[12] Recycled water production reduces the amount of treated sewage discharged into Santa Monica Bay by 5 tons a day. "Recycled Water, Facilities," https://www.westbasin.org/water-supplies/recycled-water/facilities/

of chlorine disinfection and the microfiltration/reverse osmosis (MF/RO) treatment processes. Title 22 recycled water produced at the Little Facility is piped to three satellite treatment facilities to be further treated to meet the individual industrial needs. Two satellites are located directly on the premises of the Chevron and the PBF Energy refinery. The third satellite serves a Marathon refinery but is located about 1.2 miles from the site. These satellites provide a blueprint for decentralized treatment: they are built on-site at (or near) industrial facilities to achieve the standards needed at particular refineries through point-of-use treatment.

The precedent of the West Basin Water District shows that technologies to recycle water for industrial use exist and that on-site industrial water treatment can nicely complement the centralized treatment performed at municipal wastewater reclamation plants.

Promoting Water Security and Resilience in Illinois

Decades of unsustainable groundwater withdrawals nationwide are leading to land subsidence, surface-water flow reductions, and loss of wetlands.[13] The most dramatic case in the United States is the Ogallala Aquifer, which underlies 112 million acres of land in parts of eight Great Plains states, stretching north-south from South Dakota to Texas.[14] Since the introduction of irrigation, the aquifer's groundwater has supported the cultivation of water-intensive crops, reducing availability by 9% and leading to an overall water-level decline of 14 feet.[15] Today, the aquifer supplies one-quarter of the total water supply for US agriculture, responsible for producing one-fifth of the nation's wheat, corn, and cotton.[16] As a result, the Ogallala Aquifer contributes to groundwater depletion more than any other aquifer system in the United States. It is projected that 40% of the currently irrigated Great Plains will not be able to support irrigated agriculture by 2100.[17] Communities in the region have already seen streams and wells go dry, and many suffer from displacement and declining populations.[18] With mighty rivers drying up and vast aquifers collapsing, the world cannot afford to waste water or to categorize it as waste.

We do not recommend supplying recycled water from the Greater Chicago area to the Great Plains or to the water-stressed West (although we closely follow recycling efforts in these regions).[19] We highlight these staggering statistics in order to emphasize the urgency of increasing overall water supply. It stands to reason that Illinois will need to absorb people displaced due to nonviability of watersheds in other states and will need to upscale its agricultural and industrial production to offset decline in other parts of the

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[13] Leonard F. Konikow, Groundwater Depletion in the United States (1900–2008): U.S. Geological Survey Scientific Investigations Report 2013–5079 (Reston, VA: US Department of the Interior, US Geological Survey, 2013), https://pubs.usgs.gov/sir/2013/5079/SIR2013-5079.

[14] US Department of Homeland Security, Analysis of High Plains Resource Risk and Economic Impacts (2015), https://rrbwp.nebraska.gov/Reference/OCIA%20-%20Analysis%20of%20High%20Plains%20Resource%20Risk%20and%20Economic%20Impacts%20%282%29.pdf.

[15] V. L. McGuire, Water-Level Changes in the High Plains Aquifer, Predevelopment to 2009, 2007–08, and 2008–09, and Change in Water in Storage, Predevelopment to 2009, US Geological Survey Scientific Investigations Report 2011-5089, US Geological Survey, 2011, https://pubs.usgs.gov/sir/2011/5089/.

[16] S. Taghvaeian, S. Frazier, D. Livingston, and G. Fox, "The Ogallala Aquifer," Oklahoma State University. https://extension.okstate.edu/fact-sheets/the-ogallala-aquifer.html.

[17] J. M. Deines, M. E. Schipanski, B. Golden, S. C. Zipper, S. Nozari, C. Rottler, B. Guerrero, and V. Sharda, "Transitions from Irrigated to Dryland Agriculture in the Ogallala Aquifer: Land Use Suitability and Regional Economic Impacts," Agricultural Water Management 233 (2020): Art. 106061, https://doi.org/10.1016/j.agwat.2020.106061; L. Bessire, "The Next Disaster Coming to the Great Plains," The Atlantic, December 26, 2021, https://www.theatlantic.com/ideas/archive/2021/12/kansas-aquifer-ogallala-water-crisis-drought/621007/.

[18] Bessire, "Next Disaster."

[19] Sarah Hays, "Accelerating Environmental Equality in Rural Communities, Kaoru Ikuma Receives $3.2 Million EPA Grant." Research News—Iowa State University (blog), October 21, 2022, https://www.research.iastate.edu/news/accelerating-environmental-equality-in-rural-communities-kaoru-ikuma-receives-3-2-million-epa-grant/. In California, water recycling has successfully expanded across all industries through Title 22 state regulations. Examples include the Water Replenishment District of Los Angeles County and the Orange County Water District, which use recycled water for groundwater recharge and seawater barrier injections. See A. K. Wong and P. H. Gleick, "Overview to Water Recycling in California: Success Stories," Environmental Management and Health 11, no. 3 (2020): 216–38, https://doi.org/10.1108/09566160010333269.

country. However, Illinois is not immune to the impacts of rapidly changing water geography.

In Illinois, groundwater supply seems to present a more pressing water challenge than drought-related scarcity. Precipitation in the Great Lakes region is projected to increase, but with seasonal variation. While winter and spring are expected to be wetter, summer precipitation is projected to decrease by 5-15% in the Great Lakes basin, likely leading to increased demand during that season.[20] Central and southern Illinois, where major surface water bodies like Lake Michigan or the Mississippi River do not meet water needs as they do elsewhere in the state, are more vulnerable to drought.[21] Rural households that depend on shallow, private wells are particularly sensitive to drought because a small decline can cut their supply. Although droughts are less common in Illinois than in other parts of the United States, groundwater depletion is a water supply issue resulting from the historical impacts of water withdrawals.

The aquifers that supply groundwater to many northern Illinois communities are part of the Cambrian-Ordovician aquifer system, which extends across Minnesota, Wisconsin, Iowa, Missouri, Illinois, Indiana, and Michigan.[22] The aquifer system consists of sandstone, which is highly permeable and allows for a substantial groundwater supply.[23] Most of the water is drawn from two deep sandstone aquifers in the system: St. Peter, which is shallower and used most for human use, and the deeper Ironton-Galesville. The aquifers are separated from each other by low permeability bedrock layers (aquitards) of carbonate or shale that limit their ability to rebound from water withdrawals. The Sandwich Fault Zone also significantly limits water flow to aquifers.

Of all regions in the state, northeastern Illinois has historically placed the highest demand on the aquifer system. Although each region has its own challenges, other parts of Illinois face less severe groundwater supply issues than the northeastern part of the state. Central Illinois has a much smaller demand on groundwater sources than northern Illinois, however, due to shale aquitards that are highly impermeable, aquifers in the area are slowly declining.[24] Incremental declines are a concern because at a certain point, the groundwater from Central Illinois will mix with that from the southern part of the state where Cambrian-Ordovician aquifers are not viable for human use because of high salinity.

The Cambrian-Ordovician system began to be exploited beginning in the late 1800s, particularly to support the population and industrial expansion of the Chicago area.[25] The trend for the northeastern Illinois water supply

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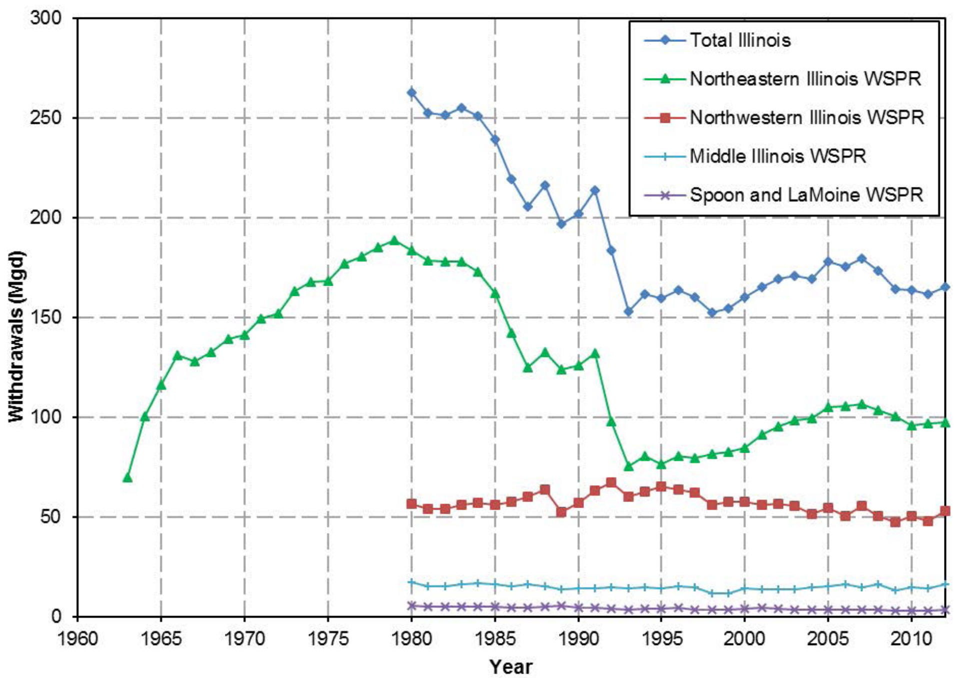
[20] "An Assessment of the Impacts of Climate Change on the Great Lakes." Environmental Law and Policy Center, March 30, 2019, https://elpc.org/resources/the-impacts-of-climate-change-on-the-great-lakes/.
[21] Illinois Department of Natural Resources, Drought Preparedness and Response Plan (Springfield: Illinois Department of Natural Resources, 2011).
[22] Konikow, Groundwater Depletion.
[23] Daniel B. Abrams, Daniel Hadley, Devin Mannix, George Roadcap, Scott Meyer, Ken Hlinka, Kevin Rennels, Kenneth Bradbury, Peter Chase, and Jacob Krause, "Changing Groundwater Levels in the Sandstone Aquifers of Northern Illinois and Southern Wisconsin: Impacts on Available Water Supply" (Contract Report No. 2015-02), Illinois State Water Survey and Wisconsin Geological and Natural History Survey, Champaign, IL, 2015.
[24] Abrams et al., "Changing Groundwater Levels."
[25] Konikow, Groundwater Depletion.

planning region (WSPR) shown in Figure 2 shows that demand on the aquifer system in northeastern Illinois increased most dramatically in the 1960s and 70s when suburban communities continued to grow west of Chicago.[26] Demand then declined in the 1980s, when many public water suppliers shifted their water source from groundwater to Lake Michigan out of fear of depleting the aquifers. In the 1980s and 1990s, nearly all communities in Cook and DuPage Counties switched to Lake Michigan supply (some large consumers like Elgin and Aurora switched fully or partially to the Fox River). While demand on the aquifers from these communities declined, allowing for slight recovery, growth of the area's westernmost communities again led to increased demand from 1993 to 2007. As a result of such unsustainable groundwater withdrawals, water levels in these vital aquifers in northeastern Illinois have been drawn down more than 300 feet.[27]

Figure 2. Groundwater Demand from the Cambrian-Ordovician Sandstone Aquifers in Four Water Supply Planning Regions (WSPRs).

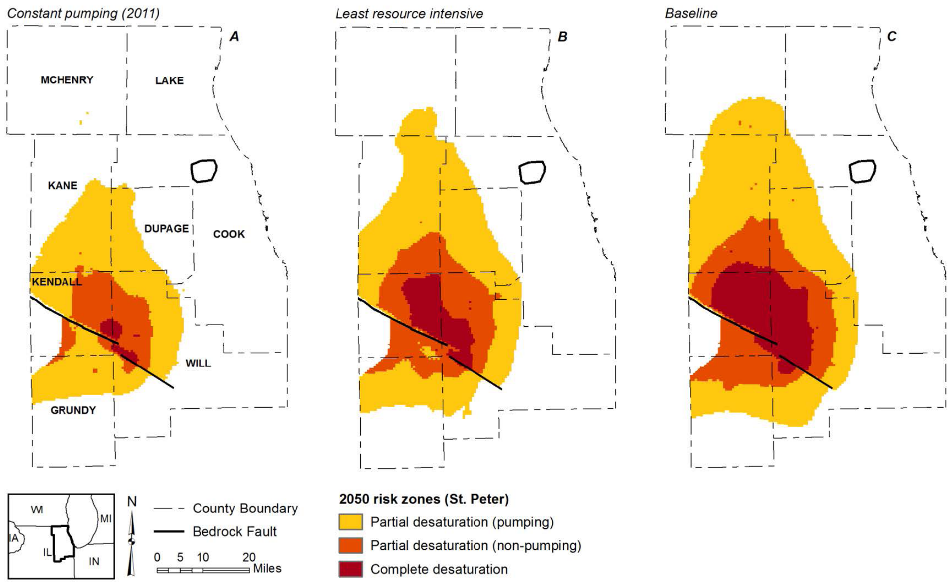


Source: Illinois State Water Survey, 2015.[28]

A major challenge for the region's groundwater levels is that recharge on a human time scale is impossible because aquitards and the Sandwich Fault Zone significantly limit the flow of water to aquifers. Even massive rain events or injection cannot adequately recharge groundwater in northeastern Illinois. The combination of continued drawdown and impossibility of recharge may result in a partial or complete desaturation in parts of northeastern Illinois by 2050 (Figure 3).[29]

[26] The Illinois DNR funded the development of water supply planning regions (WSPRs) throughout the state; the focus here is on the northeastern Illinois WSPR. See D. B. Abrams and C. Cullen, Analysis of Risk to Sandstone Water Supply in the Southwest Suburbs of Chicago (Champaign: Illinois State Water Survey, 2020).
[27] Abrams et al., "Changing Groundwater Levels."
[28] Abrams et al., "Changing Groundwater Levels."
[29] Desaturation refers to when water levels fall below the top of the aquifer, which can lead to wells going dry or becoming unfeasible for withdrawal as well as water quality issues by exposing the aquifer to oxygen.

Figure 3: Simulated Risk of Desaturation for the St. Peter Sandstone Aquifer by 2050 using Three Scenarios: a) Pumping Held Constant at 2011 Rates, b) Least Resource Intensive Pumping Rates, and c) Pumping Rates Consistent with Baseline Growth Rates.



Source: Illinois State Water Survey, 2015.[30]

Water security or the ability to depend on stable water supply amid anomalies in environmental, political, and social conditions requires scenario modeling for a variety of possible events. As much as recycled water can help to stabilize communities facing the loss of a water source and enable them to grow, it can offer the certainty of an emergency water backup.[31]On this count, we propose that, in an eventual centralized system, output from some of the Metropolitan Water Reclamation District of Greater Chicago's (MWRD) seven treatment plants be prepared to achieve standards for drinking water, if needed in case of an emergency (e.g., large-scale flooding or power outage).

The intent here is not for this water to regularly supply domestic uses, but rather to have a backup in the case of emergency at drinking water treatment plants or in Lake Michigan. Should any challenge to Lake Michigan or its drinking water plants transpire, having backup supply on hand would redouble resiliency. Additionally, securing backup supply by treating wastewater to drinking water levels could safeguard Illinois communities beyond Cook County should they find themselves in a temporary emergency situation in which an alternate source of water becomes necessary. A local backup scaled to communal water needs is preferable to the costlier alternative of bottled water, which also adds to plastic pollution.

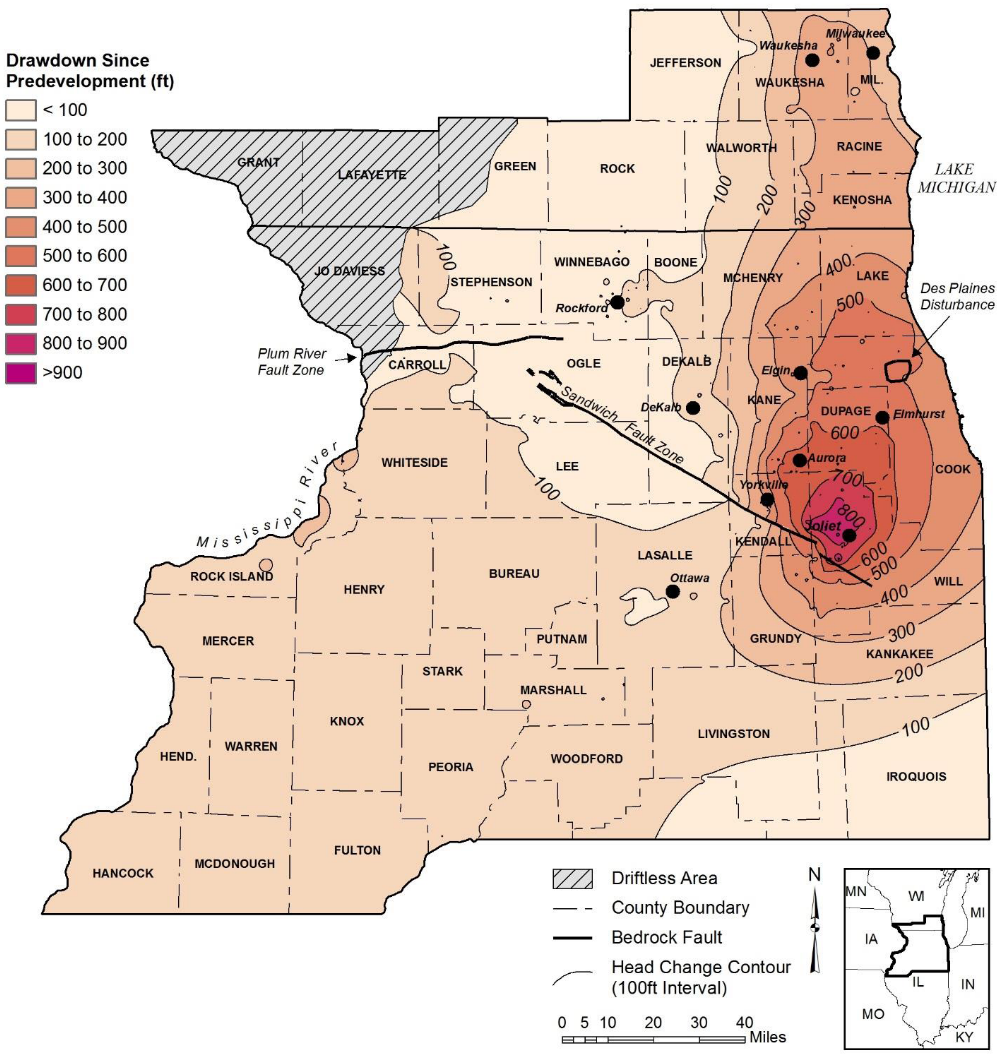
[30] Abrams et al., "Changing Groundwater Levels."

[31] Heavy rainfall overwhelmed the San Francisco Bay Area sewage system and resulted in a loss of 14 million gallons of water in the midst of a historic drought that is expected to last until 2030. Victoria Kim, "Millions of Gallons of Untreated Stormwater and Sewage Are Being Released in Northern California," New York Times, January 14, 2023, https://www.nytimes.com/live/2023/01/14/us/california-weather-storms-forecast?smid=url-share#untreated-storm-water-sewage-san-francisco-bay-area; A. Borunda, "The Drought in the Western US Could Last until 2030," National Geographic, February 14, 2022, https://www.nationalgeographic.com/environment/article/the-drought-in-the-western-us-could-last-until-2030. Since 2021, Mississippi has experienced three major water outages due to an aged and underfunded water system that routinely fails. Recently, the city of Jackson shut down schools and businesses as a result of burst pipes and a boiled water notice. See Oliver Laughland "'This Is No Way to Live': Mississippians Struggle with Another Water Crisis," The Guardian, January 7, 2023, https://www.theguardian.com/us-news/2023/jan/07/jackson-mississippi-water-outage-neighbors-helping; Mark Strassman, "Water Crisis Forces Closures in Jackson, Mississippi: 'Full Recovery Will Take Many Years," CBS News, January 5, 2023, https://www.cbsnews.com/news/jackson-mississippi-boil-water-school-business-closures/.

The Joliet Water Transfer

The biggest aquifer drawdown from a single community has been in the city of Joliet (the third most populous city in Illinois), where the aquifer's water level has fallen by over 800 feet (Figure 4). Joliet and other southwestern suburbs of Chicago in Will, Kendall, Kane, and DuPage counties are at the highest risk of aquifer depletion and the resulting water issues. In this area, sustainable withdrawals from the aquifer would fall between 2 to 7 million gallons per day (mgd), yet recent demands range between 35 to 38 million mgd. In 2018, total demand on the sandstone aquifer in this area was 36.7 mgd, with 15.3 mgd coming from the city of Joliet alone for all uses, including industrial. Another 12.8 mgd of demand came from three large petrochemical users.[33]

Figure 4. Water-Level (Head) Drawdown in the Cambrian-Ordovician Sandstone Aquifers, Predevelopment to 2014.



Source: Illinois State Water Survey, 2015.[34]

[32] Abrams and Cullen, Analysis of Risk to Sandstone Water Supply.
[33] These users are ExxonMobil, INEOS (Flint Hills), and LyondellBassell, which are part of the SWPG studied in Abrams and Cullen, Analysis of Risk to Sandstone Water Supply.
[34] Abrams et al., "Changing Groundwater Levels."

After becoming aware of the mismatch between its sizable needs and disappearing water, Joliet officials began to explore potential alternatives. The city considered groundwater and surface-water alternatives from the Des Plaines, Kankakee, Illinois, and Fox rivers and various suppliers of Lake Michigan water.[35] After narrowing down to two Lake Michigan options (from Chicago and Hammond, Indiana), the City of Joliet submitted a request to receive treated drinking water from the Chicago Department of Water Management, which offered a less costly, lower-risk option.[36]

The Deal with Chicago

In March 2021, Joliet entered an agreement with the City of Chicago to switch its water supply to Lake Michigan water, treated by the Chicago Department of Water Management. [37] Chicago agreed to begin supplying Joliet with water no later than January 1, 2030 for a duration of 100 years. The City of Chicago has verified that it has sufficient capacity to supply Joliet in the range of 30 mgd to 95 mgd, and it anticipates having sufficient capacity for the 100-year term of the agreement. Joliet will then supply the water to its customers within and beyond its municipal boundaries.[38] Joliet may also supply water to wholesale purchasers within 35 miles of its municipal boundaries. The two cities have planned to take a coordinated approach to the financing, design, and construction of the project. Each city will own, operate, and maintain its respective project infrastructure.[39]

Pursuant to the agreement and state legislation authorizing the acquisition of a common water supply for two or more municipalities, Joliet formed the Grand Prairie Water Commission (GPWC), a regional water commission of six southwest suburban communities—Channahon, Crest Hill, Joliet, Minooka, Romeoville, and Shorewood—all of which will receive treated Lake Michigan water under the agreement (Figure 5).[40] Currently, these communities rely on the deep sandstone aquifer and expect a large increase in demand by 2050 (Crest Hill is the exception, as it relies on the shallow aquifer).[41] Joliet had originally initiated talks with as many as thirteen communities that expressed interest in a regional water supply, some that relied on the dwindling aquifer and others that were looking for a new Lake Michigan supplier.[42] Consultants

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[35] City of Joliet, City of Joliet Alternative Water Source Study: Phase I FINAL Report, January 31, 2019, https://docs.wixstatic.com/ugd/38f500_56d76d20806543cebeabc1b6a631785c.pdf.

[36] City of Joliet, Alternative Comparison Summary—Alternative Water Source Program, December 2020, https://www.rethinkwaterjoliet.org/_files/ugd/3961f7_9e4e556703aa49329571fe2b87cf7953.pdf.

[37] City of Chicago and City of Joliet, "Preliminary Agreement with Respect to an Anticipated Water Supply Agreement Between the City of Chicago and the City of Joliet," March 2021.

[38] City of Chicago and City of Joliet, "Preliminary Agreement." The agreement authorizes Joliet to supply water to subsequent purchasers within 35 miles of its limits, as long as those purchasers receive an allocation permit from the Illinois DNR: "'Subsequent Purchasers' shall mean wholesale purchasers of water located outside of Joliet's corporate limits."

[39] This public-public partnership between the two cities is one that we propose be enhanced through the adoption of water recycling, hence incorporating MWRD, as we outline elsewhere in this report.

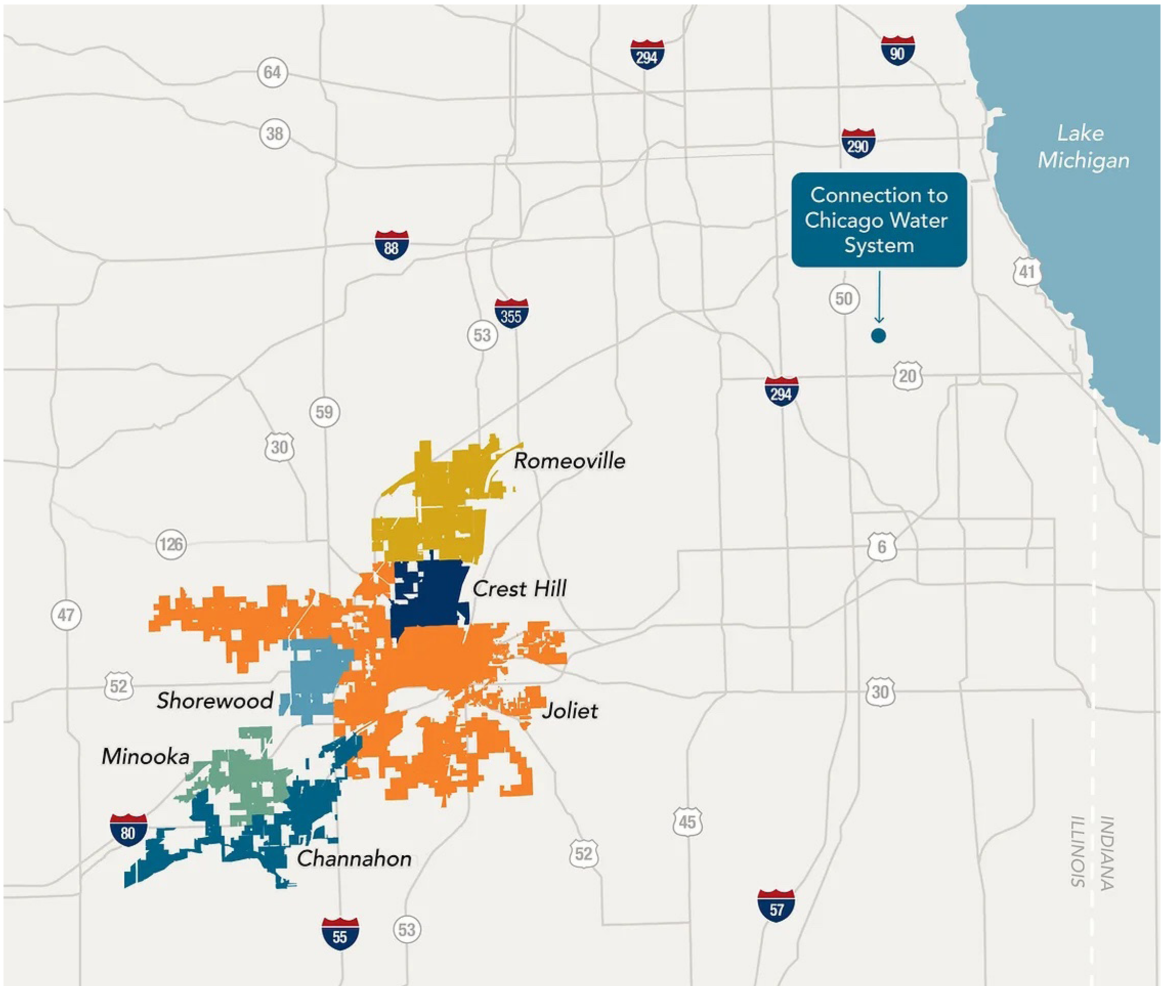
[40] See Regional Water Commissions Act, Pub. L. No. 102-0684 (2021), https://www.ilga.gov/legislation/publicacts/fulltext.asp?Name=102-0684&GA=102; City of Crest Hill, Village of Channahon, City of Joliet, Village of Minooka, Village of Romeoville, and Village of Shorewood, "Preliminary Agreement Regarding Formation of a Regional Water Commission," February 2022, https://www.rethinkwaterjoliet.org/_files/ugd/3961f7_9de0f3be9bd84020a66a23d1a74d15e1.pdf. See also the website of the Grand Prairie Water Commission (https://www.gpwc-il.org).

[41] Abrams and Cullen, Analysis of Risk to Sandstone Water Supply.

[42] City of Joliet, "Bringing Lake Michigan Water to the Southwest Suburbs," Mayors & Managers Meeting, January 14, 2021, https://s3.documentcloud.org/documents/21062809/joliet-powerpoint.pdf.

found that the price of making the switch and its timing were the most important factors in determining whether a community joined the GPWC.[43] Lockport, for example, opted out because of the cost and the viability of other options like the Kankakee River.[44] Three other communities (Oswego, Yorkville, and Montgomery) instead joined the DuPage Water Commission to receive Lake Michigan water.[45]

Figure 5. GPWC Members Crest Hill, Channahon, Joliet, Minooka, Romeoville, Shorewood.

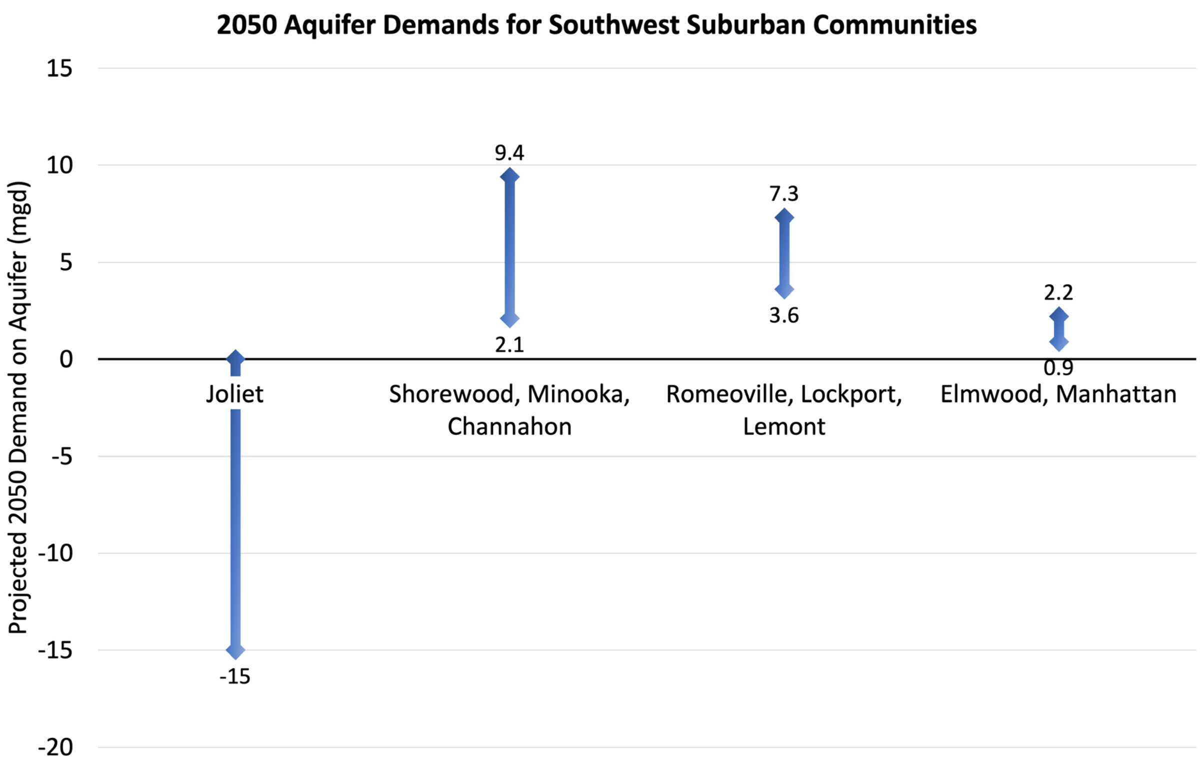


Source: Grand Prairie Water Commission, 2022.[46]

[43] Pete Wallers, Alternative Water Source Program, 2020 Evaluation, Regional Outreach Meetings Summary (Sugar Grove, IL: Engineering Enterprises Inc.), November 12, 2020, https://www.rethinkwaterjoliet.org/_files/ugd/3961f7_aa53afb9468e42c28fd6767e8f2882cc.pdf.
[44] John Lippert, "Pipeline to Chicago Could Make Joliet Mayor the New Suburban Water Czar," Illinois Answers Project, September 16, 2021.
[45] Linda Girardi, "Oswego, Yorkville and Montgomery to Bring in Lake Michigan Water with Connection through DuPage Water Commission," Chicago Tribune, December 20, 2021, https://www.chicagotribune.com/suburbs/aurora-beacon-news/ct-abn-water-supply-st-1221-20211220-uteiis2ohngupkdifcumh5wmoi-story.html.
[46] See the website of the Grand Prairie Water Commission (https://www.gpwc-il.org).

The historic agreement in which the City of Chicago pledged to supply Joliet with treated Lake Michigan water will not be sufficient to alleviate risk to the regional groundwater supply.[47] The Illinois State Water Survey (ISWS) found that most sandstone wells in the southwestern suburbs, including Joliet,[48] are at risk of not meeting future demand even when accounting for Joliet's switching off groundwater supply.[49] Figure 6 shows that while Joliet's switch will significantly reduce overall aquifer demand, increases in demand from other communities will counteract this decline. Accordingly, the ISWS projects that most communities in the region will be forced off the aquifer with the only uncertainty being how soon this occurs. Water conservation and changes to suburban development patterns could lessen the strain, but future demand is unpredictable, and unaccounted-for demands from new users can accelerate projected groundwater losses by decades.[50] Unexpected population growth and new industrial demands could accelerate the already precarious circumstances.

Figure 6. Projected 2050 Aquifer Demand Ranges for Southwest Suburban Communities.



Based on data from Illinois State Water Survey, 2020.[51]

[47] City of Chicago and City of Joliet, "Preliminary Agreement."
[48] The ISWS addresses the Southwest Water Planning Group (SWPG) Region, which includes Elwood, Channahon, Joliet, Lemont, Lockport, Minooka, Romeoville, Shorewood, Crest Hill, Frankfort, New Lenox, and Plainfield. The SWPG also includes ExxonMobil, INEOS–Flint Hills, and LyondellBasell. See Abrams and Cullen, Analysis of Risk to Sandstone Water Supply.
[49] Abrams and Cullen, Analysis of Risk to Sandstone Water Supply.
[50] This claim is supported by notes taken by the research team during a meeting with the ISWS. D. B. Abrams, D. Mannix, and C. Cullen, Meeting with Illinois State Water Survey (ISWS) on Illinois Water Supply Issues [Zoom], October 13, 2022.
[51] Abrams and Cullen, Analysis of Risk to Sandstone Water Supply.

In order to meet current and projected water demand in northeastern Illinois, we recommend that every new community replacing or supplementing supply with Lake Michigan water build a dual-pipeline system. In the dual-pipeline system, one line is dedicated to treated Lake Michigan water for domestic supply and a second line is dedicated to treated wastewater from the MWRD (recycled water) to support industrial needs.[52] Given its large capacity, the Stickney Water Reclamation Plant could easily meet Joliet's industrial water demand. Stickney has a capacity of approx. 700 mgd (average flow 610 mgd in 2021 and 714 mgd in 2022 (from January to September 2022 data). Some or all can be used for recycled water for Joliet industries.

As it stands, the conveyance agreement between Chicago, Joliet, and the other GPWC members relies on two existing and two new infrastructure components.[53]

I. existing water supply and production facilities owned by the City of Chicago, a purification plant (Eugene Sawyer Water Purification Plant), a pumping station (Southwest Pumping Station), and the South Tunnel System that conveys water between the two.[54]

II. new water transmission infrastructure to convey the water to the southwestern suburbs

III. new water delivery infrastructure to provide water to individual members of the commission.

IV. existing and new infrastructure that distributes water from the municipalities to their individual customers. [55]

Our plans for water recycling, as we detail below, would depend on these same infrastructure components with variations in terms of a dual transmission main and delivery lines to industrial users stemming from this main. The line conveying recycled water would reduce the overall allocation from Lake Michigan thereby preserving higher volumes for human consumption and ecosystem stability. Vitally, incorporation of recycled water expands total supply so that there is both more source water to meet human needs and more water for industrial processes.

[52] Most states mandate that recycled water distribution pipelines be purple; Pantone 512 or 522 is preferred. See the EPA, 2012 Guidelines for Water Reuse (EPA/600/R-12/618), https://www.epa.gov/sites/default/files/2019-08/documents/2012-guidelines-water-reuse.pdf.

[53] City of Crest Hill et al.,"Preliminary Agreement Regarding Formation of a Regional Water Commission."

[54] Construction of the pumping station will begin in 2025 and make part of Durkin Park unavailable to residents. To remedy this, Joliet will pay the Chicago Park District for improvements at nearby parks and finance a new field at Durkin Park after the construction. CDWM, "Chicago Improvements at Southwest Pumping Station & Durkin Park," https://www.chicago.gov/content/city/en/depts/water/supp_info/durkin-park-water-project.html.

[55] To receive permission for an allocation of Lake Michigan water, IDNR requires replacement of leaky pipes to achieve less than 10% non-revenue water.

Joliet's Industrial Character

Historically, the city was dubbed the "City of Stone and Steel."[56] The "stone" refers to quarrying rich deposits of dolomite limestone that began in the 19th century. The "steel" refers to the industry that fueled expansion of the city until the Great Depression. Situated at an engineered crossroads of railroads and canals, Joliet has a location that allowed its industries to prosper. The presence of the steel industry and the labor force it attracted brought along other industries as well: wire mills, coke plants, stove companies, horseshoe factories, brick companies, foundries, boiler and tank companies, machine manufacturers, can companies, bridge builders, plating factories, steel car shops, and many others.[57] This industrial history set the blueprint for modern extractive industries and is reflected in the land uses of the city today.

Currently, the city of Joliet has characteristics of a suburb with large developments and landscaping that requires high water use, as well as sprawling industrial sites. According to CMAP's 2015 land use inventory, commercial and industrial uses made up 14% of Joliet's overall land use, or about 5,590 acres (Figure 7).[58] In all of Will County, these categories make up just 6% of land use, suggesting that these land uses are particularly prevalent in Joliet and present a greater challenge for industrial water supply than elsewhere in the county. The city's water-intensive landscape is further confirmed by these details: an additional 19% of land use is devoted to transportation, the city has less park acreage than average in northeastern Illinois, and it has more impervious acres per household than the region overall (Figure 8).

In 2022, the most dominant business industries in Joliet were retail trade (15%), health care and social assistance (13%) of all businesses.[59] Less common businesses were mining (<1%), construction (6%), manufacturing (3%), wholesale trade (2%), and transportation and warehousing (3%). Despite being a small proportion of all businesses, some of these industries seem to have an outsized impact on the landscape. The industrial business parks of CenterPoint and NorthPoint, for example, occupy a combined 1,400 acres.[60] This footprint should be considered when evaluating the impact of the city's 99 manufacturing businesses and 105 warehousing businesses.

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[56] Bruce Hodgdon, "Steeling Joliet's Past," Forest Preserve District Will County, May 9, 2017, https://www.reconnectwithnature.org/news-events/big-features/steeling-joliet-past-iron-works-historic-site/.

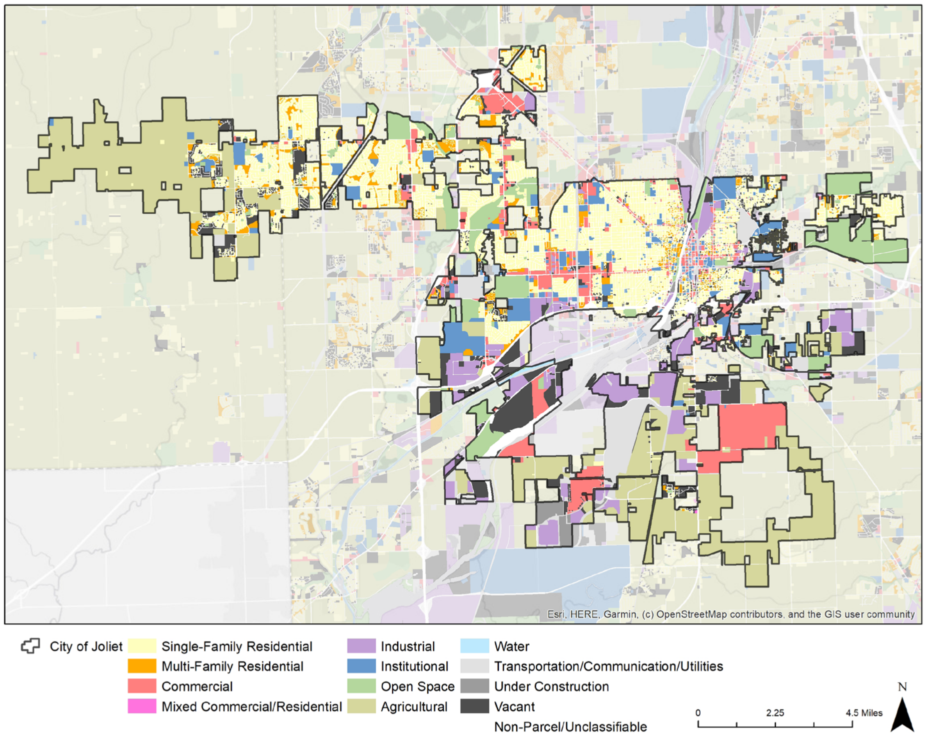
[57] Robert Sterling, "Joliet, IL," Encyclopedia of Chicago, http://www.encyclopedia.chicagohistory.org/pages/676.html.

[58] "Joliet: Community Data Snapshot," Chicago Metropolitan Agency for Planning (CMAP), July 2022, https://www.cmap.illinois.gov/documents/10180/102881/Joliet.pdf; "Will County: Community Data Snapshot," CMAP, July 2022, https://www.cmap.illinois.gov/documents/10180/102881/Will+County.pdf. Commercial uses include shopping malls, retail centers, large-site retail, urban mix, office, cultural/entertainment, and hotel/motel. Industrial uses include mineral extraction, manufacturing/processing, warehousing/distribution, general industrial, flex uses, and storage. Institutional uses include medical, educational, governmental, prison and correctional, and religious facilities. See CMAP, Chicago Metropolitan Agency for Planning's 2015 Land Use Inventory for Northeastern Illinois, Version 1.0, November 2020, https://www.cmap.illinois.gov/data/land-use/inventory.

[59] "Joliet Business Summary," ESRI and Data Axle, 2022.

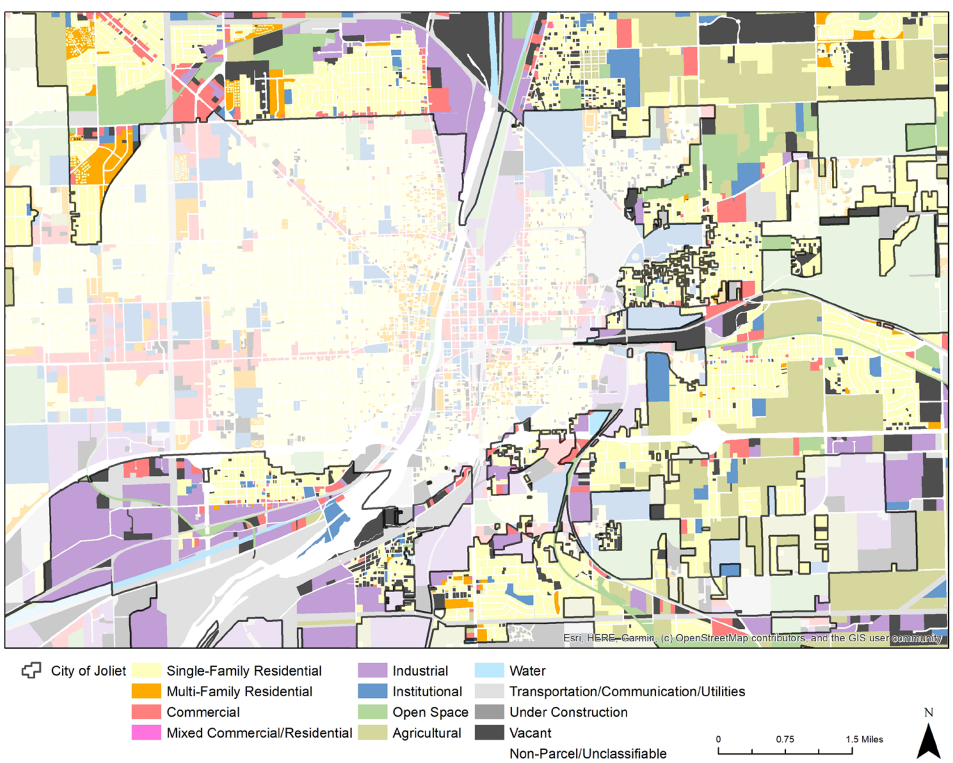
[60] See the City of Joliet's "Data Hub," at https://www.joliet.gov/business/economic-development/data-hub.

Figure 7. Land Use, City of Joliet



Based on data from Land Use Inventory, Chicago Metropolitan Agency for Planning, 2020.[61]

Figure 8. Land Uses in Areas Immediately Outside Downtown Joliet.



Based on Land Use Inventory, Chicago Metropolitan Agency for Planning, 2020.[62]

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[61] Chicago Metropolitan Agency for Planning's 2015 Land Use Inventory.
[62] Chicago Metropolitan Agency for Planning's 2015 Land Use Inventory.

Some big names in heavy industry with the most National Pollution Discharge Elimination System (NPDES) permitted outfalls include BP (Amoco), Caterpillar, Midwest Generation, ExxonMobil, and Dow Chemical.[63] The ExxonMobil tar sands refinery and the PQ Corporation chemical plant, in particular, are among the city's biggest water users.[64] Joliet and its surrounding communities also serve as "America's largest inland port," logistically moving products through enormous warehouses to individual buyers.[65] In fact, "nearly four percent of US gross domestic product, $735 billion worth, moves through" Joliet each year.[66] The expanding trucking hubs that enact logistics render diesel air pollution in Joliet worse than at least 90% of the US, according to the US EPA's environmental justice mapping tool.[67] Rather than implementing mitigation measures for diesel air pollution or adopting water conservation techniques in the face of a tapped aquifer, Joliet looks to expand its logistics industry.

Over the last twenty years, the exponential growth of the warehouse and logistics sector has dramatically changed the industrial landscape in Joliet. This is due to a hot logistics market and the steady rise of e-commerce. Global retailers, logistics providers, and product distributors such as Amazon, Walmart, IKEA, Home Depot, Mars, and Whirlpool are just a few of the major tenants in warehouses and distribution centers across Joliet's twenty-one industrial parks which constitute nearly one-third of the city.[68] Some have described the sprawl of these boxed facilities as an enormous, horizontal equivalent game of Tetris.[69] Since 2010, the workforce in transportation, warehousing, and utilities has grown 3%. The transportation, warehousing, and utilities sector is ranked as the third-largest employer and employed 11.2% of Joliet population in 2021.[70]

The City of Joliet continues to see a linear trend in parcels that are designated as nonfarm (industrial, commercial, and residential). Joliet had a combined commercial and industrial Equalized Assessed Value of over $1 million in 2020.[71] In September 2022, Walmart opened the first of four next-generation fulfillment centers spanning nearly 1.1 million square feet.[72] Although warehouses are believed to use less water than other industrial users,

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[63] An NPDES permit allows for a facility to discharge a specified amount of a pollutant into a receiving water. "NPDES Facilities in Illinois," Illinois Environmental Protection Agency, September 2009, http://www.epa.state.il.us/water/permits/waste-water/npdes-statewide.pdf. See also EPA, "National Pollutant Discharge Elimination System (NPDES)," https://www.epa.gov/npdes/npdes-permit-basics.

[64] Adam Mahoney, "America's Largest Inland Port Is Running Out of Water," Grist, February 24, 2022, https://grist.org/cities/water-pipeline-joliet-illinois/.

[65] Mahoney, "America's Largest Inland Port."

[66] Mahoney, "America's Largest Inland Port."

[67] Environmental Protection Agency, EJScreen: Environmental Justice Screening and Mapping Tool, 2022.

[68] City of Joliet, "Data Hub."

[69] Alexander Sammon, "Elwood, Illinois (Pop. 2,200), Has Become a Vital Hub of America's Consumer Economy. And It's Hell," New Republic, January 9, 2019, https://newrepublic.com/article/152836/elwood-illinois-pop-2200-become-vital-hub-americas-consumer-economy-its-hell.

[70] City of Joliet, "Data Hub."

[71] The equalized assessed value is defined as the property value after equalization. "Property Tax Part I: Overview of the Property Tax System," CMAP, https://www.cmap.illinois.gov/documents/10180/176267/RTPTFOverview%2BRegressivity09-02-2011.pdf/5b7a825f-4dea-44e9-baba-2fd976f6253d; "Joliet," CMAP.

[72] Evelyn Holmes, "EXCLUSIVE: Look inside Walmart's New Next-Generation Fulfillment Center in Joliet," ABC7 Chicago, September 27, 2022, https://abc7chicago.com/walmart-locations-amazon-fulfillment-center-near-me-joliet-il/12273322/.

but megacorporation warehouses in Joliet withdrew almost 21 million gallons of water in 2021.[73]

Joliet is currently pursuing land annexation to expand its capacity for industrial and warehouse development, some of which is water-intensive. The planned annexation has resulted in a court case.[74] Openlands, Sierra Club, and Say No to NorthPoint (local residents opposing carbon-intensive logistics on farmland)[75] joined a lawsuit alleging that the City of Joliet violated its own zoning ordinances to bring the NorthPoint Intermodal Facility to the city.[76] Plaintiffs argue that Joliet failed to comply with its own zoning in an attempt to annex land for NorthPoint, a proposed warehousing and intermodal facility covering nearly 5 square miles between the Abraham Lincoln National Cemetery and the Midewin National Tallgrass Prairie.[77] Plaintiffs also contend that proper public notice was not given before a Plan Commission hearing considering zoning changes for the project's approval, which did not allow sufficient opportunity for residents to organize against the project.[78] This case is just one among six involving Joliet and NorthPoint.[79]

Whatever the court's final disposition, the NorthPoint facility is relevant to the Chicago-Joliet agreement insofar as it would draw around 1,000 gallons of water per minute –or 1.4 million gallons per day –in a city where lack of available water has necessitated plans for delivery from Chicago. On its own, Joliet does not have the water to support the logistics hub. The questions that follow are whether Chicago has the water to support the Kansas City-based warehouse developer and whether Joliet residents can afford to subsidize the infrastructure to serve it. As a result of projected water debt, the City of Joliet has cut planned subsidies for a history museum, a music and theater venue, and a riverfront bandshell, amenities that benefit taxpayers and that they are losing due to anticipated costs of water.[80] In response, Joliet City Council member Cesar Guerrero proposed a graduated water tax in which industrial and commercial users would pay a slightly higher rate.[81] This proposal would shift a larger share of the financial burden to companies that use the most water, inspired by Baltimore County rates that vary for residential, commercial, and industrial users (increasing in that order).[82] Through graduated water pricing, corporations that financially benefit from public water supply, particularly those that require the highest volumes of water, would pay more.[83]

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[73] In Will County, these megacorporation warehouses account for only 2% of 300 warehouses. Mahoney, "America's Largest Inland Port."
[74] Lippert, "Pipeline to Chicago."
[75] "Who We Are," Just Say No to NorthPoint, https://www.no2northpoint.com/whoweare/.
[76] Stacy Meyers, "Why Openlands Has Joined a Lawsuit against the City of Joliet," Openlands, November 18, 2020, https://openlands.org/2020/11/18/why-openlands-has-joined-a-lawsuit-against-the-city-of-joliet/.
[77] The referred case is ongoing and yet to be decided. See Elwood v. Joliet, No. 20CH590 (12th Cir.).
[78] Bob Okon, "Judge Grants Preliminary Injunction, Joliet Considers NorthPoint Options," Shaw Local News Network, October 5, 2020, https://www.shawlocal.com/2020/10/05/judge-grants-preliminary-injunction-joliet-considers-northpoint-options/az4e2ha/.
[79] "Pending Lawsuits against Joliet & NorthPoint in the 12th Judicial Circuit Court of Illinois," Stop NorthPoint, https://www.stopnorthpoint.com/about/pending-lawsuits/.
[80] Lippert, "Pipeline to Chicago."
[81] "Joliet Residents Protest Plan to Hike Water Rates," Illinois Answers Project, November 16, 2021, http://illinoisanswers.org/2021/11/16/joliet-residents-protest-plan-to-hike-water-rates/.
[82] "Metropolitan District Rates," Baltimore County Government, 2022, https://www.baltimorecountymd.gov/departments/public-works/metro-finance/rates.
[83] "Joliet Residents Protest."

A Proposed Solution for Joliet—and Beyond

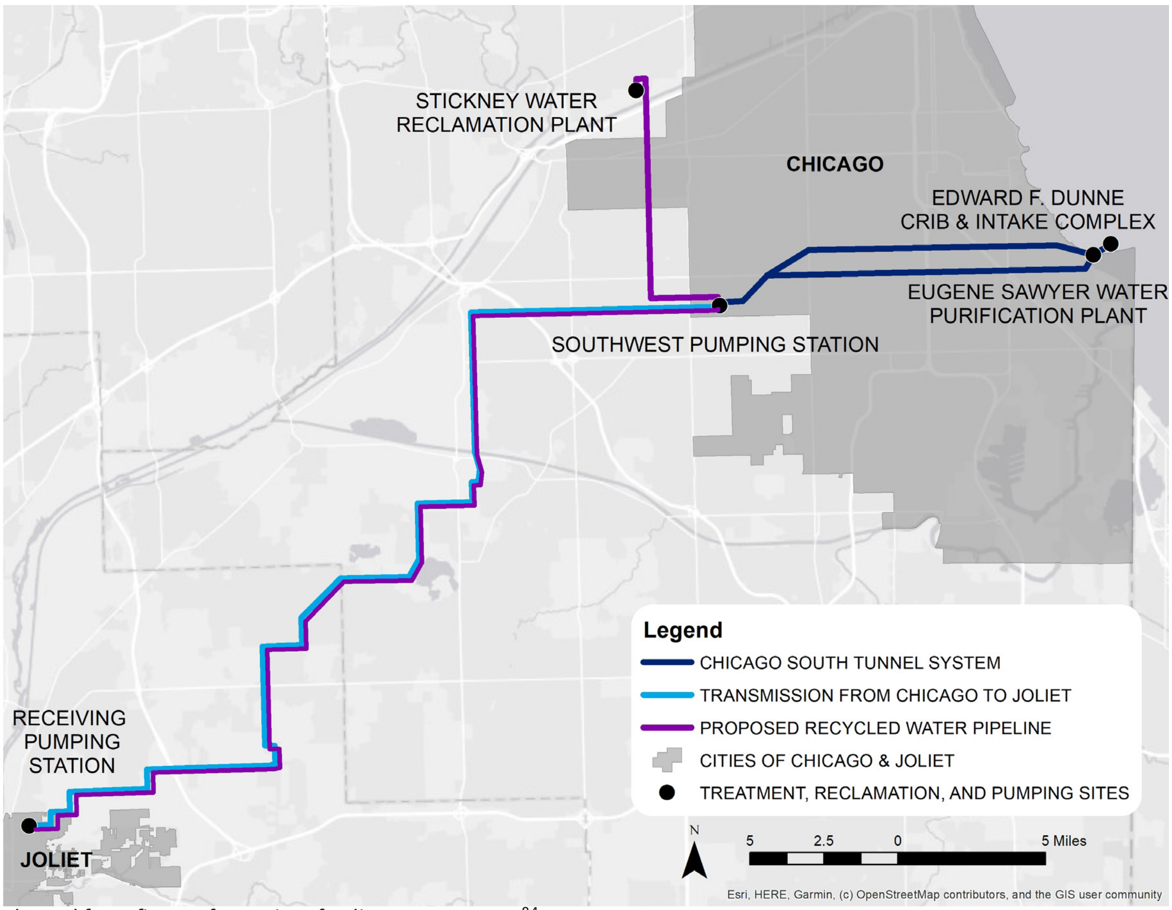
Water recycling can alleviate the tension between industrial water demand and water cost to residents (as in the case of Joliet) by introducing an additional water supply source. MWRD is well positioned to expand availability of water supply to Joliet and the Grand Prairie Water Commission. Treated wastewater from the Stickney Water Reclamation Plant has appropriate water quality and quantity to meet industrial demands in the area. Current and projected water demand in northeastern Illinois can be met through a dual-pipeline system in which one line is dedicated to treated Lake Michigan water for domestic supply, and a second line is dedicated to recycled water from the MWRD to support industrial needs. The line conveying recycled water reduces the overall allocation from Lake Michigan, thereby preserving higher volumes for human consumption and ecosystem stability.

A second pipeline carrying recycled water to industrial users can run alongside the pipeline conveying drinking water to Joliet. The recycled water pipeline could originate from the MWRD Stickney Wastewater Treatment Plant and run alongside the drinking water transmission main from the Chicago Department of Water Management within the same easement. Connecting the Stickney plant to the Southwest Pumping Station (which will supply water to Joliet) requires an approximately 8-mile pipeline, as shown in Figure 9(a). The pipes can be constructed at the same time. According to our estimates, the Stickney Water Reclamation Plant can supply the entirety of both the City of Joliet's and Grand Prairie Water Commission's (GPWC) industrial water needs.

In addition to the Stickney Water Reclamation Plant, we assessed the Calumet Water Reclamation Plant (CWRP) as a potential source of recycled water. Figure 9(b) shows the potential alignment of a recycled water pipeline connecting CWRP to the Eugene Sawyer Purification Plant (ESPP) pipeline route. CWRP could meet Joliet's industrial water demand and provide better quality water than SWRP, due to the seasonal disinfection at CWRP. Additionally, the recycled water pipeline could follow the right-of-way of an existing intercepting sewer that connects to ESPP. However, further evaluation is required to check the viability of the CWRP recycled water source and the proposed pipeline alignments.

The proposed Chicago-Joliet pipeline will be the farthest-reaching Lake Michigan pipeline in Illinois. We have modeled our proposal on these existing plans. Its structure pertains to the other communities that will request Lake Michigan water due to groundwater depletion. Recycled water is intended to supply only industrial, commercial, and, potentially, some irrigation needs. Treated Lake Michigan water would supply all needs for human consumption, healthcare, and sanitation. Recycling water expands total supply so that there is both more source water to meet human needs and more water for industrial processes. We have further recommended that every new community replacing or supplementing supply with Lake Michigan water build a dual-pipeline system.

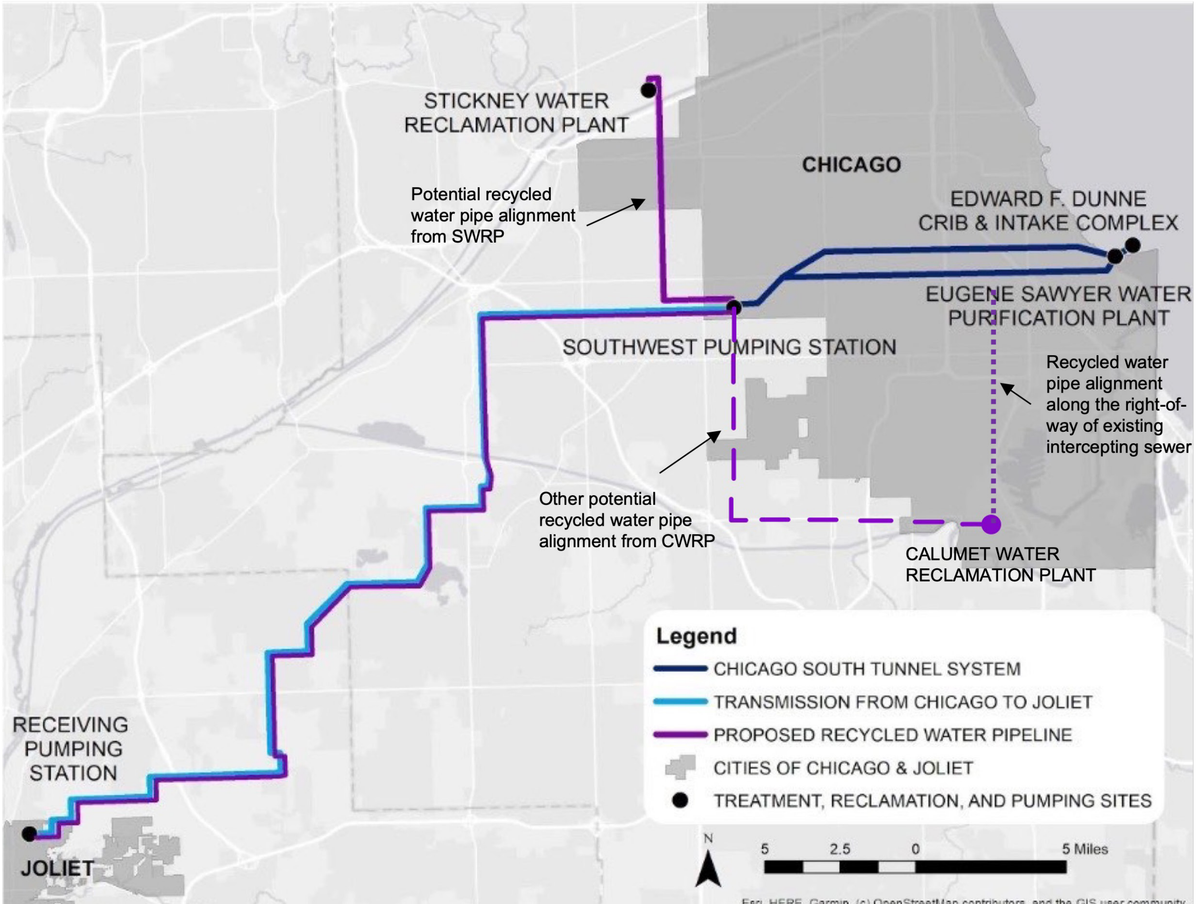
Figure 9(a). Proposed Dual-Pipeline Infrastructure Pathways Connecting Joliet to Treated Lake Michigan Water (CDWM) and Recycled Water from Stickney WRP (MWRD).



Adapted from figures from City of Joliet, 2020 & 2021.[84]

[84] City of Chicago and City of Joliet, "Preliminary Agreement"; City of Joliet, "Basis of Design Attachment D," Rethink Water Joliet, December 2020, https://www.rethinkwaterjoliet.org/_files/ugd/3961f7_d01bc7a35d24437fab90dc373ce312bf.pdf.

Figure 9(b). Proposed Dual-Pipeline Infrastructure Pathways Connecting Joliet to Treated Lake Michigan Water (CDWM) and Recycled Water from Calumet WRP (MWRD).



Adapted from figures from City of Joliet, 2020 & 2021.[85]

The dual pipeline can be implemented in one of two ways:

1. Decentralized –MWRD keeps its existing wastewater treatment system and delivers wastewater treated to currently permitted levels consistent with discharges to canals (Stickney and Lemont), channels (O'Brien), rivers (Calumet and Hanover Park), and creeks (Egan and Kirie). End users further treat wastewater, if necessary, before reusing it (point-of-use).

2. Centralized –MWRD upgrades the wastewater treatment system, as needed, to meet specific end users' water quality standards and delivers the recycled water with no further treatment required (fit-for-purpose). Notably, MWRD could extend the current existing wastewater treatment process to be more effective by disinfecting the water all year round instead of seasonally disinfecting for some specific reuse applications (e.g., toilet flushing, air conditioning, golf course irrigation, etc.), where only additional disinfection may be needed. MWRD could consider expanding the level of treatment using advanced treatment technologies such as reverse osmosis or microfiltration to accommodate more recycled water reuse applications (e.g., agriculture, indirect/direct potable use).

[85] City of Chicago and City of Joliet, "Preliminary Agreement"; City of Joliet, "Basis of Design Attachment D," Rethink Water Joliet, December 2020, https://www.rethinkwaterjoliet.org/_files/ugd/3961f7_d01bc7a35d24437fab90dc373ce312bf.pdf.

Both scenarios have a distinct set of advantages and disadvantages that may influence the option selected. For instance, expanding a wastewater reclamation plant requires additional infrastructure, cost, and space. The technology requirements, as well as the cost burden of adopting treatment technologies, would also differ.

Though our long-term recommendation would be that MWRD pioneer centralized approaches [scenario #2 above] by extending current treatment plants into full-scale resource-recovery hubs that produce water, biogas, and reclaimed minerals and metals from wastewater, our short-term recommendation is the decentralized option.

First, a decentralized approach is the most flexible and allows end users to determine the necessary amount of treatment to satisfy their needs.[86] Producing water viable for particular uses while maintaining safety standards is known as a "fit-for-purpose" model. In determining quality thresholds, treatment goals (e.g., salt reduction for irrigation or industrial reuse) are specifically tailored to end users' needs, safe for the public and the environment while also being cost-effective. This is a frequently used strategy in developing water-recycling solutions.

Second, there is currently uncertainty around the types of regulations that would be required at a centralized treatment plant because Illinois does not have active water reuse standards. The US Environmental Protection Agency (EPA) has published guidelines for water reuse that states can follow to establish criteria or requirements for various water reuse programs. The EPA guidelines are not enforceable but do provide suggestions for any water reuse programs and for engineers or stakeholders involved in the evaluation, planning, design, and management of water reuse facilities. To date, 43 states have created laws, regulations, or guidelines for agricultural reuse to irrigate processed food crops and nonfood crops, 40 states for restricted urban reuse, 32 states for unrestricted urban reuse, and 31 states for industrial reuse. Existing guidelines vary substantially by state. For example, water reuse in California is regulated under Title 22 of the California Code of Regulations, which permits 40 water reuse applications permitted for tertiary disinfected recycled water, 24 reuse applications for secondary disinfected recycled water, and 7 for non-disinfected recycled water. On the basis of task forces currently working at federal,[87] state,[88] and municipal levels,[89] we anticipate that guidelines on water recycling will be put forward in Illinois sometime in the next few years. The decentralized

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[86] "Water Trends That Will Reshape the Industry in 2023," H20 Global News, https://h2oglobalnews.com/water-trends-that-will-reshape-the-industry-in-2023/.

[87] On the EPA Water Reuse Action Plan, see "Water Reuse Action Plan," at https://www.epa.gov/waterreuse/water-reuse-action-plan.

[88] Illinois HB5854 would establish a Water Reuse Task Force. See "Bill Status of HB5854," Illinois General Assembly, https://ilga.gov/legislation/billstatus.asp?DocNum=5854&GAID=16&GA=102&DocTypeID=HB&LegID=141791&SessionID=110.

[89] On August 31, 2017, the MWRD Board of Commissioners authorized, as part of the MWRD's resource recovery initiatives, the sale of treated effluent water to interested parties. Interested parties are responsible for obtaining any required regulatory approval for the proposed use prior to purchasing the water. The Illinois Department of Public Health (IDPH) has taken the lead on the regulatory aspects of these efforts. A request letter must be sent to IDPH detailing the proposed use for each specific use or user, then IDPH will determine whether proposed use is acceptable and will impose any restrictions necessary to safeguard the public.

option allows for the practice of reuse to begin even as regulation and standards become established for a more centralized system.

Third, and finally, the decentralized scenario allows for completion of a dual pipeline within the timeframe of the Chicago-Joliet water agreement: delivery by January 1, 2030. Given the pressing regional water needs and communities facing groundwater collapse, satisfying industrial needs with recycled water using a decentralized approach in the short term is a key step on the way to full-scale resource reclamation.

The long-term goal of this project and the next phase of its inquiry is a centralized approach to water recycling in which MWRD plants extend treatment and disinfection in tandem with full-scale recovery of biogas and other resources. A centralized approach confers additional benefits of exceptional water quality that can meet a full range of non-potable, even potable, uses while transforming the very notion of wastewater. As it meets immediate needs, supplying out-of-basin industrial users with wastewater treated to current standards marks a first step along the way to broad resource recovery. An additional advantage derives from reducing barriers to adoption of recycled water. Most resistance to a recycled water supply mounts from reactions of disgust to using what we send down the drain as drinking water. Although this public reaction (commonly known as the "yuck factor")[90] is changing in tandem with scenarios of global water stress, sidestepping the issue of recycled water for drinking or agriculture expedites adoption. The absence of supply alternatives creates wide acceptance of recycled water. As shown in Southern California, treated wastewater and heavy industrial users make a perfect match.

Supply competition between the Chicago Department of Water Management (CDWM) and the Metropolitan Water Reclamation District of Greater Chicago (MWRD) would be counterproductive. In order for the dual-pipeline system to flourish and sustain additional communities, we recommend a public-public partnership between the Metropolitan Water Reclamation District and the Chicago Department of Water Management that distributes water, sets rates, and collects bills from industrial customers. A partnership of this nature would help to balance costs incurred and revenue gained by the two collaborating agencies.

The Chicago Department of Water Management –supplier of drinking water across Cook, DuPage, and Will Counties– counts on bulk rates paid by industrial users. If an existing user were to switch to recycled water, then the CDWM would confront a shortfall. We recommend that the CDWM and MWRD create a public-public partnership to coordinate supply of drinking and recycled water. In this way, MWRD can provide treated wastewater at wholesale prices to the CDWM or to other municipal water departments.

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[90] Kimberly Duong and Jean-Daniel M. Saphores, "Obstacles to Wastewater Reuse: An Overview," Wiley Interdisciplinary Reviews: Water 2, no. 3 (2015): 199–214.

Creating new revenue streams from waste stands among the main economic goals of the dual-pipeline system. Such revenue can be leveraged with federal funding to update and innovate water infrastructure. Governed by the diversion limit set by the US Supreme Court, the City of Chicago already supplies treated drinking water to 5.4 million customers (about 40% of Illinois's population) in Chicago and 120 suburbs.[91] Although prices have risen steadily in the 21st Century, suburban municipalities obtain water from the CDWM at a wholesale rate, then supply it to their residents. In some cases, a given municipality serves as a hub, supplying water to nearby suburbs and towns. In the same vein, MWRD could wholesale treated wastewater to water departments, which could choose to leave current rate structures unchanged even with the new supply. This approach would result in no net financial loss to water departments and would still bring revenue into the MWRD.

It is also possible that some industries might resist the current rate structure applied to recycled water. If such resistance were mounted, then it could be addressed through policy that requires industrial users in communities switching to a Lake Michigan water supply to adopt recycled water. Educating industrial users about current and projected water availability might also elucidate the need and inspire participation. Another plausible approach is to raise bulk rates of treated Lake Michigan water. This would keep the option of a Lake Michigan supply open to industrial users, who would have to contribute more in order to access it. With higher bulk rates for treated drinking water, recycled water would present a dependable, lower-cost alternative. Such an approach could also work in tandem with a graduated water tax that sets higher industrial rates for bulk treated drinking water and lower rates for recycled water.

In the case of the Edward C. Little Water Recycling Facility in El Segundo, California, industrial users contribute to the capital costs of the recycled infrastructure maintenance and construction projects.[92] The Chevron, PBF Energy, and Marathon refineries thereby secure a stable water supply in the midst of California's megadrought. Similarly, industrial users in Joliet and the Grand Prairie Water Commission could contribute directly to the capital costs of water-recycling infrastructure in order to secure both the desired quantity and desired quality of water. This approach has the advantage of lowering the project's overall costs and alleviating some of the infrastructure cost burden on residents.

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[91] Wisconsin v. Illinois, 449 U.S. 48 (1980); Randy Conner, "Department of Water Management 2021 Budget Hearing, Remarks of Randy Conner, Commissioner," CDWM, November 2020, https://www.chicago.gov/content/dam/city/depts/obm/supp_info/2021Budget/DepartmentStatements/DWM.pdf.

[92] Between March 1, 2021, and August 31, 2023, the City of Torrance, the Torrance Refining Company (PBF Energy), and the West Basin Municipal Water District entered a tripartite agreement for the delivery of nitrified and low- and high-pressure boiler-feed recycled water. Moggia, 2021 Annual Comprehensive Financial Report.

Economic, Environmental, and Social Considerations of a Decentralized Water Recycling Approach

In the previous section, we lay out our short-term proposal to institute water recycling in the northeastern Illinois region using a decentralized, point-of-use treatment approach. Under this approach, MWRD would keep its existing wastewater treatment capabilities and deliver treated wastewater to Joliet and the Grand Prairie Water Commission for industrial users. In this section, we discuss the benefits and costs of adopting this approach relative to the baseline scenario of the existing agreement to construct a single pipeline. We consider a broad range of factors, including economic, environmental, and social benefits.

In addition to the Stickney Water Reclamation Plant, we assessed the Calumet Water Reclamation Plant (CWRP) as a potential source of recycled water. Figure 9(b) shows the potential alignment of a recycled water pipeline connecting CWRP to the Eugene Sawyer Purification Plant (ESPP) pipeline route. CWRP could meet Joliet's industrial water demand and provide better quality water.

There is significant potential for water reuse in Cook County based on MWRD's seven waste reclamation plants' treated wastewater data. Table 1 shows that treated wastewater from Calumet, O'Brien, Egan, Kirie, and Hanover Park WRPs has the potential to be reused for Urban Reuse (restricted), Agricultural Reuse (processed food crops and nonfood crops), Impoundments (restricted), Environmental Reuse, and Industrial Reuse with or without minimum additional treatment.[93]

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[93] Urban reuse (unrestricted) is use of recycled water for non-potable applications in municipal settings where public access is not restricted (e.g., toilet flushing, air conditioning, irrigation of parks, golf courses, residential landscaping, school yards). Urban reuse (restricted) is the use of recycled water where public exposure is controlled, such as irrigation of highway medians and subsurface irrigation. Agricultural reuse (food crops) is the use of recycled water to irrigate food crops intended to be eaten raw. Agricultural reuse (processed food crops and non-food crops) is the use of recycled water to irrigate crops that are processed before consumed, and irrigation of non-food crops (e.g., seed, industrial, processed food, fodder, orchard). Impoundment (unrestricted) is the use of recycled water in an impoundment in which no limitations are imposed on body-contact water recreation activities (some states categorize snowmaking). Impoundment (restricted) is use of recycled water in an impoundment where body contact is restricted (some states include fishing and boating). Environmental reuse is the use of recycled water to create, enhance, sustain, or augment water bodies, including wetlands, aquatic habitats, or stream flow. Industrial reuse is the use of recycled water in industrial applications and facilities, power production, and extraction of fossil fuels.

Table 1. Comparison of Treated Wastewater Quality (Averages from January to December 2021) at MWRD's Seven WRPs with the USEPA Guidelines for Different Water Reuse Applications.

Water Quality Parameter	USEPA Guideline Limit	Treated Water Quality at Seven MWRDGC Plants						
		Stickney	Calumet	O'Brien	Egan	Kirie	Hanover Park	Lemont
Urban Reuse (Unrestricted): The use of recycled water for non-potable applications in municipal settings where public access is not restricted (toilet flushing, air conditioning, irrigation of parks, golf courses, residential landscaping, school yards)								
pH	6.0–9.0	7.1	7.2	7.1	7.2	7.4	6.8	7.3
BOD (mg/L)	≤ 10	<6	7	5	5	3	5	9
NTU	≤ 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coli (cfu/100 mL)[94]	None	9306	17	67	15	8	9	10859
Chlorine (mg/L)	1 (min.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Urban Reuse (Restricted): The use of recycled water where public exposure is controlled. Irrigation of areas such as highway median, and subsurface irrigation								
pH	6.0–9.0	7.1	7.2	7.1	7.2	7.4	6.8	7.3
BOD (mg/L)	≤ 30	<6	7	5	5	3	5	9
TSS (mg/L)	≤ 30	<5	5	4	3	2	4	7
Fecal Coli (cfu/100 mL)	≤ 200	9306	17	67	15	8	9	10859
Chlorine (mg/L)	1 (min.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Agricultural Reuse (Food Crops): The use of recycled water to irrigate food crops that are intended to be eaten raw								
pH	6.0–9.0	7.1	7.2	7.1	7.2	7.4	6.8	7.3
BOD (mg/L)	≤ 10	<6	7	5	5	3	5	9
NTU	≤ 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coli (cfu/100 mL)	None	9306	17	67	15	8	9	10859
Chlorine (mg/L)	1 (min.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A

[94] Geometric mean of reported January–December 2021 data. This applies to numbers for fecal coliforms anywhere in this table.

Agricultural Reuse (Processed Food Crops and Nonfood Crops): The use of recycled water to irrigate crops that are processed before consumed, and irrigation of nonfood crops (seed crops, industrial crops, processed food crops, fodder crops, orchard crops, etc.)								
pH	6.0–9.0	7.1	7.2	7.1	7.2	7.4	6.8	7.3
BOD (mg/L)	≤ 30	<6	7	5	5	3	5	9
TSS (mg/L)	≤ 30	<5	5	4	3	2	4	7
Fecal Coli (cfu/100 mL)	≤ 200	9306	17	67	15	8	9	10859
Chlorine (mg/L)	1 (min.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Impoundments (Unrestricted): The use of recycled water in an impoundment in which no limitations are imposed on body-contact water recreation activities (some states categorize snowmaking)								
pH	6.0–9.0	7.1	7.2	7.1	7.2	7.4	6.8	7.3
BOD (mg/L)	≤ 10	<6	7	5	5	3	5	9
NTU	≤ 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coli (cfu/100 mL)	None	9306	17	67	15	8	9	10859
Chlorine (mg/L)	1 (min.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Impoundments (Restricted): The use of recycled water in an impoundment where body contact is restricted (some states include fishing and boating)								
BOD (mg/L)	≤ 30	<6	7	5	5	3	5	9
TSS (mg/L)	≤ 30	<5	5	4	3	2	4	7
Fecal Coli (cfu/100 mL)	≤ 200	9306	17	67	15	8	9	10859
Chlorine (mg/L)	1 (min.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Environmental Reuse: The use of recycled water to create, enhance, sustain, or augment water bodies, including wetlands, aquatic habitats, or stream flow								
Variable but not exceed:								
BOD (mg/L)	≤ 30	<6	7	5	5	3	5	9
TSS (mg/L)	≤ 30	<5	5	4	3	2	4	7
Fecal Coli (cfu/100 mL)	≤ 200	9306	17	67	15	8	9	10859
Chlorine (mg/L)	1 (min)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Industrial Reuse (Once-through Cooling)								
pH	6.0–9.0	7.1	7.2	7.1	7.2	7.4	6.8	7.3
BOD (mg/L)	≤ 30	<6	7	5	5	3	5	9
TSS (mg/L)	≤ 30	<5	5	4	3	2	4	7
Fecal Coli (cfu/100 mL)	≤ 200	9306	17	67	15	8	9	10859
Chlorine (mg/L)	1 (min.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Industrial Reuse (Recirculating Cooling Towers)								
pH	6.0–9.0	7.1	7.2	7.1	7.2	7.4	6.8	7.3
BOD (mg/L)	≤ 30	<6	7	5	5	3	5	9
TSS (mg/L)	≤ 30	<5	5	4	3	2	4	7
Fecal Coli (cfu/100 mL)	≤ 200	9306	17	67	15	8	9	10859
Chlorine (mg/L)	1 (min.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Groundwater Recharge (Non-potable Reuse)								
Site Specific								
Groundwater Recharge (Indirect Potable Reuse)								
pH	6.5–8.5	7.1	7.2	7.1	7.2	7.4	6.8	7.3
TOC (mg/L)	≤ 2	N/A	8	6	10	7	11	N/A
NTU	≤ 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coli (cfu/100 mL)	None	9306	17	67	15	8	9	10859
Chlorine (mg/L)	1 (min.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Meet Drinking Water Standards								

Based on data from Metropolitan Water Reclamation District, 2021.[95]

[95] MWRD, "Final Effluents"; EPA, 2012 Guidelines for Water Reuse, 2012, https://www.epa.gov/sites/default/files/2019-08/documents/2012-guidelines-water-reuse.pdf.

Benefits of the Approach

Remaining Within Lake Michigan Diversion Limits

The US Supreme Court sets Illinois's limits for drinking water and canal allotments from Lake Michigan at a 40-year average of 2.1 billion gallons a day (bgd), or 3,200 cubic feet per second (cfs).[96] The average diversion from 1981 through 2015 was just under 2 bgd, just 86.6 mgd shy of the limit.[97] The court decree also has an average diversion annual limit of 3,680 cfs, which has been exceeded three times, even though only twice is allowable. The state also exceeded the absolute annual maximum diversion of 3,680 cfs in WY93 (water year 1993).[98]

Groundwater demand from Joliet in 2018 was 15.3 mgd and 19.3 mgd for all GPWC members (except for Crest Hill). The maximum daily demand for GPWC members in 2050 is projected to be approximately 55 mgd.[99] These demand figures presented in Table 2 include industrial users who source their water from these municipalities. Chicago has agreed to supply Joliet and its customers a water supply within the range of 30-95 mgd.[100] If Joliet and GPWC hit the upper end of this range, then the diversion limit will be quickly met. Even though this might not happen immediately, outsized demand for Lake Michigan water exists across Illinois, and the diversionary limit must be kept in mind.

Table 2. Total 2018 Sandstone Demands from Communities in the Grand Prairie Water Commission (GPWC) and Industries in the Region.

Municipality	2018 Water Demand (MGD)
Channahon	0.5
Joliet	15.3
Minooka	0.6
Romeoville	2.1
Shorewood	0.8
Total	19.3

Based on data from Illinois State Water Survey, 2020.[101]

[96] This threshold inextricably binds decisions about drinking water and wastewater.
[97] "Water Management and Diversion Accounting Activities: 2021 Annual Report." US Army Corps of Engineers, February 2022, https://www.lrc.usace.army.mil/Portals/36/docs/divacct/annual/LRC_WM_Annual_Report_2021.pdf.
[98] The US Geological Survey defines water year as the 12-month period October 1, for any given year through September 30, of the following year. "Explanations for the National Water Conditions," US Geological Survey, 2016, https://water.usgs.gov/nwc/explain_data.html.
[99] This number is based on Scenario 13, which does not include Lemont. See Table 2-6 in City of Crest Hill et al., "Preliminary Agreement."
[100] City of Chicago and City of Joliet, "Preliminary Agreement."
[101] Abrams and Cullen, Analysis of Risk to Sandstone Water Supply. Crest Hill is excluded because it relies on the shallow rather than deep sandstone aquifer that is the focus of the ISWS report. Additionally, industries refers to those industries in the municipalities listed in Table 2 as well as all the municipalities in the study region, which includes the Southwest Water Planning Group (SWPG) members: Elwood, Channahon, Joliet, Lemont, Lockport, Minooka, Romeoville, Shorewood, Crest Hill, New Lenox, Plainfield, Frankfort, ExxonMobil, INEOS–Flint Hills, and LyondellBasell.

The entirety of these industrial water demands can be met by recycled water from the Stickney WRP. Based on the reported data, the average discharge of treated wastewater at Stickney was 610 mgd in 2021 and 714 mgd in 2022 (January–September); hence, the Stickney plant can supply enough treated wastewater for industrial use in Joliet and to cover other industries in the larger GPWC region. The dual pipeline will effectively expand the supply of water available in the region. In particular, this expanded supply will help Illinois remain within its allowance for diversion from Lake Michigan. Although we have not been able to establish the exact nature of the consequences for exceeding diversionary limits, our proposal would ensure that Illinois stays within diversionary limits and avoids any potential penalties.

A New Revenue Stream

We specifically recommend that MWRD wholesale treated wastewater to the Chicago Department of Water Management. No matter the wholesale price, MWRD gains a stream of revenue in place of incurring costs to treat and discharge wastewater. CDWM, in turn, should include recycled water in its allocation to Joliet and the GPWC members, as well as to any community that requests water in the future.

In many cases, water recycling is incentivized through a lower cost than drinking water. This means that industrial or agricultural users pay a substantially lower rate for recycled water, which makes it more cost-effective than other source water. In some cases, this lower rate is subsidized by higher costs for sewage. Lower costs for bulk water can further balance costs incurred when a given industry needs to install on-site treatment to achieve a water quality fit for their needs.

In our case, according to its 2022 budget, the MWRD allocated $239.6 million to collecting, storing, and treating wastewater from combined sewer systems.[102] More than half of the maintenance and operation budget is allocated to the Stickney WRP (Table 3) and the area it serves.

[102] The MWRD maintains and operates its facilities by collecting and treating wastewater through operation of its seven WRPs, intercepting sewers, and TARP. MWRD, 2022 Budget, December 2021, https://mwrd.org/sites/default/files/documents/2022_FINAL_Budget_Book_Web_Version_After_Optimizing1.pdf.

Table 3. 2022 Metropolitan Water Reclamation District (MWRD) Maintenance and Operation Budget.

Allocation	Dollars ($)
Treatment	37,382,312
Collection	27,466,360
Solids Processing	31,879,638
Solids Utilization	18,822,216
Flood & Pollution Control	1,459,675
General Support	2,740,099
Total	119,768,300

Based on data from MWRD, 2021.[103]

Currently, the Stickney WRP discharges treated wastewater into the Sanitary and Ship Canal. This protects Lake Michigan water quality, but it also represents a significant loss of water and potential revenue. Instead, treated wastewater should be delivered to users – in this case, industrial users in the Joliet area. Converting treated wastewater into a rate-bearing water source would help satisfy growing water needs in northeastern Illinois and introduce a new stream of revenue for MWRD.

For MWRD, pricing recycled water at a lower price than drinking water to encourage adoption is a cogent strategy to scale operations. To this end, as part of the MWRD's resource-recovery initiatives, on August 31, 2017, the MWRD Board of Commissioners authorized the sale of treated wastewater for $1.00 per 1,000 gallons (adjusted as warranted according to market conditions).

It could also remain the case that CDWM-supplied municipalities maintain their markups even when recycled water constitutes part of their total supply. In that case, pricing may not be affected by the increase in supply due to water recycling. Rate structures could remain as they are and cause no disruption to the budgets of municipal drinking water suppliers. No matter the ultimate price set on recycled water by CDWM or other municipalities who buy it, MWRD can offset its budgetary costs with a new stream of revenue from wholesaling recycled water.

Curbing Nutrients

Reducing discharge into waterways through water recycling can prevent increasing levels of cyanobacteria while balancing Chicago metropolitan flooding and inland groundwater depletion. Incorporating recycled water into new Lake Michigan allocations, including Joliet and the GPWC, will reduce the nutrient load from MWRD into bodies of water. Nitrogen and phosphorus constitute part of human and animal waste. Sewage, particularly when untreated and discharged during a rain event, contains high levels of nitrogen

[103] The MWRD maintains and operates its facilities by collecting and treating wastewater through operation of its seven WRPs, intercepting sewers, and TARP. MWRD, 2022 Budget, December 2021, https://mwrd.org/sites/default/files/documents/2022_FINAL_Budget_Book_Web_Version_After_Optimizing1.pdf.

and phosphorus, which spike growth of blue-green algae that can bloom and overtake the water. As they decompose, the algae consume the small amount of oxygen in water, preventing other plants and animals from surviving. Their decomposition can also release toxic compounds such as microcystin.[104] The pairing of algae blooms and oxygen depletion can create a dead zone in otherwise living water. Urban flooding in a rain event spikes these processes and their toxic effects.

Cities inevitably have high nutrient levels in wastewater because of their dense population. But the negative impacts of these nutrients occur across multiple geographies. Along with contributions from wastewater, suburbs contribute high levels of nutrients (e.g., nitrogen and phosphorus) due to landscaping that relies on fertilizers. In rural communities, industrial agriculture and concentrated animal feeding operations (CAFOs) for mass production of meat, eggs, and dairy spike nutrient levels that overflow into water. Harmful algal blooms in rural waterways result from runoff after the rain peels off nutrients in manure and fertilizer from the fields where they were applied. This has resulted in dead zones in water bodies such as the Illinois River[105] and Lake Michigan's Green Bay.[106]

The Chicago Sanitary and Ship Canal connects with the Des Plaines River then the Illinois before merging with the Mississippi River (Figure 10), already coursing with nutrients from these multiple landscapes. All contribute to a dead zone in the Gulf of Mexico which has reached the size of the State of New Jersey.

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[104] "Cyanobacteria and Cyanotoxins: Information for Drinking Water Systems," EPA, September 2014, https://www.epa.gov/sites/default/files/2014-08/documents/cyanobacteria_factsheet.pdf; "Cyanobacteria Blooms FAQs," National Center for Environmental Health, https://www.cdc.gov/habs/pdf/cyanobacteria_faq.pdf.

[105] The Illinois EPA confirmed the presence of the algal toxin microcystin at levels 12 times higher than the federal standard along the northern bank of the Illinois River. Kim Biggs, "Illinois Officials Confirm Algal Bloom on Portions of the Illinois River," Illinois EPA, June 17, 2021. https://www2.illinois.gov/epa/about-us/Documents/News%20Releases/2021/06.17.21%20HAB%20Illinois%20River-Final.pdf.

[106] Although Green Bay contains less than 2% of the total water volume of Lake Michigan, it represents one-third of the entire nutrient runoff that flows into the lake. Lee Berquist and Mark Hoffman, "As Dead Zones Choke the Waters of Green Bay, Controlling What Washes Off the Land Proves a Costly Challenge," Pulitzer Center, December 18, 2019, https://pulitzercenter.org/stories/dead-zones-choke-waters-green-bay-controlling-what-washes-land-proves-costly-challenge.

Figure 10: From the Chicago Sanitary and Ship Canal to the Gulf of Mexico.

Source: Illustration by David Wilson in Havrelock and Blackburn, 2020.[107]

Shifting societal orientations toward waste can produce beneficial products through nonextractive means. By employing advanced treatment techniques, water recycling can produce high-quality water free of nutrients and other contaminants. Implementing sophisticated treatment and disinfection techniques also presents the perfect opportunity to harvest minerals from wastewater. In this way, a wastewater treatment plant can become a productive site that yields water, energy, and essential minerals through closed-loop processes. Implementing large-scale water reuse provides the perfect occasion for MWRD to upscale its harvesting and upgrade its treatment technologies to address additional emerging contaminants.[108]

MWRD has already begun to lead the way through wastewater harvesting that yields a vital product.[109] MWRD teamed up with Ostara Nutrient Recovery

[107] Havrelock and Blackburn, "What to Do with the Chicago River?"

[108] Brian Chaplin, cofounder of Zyvant Research and Innovation and UIC professor, has developed a reactive electrochemical membrane that can destroy PFAs in water with 99% efficiency. Jelena Radjenovic, Nick Duinslaeger, Shirin Saffar Avval, and Brian P. Chaplin, "Facing the Challenge of Poly- and Perfluoroalkyl Substances in Water: Is Electrochemical Oxidation the Answer?" Environmental Science and Technology 54, no. 23 (2020): 14815–29, https://doi.org/10.1021/acs.est.0c06212; Marisa Sloan, "CEOs Discuss New Approaches for PFAS Destruction." Medill Reports, October 20, 2020, https://news.medill.northwestern.edu/chicago/ceos-discuss-new-approaches-for-pfas-destruction/. In March 2023, the US EPA introduced regulation for PFAS in drinking water, https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

[109] Kari Lydersen, "3 Environmental Groups to Sue Water District," New York Times, March 5, 2011, https://www.nytimes.com/2011/03/06/us/06cncpulse.html.

Technology for the world's biggest harvest of nutrients from wastewater.[110] In a massive closed loop, Ostara harvests phosphorus and nitrogen at the Stickney WRP to create Crystal Green fertilizer. As a continuous-release fertilizer, Crystal Green boosts the growth of plants without overloading them with nutrients or relying on a petrochemical base.[111] It activates roots without excess nutrients that run into waterways during rain. In short, nutrients, previously dispensed at a high cost, are now a socially beneficial product that brings revenue back into MWRD.

The harvesting process models beneficial reclamation of waste that can address shortfalls from unforeseen circumstances. For example, global fertilizer supply and prices were disrupted in 2022 due to the Russian invasion of Ukraine and the resulting sanctions.[112] Wastewater treatment plants across the globe should begin harvesting nutrients for fertilizer as MWRD does. Repurposing the elements of wastewater also can allow the MWRD to anticipate regulation of other emerging contaminants, such as PFAS and microplastics.[113] Treatment technologies can remove these contaminants in order to produce safe water.[114] In this way, the world's largest wastewater agency can become the world's largest resource-recovery enterprise.

Redirecting water in pipelines and curbing nutrient load can alleviate downstream flooding. "In 2019 the Midwest experienced its worst series of flood events on record all along the Mississippi, Missouri, and Platte Rivers killing three people, affecting some 14 million, and costing the region an estimated $6.2 billion according to the National Oceanic and Atmospheric Administration."[115] As rivers were swelling, the Greater Chicago area continued to divert its wastestream downriver because there was no alternative. There is minimal storage for treated wastewater, and MWRD plants must discharge it to open more space in TARP. Acting otherwise would exacerbate urban flooding and combined sewer overflow. Diverting some treated wastewater through pipelines to industrial end users can help to mitigate flooding.[116] The Fourth National Climate Assessment projects further increases in precipitation and flooding, meaning that a productive destination for rain must be found.[117]

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[110] Allison Fore, "The Metropolitan Water Reclamation District of Greater Chicago and Ostara to Open World's Largest Nutrient Recovery Facility," MWRD, May 18, 2016, https://mwrd.org/sites/default/files/2019-04/160518_MWRD_nutrient_recovery_facility.pdf.

[111] Kaine Korzekwa, "Study Shows Struvite Good Phosphorus Source for Crops," Phys.org, February 14, 2022, https://phys.org/news/2022-02-struvite-good-phosphorus-source-crops.html.

[112] Ruhi Soni, "Fertilizer Sector Set for Biggest Profits in Years on Russia-Ukraine Conflict," Reuters, May 2, 2022, https://www.reuters.com/business/fertilizer-sector-set-biggest-profits-years-russia-ukraine-conflict-2022-05-02/.

[113] Michael Hawthorne, "Sewage Sludge Contaminated with Toxic Forever Chemicals Spread on Thousands of Acres of Chicago-Area Farmland," Chicago Tribune, July 31, 2022, https://www.chicagotribune.com/news/environment/ct-pfas-sludge-illinois-farmland-20220731-7xqijchadfhilbvkut3ndw5uja-story.html. In March 2023, the US EPA introduced regulation for PFAS in drinking water, https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

[114] It is well known that COVID-19 can be found in wastewater. Importantly, "there is no information to date that anyone has become sick with COVID-19 because of direct exposure to treated or untreated wastewater" and "the virus that causes COVID-19 is inactivated by the disinfection methods used in wastewater treatment." "How COVID-19 Spreads," Centers for Disease Control and Prevention, https://www.cdc.gov/socialmedia/syndication/405380/403327.html.

[115] "The Future of Water Reuse: Midwest States Poised for Growth," Bluefield Research.

[116] "USA – Floods in Illinois and Michigan after Days of Heavy Rain," FloodList, May 19, 2020, https://floodlist.com/america/usa/floods-illinois-michigan-may-2020.

[117] D. R. Reidmiller, C. W. Avery, K. E. Easterling, K. E. Kunkel, K. L. M Lewis, T. K. Maycock, and B. C. Stewart, Impacts, Risks, and Adaptation: Fourth National Climate Assessment, vol. 2 (Washington, DC: Global Change Research Program, 2018), nca2018.globalchange.gov.

Accommodating Regional Growth

In a state and metropolitan region of apparent water abundance, dwindling groundwater supplies may not seem perilous when alternative water sources exist. But the Chicago metropolitan area is expected to grow by 2.3 million residents and add 900,000 jobs by 2050. Owing to water conservation and efficiency practices, CMAP projects overall water demand to increase by only 1% from 2013 to 2050.[118] Around 1.47 million of the projected new residents and 470,000 jobs are predicted in groundwater-dependent communities, where water supply concerns are most pressing.[119] In the eleven-county metropolitan area, Lake Michigan supplies 85% of all water used for public supply.[120]

Among the water sources that supply northeastern Illinois, withdrawals are expected to decline only from Lake Michigan while increasing for the Fox and Kankakee Rivers, other rivers, and aquifer sources. However, regulatory, financial, and technical barriers can prevent a community from switching water sources.[121] For example, regulations that cap diversion of Lake Michigan water, infrastructure costs, and ecological concerns all limit the capacity for a community to adopt its water as alternate supply. All water bodies, including Lake Michigan, can become exhausted by rising temperatures and extensive diversion.[122] Therefore, every diversion decision must be made in light of climate change projections and cumulative stress on the given water body. Great Lakes diversion expert Peter Annin takes depletion of the freshwater Aral Sea as an example in admonishing Greater Chicago for its drain on Lake Michigan.[123]

Availability of water is key to sustaining food production and supporting growth in jobs, housing, and amenities. Therefore, increasing the total amount of water available through technologies such as water recycling correlates with both population and economic growth. Our water-recycling framework fits into a larger plan for sustainable economic development. Immediate gains for Chicago include turning a massive waste stream into rate-bearing water and anchoring resource-recovery hubs at existing water reclamation plants and industrial corridors.

Environmental Sustainability

As part of its program for an alternative water supply, Joliet established a "Strategy for Sustainable and Resilient Design" (based on the Institute for Sustainable Infrastructure's (ISI) Envision framework) that includes five categories of sustainability and resiliency priorities: quality of life, leadership, resource allocation, natural world, and climate and resilience. A recycled water

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[118] CMAP, Changing Water Demand: Projecting Water Use in the Chicago Region to 2050 (Chicago: CMAP, 2019).
[119] CMAP, Changing Water Demand.
[120] The eleven-county region includes Boone, Cook, DeKalb, DuPage, Grundy, Kane, Kankakee, Lake, McHenry, and Will. IDNR, Drought Preparedness.
[121] CMAP, Changing Water Demand.
[122] The Colorado River is among the most dire examples; there, declines driven by unsustainable demand have drained three-quarters of the nation's largest reservoirs (Lake Mead and Lake Powell). Such declines have prompted water cuts for farmers and a potential threat to hydroelectric power supply in the region. See J. Partlow and K. Brulliard, "US Announces More Water Cuts as Colorado River Hits Dire Lows," Washington Post, August 17, 2022.
[123] Peter Annin, The Great Lakes Water Wars (Washington, DC: Island Press, 2018).

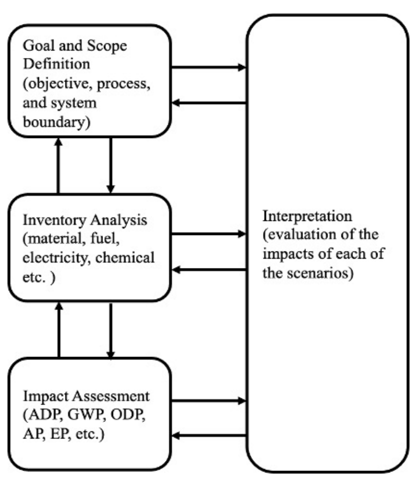
supply helps to achieve these priorities, particularly "resource allocation."[124] These priorities include preserving water resources and reducing operational water consumption through the efficient use of Lake Michigan supply. In immediate terms, water recycling contributes to conservation goals by reducing strain on the lake, and it can be economically profitable for the MWRD. In addition, water recycling can support the natural world priority of reducing wastewater discharge into local waterways and the climate and resilience priorities by expanding the availability of water supply. Water recycling also supports 9 of the 17 UN Sustainable Development Goals, which address drinking water supply, sanitation, and environmental sustainability.

It is worth noting that pump stations play a critical role in transporting the recycled water from the treatment plants to the Southwest Pumping Station/ Durkin Park. There are currently pump stations located at SWRP and CWRP. However, further analysis may be needed to determine their feasibility and capacity for meeting the current and future demands. As part of our future tasks, we will carry out a thorough analysis to assess the existing pump stations and determine if new infrastructure will be needed to ensure the reliable and efficient delivery of recycled water to the end-user. For sustainability assessment analysis, a typical energy required by a pump is assumed.

Water recycling can provide a sustainable, resilient water supply for Joliet. This preserves freshwater resources, has less of a harmful impact on the environment, is economically profitable for the MWRD, and meets Joliet's water needs. Our proposal also supports 9 of the 17 UN Sustainable Development Goals, which address drinking water supply, sanitation, and environmental sustainability.

To reach this conclusion, we conducted an environmental sustainability assessment to quantify the broader environmental benefits that can be realized by water recycling. We considered three scenarios for the Chicago-Joliet water agreement:

Figure 11. Life Cycle Assessment Framework for Environmental Sustainability Assessment.



Based on ISO14040 International Organization for Standardization, 2006.[125]

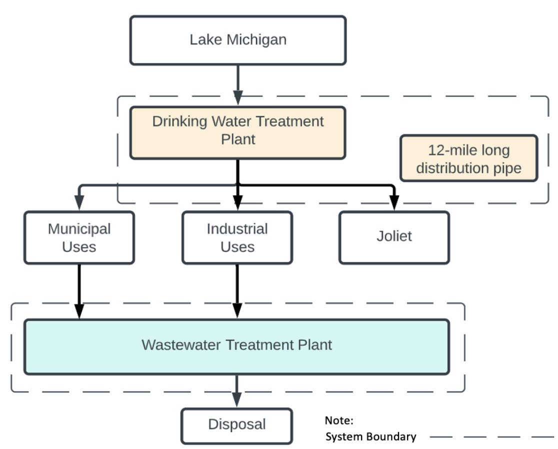
[124] "Alternative Water Source Program: Strategy for Sustainable and Resilient Design." Rethink Water Joliet, https://www.rethinkwaterjoliet.org/_files/ugd/3961f7_ead2d17af030410681ad7dfea37dcc1c.pdf.
[125] ISO 14040; Environmental Management-Life Cycle Assessment, Principles and Guidelines.

- *Scenario A*—the current water use cycle from the water treatment process, delivery to users, wastewater treatment process, and disposal.
- *Scenario B*—supplying water to Joliet's industries with recycled water from Stickney WRP as is.
- *Scenario C*—supplying recycled water to industrial and other non-potable uses in Joliet with recycled and disinfected water from Stickney WRP.

We base our environmental sustainability assessment on the standard life cycle assessment (LCA), per ISO 14040[126] and ISO 14044 (Figure 11).[127] ISO 14040 clearly describes the LCA practice, applications, and constraints; ISO 14044 includes guidance on life cycle inventory analysis, impact assessment, LCA interpretation, data gathering, and quality concerns. The LCA methodology includes (1) goal and scope definition, (2) inventory analysis, (3) impact assessment, and (4) interpretation (Figure 11). For the analysis, the product's life is considered from cradle to gate, meaning that the entire life cycle of the product process from treatment plants to disposal is considered.[128] In this study, impacts were assessed using SimaPro and ecoinvent 3.0 databases.The first step of an LCA is to determine the system boundary, which consists of the unit processes or activities to be included in the study. We defined these as follows:

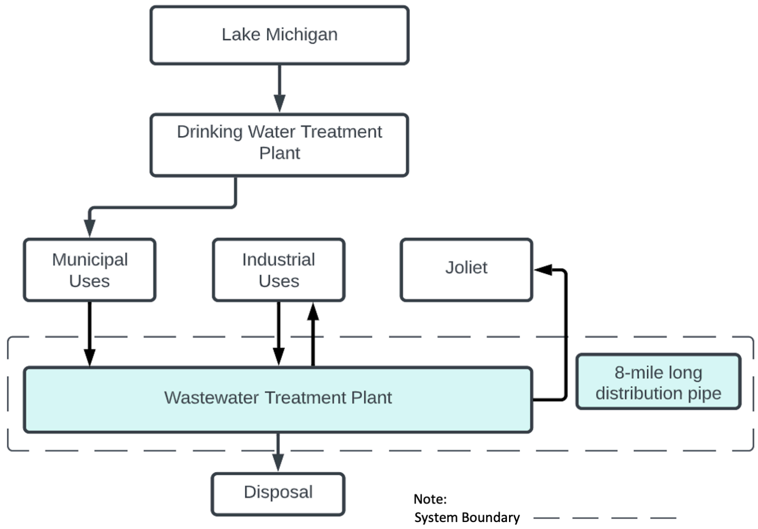
- Scenario A (no reuse) includes a water treatment process, wastewater treatment process, and an approximately 12-mile distribution pipe from Eugene Sawyer Purification Plant to Southwest Pumping Station/ adjacent to Durkin Park, as depicted in Figure 12(a).
- Scenario B (reuse) includes a wastewater treatment process and an approximately 8-mile distribution pipe from Stickney WRP to Southwest Pumping Station/Durkin Park, as depicted in Figure 12(b).
- Scenario C (reuse with disinfection) includes a wastewater treatment process, UV disinfection, and an 8-mile distribution pipe from Stickney WRP to Southwest Pumping Station/Durkin Park, as depicted in Figure 12(c). We assume a UV disinfection for this sustainability assessment only; further sustainability assessments should be conducted for other disinfection treatment technologies.

Figure 12. Diagram of Scenarios:
(A) Current Water Use Scenario Considering Joliet–Chicago Agreement,
(B) Reuse Scenario, and
(C) Reuse Scenario with Disinfection.

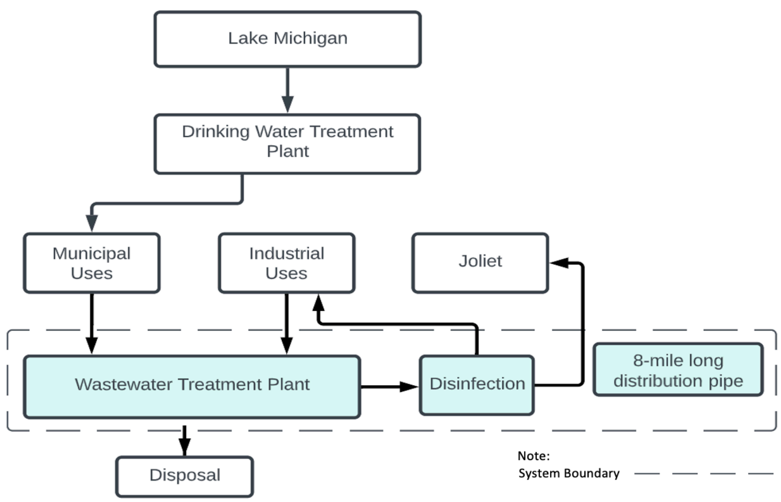


(a) Scenario A

[126] International Organization for Standardization (ISO), ISO 14040; Environmental Management-Life Cycle Assessment, Principles and Guidelines. International Organization for Standardization: Geneva, Switzerland, 2006.
[127] ISO 14044.
[128] Krishna R. Reddy, Claudio Cameselle, and Jeffrey A. Adams, Sustainable Engineering: Drivers, Metrics, Tools, Engineering Practices, and Applications (Newark, NJ: John Wiley & Sons, 2019).



(b) Scenario B

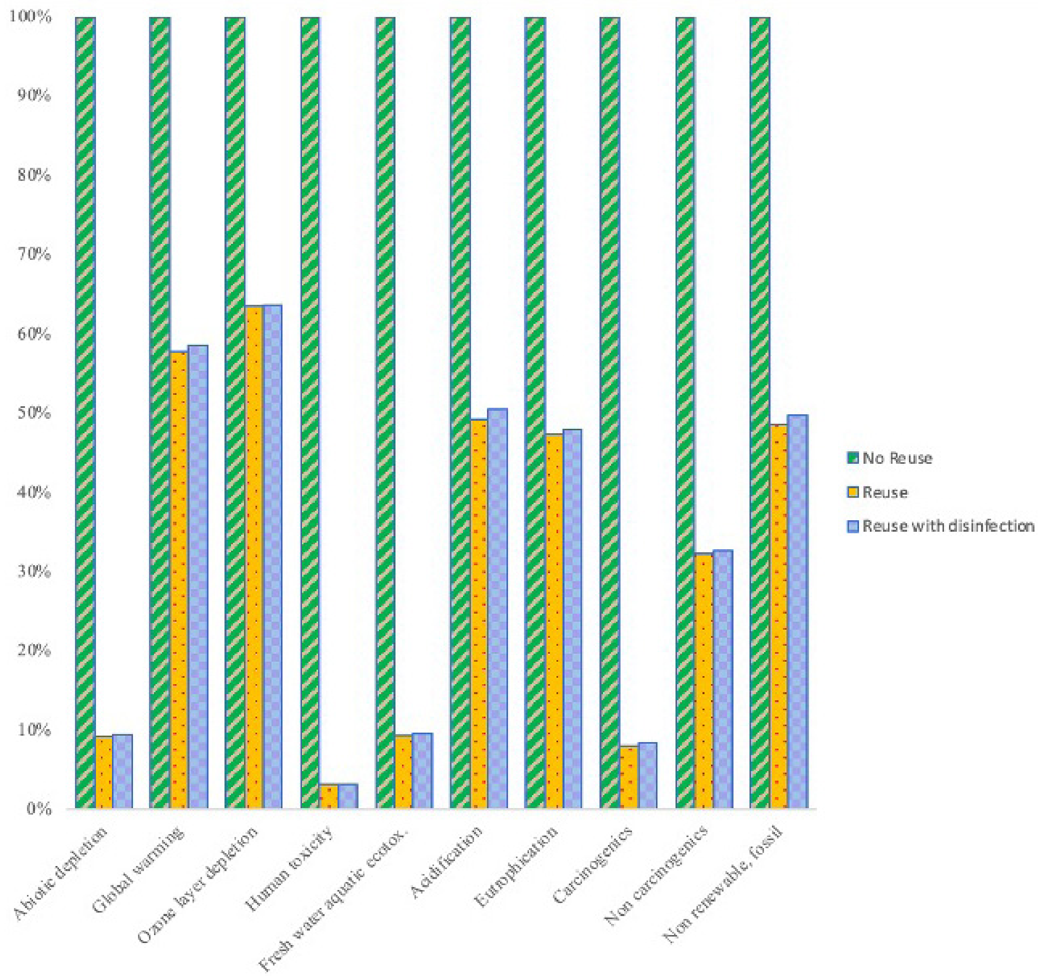


(c) Scenario C

Based on the LCA results, the treatment and delivery of every 1 million gallons of water in Scenario B (reuse) can reduce the following: 91% of antimony equivalents of abiotic depletion, 42% of carbon dioxide equivalents of global warming potential, 36% of trichlorofluoromethane equivalents of ozone layer depletion (contributes to reducing stratospheric ozone depletion), 97% of 1,4 dichlorobenzene equivalents of human toxicity potential (refers to exposure and effects of toxic chemicals on the human environment), 91% of 1,4 dichlorobenzene equivalents of freshwater aquatic ecotoxicity potential (refers to impact on freshwater ecosystems), 51% of sulfur dioxide equivalents of acidification potential for soils and water.

Scenario C (reuse with disinfection) yields slight increase in environmental impacts as compared to scenario B due to augmentation of disinfection in the treatment process. Water reuse, with or without disinfection, can significantly reduce the environmental impact of the current scenario (no water reuse applications) by 36% to 97% (Figure 13). Overall, water recycling is the most environmentally sustainable option.

Figure 13. Environmental Impact Comparison between Scenario A (No reuse), Scenario B (Reuse), and Scenario C (Reuse with disinfection).



Based on SimaPro result and Ecoinvent 3.0 databases.

We also monetized the reduction in carbon emissions using the Social Cost of Carbon, by which each ton of carbon dioxide emission imposes societal costs of approximately $185.[129] We estimate that the benefits of water recycling are on the order of $11,000 for every 1 million gallons of treated water.

Sources of Funding

Recently available federal funding can support the design and implementation of the infrastructure needed to build a dual pipeline to supply recycled water to Joliet. Illinois will receive more than $148 million from the federal Bipartisan Infrastructure Law to fund water infrastructure improvements through its State Revolving Fund (SRF).[130] This is in addition to the $79 million in regular funding for the Illinois SRF program regularly accessed by the MWRD.

[129] "Social Cost of Carbon More than Triple the Current Federal Estimate, New Study Finds," Resources for the Future, https://www.rff.org/news/press-releases/social-cost-of-carbon-more-than-triple-the-current-federal-estimate-new-study-finds/.

[130] Allison Lippert, "Biden-Harris Administration and EPA Announce Delivery of Historic Water Infrastructure Funding from the Bipartisan Infrastructure Law to Illinois," EPA, October 11, 2022. https://www.epa.gov/newsreleases/biden-harris-administration-and-epa-announce-delivery-historic-water-infrastructure-15.

Evidently, such funding is crucial for Joliet. In March of 2022, for example, Representative Lauren Underwood (IL-14) secured $3.5 million for Joliet to replace aged leaking water mains.[132] Being granted an allocation of Lake Michigan water requires replacement of leaky pipes in order to have less than 10% nonrevenue water (from leaks and spills).[133] Other communities that want to procure Lake Michigan water will need funding for similar purposes.

Another funding source is the EPA's Water Infrastructure Finance and Innovation Act (WIFIA), a federal credit program that provides long-term, low-cost loans for regionally and nationally significant projects, including for water recycling.[134] Supplying water to a region crucial to the production and transport of goods nationwide, and reducing the amount of wastewater discharged into the Gulf of Mexico is certainly of regional and national significance. The EPA has also provided over $6 million in grants and other funding to institutions researching the sources, applications, and barriers to water reuse.[135] The grantees seek to accelerate adoption of water recycling in rural communities and use wastewater-based epidemiology to understand pathogen loading, microbial risk, and chemical risk reduction for reuse applications.

The federal Support to Rehydrate the Environment, Agriculture, and Municipalities Act (STREAM) is another promising funding source. If passed, this act aims to authorize $300 million for water reuse projects to help communities generate water supplies for drinking, irrigation, restoration, and other uses.[136]

In addition to federal funding, new revenue streams can enable infrastructural maintenance and improvement. Turning the pure costs of storing, treating, and removing effluent and precipitation combined in sewers into rate-generating water is such an additional stream of revenue.

Costs of the Approach

Infrastructure Costs

When it comes to water supply, conveyance infrastructure constitutes the highest cost. This influences our central recommendation for transferring recycled water as part of a dual-pipeline system with drinking water and recycled water. Water infrastructure is expensive to build, routing can be

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[131] Lauren Underwood, 14th District of Illinois, "Underwood, White House Infrastructure Coordinator Mitch Landrieu Announce New Bipartisan Infrastructure Law Funding for Illinois Communities to Ensure Safe Drinking Water," October 13, 2022, https://underwood.house.gov/media/press-releases/underwood-white-house-infrastructure-coordinator-mitch-landrieu-announce-new.

[132] City of Crest Hill et al., "Preliminary Agreement."

[133] "WIFIA Program," EPA, June 2022, https://www.epa.gov/system/files/documents/2022-06/wifia-onepager.pdf.

[134] "National Priorities: Water Innovation, Science and Engagement to Advance Water Reuse Grants," EPA, October 5, 2022, https://www.epa.gov/research-grants/national-priorities-water-innovation-science-and-engagement-advance-water-reuse-1.

[135] "WateReuse Celebrates Introduction of Water Reuse Funding Bill," WaterWorld, May 26, 2022, https://www.waterworld.com/drinking-water/infrastructure-funding/press-release/14277233/watereuse-celebrates-introduction-of-water-reuse-funding-bill.

challenging due to the existing built environment (e.g., roadways, bridges, buildings) and underground utilities, and inertia can hinder a switch by industries if they are not in immediate peril of losing supply. For this reason, we suggest leaving current in-basin and suburban industries as they are but creating lines of recycled water supply where new conveyance infrastructure is under construction.

We present two sources of recycled water for Joliet, one originating from the Stickney WRP and one originating from the Calumet WRP. Both can utilize the same easement as the Chicago-Joliet freshwater pipeline (Southwest Pumping Station/Durkin Park to Joliet). Using the same easement would result in no additional land acquisition costs for the approximately 30-mile stretch. The option from the Stickney WRP would require an additional 8.2 miles of pipe from the Stickney WRP to the Southwest Pumping Station/Durkin Park which will incur easement costs. Taking those costs per mile of new easement as proportional to the estimated easement cost from the Southwest Pumping Station/Durkin Park to Joliet, we estimate these costs to be approximately $752,566 for the new 8.2-mile stretch of pipe. For the option from the Calumet WRP, we estimate the easement costs to be approximately $1,101,317 for the new 12-mile stretch of pipe.

We derive our projected costs for construction and piping from estimates for transferring drinking water from Southwest Pumping Station/Durkin Park to Joliet, estimated as part of a feasibility study commissioned by the City of Joliet.[136] The approximately 30-mile stretch of pipes with 60 mgd capacity has an estimated cost of $285,563,000 for transmission mains and appurtenances; this estimate includes a 25% contingency budget for unanticipated costs. Assuming that the transmission main costs for recycled water will be the same for this new pipeline, we use the per-mile cost of pipe estimated for Southwest Pumping Station/Durkin Park to Joliet to calculate the cost of the Stickney WRP and the Calumet WRP options. We estimate the additional 8.2 miles of pipeline needed from the Stickney WRP at $78,053,881 and the additional 12 miles of pipeline needed from the Calumet WRP at $114,225,192.

Technology Considerations for Water Reuse

Under our current proposal for the dual pipeline, industrial facilities should expect to adopt recycled water. Industrial facilities would therefore bear the cost of treating the water to meet their needs. The choice of technology they adopt to do so (e.g., on-site water treatment systems) will depend on several factors, including the particular water quality standards they require and the quality of the treated wastewater they receive.[137] In evaluating technology considerations for a particular industry, standard practice would be to assess costs using a model technology that would treat water to a set of prescribed standards. Given that we are evaluating feasibility for a broad array of industrial users with different treatment requirements, this approach is not feasible. We

[136] City of Joliet, "Basis of Design Attachment D."
[137] Aidan Francis Meese, David J. Kim, Xuanhao Wu, Linh Le, Cade Napier, Mark T. Hernandez, Nicollette Laroco, et al., "Opportunities and Challenges for Industrial Water Treatment and Reuse," ACS ES&T Engineering 2, no. 3 (2021): 465–88.

instead discuss a range of potential treatment technologies to accommodate the broad range of industries and their different needs.

Wastewater treatment technologies can be designed specifically to treat certain contaminants in the wastewater to better fit the final uses of recycled water. Different treatment technologies have been developed and have proved to be effective in achieving the desired water quality for various reuse purposes, particularly in treating contaminants such as fecal coliforms, total suspended solids, total dissolved solids, biochemical oxygen demand, nephelometric turbidity unit, chlorine (all listed in the EPA's water reuse guidelines). Table 4 summarizes these treatment technologies. Treatment technologies or unit processes such as secondary treatment, depth filtration, surface filtration, microfiltration, ultrafiltration, and dissolved air flotation are suitable to treat suspended solids. Disinfection, depth filtration, surface filtration, microfiltration, nanofiltration, reverse osmosis, and advanced oxidation are fit to treat fecal coliforms. Nanofiltration, reverse osmosis, electrodialysis, and ion exchange can be used to degrade dissolved solids in wastewater.

Table 4. Unit Operations and Processes to Remove Different Constituents in Water Reuse Applications.

Constituent Class	Suspended Solids	Dissolved organic matter	Total Dissolved Solids	Bacteria	Protozoan cysts and oocysts	Viruses
Secondary Treatment	✓	✓	-	-	-	-
Secondary with nutrient removal	-	✓	-	-	-	-
Depth filtration	✓	-	-	✓	✓	-
Surface filtration	✓	-	-	✓	✓	-
Microfiltration	✓	-	-	✓	✓	-
Ultrafiltration	✓	-	-	✓	✓	✓
Dissolved Air Flotation	✓	-	-	-	✓	✓
Nanofiltration	-	✓	✓	✓	✓	✓
Reverse Osmosis	-	✓	✓	✓	✓	✓
Electrodialysis	-	-	✓	-	-	-
Carbon adsorption	-	✓	-	-	-	-
Ion exchange	-	-	✓	-	-	-
Advanced Oxidation	-	✓	-	✓	✓	✓
Disinfection	-	✓	-	✓	✓	✓

Adapted from Asano, 2007.[138]

[138] Takashi Asano, Water Reuse: Issues, Technology, and Applications (New York: McGraw-Hill, 2007), https://www.accessengineeringlibrary.com/content/book/9780071459273.

Treated wastewater produced at all of MWRD's WRPs meets federal standards and regional regulations for discharge into canals (Stickney and Lemont), channels (O'Brien), rivers (Calumet and Hanover Park), and creeks (Egan and Kirie). Depending on the exact nature of the use, this suggests that treated wastewater from any of one MWRD's WRPs can be reused with little to no additional treatment. Nevertheless, there is an opportunity for improvement within the WRPs that are currently not required to disinfect their treated wastewater, or that seasonally disinfect it to begin disinfecting all year round. In the State of Illinois, Illinois Administrative Code 35.C.2.378 indirectly affects water reuse in Illinois as it identifies three types of surface waters; (1) Seasonally Protected Water, (2) Year-Round Protected Waters, (3) Unprotected Waters. In seasonally protected water, from May through October fecal coliform counts should not exceed 200 fecal coliforms per 100 mL (Calumet, O'Brien, Egan, Kirie, and Hanover Park WRPs). In year-round protected waters, fecal coliform should not exceed 2,000 fecal coliforms per 100 mL. In unprotected waters, there are no standardized counts for fecal coliforms (Stickney and Lemont). From MWRD's treated wastewater data,[139] it was also found that the TDS concentration at Stickney, Calumet, and Lemont WRPs fall into the "Slight to Moderate" and "severe" degree of restrictions on irrigation reuse. The TDS data are not provided for the other WRPs. Additional treatment for TDS removal may be required at these 7 WRPs if water reuse projects are considered in the future, especially for agricultural applications. The fecal coliform counts were also higher at Stickney and Lemont without disinfection compared to other plants with disinfection technologies (Table 1). Treatment technologies can be selected considering the current water quality, the end uses of recycled water, desired water quality, the existing land availability at these WRPs, and other relevant considerations.

Industrial plants must also consider the capital, operating, worker training, and installation costs associated with a potential on-site water treatment system. Some industrial users may be able to offset some of these costs by engaging with MWRD or other public water systems in the form of a public-private partnership. Doing so would allow them to be eligible for and access funding from federal grants and financing programs that are typically available only to public water systems.[140]

Health Risk Assessment

There is substantial heterogeneity in the quality of water required by industrial users. The quality of the effluent industrial facilities receive, their particular water quality standards they adopt to treat the water, and the ultimate end use may have health and safety implication risks and will determine potential exposure pathways. Although non-potable applications for recycled water that has undergone secondary treatment and disinfection (e.g., industrial cooling) generally pose negligible risk of human exposure,[141]

[139] Average TDS is 692 mg/L at Stickney WRP, 793 mg/L at Calumet WRP, and 1,147 mg/L at Lemont WRP.

[140] Isabella Georgiou, Serena Caucci, Jonathan Clive Morris, Edeltraud Guenther, and Peter Krebs, "Assessing the Potential of Water Reuse Uptake through a Private-Public Partnership: A Practitioner's Perspective," Circular Economy and Sustainability (2022): 1–22.

[141] National Research Council, Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater, National Academies Press, January 10, 2012, https://nap.nationalacademies.org/catalog/13303/water-reuse-potential-for-expanding-the-nations-water-supply-through.

we assess potential occupational health and safety risk factors that would necessitate industrial plants to implement management protocols to ensure worker health and safety.

Our health-based assessment considers precautions consistent with OSHA standards for wastewater practices, described in a variety of regulations, including 29 Code of Federal Regulations (CFR) 1910 for general industries, 29 CFR 1926 Subpart AA for confined spaces, and 29 CFR 1910.1030 for bloodborne pathogen standards (specific to employees in wastewater treatment plants).[142] It should be noted that these precautions represent an upper bound in terms of the costs they would impose on industrial plants since they are primarily applicable to wastewater treatment plant workers who handle untreated raw effluent.

Treating recycled wastewater at industrial facilities may involve contact with the water. Workers may potentially be exposed to chemicals used in water processing and treatment operations and fumes; and microbiological exposures to organisms (e.g., parasites, fungi, viruses, bacteria, or other bloodborne pathogens). Chemical, aerosol, microbiological, and physical health risks may lead to a range of short-term and long-term injuries and illnesses (e.g., skin, eye, respiratory irritation); adverse health outcomes due to chemical or aerosol fume exposures; burns and disfigurement from chemicals or flames; cuts, wounds, and limb loss/accidental amputations from sharp tools and equipment; acute poisoning; accidental drowning (e.g., in treatment ponds, vats, or clarifiers); blunt force trauma due to slips, trips, falls, and being struck or trapped by moving or falling objects; electric shock; and chronic diseases including allergies, dermatitis, and respiratory health outcomes. To be in compliance with OSHA regulations, workers handling effluent must follow recommended practices to minimize potential exposures via use of personal protective equipment (e.g., respirators, gloves, overalls, goggles, face mask, splash-proof face shield, waterproof gloves, boot and shoe covers) to protect workers who handle wastewater from potential inhalation and dermal contact-related exposure agents.

Workers may face other types of health risks, such as exposure to unregulated substances (e.g., pharmaceuticals, endocrine disrupting compounds, nanoparticles/fibers) that are known to be present in wastewater or are anticipated to be present. In this case, further precautions might be taken to ensure worker health and safety. In these circumstances, plant industrial hygienists and occupational health and safety personnel should develop safety protocols to protect workers from potentially harmful exposures. In addition, the industries receiving the recycled wastewater may have their own federal and state OSHA regulations applicable to the industrial sector in which they operate (depending on their 6-digit North American Industry Classification System [NAICS] code). Each industry or plant using the recycled water in operations (e.g., in cooling towers) must comply with the specific OSHA

[142] Title 29: Labor, Code of Federal Regulations § (1994), https://www.ecfr.gov/current/title-29/subtitle-B/chapter-XVII/part-1910.

exposure limits and rules and regulations to ensure health and safety of their workers. A particular note of caution for worker exposures is aerosols generated by the receiving industries that may contain respiratory fractions of bacteria and carcinogenic metal(loid)s, similar to aerosols generated during biological treatment in wastewater treatment plants using oxidation ditch, an extended aeration process.[143]

We recommend collecting relevant additional data to perform a project-specific human health and ecological risk assessment, depending on the intended use of recycled water and identification of specific exposure routes and the receptors. In general, backward risk assessment may be performed to determine the treatment standards for different types of water reuse applications, which can then be used to select appropriate treatment technologies to meet the treatment levels needed to protect human health and the environment.

Additional investigation and collaboration should occur with the Illinois Department of Public Health. As part of MWRD's 2017 resource-recovery initiative, the Illinois Department of Public Health (IDPH) committed to taking the lead on the regulatory aspects of water reuse. According to the 2017 arrangement, a request letter must be sent to IDPH detailing any proposed recycled water use for each specific use/user. IDPH then determines whether the proposed use is acceptable and imposes any restrictions necessary to safeguard the public. In the case of MWRD's supply to Joliet and the Grand Prairie Water Commission, it makes optimum sense to include IDPH in deliberations and to collaboratively establish a regulatory framework for the project as a whole, as well as for specific end users.

[143] T. Yang, Y. Han, J. Liu, and L. Li, "Aerosols from a Wastewater Treatment Plant Using Oxidation Ditch Process: Characteristics, Source Apportionment, and Exposure Risks," Environmental Pollution 250 (2019): 627–38, https://doi.org/10.1016/j.envpol.2019.04.071.

Topics for Future Exploration

The City of Chicago's Lake Michigan water supply is likely to face pressure in the coming years because of increasing water demand from communities throughout Will, Kendall, Kane, and DuPage counties. In this report, we have laid out a dual-pipeline proposal for a decentralized, point-of-use approach to serve industry in the Joliet region with MWRD-recycled water. Our next phase of work will build the constituency and raise funds to materialize this plan. Our next phase of research will consider treatment technology advancement and how existing plants can grow into resource-recovery hubs. We hope to close the water loop by always deriving use from waste and thereby reducing the need for extraction. We will simultaneously explore the cost pressures placed on water rate payers by new infrastructure and conceive tangible solutions to ease them.

Toward a Centralized Vision of Water Recycling

The immediacy of groundwater collapse in northeastern Illinois and the imminent construction of a treated drinking water pipeline from Chicago to Joliet influenced our proposal to build a recycled water pipeline as part of the project. Initiating a wholly new infrastructure project entails a number of hurdles. In contrast, our dual-pipeline proposal coincides with a major water infrastructure project that will be built in less than a decade. The pipeline from Chicago to Joliet will be built because it is necessary for the third-largest city in Chicago to remain viable. As much as we seek to sustain the Joliet region with Chicago water, we look to make provision for the full range of communities who are soon to find themselves without a dependable source of water.

This decentralized proposal, developed in light of the Illinois State Water Survey's modeling of acute water emergencies, is one step along the way to a larger transformation of waste management into resource recovery. Our next phase of research will pursue specific recommendations for working with MWRD to adapt its seven WRPs into state-of-the-art water-recycling facilities that harvest minerals and capture biogas.[144] Similar to the five varieties of "designer" water produced in El Segundo, California, we recognize the potential for MWRD's seven plants to each produce a specific grade of water tailored to meet particular non-potable and even potable uses.

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[144] Biogas and solar energy generation can constitute part of centralized resource recovery: "West Basin's Water Recycling Facility also houses a 60,000 square foot solar power generating system that has reduced emissions of carbon dioxide by over 356 tons in one year's time. These emissions reductions are equivalent to planting nearly 100 acres of trees or not driving 890,007 miles." "Facilities," West Basin Municipal Water District, https://www.westbasin.org/water-supplies/recycled-water/facilities/.

For example, producing water fit for irrigation could advance agricultural production and food security. Although our initial inquiry focused on supply to the agricultural sector, we discovered more pressing scenarios of water scarcity in counties closer to Chicago. Supply within northeastern Illinois has the advantage of shorter distribution lines which are less costly. Nevertheless, devoting some MWRD capacity to water for irrigation remains a sound plan, as does reaching standards for potable water in the name of emergency supply and a wide range of other uses. The WRPs that serve industrial areas (Stickney, Lemont, and Calumet) are best positioned to recycle water for industrial and certain commercial uses. Adaptation of WRPs in this way can anchor green industry and spur innovation in water reuse. As discussed above, MWRD's successful harvesting of nitrogen and phosphorus for Crystal Green fertilizer indicates the wide social value of a closed-loop approach to wastewater. Beyond these nutrients, a range of metals can be harvested from wastewater and repurposed in ways that introduce additional streams of revenue.[145]

Shifting societal orientations toward waste can produce beneficial products through nonextractive means. Repurposing the elements of wastewater at state-of-the-art water-recycling plants also offer a way to anticipate regulation of emerging contaminants.[146] Treatment technologies, based on scientific studies involving a wide range of emerging contaminants in water, can remove these contaminants in order to produce safe water. The world's largest wastewater agency can become the world's largest resource-recovery enterprise.

Capturing biogas, a clean energy source, factors among the benefits of extending water treatment plants to full-scale resource-recovery hubs. Upgrading water treatment facilities and extending them to full recycling can provide the occasion to implement biogas capture and resource reclamation from wastewater. Sourcing energy in this manner builds on legislative scaffolding in the State of Illinois, primarily the Climate and Equitable Jobs Act (CEJA), which seeks to improve and scale production through renewable energy. By 2050, the act will direct Illinois to 100% renewable and carbon-free energy.[147] To work toward these goals, the Illinois Commerce Commission will expand aid programs, initiatives, and directives to support a responsible transition away from carbon-intensive energy while creating green jobs and remediating communities.

The MWRD has already begun to source biogas from wastewater. According to its draft Climate Action Plan, in 2020 the MWRD produced 1,104,400 million British thermal units (Btu) of biogas, which accounts for 25% of MWRD's energy needs.[148] The MWRD currently utilizes over 90% of the biogas generated at four of its water reclamation plants (Hanover, Stickney, Calumet, and Egan) for process heat and to heat and cool buildings. In this way, the MWRD has

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[145] Madhu Agarwal and Karam Singh, "Heavy Metal Removal from Wastewater Using Various Adsorbents: A Review," Journal of Water Reuse and Desalination 7, no. 4 (2017): 387–419.
[146] Hawthorne, "Sewage Sludge."
[147] Illinois Clean Jobs Coalition, Support SB2408: A Comprehensive Climate and Equitable Jobs Act, September 9, 2021, http://ilcleanjobs.org/wp-content/uploads/2021/09/SB2408-Bill-FactSheet_-9.9.2021.pdf.
[148] MWRD, "Climate Action Plan of the Metropolitan Water Reclamation District of Greater Chicago," November 19, 2021.

reduced 50,000 metric tons of carbon dioxide equivalents from electrical usage, 172,000 from new settling tanks at the Stickney WRP, 17,000 from biosolids land application for crops, and 5,000 from planted trees. In order to provide 100% of MWRD's energy needs (average electricity usage 675,495,822 kWh per year and an assumed average demand of 77 MW) through biogas, anaerobic digester capacity would need to increase between 38-117%.

Augmenting capacity for biogas capture is important for the region's energy requirements because the available infrastructure and digester feedstock needed to produce biogas is currently insufficient. MWRD has plans to increase production with contracts in place to increase biogas recovery at the Stickney and Hanover Park WRPs. Plans include installing co-firing boilers that allow two types of fuels to be burned at once, thereby improving and increasing biogas utilization. A combined heat and power system is also to be installed at the Egan water reclamation plant by 2024. There is further potential to increase biogas production throughout the Midwest because hydrogen can be produced from it.[149] However, possible environmental impacts to surrounding communities limit rapid upscaling of biogas production. Notably, three of the four MWRD WRPs with digesters are located in environmental justice communities, which experience disproportionate environmental harms or risks. Plans for biogas capture must include consideration of the extent to which increased air pollution, odors, and traffic can add to the cumulative burden of environmental justice communities.[150]

The Affordability Challenge

Any large-scale infrastructure project has implications for taxpayers and utility bill payers and can exacerbate existing affordability issues. Water affordability refers to a drinking water provider's effort to offer reasonably priced water to the community while still receiving the revenue needed to maintain water system operations. However, affordability fluctuates on the basis of the median income of particular communities as well as the money available to particular households. Because an affordable water bill for a high-income earner looks very different from one for a low-income earner, affordability experts increasingly recommend a graduated approach to water rates.

In the Great Lakes region, average water rates grew by 80% and water bill growth outpaced income growth in 78% of communities in northeastern Illinois between 2008 and 2018.[151] According to the City of Joliet's estimations, the

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[149] One way to produce hydrogen is to use electrolysis, a method that uses an electric current to split water into oxygen and hydrogen. Electrolysis is an alternative technology that can be used to purify water for reuse purposes (water recycling). If a renewable energy source is used to produce the electric current, it can be considered green hydrogen. A. K. Chopra, Arun Kumar Sharma, and Vinod Kumar, "Overview of Electrolytic Treatment: An Alternative Technology for Purification of Wastewater," Archives of Applied Science Research 3, no. 5 (2011): 191–206; Cecilia Harris, "Hydrogen Energy Demands Could Be Met with Wastewater," Australian Water Association, September 10, 2021, https://www.awa.asn.au/resources/latest-news/technology/innovation/hydrogen-energy-demands-could-met-wastewater.
[150] To increase digester capacity, additional high-strength organic matter would need to feed to the digesters on the order of a hundred tank trucks a day.
[151] "Water Affordability: A Growing Challenge," Elevate, January 18, 2022, https://www.elevatenp.org/water/water-affordability-a-growing-challenge/.

Chicago pipeline will require annual increases in resident water bills until at least 2040, an unfavorable scenario for 13% of residents who live below the federal poverty line.[152] Spreading costs in a regional commission reduces the overall bill for any one community; however, residents will still see significant increases in the cost of water. Average monthly water bills are estimated to more than double from $34 in 2021 to $75-$79 in 2030.[153]

The impact of rising water bills should be considered in socio-demographic contexts. Joliet is the most populous municipality in Will County, accounting for 22% of its overall population.[154] Between 2000 and 2020, Will County and Joliet saw a 43% and 35% growth in housing units, respectively.[155] In 2021, the median household income in Joliet was $76,495 compared to $93,752 in Will County (Table 5).[156] While this median income may be high relative to certain municipalities, moderate-income families in Joliet spent 57% of their income on housing and transportation costs in 2012-2016.[157] What remains will be reduced by costlier water bills. Additionally, most of Will County's population is non-Hispanic-White (60%) while more than half of Joliet's population is composed of non-Hispanic Black and Hispanic or Latino (16% and 34%, respectively).

Table 5. Economic Characteristics of Joliet and Will County

Economic Characteristics	*Joliet*	*Will County*
Median Household Income	$76,495	$93,752
Less than $10,000	5.2 %	3.7 %
$10,000 to $14,999	2.2 %	2.0 %
$15,000 to $24,999	6.0 %	4.2 %
$25,000 to $34,999	5.7 %	5.1 %
$35,000 to $49,999	9.9 %	8.9 %
$50,000 to $74,999	20.0 %	16.4 %
$75,000 to $99,999	14.5 %	12.8 %
$100,000 to $149,999	20.6 %	22.5 %
$150,000 to $199,999	8.9 %	11.5 %
$200,000 or more	7.1 %	13.1 %
Percent in Poverty	12.6 %	8.0 %

Data from American Community Survey, 2021.[158]

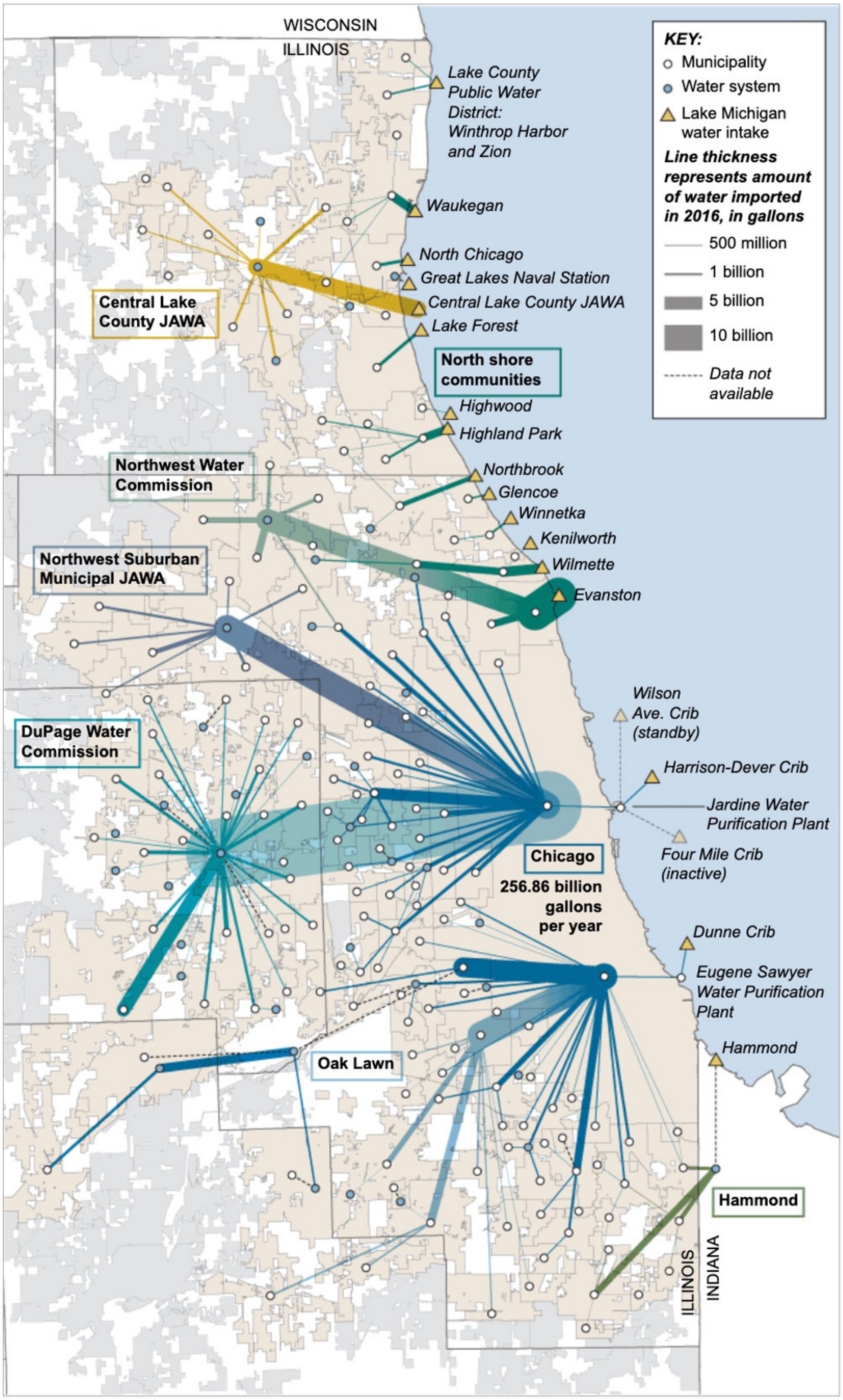
[152] Nearly 13% of Joliet residents live below the poverty line. US Census Bureau, 2021 American Community Survey 1-Year Estimates, Table S1701.
[153] Brian Kazyak, Allison Swisher, Joe Johnson, and Theresa O'Grady, "Virtual Stakeholder Meeting," June 17, 2021, https://db3eaa5b-627b-4351-a0d6-a59bfce6a4d6.filesusr.com/ugd/3961f7_9f93dfca74364bf895c87738839a3fbb.pdf.
[154] US Census Bureau, 2020 Decennial Census, Table P1.
[155] City of Joliet, "Data Hub."
[156] US Census Bureau, 2021 American Community Survey 1-Year Estimates, Table S1901.
[157] "Joliet," CMAP.
[158] US Census Bureau, ACS 1-Year Estimates, Table S1901

Water affordability can become compounded in many ways. In Chicago, the cost of water more than tripled between 2007 and 2018. In 2007, the cost of water for a family of four was about $178, and by 2018 it was $576.[159] Money raised through increased rates was not funneled to the CDWM but rather filled other budgetary shortfalls. These increased rates have become increasingly onerous for low-income residents. The burden was compounded between 2007 and 2018 when 150,000 water shutoff notices were issued for nonpayment. Almost 40% of the shutoffs were concentrated in just five of the city's poorest zip codes on the South and West Sides.[160]

Disparities in the experience of water rates are further reflected in data that show how affluent suburbs tend to have lower water bills than low-income suburbs, where bills can be staggering. In some cases, this is because low-income townships are more likely to have privatized waterworks due to their need for cash infusion and to unload the costs of municipal services. Moreover, municipal services are easily covered in higher-income suburbs while they falter in those with shrinking or lower-income populations. According to "The Water Drain" series by the Chicago Tribune, low-income communities of color tend to have the highest, often economically debilitating, water bills (Figure 14-15).[161]

[159] María Inés Zamudio, "Chicago's Water Prices Are Skyrocketing Faster Than Other Great Lakes Cities," WBEZ Chicago, February 14, 2019, https://www.wbez.org/stories/chicagos-water-prices-are-skyrocketing-faster-than-other-great-lakes-cities/69951240-ea15-40c7-a649-5b6787e35b6b.
[160] Zamudio, "Chicago's Water Prices Are Skyrocketing."
[161] Ted Gregory, Cecilia Reyes, Patrick M. O'Connell, and Angela Caputo, "Tribune Investigation: The Water Drain," Chicago Tribune, 2017, https://graphics.chicagotribune.com/news/lake-michigan-drinking-water-rates/index.html.

Figure 14. Distribution of Drinking Water Providers Throughout the Chicago Area.



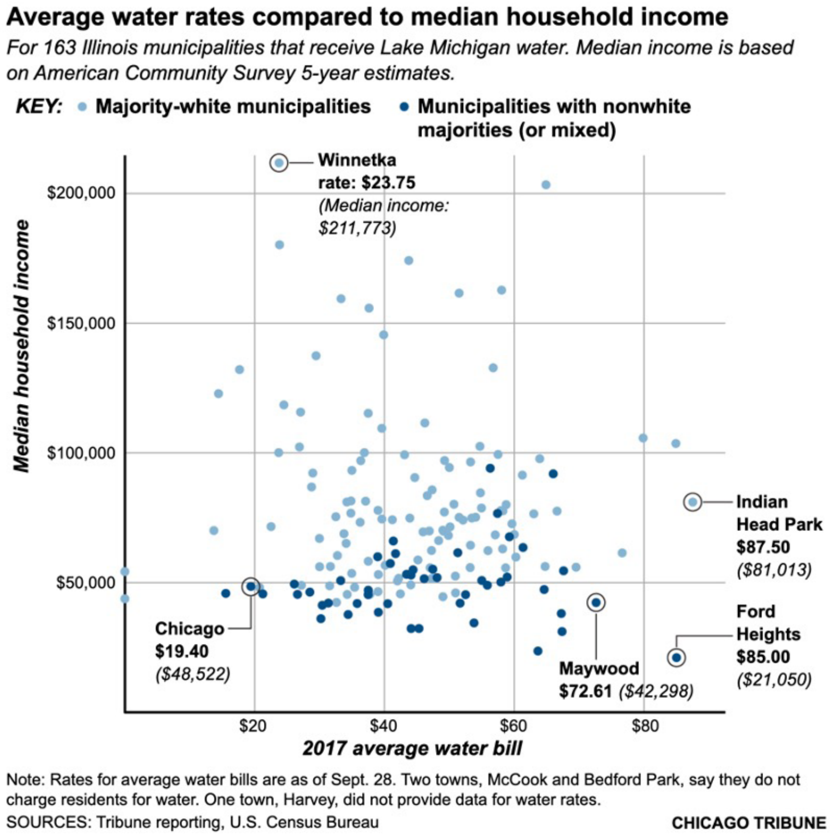
Note: Water import figures are taken from Annual Water Use Audit Forms for 2016, where possible. If figures for imported water are not available for a community, they have been substituted with the total exported to that community from another municipality or water system.

Sources: Tribune reporting, Illinois Department of Natural Resources, Illinois State Water Survey

Chicago Tribune, 2017.[162]

[162] Gregory et al., "Tribune Investigation."

Figure 15. Average Water Rates Compared to Median Household Income, by Municipality.



WBEZ Chicago, 2019.[163]

Many suburban municipalities find themselves caught in a situation where the expectation for steady services conflicts with a general aversion to higher taxes. One way municipalities raise revenue while not stoking anti-taxation ire is to use water as an enterprise fund. Although cases exist where water meters are installed and households can adopt conservation measures to lower bills, most people cannot control their water use or moderate their bills. The irreducible human need for water puts its cost in a category of its own and places questions of supply in ethical and humanitarian contexts. At once, practical issues of operation mean that funds must come from somewhere. This paradox of pricing throws up a barrier to MWRD's direct supply of treated wastewater to industrial end users at a competitive price because municipalities often count on the rates of bulk users in their overall budgets. Our proposal addresses this aspect of the paradox by recommending public-public partnerships between MWRD and drinking water utilities such as the Chicago Department of Water Management. MWRD's wholesale of water to CDWM makes the water department whole while introducing a new stream of revenue into MWRD.

The affordability challenge persists when it comes to the implications of large-scale infrastructure projects on water rates. For example, the new infrastructure necessary for the network of water supply (both the single and dual-pipeline plans) promises to be costly for Joliet and GPWC members. These costs will devolve to residents whose water bills cover a

[163] Zamudio, "Chicago's Water Prices Are Skyrocketing."

large portion of infrastructure financing. As municipalities such as Joliet take action for a new source of water, there is also a need to distribute the cost of infrastructure among stakeholders to keep rates as low as possible for water utility customers.[164] This means that new water infrastructure projects must integrate policies around water affordability and equity to support low-income households.

Addressing the affordability challenge of our dual-pipeline plan requires investigation of the proper water rates for industrial users and of the degree to which public-private partnerships for infrastructure development should be part of the financing. We also need to consider possibilities for joining policies of supply increase through recycled water with a graduated water pricing structure.

Costs associated with a centralized system of water recycling that requires infrastructure upgrades and installation of new technology could further exacerbate the lack of water affordability. The scale of the affordability problem and its potential solutions are beyond the scope of this report. However, we emphasize that water affordability must be a central consideration in order for water recycling, a dual-pipeline system, and centralized resource-recovery hubs to meet with success in an equitable and fair manner. In the next stage of our work, we intend to deeply engage affordability implications of water recycling in conjunction with pricing strategies that could alleviate the burdens of high water rates.

The Next Phase of Our Work

Our next phase of work involves building a coalition to actualize strategies for water recycling, including:

- Metropolitan Water Reclamation District of Greater Chicago
- Chicago Department of Water Management
- City of Joliet
- Municipalities in the Grand Prairie Water Commission
- Illinois Department of Natural Resources
- Illinois Department of Public Health
- State of Illinois Water Reuse Task Force
- Office of the Illinois Governor

We are also planning to conduct research in several outstanding areas:

- Water affordability implications
- Strategies for partnership with industry
- Water quality needs of the industries to be served by recycled water
- Identifying ideal health and safety standards for the respective uses of recycled water

[164] A common way to price water is through a rate that allocates funds for necessary infrastructure, maintenance, and operation.

- Municipal responses to the dual-pipeline system for water supply
- Further research on a centralized approach to water recycling, e.g., specific technologies for a centralized approach to resource recovery, including centralized disinfection, expanded treatment technologies
- Scenario planning around future idealized water systems in northeastern Illinois that accounts for demographic changes, climate migration, and growth in water supply planning
- Potential use of wastewater for agriculture and other non-potable reuse.
- Economic and job creation impacts of the construction and operation of new infrastructure and facilities.

Conclusion

Places with greater availability of water and sites of perennial flooding, including northeastern Illinois, should become water-recycling hubs. Technologies and uses for recycled water are advancing rapidly in response to global water stress. Acute water scarcity propels major water infrastructure efforts forward with the drive to support life outweighing cost concerns. Due to the relative water abundance in the Great Lakes watershed and the diversion limits of the Great Lakes Compact, water recycling remains under-examined in this part of the world.

As an exception to the Great Lakes Compact, the Chicago area already transfers its wastewater out of the basin through the Chicago Sanitary and Ship Canal. This contributes to downstream nutrient loading as it loses potentially valuable forms of water and energy. In light of accelerating depletion of rivers and aquifers, the very classification of water as waste requires reconsideration. Even with its aquatic borders of the Mississippi River and Lake Michigan, the State of Illinois faces profound water supply challenges, most pressingly in communities dependent on the rapidly declining Cambrian-Ordovician aquifer. MWRD can recycle water and deliver it to industrial users in communities requesting new allocations from Lake Michigan. Due to constraints on the amount of water Illinois can extract from Lake Michigan, industrial and other commercial needs in these communities should be met with recycled water. This has the advantage of enlarging the overall water supply so that the highest number of drinking water needs can be accommodated.

Water recycling can correct imbalances of flooding and water scarcity in the case of Chicago's supply to Joliet. Our recommendations can also be implemented wherever there is sizable water need in Illinois. In other words, pipelines of recycled water from MWRD water reclamation plants could and should run wherever water supply requires augmentation. Although MWRD has the potential to supply recycled water to industries in Chicago or its suburbs, more substantial cost and policy barriers exist in such cases. Absent a scenario of water scarcity, there is little motivation to build new water infrastructure. For this reason, we tie construction of recycled water pipelines to the development of new supply mains from Chicago. This reduces costs of infrastructure, construction and land acquisition. It also lowers resistance to adoption and supports economic and population growth in water-insecure communities while introducing new revenue for the MWRD. To ensure that municipalities do not throw up barriers to water reuse, MWRD should enter into partnerships with drinking water utilities. Due to capacity, it is likely that the Chicago Department of Water Management will be the main supplier across northeastern Illinois. The partnership between agencies will involve wholesale of recycled water with its pricing determined by the drinking water supplier in conjunction with strategies for widespread water affordability.

The distribution of water across Illinois in order to secure water-stressed municipalities can foster productive relationships among communities in the same state, enabling collaboration on other economic imperatives and additional strategies for climate change adaptation. In this way, our proposal represents an exercise of water diplomacy within a single state. For water delivery and sharing to meet with success, soft infrastructure –durable, long-term partnerships and cross-agency coordination– must develop in parallel to the hard infrastructure. Within the Midwest and United States more broadly, Illinois has an important role to play as a site of adaptation and innovation, as well as a climate haven.

We have addressed multiple simultaneous crises: the need to reduce strains on aquifers in Illinois, the need for productive uses for increased volumes of rain, the need to reduce nutrient inputs into water that cause harmful algal blooms and other environmental impacts, and the need to design new forms of industry and employment that do not pose high risks to human and ecosystem health. In our plans for resource recovery, we outline integrated solutions to meet these challenges.

Our multidisciplinary team considered successful precedents for water recycling in international and US national contexts and the uses to which it is applied. Appraisal of MWRD's current operations and future plans informed our sense of what might be possible in the short and the long term. Consultation with the Illinois State Water Survey informed our understanding of the most pressing water supply challenges in Illinois and affirmed our thesis that water recycling has a vital role to play in securing ample supply for drinking water, industrial use, and future growth. After modeling a number of possible scenarios, we concluded that the Chicago-Joliet agreement offers an ideal case for incorporation of recycled water. Moreover, it represents an unprecedented opportunity for immediate implementation in ways that accrue distributed benefits. To test this hypothesis, we conducted sustainability and health risk assessments and cost-benefit analysis. Although water infrastructure cannot be constructed without costs, we provide a plan to keep them low. The benefits for both parties in the water transfer agreement outweigh the costs of building pipelines.

Chicago, the City of Big Shoulders, has a history of hulking factories and mass production powered by labor and continuous streams of immigration. It achieved greatness in the form of capital, culture, and middle-class stability. It failed with segregation, redlining, and piling industrial wastes on the public while the litterers skipped out on the bill. These currents of history merge in the present, when Chicago and Illinois are bastions of democracy in an increasingly authoritarian age. Broad constituencies in Illinois and Chicago believe in climate change and are equipped to face it with strength, skill, and speed. We have the element essential to thrive – fresh water. We also have industrial-scale water treatment plants that can be updated with cutting-edge technology sourced from Chicago labs and start-ups. Both drinking water and reclamation plants are in need of updating and the distribution system needs reconstruction according to lead and copper-free water standards. The cost of doing so is high, but the cost of not doing so is catastrophic. The benefit is a future in which the Illinois coastline produces the world's best water for multiple uses and supplies it to other municipalities and counties to enable them to flourish. Lake Michigan water will reliably flow through millions of Illinois taps and pipes, attracting enterprise and population to the region as a whole. In addition to public funding and private contribution, future water rates and sales will support the maintenance and operation of state-of-the-art water treatment.

Because water supply has a humanitarian dimension, any rate structure must prioritize water affordability. In addition to its economic nature, the transfer of water is a political act of choosing to ally with a particular group by pledging to sustain them. There is no questioning the bond between Chicago and its collar counties: they are integrated by virtue of geography. As much as Chicago must meet the water needs in its region, inland recipients must play their role. Conservation measures must be adopted and industrial processes reappraised in terms of their waste generation and carbon footprint. A long-term vision for this project is for water recycling to supply resource reclamation hubs and green industrial centers across northeastern Illinois. Such a just transition from fossil fuel to sustainable production can broadly increase well-being through public health benefits and good paying jobs. With water, social stability, and prosperity, Illinois will be an oasis in the center of the United States.

The will and the way to realize a bright future are present in Illinois. Federal, state, county, and city governments have aligned views on water, labor, and climate change adaptation. Water research and advanced technology development are well underway statewide at Illinois public universities. Young Illinoisans from the full range of backgrounds are eager to work toward a sustainable future. We can provide it for them. Recycling water marks an important step that is feasible and actionable.

Appendix A- Barriers and Drivers to Water Recycling Adoption

The following appendix presents policy, economic, social, technical, legal, institutional, regulatory, and environmental barriers and drivers to water recycling. Using a literature review of barriers and drivers, our team discussed barriers and drivers in our case-specific context.

BARRIERS AND DRIVERS[165]

Policy

Barriers

- Policy frameworks that lack openness, lock in regulatory pathways, and are fragmented or contradicting (Lee & Jepson 2020).
- Political leaders that are not unified behind water reuse effort (Tortajada & Nambiar 2019).
- Lack of knowledge of the groundwater emergency and the potential for water reuse among political leaders and the public. Groundwater is out of sight and out of mind, so it can be hard for people to grasp.
- Regulations in Illinois discourage water reuse because of low water quality standards.
- The Chicago Construction Code and Illinois Plumbing Code require that water meet a safe drinking water standard, water reuse needs a special permission under these codes.

Drivers

- Strategies, targets, and guidelines aiming to promote water use (Lee & Jepson 2020).
- The 2017 MWRD policy of supplying reused water with case-by-case approval from the IDPH. (This becomes a barrier if there are certain levels of elements exceeding regulations, which triggers further regulation).

Economic

Barriers

- High initial investment and lack of funding (Lee & Jepson 2020).
- Water affordability for households and sometimes higher cost of reused water relative to other options for non-residential users (Lee & Jepson 2020).
- High cost of infrastructure and how to price reclaimed water to be attractive for potential users. Consumers' willingness to pay will depend on the intended use of the water, the availability of alternatives, and the occurrence of a crisis (Duoung & Saphores 2015).

[165] The information in this table contains barriers and drivers identified in the academic literature (with in-text citations and a bibliography in Appendix C) as well as those identified by our team related to our specific case.

- Economics and lack of funding are the most significant barriers to the adoption of water reuse and recovery practice in the US (Sanchez-Flores, Conner & Kaiser 2016).
- The technology is already there, it is the cost of technology that is a limiting factor.
- Discourse that tends to focus on high costs and skepticism of technology's integrity, an absence of public education efforts (Tortajada & Nambiar 2019).
- Need to educate policy makers, agencies, regulators, customers, and the public (Wong & Gelick 2000).

Drivers

- Subsidies, rebates, tax incentives, and foreign incentives that reduce the cost of reused water, making residents more willing to pay for it and creating incentives for utilities to invest in water reuse (Lee & Jepson 2020).
- Recycled water could be part of a more comprehensive reform of industrial and commercial water rates. Does there need to be a policy mandating industrial users use recycled water, especially if they are building a pipeline from Lake Michigan? Or, industrial users could pay a premium for groundwater or Lake Michigan water to incentivize reuse.
- In Joliet, domestic users are shouldering the cost. There is already a movement to have industrial users pay more or shoulder some of the cost of building the infrastructure.
- Price recycled water lower to incentivize its use.
- Tiered water pricing: industrial water users pay more to receive Lake Michigan water but less for adopting reused water.
- All the energy, materials, and resources from wastewater are wasted. These are indirect costs. The social cost of carbon/carbon footprint can be considered a driver. In addition, there are sustainability benefits from reusing the water.

Technical

Barriers

- Insufficient infrastructure and facilities; inefficient or inconvenient location; and poor maintenance, operation, and monitoring.
- Health risks such as microbial pathogens and pharmaceuticals and personal care products (PPCPs) (Duoung & Saphores 2015).
- Some plants may not have the real estate to increase treatment capacity or adopt a more advanced treatment.
- Delivery infrastructure is also a problem.
- The technologies of MWRD need to be more advanced to do certain processess like reverse osmosis.
- Additional stages of treatment are needed for particular applications and uses.

Drivers

- New treatment technologies that address cost and quality concerns, maintenance, operation, and monitoring of recycled water. (Lee & Jepson 2020).
- There are already a lot of technologies that can treat the water to the level desired and MWRD already has technologies that have many capabilities for reusing water for industrial uses and irrigation.
- MWRD is the second largest landowner in Cook County, so it should be easier to find space for increasing capacity for reuse.
- We have the chance to promote new technology development (perhaps in the context of the University of Illinois Discovery Partners Institute), which could be considered a driver.

Legal and Institutional

Barriers

- Water quality standards that are not specific to reuse, a lack of sufficient guidelines for utilities and water managers, and regulations that restrict adoption.
- It may be the case that some folks are simply using unjustifiable compliance costs as an excuse, however, we need to investigate where these types of complaints are legitimate. Where might compliance expectations need to be tweaked?
- Some of the restrictions, costs, etc. determined by bureaucrats can at times be difficult to implement on the ground.
- Sometimes industries do want to comply, and it would be easy for them to do so if not for red tape or costs that make it impossible. Some regulatory expectations can be a bit unreasonable or unfeasible.
- The demand for complete safety can impose unjustifiable compliance costs, risk-avoidance should be based on reduction of overall risk for public rather than satisfying over specific regulations. (Bixio et al. 2008)
- Clean Water Act (CWA): regulates wastewater discharges, designed to protect downstream users from untreated effluents. (Sanchez-Flores, Conner & Kaiser 2016).
- Safe Drinking Water Act (SDWA): sets maximum contaminant levels or treatment requirements for drinking water, affecting the degree to which reclaimed water can be used for potable reuse. (Sanchez-Flores, Conner & Kaiser 2016).
- Slow regulatory response (Wong & Gelick 2000).

Drivers

- Regulatory requirements to meet water quality or quantity thresholds and institutional cooperation. Centralized governance is more likely to open pathways for reuse (Lee & Jepson 2020).
- The need to meet wastewater discharge regulations or to augment water supply options through water reuse (Wong & Gelick 2000).

- Is the Great Lakes Compact one regulation that could force water conservation measures, which could include water reuse? What about effluent discharge regulations going into the Mississippi River?

Regulatory

Barriers

- The demand for complete safety can impose unjustifiable compliance costs, risk-avoidance should be based on reduction of overall risk for public rather than satisfying over specific regulations (Bixio et al. 2008).
- Clean Water Act (CWA): regulates wastewater discharges, designed to protect downstream users from untreated effluents (Sanchez-Flores, Conner & Kaiser 2016).
- Safe Drinking Water Act (SDWA): sets maximum contaminant levels or treatment requirements for drinking water, affecting the degree to which reclaimed water can be used for potable reuse (Sanchez-Flores, Conner & Kaiser 2016).
- Slow regulatory response (Wong & Gelick 2000).

Environmental

Barriers

- A return to post-drought conditions that reduce political interest in water conservation techniques.
- Illinois water scarcity issues are different from those in the west like the Colorado River or the Ogallala Aquifer drying up.
- The presumption that because we have the Great Lakes (Lake Michigan) we will never run out of water. Ignoring the fact there is a limited amount of Great Lakes water we can use.
- Lack of knowledge and the unseen aspect of groundwater shortages.

Drivers

- Increasing demand, drought, climate change, natural disasters, and other environmental crises that create water scarcity (Lee & Jepson 2020).
- Water supply enhancement and wastewater volume reduction (Wong & Gelick 2000).
- Living in a place with drought conditions has no statistically significant effect on support for reclaimed water use (Garcia-Cuerva, Berglund, & Binder 2016).
- We are already diverting high volumes of this water (single use water, which is an externality for downstream communities). In this case, we are simply closing a loop in a unidirectional flow of wastewater and making it productive in a way that can help our region grow.
- Chicago could feel good about being a water hub for the rest of the state. The water would ultimately be a revenue source where it is currently pure cost.

Social

Barriers

- There is a conception that recycled water is not pure.
- Many people assume that water reuse implies drinking water, which they are less likely to support, leading to opposition.
- People may perceive the cost of water reuse to be higher than it is.

Drivers

- In essence, all drinking water is treated and reused.
- Chicago and other lakefront communities are already selling treated Lake Michigan water to suburbs, Joliet being the farthest the water travels. So, there is already a supply chain from the city to the suburbs.
- Pointing to a One Water framework: the distinction between wastewater and drinking water is artificial. It is unusual that in Chicago there are separate drinking water and wastewater agencies/utilities (people pay separate bills for the two).
- Educate people that reclaimed water can be for uses other than drinking and promote the uses which they are more likely to support.

Appendix B: Necessary Elements for Successful Adoption of Water Recycling

In addition to barriers and drivers, necessary elements for success are strategies and solutions to overcoming the barriers presented in appendix A. We provide findings from the literature broadly followed by takeaways from team discussion of our specific case.

ELEMENTS FOR SUCCESS[166]

Structural, Nonstructural, and Managerial Techniques (Bixio et al. 2008)

Structural:

- High infrastructure requirements to support reuse, namely the extent to which the water is treated. Different uses require different benchmarks for treatment with higher quality requirements for groundwater recharge and potable reuse than for irrigation and industrial use.

Nonstructural:

- Operation and maintenance practices: multiple (independent) barrier system, extensive use of monitoring and sensing techniques, and increased motivation of the operators for more careful routine maintenance and follow up.

Managerial:

- Managerial actions need to include considerations of the local water supply market structure, the structure of the water sector, cost of reclaimed water compared to conventional water, acceptance by end users, and timing of investment cycles.
- The competitiveness of reclaimed water to conventional water must be clearly demonstrated.

Our Case:

- MWRD's preference is to find users for what they have right now.
- It is hard to persuade existing users of Lake Michigan water to switch to MWRD's effluent.
- Groundwater depletion is the main driver to adopt recycled water.
- We can make the case for implementation at the same time infrastructure gets updated or at other moments where it could make sense to switch to reused water (retrofitting).

[166] This section provides in-text citations which have corresponding full citations in Appendix C.

“Yuck” Factor

- Overcome by public education, wide participation by all stakeholders, marketing techniques, and highlighting water scarcity crises (Duoung & Saphores 2015).
- The acceptability of water reuse is inversely proportional to the level of direct exposure and residents are least accepting of water reuse in their own household but more comfortable with its use outside the household (Garcia-Cuerva, Berglund, & Binder 2016).

Cost

- Pricing should be fair for both drinking and reclaimed water (Duoung & Saphores 2015).
- Financial incentives influence residents’ willingness to participate in water reuse, lower water bills would increase the likelihood of participation (Garcia-Cuerva, Berglund, & Binder 2016).

Public Outreach

- Use multiple methods of communication to provide equal access to information and an open, fair, and transparent process to motivate public participation (Duoung & Saphores 2015).
- The need for using reclaimed water should be clearly explained(Duoung & Saphores 2015).
- Reuse projects need the full support of the scientific and health expert communities for public officials to be unified in support (Duoung & Saphores 2015).
- Build and maintain public confidence in water resource management (Hartley 2006).
- Manage information for all stakeholders—provide diverse types of information and ensure equal access.
- To keep individuals engaged and involved, create multiple motives for engagement and show commitment by listening to the public.
- Make water reuse decisions part of the broader water planning in multiple venues and ongoing at all stages of the decision-making process.
- Include criteria that specifically address fairness, trust, and credibility.
- Successful projects have long-term public engagement efforts (Tortajada & Nambiar 2019).
- “Social response is more positive when utilities are trusted; when there’s a relationship between water utility providers with the public; when community, medical, and business groups are involved; when messages are clear, sustained, and consistent; when the focus is on innovations; and when it is guaranteed that potable reused water will be safe and reliable” (Tortajada & Nambiar 2019).
- Emphasize state-of-the-art, cutting-edge, sophisticated, and thorough technology to direct attention to the safety and cleanliness of the water.
- Engender support through education and marketing efforts (Wong & Gelick 2000).

- Emphasize how this project helps MWRD move into its next generation as a resource-recovery agency. This project can provide substance to the goal.
  - » Intensive technology was used to reverse the Chicago River and build the deep tunnel and this is the next phase for large engineering efforts for MWRD.
- Find alignment with CEJA, Illinois Water Reuse Task Force, WRAP, and Infrastructure Act. People and groups who work on these legislations are looking for connections with MWRD.

Regulatory

- Riparian doctrine in the eastern US gives landowners rights to water on their property, wastewater operators are generally able to retain rights to reuse water (Sanchez-Flores, Conner & Kaiser 2016).
- Identify, prevent, and control environmental impacts and health risks (Sanchez-Flores, Conner & Kaiser 2016).

Stakeholder Involvement

- Find partnerships to share costs and make the connection between wastewater and water supply. Need to overcome the traditional institutional barriers that separate wastewater and water supply (Wong & Gelick 2000).
- Work with stakeholders as early as possible and throughout the process, deliberately identifying stakeholders and working with them to address their concerns. Establish different forums to communicate and coordinate with stakeholders (Wong & Gelick 2000).
- Multiple partnerships are necessary for financing, marketing, construction, and maintenance (Wong & Gelick 2000).
- When going from a wastewater treatment plant to a water supply business, it is necessary to establish and develop new relationships with regulatory agencies, cities, water retailers, wholesalers, potential customers, and the public.

System Structure

- Large-scale, centralized systems benefit from economies of scale in management and treatment of costs, but require significant investment in distribution systems (Sgroi, Vagliasindi, & Roccaro 2018).
- Reliance on large volume users supports a more cost-effective design (Wong & Gelick 2000).
  - » Ensures a high flow rate, reduces operational difficulties, allows planners to build for capacity and later attach smaller users.
- Tertiary treatment of water provides broad opportunities for disposal and reuse (Wong & Gelick 2000).

Stakeholders

- Since we are first modeling our proposal for Joliet, the stakeholders should be focused here. We do not need to compile a comprehensive list of all stakeholders in the Chicago region but rather create a comprehensive set of stakeholders for the Joliet case that can serve as a model for identifying the same in other cases. Afterwards, we can focus on other stakeholders in the whole region.
- This approach includes identifying:
  - » major industrial and commercial users in the Joliet region
  - » regulatory agencies and municipalities
    - ◊ what is their decision-making authority and from where does the authority derive?

Framing

- We are taking something that is currently considered waste and reclaiming it in a circular economy to become useful and generate money for the MWRD and CDWM.
- The project supports the framework of "Rust Belt to Water Belt" and "Climate Haven."
- As water dries up in other parts of the country and world, providing an alternate supply allows for the ability to sustain growth and industries and enable suburban and exurban communities to survive.
- Using technology, water reuse provides climate change resilience and the ability to absorb migrants while bringing jobs and industry.

General

- Consider larger water regimes, the existing infrastructure of the water system, and other supply options. Need to intentionally align and coordinate across sectors.
- To build trust, water utilities are expected to demonstrate institutional competence, adhere to robust safety and public health protocols, use independent experts for evaluation purposes, and engage stakeholders in project development (Tortajada & Nambiar 2019).
- Renowned water reuse project in Singapore was supported by the public for its contributions to achieving self-sufficiency and overcoming the need to import water—what are political equivalents in Chicago?
- In Santa Rosa, CA, water reuse was supported by the community because it helps to irrigate an agricultural green belt around the city.

Appendix C: Sources for Barriers and Drivers and Elements for Success

Bixio, D., C. Thoeye, T. Wintgens, A. Ravazzini, V. Miska, M. Muston, H. Chikurel, A. Aharoni, D. Joksimovic, and T. Melin. “Water Reclamation and Reuse: Implementation and Management Issues.” Desalination 218, nos. 1–3 (2008): 13–23.

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Garcia-Cuerva, Laura, Emily Z. Berglund, and Andrew R. Binder. “Public Perceptions of Water Shortages, Conservation Behaviors, and Support for Water Reuse in the US.” Resources, Conservation and Recycling 113 (2016): 106–15.

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Tortajada, Cecilia, and Sunil Nambiar. “Communications on Technological Innovations: Potable Water Reuse.” Water 11, no. 2 (2019): 251.

Van Rossum, Tony. “Water Reuse and Recycling in Canada—History, Current Situation and Future Perspectives.” Water Cycle 1 (2020): 98–103.

Wong, Arlene K., and Peter H. Gleick. “Overview to Water Recycling in California: Success Stories.” Environmental Management and Health, 2000.

Appendix D: List of Industrial Companies in Joliet

SITE
BASF CORP-JOLIET PLT[167]
BP AMOCO CHEMICAL-JOLIET[147]
CATERPILLAR, INC.-JOLIET[147]
OLIN CORP-JOLIET[147]
MIDWEST GENERATION,LLC-JOLIET[147]
EXXONMOBIL OIL-JOLIET REFINERY[147]
JOLIET EAST STP[147]
JOLIET WEST STP[147]
DOW CHEMICAL COMPANY-JOLIET PL[147]
COMMONWEALTH EDISON-JOLIET HQ[147]
JOLIET SAND & GRAVEL CO[147]
VULCAN MATERIALS-JOLIET SO 390[147]
JOLIET AUX SABLE CREEK WWTP[147]
WELSCH JOLIET PLANT[168]
AZZ GALVANIZING SERVICES-JOLIET[148]
LARAWAY RECYCLING & DISPOSAL FACILITY[148]
BLUESTONE SPECIALTY CHEMICALS LLC[148]
ROVANCO PIPING SYSTEMS INC[148]
RHO CHEMICAL CO. INC.[148]
SEELER INDUSTRIES INC[148]
ECOLAB INC.[148]
OZINGA READY MIX CONCRETE INC. - JOLIET[148]
CHROME CRANKSHAFT CO LLC[148]

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[168] EPA, "List of TRI Facilities in Envirofacts," October 19, 2022, https://enviro.epa.gov/enviro/tri_formr_v2.fac_list?rptyear=2021&facopt=fac_name&fvalue=&fac_search=fac_beginning&postal_code=&city_name=Joliet&county_name=&state_code=IL&industry_type=&bia_code=&tribe_Name=&tribe_search=fac_beginning.