HELPING COMMUNITIES PROSPER

ON TO 2050 REGIONAL WATER DEMAND FORECAST FOR NORTHEASTERN ILLINOIS, 2015-50

CMAP

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Acknowledgments

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Jim Angel, Illinois State Water Survey
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Additionally, the project team received advice and data from IDNR Lake Michigan Allocation Program, IEPA, U.S. EPA, Lake County Public Works, Illinois American Water, Utilities, Inc., and Aqua Illinois, as well as several communities across the region.

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Contents

1. Introduction

Communities across the globe face an increasing array of water resource challenges. Growing population, habitat degradation, and climate change continue to challenge the provision of clean, reliable water to residents and businesses. The Chicago region is not immune. Despite access to Lake Michigan, significant portions of the region are already encountering water supply and quality issues. In order to maintain a long-term drinking water supply, the region needs to coordinate and conserve its shared water supply resources. Understanding future demand is a key ingredient of sustainable management. Assessing long-range forecasted demands in the context of available water supply can inform local and regional planners about the sufficiency of water supply and encourage actions that conserve water, protect supply, and/or pursue alternative drinking water sources.

For the ON TO 2050 regional comprehensive plan, the Chicago Metropolitan Agency for Planning (CMAP), in partnership with Illinois-Indiana Sea Grant and University of Illinois Extension, updated the regional water demand forecast to provide decision-makers with more information about current and future water demand. This study reflects the ON TO 2050 Socioeconomic Forecast and provides a long-range water demand forecast for the seven counties of the Chicago region -- Cook, DuPage, Kane, Kendall, Lake, McHenry, and Will.

Methodology

The last regional water demand forecast, *Regional Water Demand Scenarios for Northeastern Illinois: 2005-50*, was completed in 2008 and informed *Water 2050: Northeastern Illinois Regional Water Supply/Demand Plan*. This seminal effort provided the Chicago region with a comprehensive assessment of water demand and shed light on the various water supply and demand challenges facing parts of the region.[1] Additionally, the forecast was used as an input to technical water supply analyses, including the regional groundwater flow model, to better understand potential supply and demand conflicts. Water 2050 stressed the need for water demand management throughout the region to maintain a long-term supply.

With this current effort, CMAP is building on the previous forecast and updating it for the seven-county region.[2] The water demand forecast provides the opportunity to align data with the ON TO 2050 Socioeconomic Forecast,[3] and creates a 35-year projection to the year 2050 in 5-

[1] Previous water demand forecasts include the Northeastern Illinois Planning Commission's 2002 Strategic Plan for Water Resource Management as well as the 1976 Estimated Future Water Supply Demands for Northeastern Illinois report.

[2] The 2008 regional water demand forecast was for the 11 counties of northeastern Illinois, including Boone, DeKalb, Grundy, and Kankakee counties, which are not part of the CMAP region.

[3] CMAP, "ON TO 2050 Socioeconomic Forecast Appendix," 2018, http://www.cmap.illinois.gov/documents/10180/911391/FINAL+Socioeconomic+Forecast+Appendix.pdf/84809136-9d7e-6a9e-f406-ff43c73744eb.

year intervals. As with Water 2050, the ON TO 2050 Regional Water Demand Forecast is a long-range forecast providing water demand information for planning purposes.[4] This update provides the opportunity to improve the methodology in two key ways. First, recent advancements in Illinois Water Inventory Program's wholesale distribution network data provided the opportunity to present the forecast at the municipal scale, in addition to the county and regional scales as was done in Water 2050. Municipal-scale results can make the forecast more tangible for decision makers as they are making planning decisions that affect water demand. Second, the updated methodology provides a transparent approach that can be updated with new data and trends. Stakeholders can access the data directly, update the demand drivers and equations used to generate forecasts, and contemplate the impacts of different population and employment assumptions or policies related to price and conservation on future demand.

In addition to providing the results and the methodology, this guide documents the process for future updates by CMAP or others. The methodology was informed by the previous forecast, *Regional Water Demand Scenarios for Northeastern Illinois: 2005-50*, as well as peer and academic literature review and an assessment of the data available in northeastern Illinois. A technical advisory committee provided critical feedback along the way by reviewing and confirming the projects purpose and goals, methodology, and forecast results. The technical advisory committee was composed of a variety of organizations with a range of backgrounds; including those with forecasting experience at different scales as well as stakeholders who can potentially use the results to inform their work. The technical advisory committee was composed of the following individuals:

- Daniel Abrams, Illinois State Water Survey
- Jim Angel, Illinois State Water Survey
- John Braden, University of Illinois – Urbana Champaign
- Wes Cattoor, Illinois Department of Natural Resources
- Jim Casey, Illinois Department of Natural Resources
- Bill Christiansen, Alliance for Water Efficiency
- John Dillon, Illinois Section of the American Water Works Association
- Ben Dziegielewski, Southern Illinois University Carbondale
- Danielle Gallet, Metropolitan Planning Council
- Beth Hall, Midwest Regional Climate Center

[4] The forecast is not suited for assessing infrastructure capacity/peak demands at the system level.

- Kyla Jacobsen, City of Elgin
- Walt Kelly, Illinois State Water Survey
- James Kessen, Illinois Department of Natural Resources
- Paul May, Northwest Suburban Municipal Joint Action Water Agency
- Pete Wallers, Engineering Enterprises, Inc
- Jason Zhang, Illinois State Water Survey

This project was made possible through support from the Illinois Department of Natural Resources Office of Water. CMAP partnered with Margaret Schneemann, Illinois-Indiana Sea Grant (IISG) to develop the forecast methodology. The Illinois State Water Survey (ISWS) provided critical water withdrawal data and technical assistance throughout the project. Additionally, the project team received advice and data from Illinois Department of Natural Resources (IDNR) Lake Michigan Allocation Program, Illinois Environmental Protection Agency (IEPA), U.S. EPA, Lake County Public Works, Illinois American Water, Utilities, Inc., and Aqua Illinois, as well as several communities across the region.

2. Overview of ON TO 2050 Regional Water Demand Forecast methodology

This section provides an overview of the methodology used to develop the ON TO 2050 Regional Water Demand Forecast. It includes basic information about the water use sectors considered in the forecast as well as the structure and data used for each sector.

2.1 Water use sectors

The water-use sectors included in the ON TO 2050 Regional Water Demand Forecast are:[5]

- Residential Public Water Supply (Community Water Supply (CWS))[6]
- Non-Residential Water Supply (CWS & Self-Supply)[7]
- Domestic Self-Supply

The demand forecast includes CWS, by customer class (residential, non-residential); and Self Supply (domestic, industrial & commercial), both inside and outside municipal boundaries. It is important to note that, due to data availability and quality, population projections for the domestic self-supply sector were handled separately.

2.2 Three forecast types

Three forecast methods were used, including: a reference forecast, a baseline forecast, and a regression forecast. The forecast horizon for all three forecasts is a 35 year projection (every five years from 2015-50), which aligns with the ON TO 2050 Socioeconomic Forecast for 2050.

To provide a reference forecast, a simple method is used for all sectors, allowing for observation of the impacts of adding demand drivers to the model.[8] The reference forecast was then supplemented with a baseline forecast that incorporated informed assumptions about the combined impact of demand drivers on unit use trends. Demand driver assumptions in the baseline forecast were based on expert review, historical trend analysis, and the Water 2050 regional water demand forecast. As project capacity and available data permitted, updated demand equations using historic data (from 2000-13) were developed for the residential public

[5] Withdrawals from the agriculture and power generation sectors were not included in the analysis. These sectors comprise 3 percent and 4 percent of total water use excluding once-through power (B. Dziegielewski and F.J. Chowdhury, 2008).

[6] Community water suppliers are publicly or privately-owned water suppliers that serve residential customers (at least 25 people or 15 connections).

[7] Non-residential sector includes commercial, industrial, institutional, and irrigation. As classification of entities into these categories is inconsistent across community water suppliers in the region, the non-residential sub-sectors were not addressed separately.

[8] This method equation is: baseline unit use (GPCD, GPED) * ON TO 2050 Socioeconomic Forecast (population, employment).

water supply sector and resulting coefficients from these models applied to unit use calculations for gallons per capita per day (GPCD) and incorporated into the baseline forecast.

Given that the forecast requires selecting one year of unit use for each municipality to project out into the future, the weather of that selected year could lead to distortion in the overall forecast. The most dramatic impact could occur if drought conditions lead community water supply systems to change the proportion of withdrawals by source.[9] Particularly wet summers could reduce water use associated with landscaping while extreme cold temperatures that result in water main breaks could increase water withdrawals.

Therefore, it was necessary to select a relatively weather-normal year to use as the baseline forecast year. Given that water withdrawal data is limited to an annual frequency, the Illinois State Climatologist's Office and the Midwest Regional Climate Center were consulted to identify the year closest to the 30-year normal by reviewing monthly temperature and precipitation departures from 2000 to 2013. Of the most recent years of water withdrawal data available, 2011 had the least divergence from the monthly normal (1981-2010);[10] therefore the 2011 GPCD and gallons per employee per day (GPED) values were used as the base year for the residential public water supply sector and the non-residential water supply sector. The withdrawal data from the domestic self-supply sector is limited to 5-year increments; therefore, the most recent year, 2015, was used.

Reference Forecast

The reference forecast uses a simple method to help understand population and employment impacts on water demand. This provides a reference point against which forecasts incorporating demand drivers other than population and employment can be compared. The reference forecast assumes no further conservation and efficiency gains in the future. The method holds unit water use (GPCD, GPED) constant at the baseline level. The baseline level was determined for each water use sector based on ISWS Illinois Water Inventory Program (IWIP) data on total water use, converted to unit use by other factors (population for GPCD, employment for GPED), and calculated for a weather-normal year (most recent weather-normal year determined to be 2011).[11]

This method provides a reference forecast, and does not incorporate impact of demand drivers (coefficients), that is, a fixed rate of unit use over time is assumed, as follows:[12]

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[9] However, the methodology has a mechanism to adjust for that source variation, see section 3.1.

[10] Jim Angel, State Climatologist, Illinois State Water Survey, Prairie Research Institute, University of Illinois at Urbana-Champaign, personal communication, March 21, 2018.

[11] Of the most recent years of water withdrawal data, 2011 was determined to exhibit temperature and precipitation patterns that more closely resembled the 30-year weather normal (1981-2010) than other available years; see Section 3.3.

[12] The unit-use coefficient method assumes that future water demand will be proportional to the number of users *Ncit* while the future average rate of water use, *qcit* is usually assumed to remain constant or is changed based on some

Residential Sector (CWS, Domestic Self Supply):

MGD = (Population Served*GPCD)/1,000,000

Non-residential sector (CWS & Industrial/Commercial Self Supply):

MGD = (total employment*GPED)/1,000,000

Generically,

$$Q_{itc} = N_{itc} \cdot q_{itc}$$

where:

MGD = millions of gallons per day
Q = annual water withdrawals
N = population projections for residential sector/employment projections for non-residential sector
q = Baseline GPCD /baseline GPED (for 2011)
i = study area (municipality (facility) or county)
t = year (5-year increments 2015-50)
c = customer class (residential/non-residential/domestic self supply)

Housing density and employment assumptions in the ON TO 2050 Socioeconomic Forecast: CMAP's ON TO 2050 Socioeconomic forecast estimates the 2050 age distribution, race/ethnicity, household size, and similar factors for the region's residents, as well projecting employment trends by sector in five-year intervals (2015-50). The socioeconomic forecast considers birth, death, and migration trends with data from county health departments and the U.S. Census Bureau. Moody's Analytics, an economic research firm, forecasts employment by major categories each year, in each county, for the entire country. CMAP incorporates that data, as well as impacts of policy recommendations from GO TO 2040 and ON TO 2050, into a model that calculates future population and employment statistics for the region.[13] The policy recommendations emphasize infill and redevelopment, natural land protection, and multi-modal transportation access. Therefore the forecast inherently includes assumptions about housing density and sectoral employment.

Results for the water use sectors are presented at the municipal, county, region, and water source scale (**Table 2.1**). Geographical discrepancies in the data (between municipal population and service area population served; between municipality and county) were assessed and

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assumptions. Modeling of water demand usually concerns the future changes in average rate of water usage, *qcit*, in response to changing future conditions.

[13] CMAP, 2018, ON TO 2050 Socioeconomic Forecast Methodology, see http://www.cmap.illinois.gov/onto2050/socioeconomic-forecast.

addressed to the extent possible. Reconciliation of water use data with geographic data is described in Section 4 of this process guide.

Table 2.1: Water Demand Forecast Geography

Sector	Geography	Format of results
Residential Community Public Water Supply (CWS)	Municipality and county remainder	Region, County, Municipality and county remainder
Non-Residential Water Supply (CWS & Self-Supply)[14]	Municipality and county remainder	Region, County, Municipality and county remainder
Domestic self-supply	County	Region, County
Total	Region	7-county regional total; further broken down by county and water source.[15]

Baseline Forecast

In addition to the reference forecast, which embeds assumptions contained in the ON TO 2050 socioeconomic forecast, a simple method will be used for relaxing the fixed unit use assumption, based on informed assumptions about overarching trends due to factors driving per unit water use.[16] (**Table 2.2**).

Table 2.2: Demand driver assumptions for baseline forecast

Demand Drivers	Assumptions
Housing Density	ON TO 2050 Population Forecast
Conservation trend* (-)	Historic trend of 0.7 annually 50% higher than historical trend
Employment (%)	ON TO 2050 Employment Forecast

Historic/Conservation Trend: In northeastern Illinois, GPCD has a historic trend of decline of 0.7 percent per year in average gallon per capita rates over the period 1990-2005.[17] This simple

[14] There is insufficient data to classify non-residential CWS as a separate sector given how employment data is organized, so non-residential public and self-supply will be treated together.

[15] There are five major sources in the Chicago region -- shallow groundwater, sandstone groundwater, Lake Michigan, Fox River, and Kankakee River. In addition, other surface waters --- such as the Chicago River, Calumet-Sag Channel, Des Plaines River, DuPage River, and Salt Creek -- are used by industrial and commercial businesses with separate intakes.

[16] Least Resource Intensive (LRI) scenario assumptions and assumptions inherent in the CMAP population forecasts will be used in preparing the forecast, as amended by conversation with water conservation and efficiency experts on the technical advisory committee.

[17] Dziegielewski Benedykt, 2009, "Residential Water Use in Northeastern Illinois, Estimating Water-use Effects of In-fill Growth versus Exurban Expansion," Memorandum Report prepared for CMAP, Southern Illinois University Carbondale.

analysis does not separate causal factors from one another, and so, this historic trend captures the influence of all factors influencing residential water uses.

Two national initiatives, the Energy Policy Act of 1992 (EPAct) and the U.S. EPA WaterSense program, have contributed to declines in residential water use.[18] According to the Water Resource Foundation's Residential End Uses of Water Study V2 (REU2016), residential indoor water use in 2016 was 58.6 GPCD, a decline from 69.3 GPCD in 1999, or 15 percent. These declines are attributed to more efficient fixtures and appliances, and not to occupancy or behavior changes. Outdoor residential water use is more difficult to gauge, due to variances in local weather conditions, irrigated areas, water costs, landscape components, etc. A 100 percent saturation/market penetration of current technical potential for water efficient improvements would result in an indoor GPCD of 30 – 40 GPCD.

Regression Forecast

This method collects historic data on water use and selected demand drivers for the period 2000-13, performs a multiple regression analysis to update the coefficients, and uses the updated coefficients to calculate the forecasted unit-use (GPCD). The updated unit-use was then be applied to the baseline forecast.

Water use, adjusted to unit water use (GPCD) was modeled as a function of several demand drivers, and dummy variables[19] (see **Table 2.3**).[20] Binary dummy variables will be included for the drought years (2005, 2012) and polar vortex years (2013-14), and binary (dummy) variables for fixed effects. Because this model significantly expands the number of subjects (from 26 major systems to more than 200 communities) a grouping analysis was used for fixed effects, as determined by a cluster analysis of municipalities to capture characteristics related to water use

[18]The EPAct established the first uniform plumbing standards that became mandatory nationwide in 1994. As technology has evolved, the EPAct standards continue to be revised accordingly. www.allianceforwaterefficiency.org/uploadedFiles/Resource_Center/Library/codes_and_standards/US-Water-Product-Standard-Matrix-Aug-2011.pdf. The U.S. EPA launched the voluntary WaterSense partnership in 2006, a program that provides nationally recognized water efficiency product branding, and also works with partners to implement water conservation programming.

[19] An outlier analysis will be conducted, and possible outlier dummies included indicating outliers (spikes) in the data (which assume the value of 1 for observations that are outliers and zero otherwise). It is anticipated that these will include areas with geographical discrepancies (between the population served by the community water supplier and the municipal population).

[20] The specification will be a double-log regression model (i.e., ln y = B0 + B1 ln x).

not explained by other variables in the analysis, including weather-normal (2011) GPCD[21] and population served.[22]

The output of the regression model is updated coefficients to use in the unit use (GPCD) forecast calculation. Updated model coefficients will be incorporated into the unit water use calculation for the water demand forecast, as follows:[23]

$$GPCD = e^{y}$$

Where *e* is an exponential function and *y* is the estimated demand equation for the residential water sectors.

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[21] With the growing use of GIS modeling and increased ability of computational methods to handle large data sets, there is increasing evidence that physical characteristics and social spatial patterns influence household water use. Clustering based on the level of water use (the dependent variable) can better reflect regional characteristics than clustering based on independent variables. This is because typical socio-economic predictors of per capita daily consumption for water demand fail to account for unique urban characteristics of cities within a region. This is important due to significant correlations between water consumption and land use, though this may not have been the case historically, prior to rapidly changing high-density urbanization. See: Choi, T. et al (2010). Water Demand Forecasting by Characteristics of City Using Principal Component and Cluster Analyses. Environmental Engineering Research, 15(3): 135-140.

[22] Population served is a proxy for community capacity. The smaller the population served, the smaller the size of the utility, and the less technical (scale economies), managerial and financial capacity of the water supply system. Lower capacity, less production efficiencies, and the greater the GPCD due to distribution system inefficiencies.

[23] Note: Logs and exponents are inverse functions of one another. If y = *ln* x then x = in EXCEL: EXP.

Table 2.3. Residential public water supply (CWS) water demand estimation variables

Definition Name		Cross Section Geography	Time series	Data Source (s)
Dependent Variable(s)				
GPCD	Water Supply Withdrawals in Gallons Per Capita per Day (GPCD) Calculated as Average Annual MGD divided by US.Census Population.	Municipality/ Unincorporated County	Annual 2000-2014	ISWS IWIP IDNR LMO-2 U.S. Census
Independent Variables				
Price (-)	Marginal residential price of water Calculated as difference in the total water bill at 5,000 gallons and 6,000 gallons.	Municipal	Annual 2000-2014	Dziegielewski, Kiefer, Bik, 2004;[24] IDNR, IISG
Housing Density (-)[25]	Housing Units/land area	Municipality/ Unincorporated County	Annual 2000 - 2015	U.S. Census, Decennial U.S. Census, ACS
Conservation trend (-)	Zero for 2000, 1 for 2001, 2 for 2002 etc.	n/a	Annual 2000-2014	Definitional
Income (+)	Median Household Income	Municipality/ Unincorporated County	Annual 2000-2014	U.S. Census, Decennial U.S. Census, ACS
Dummy Variables	To account for municipal level fixed effects, drought years (2005, 2012), polar vortex years (2013-2014), geographical discrepancies, outliers	n/a		Cluster Analysis Definitional

[24] Dziegielewski, B., J.Kiefer, T.Bik (2004) Water Rates and Ratemaking Practices in Community Water Systems in Illinois. Project Completion Report. Department of Geography Southern Illinois University Carbondale. Actual report only contains values for 2003.

[25] As housing density increases, (average units per acre) average water use per dwelling unit decreases; in part due to smaller lot sizes and less outdoor irrigation. Ongoing urban intensification will accelerate housing density and the associated water use trends. Given constant household sizes, GPCD likewise would decrease. A complication arises, however, as per capita water use has also been found to increase with housing density. This is attributed to the small household sizes in higher density housing (counter-acting economies of scale in water use) and lack of individual meters in more dense housing.

3. Demand forecast results

Total water demand in the Chicago region is projected to stay relatively stable despite the demands of a growing population and economy. Section 3.1 presents the regional water demand forecast, which includes two water sectors -- the residential public water supply and non-residential water supply sectors. Then each sector is presented separately. Section 3.2 presents the forecast for the domestic self-supply sector, which was handled separately due to variation in how population forecasts were derived.

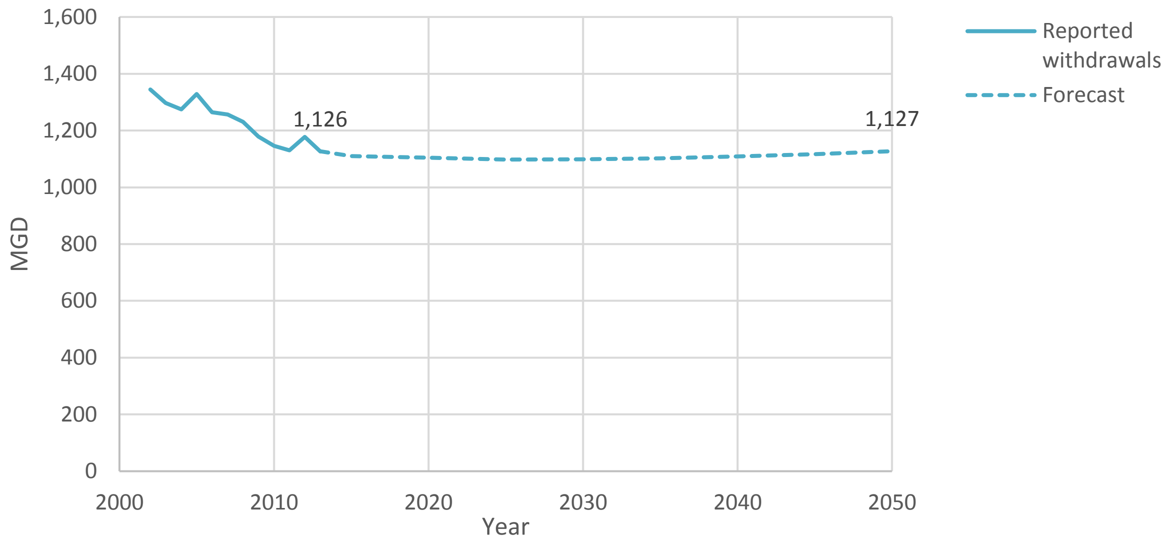
3.1 Regional water demand forecast

Total water demand in the Chicago region is projected to stay relatively stable despite the demands of a growing population and economy (**Figure 3.1**). By 2050, total water withdrawals are estimated to be 1,127 million gallons per day (MGD), an increase of less than 1 percent from the 1,126 MGD withdrawn in 2013.[26] During this same period, the region is projected to add more than 2.3 million residents and 900,000 jobs (**Figure 3.2)**.[27] Overall water use is estimated to be stable because the amount of water used per resident or per employee is anticipated to follow historic trends and continue to decline. The regional water demand forecast includes two water sectors -- residential public water supply using the regression forecast and non-residential water supply using the baseline forecast.

The vast majority of projected withdrawals are attributed to water use within Cook County (**Figure 3.3**). While water demand within Cook County is anticipated to decline in the future, other counties -- most notably Kendall, Kane, McHenry, and Will -- are projected to see increases in water demand (**Table 3.1**). **Figure 3.4** provides projected water demand by each forecasted municipality in 2050. Outside of water use in the City of Chicago, two clusters of higher water use -- northern Cook County and the area at the confluence of DuPage, Kane, Kendall, and Will County. **Figure 3.5** provides an estimated percent change in demand from 2011 to 2050 for each forecasted municipality. Approximately 80 percent of the region's population currently resides in communities projected to experience a decline in total water use by 2050. These areas are continuing to grow, with a projected 1.26 million new residents and 580,000 new employees by 2050. The remaining 20 percent of the population currently reside in communities projected to experience an increase in total water use. These areas are growing much faster than the rest of the region, with a projected 89 percent increase in population (1.47 million) and 71 percent in employment (470,000) from 2011 to 2050.

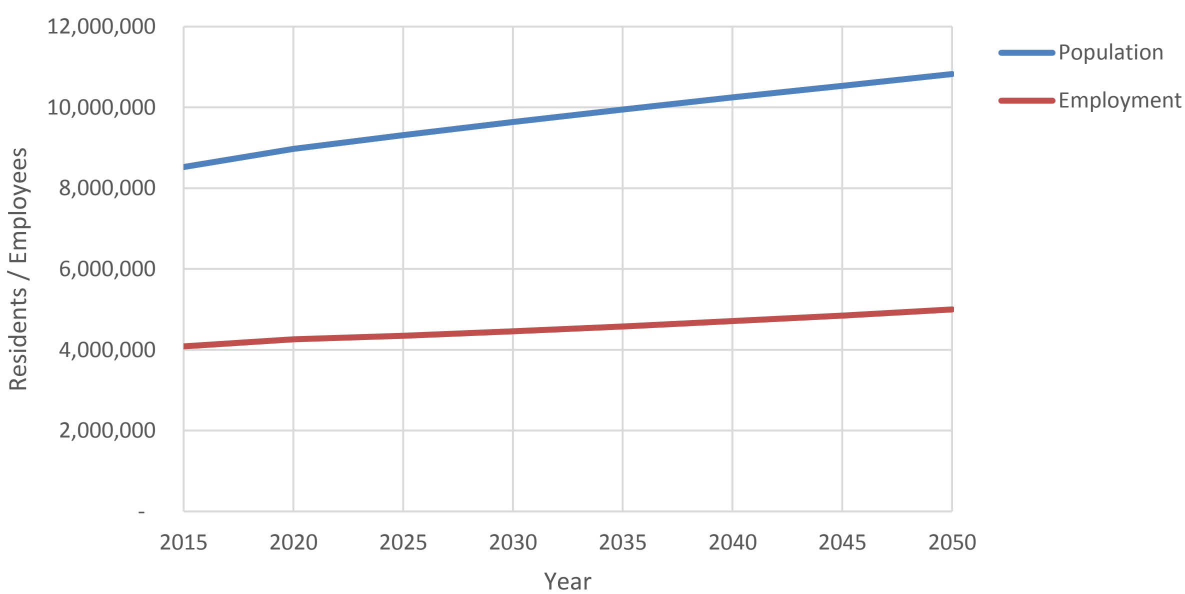
[26] Water withdrawals reflect annual values expressed as average daily rates. Actual withdrawals will be higher during peak summer season and maximum-day use and lower during winter season and off-peak days.
[27] CMAP, "ON TO 2050 Socioeconomic Forecast Appendix: Draft for Public Comment," 2018, https://www.cmap.illinois.gov/2050/draft/appendices. Additional population and employment values compare 2015 to 2050.

Figure 3.1. Regional water demand forecast,[a] reported withdrawals (2002-13) and forecast (2015-50), MGD



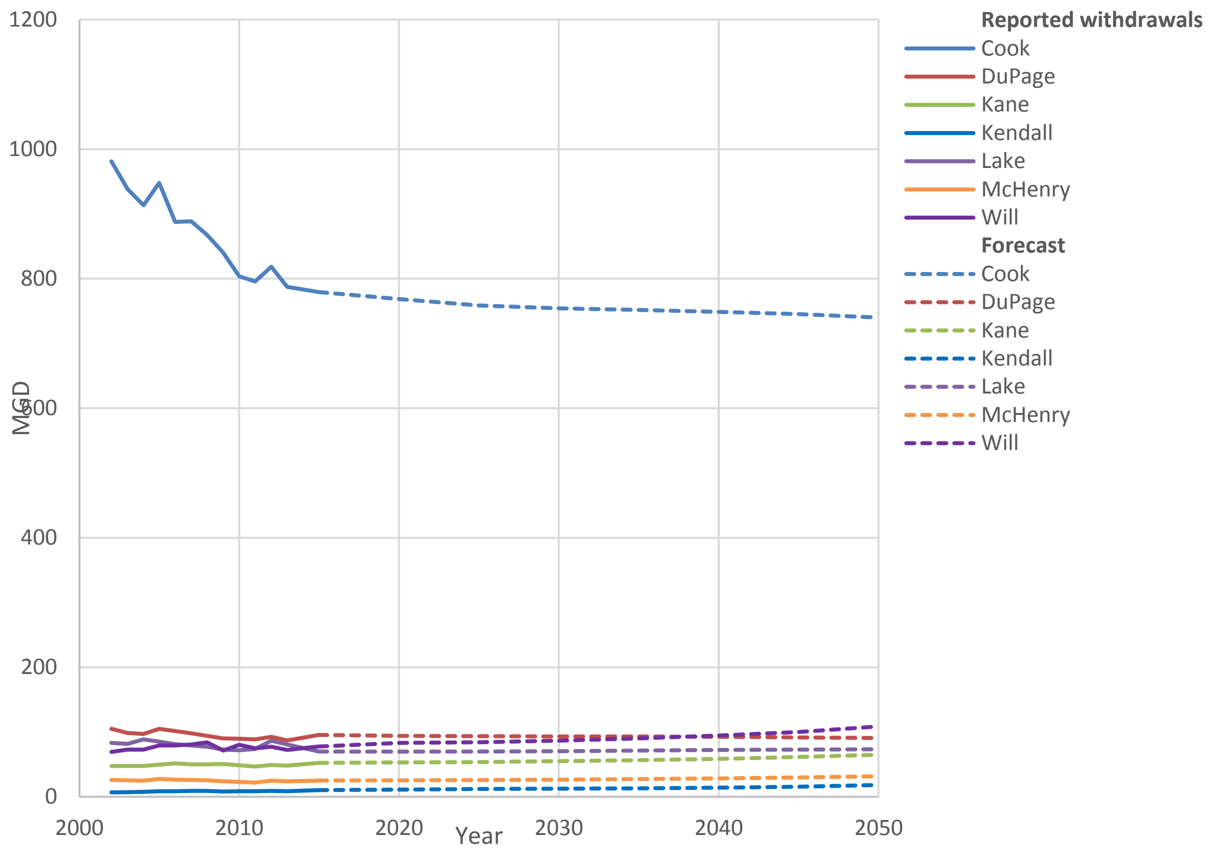
[a] Forecast includes withdrawals from public water suppliers, industrial and commercial self-supply. The domestic self-supply sector is handled separately.
Source: CMAP ON TO 2050 Regional Water Demand Forecast

Figure 3.2. Population and employment growth as estimated by the ON TO 2050 Socioeconomic Forecast, 2015 to 2050



Source: CMAP ON TO 2050 Socioeconomic Forecast.

Figure 3.3. Regional water demand forecast by county, reported withdrawals and forecast, MGD



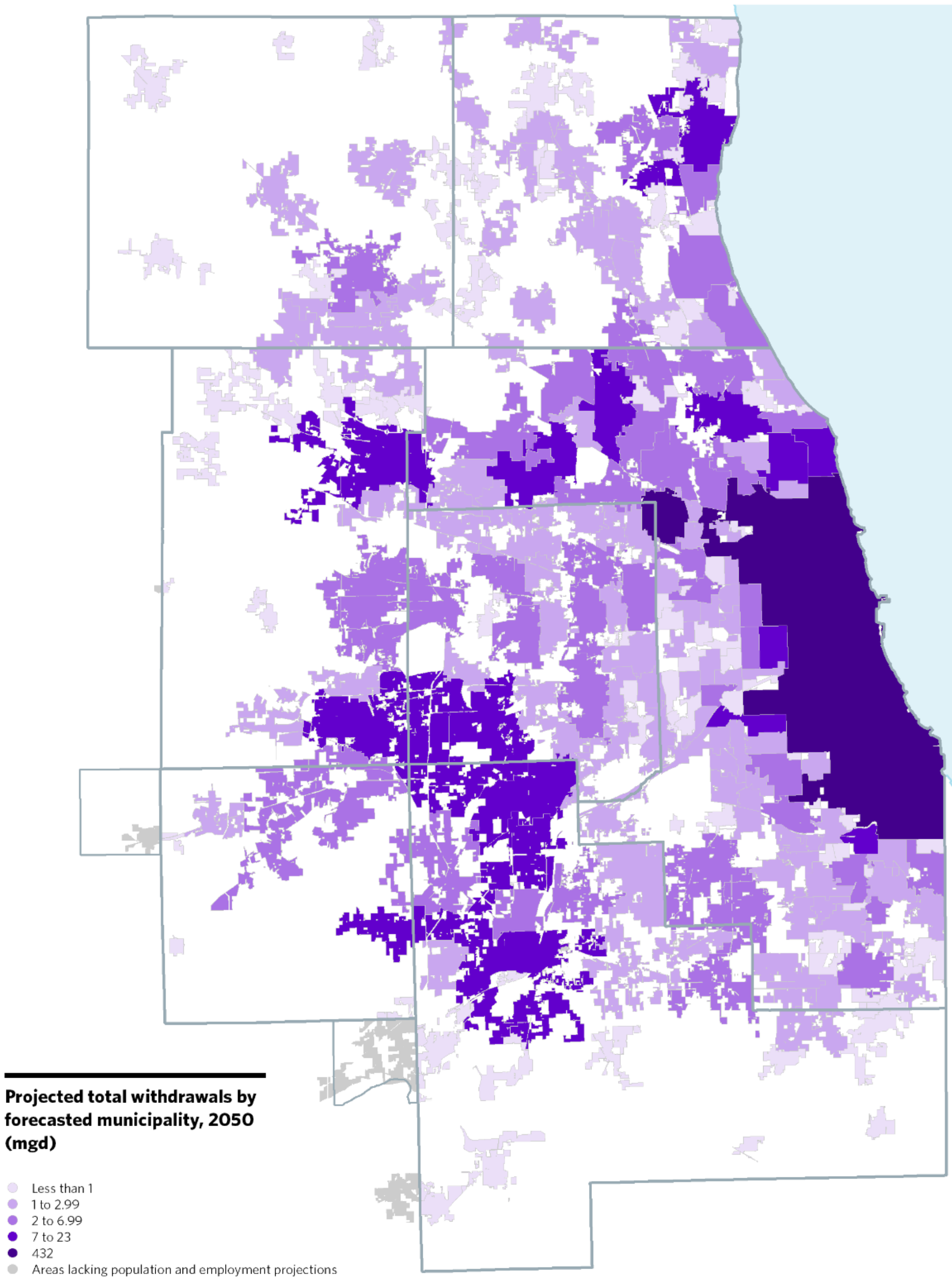
Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Table 3.1. Percent change in water demand by county, 2011 and 2050

County	Total Use, MGD		Percent Change
	2011	2050	
Cook	804	740	-9%
DuPage	91	91	-1%
Kane	48	65	26%
Kendall	9	18	51%
Lake	78	73	-6%
McHenry	23	32	27%
Will	77	109	29%

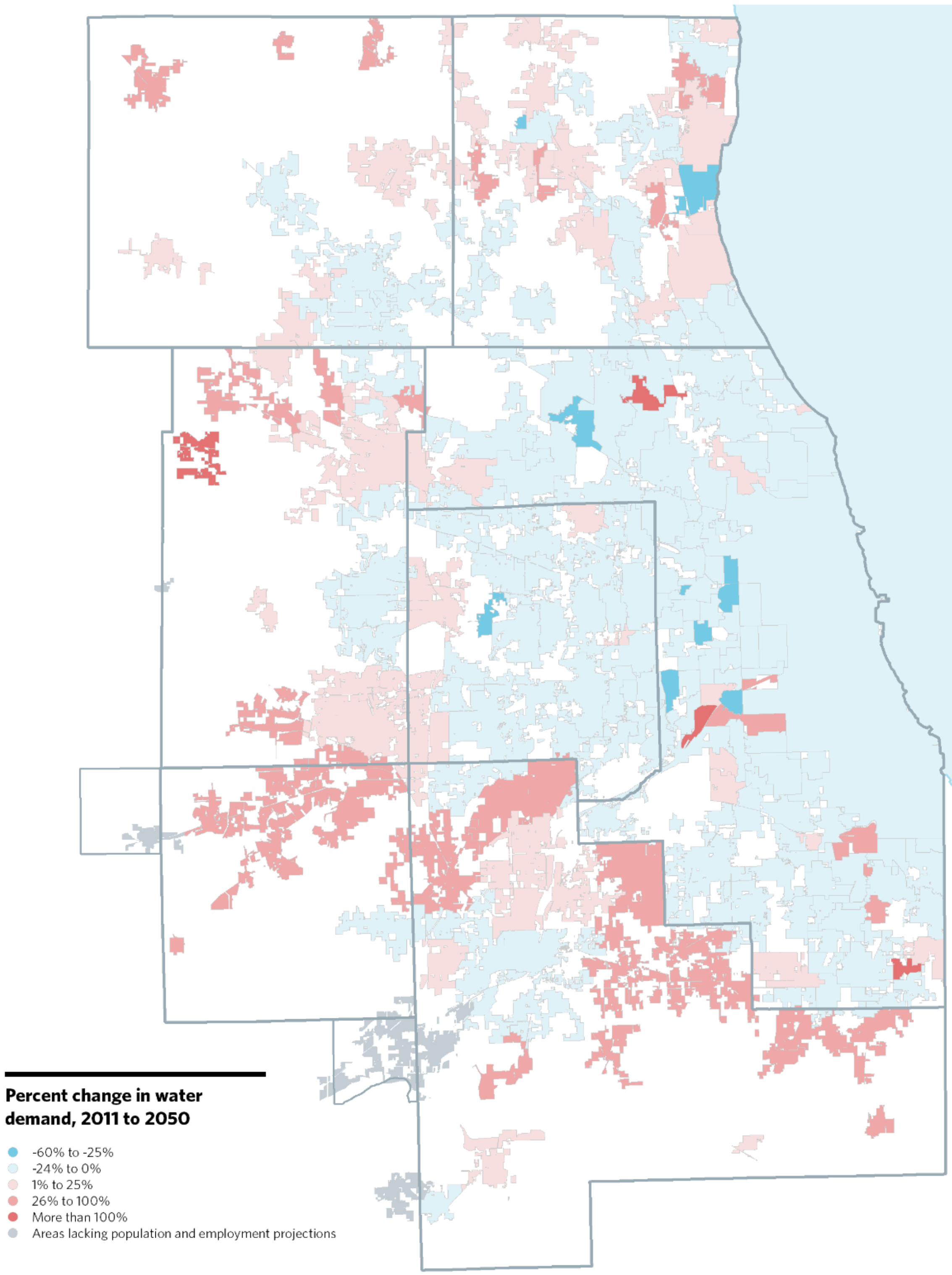
Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Figure 3.4. Projected total withdrawals by forecasted municipality, 2050



Note: Full municipal water demand forecasts were not possible for the six municipalities only partially within the CMAP ON TO 2050 Socioeconomic forecast area.
Source: Chicago Metropolitan Agency for Planning, 2018

Figure 3.5. Percent change in total water demand by forecasted municipality, 2011-50



Note: Full municipal water demand forecasts were not possible for the six municipalities only partially within the CMAP ON TO 2050 Socioeconomic forecast area.
Source: Chicago Metropolitan Agency for Planning, 2018

Overall, the region is projecting increased water demand in locations at the edges of the region, which rely on the shallow and sandstone aquifers as well as the Fox and Kankakee Rivers as water sources. **Figure 3.6** displays the primary water source for each of the 245 municipalities as of 2011. **Figure 3.7 and Table 3.2** provide the current and projected water withdrawals by water source. Water withdrawals from Lake Michigan are forecasted to decline by 77 MGD or 8 percent by 2050; all other water sources are projected to experience an increase in withdrawals.

Communities and industrial and commercial facilities may switch sources in the coming years. However, predicting when and to what source is not possible through this effort. The forecast assumes that communities and facilities will continue to rely on their current source, as shown in **Figure 3.6**. However, this is unlikely for a variety of reasons that are unique to each water source. Current estimates by ISWS indicate the amount of sandstone groundwater withdrawals are currently twice the rate of recharge[28] and desaturation of this resource will likely force communities and businesses to switch to the Fox and Kankakee Rivers or Lake Michigan.[29] Shallow groundwater sources are also facing quality and quantity constraints that may inspire similar shifts.[30,31]

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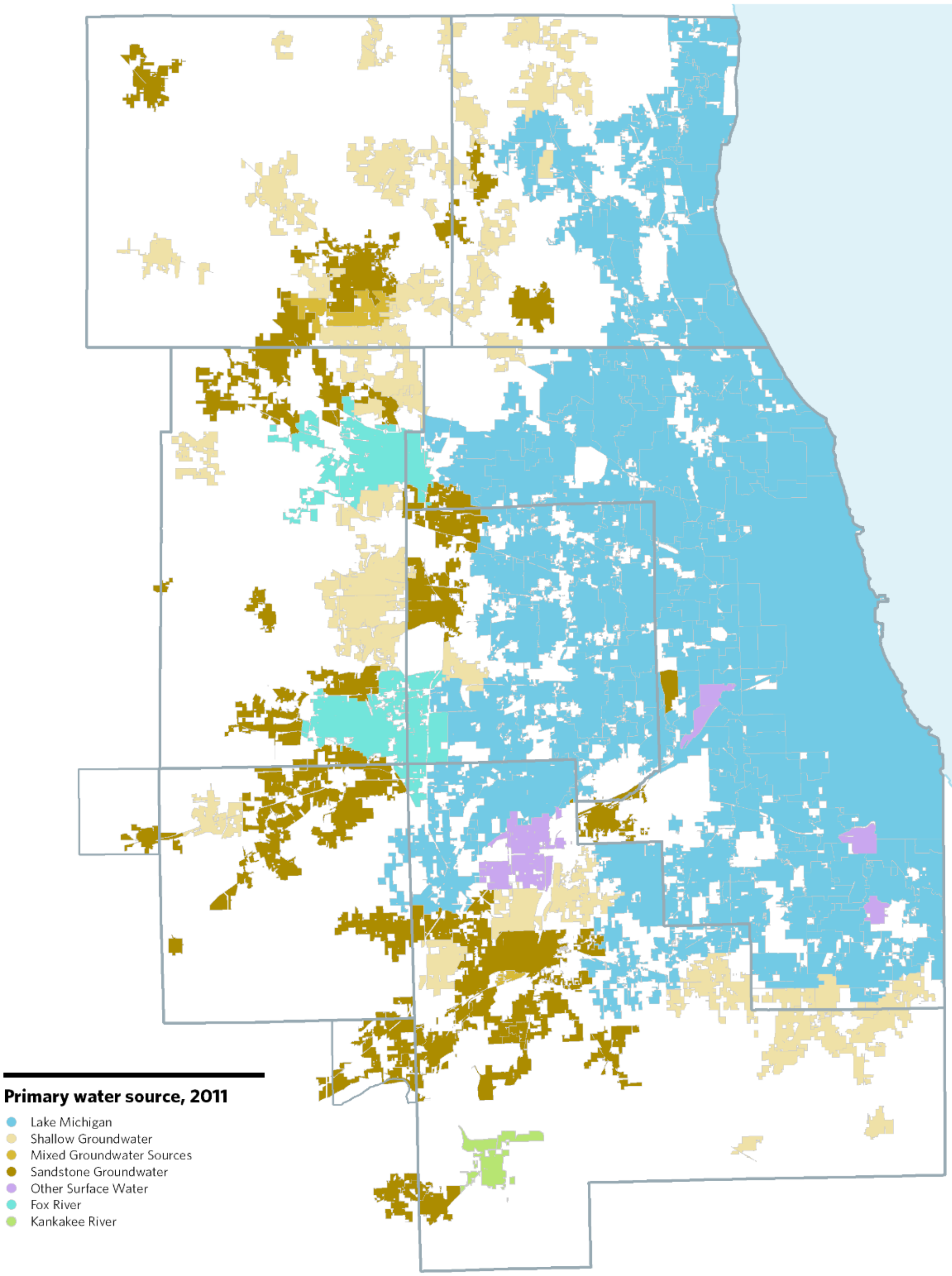
[28] Abrams, Daniel B. 2017, "The Illinois Groundwater Flow Model: New Applications and Insights for Northeastern Illinois," Presentation to the Northwest Water Planning Alliance Technical Advisory Committee on October 24, 2017.

[29] Abrams, Daniel B. et all, 2015, "Changing Groundwater Levels in Sandstone Aquifers of Northern Illinois and Southern Wisconsin: Impacts on Available Water Supply," Illinois State Water Survey, Contract Report 2015-02.

[30] Walton R. Kelly, Daniel R. Hadley, Devin H. Mannix, "Shallow Groundwater Sampling in Kane County, 2015," Illinois State Water Survey, March 2016, http://www.isws.illinois.edu/pubdoc/CR/ISWSCR2016-04.pdf.

[31] Walton R. Kelly, Samuel V. Panno, Keith Hackley, "The Sources, Distribution and Trends of Chloride in the Waters of Illinois," Illinois State Water Survey, March 2012, http://www.isws.illinois.edu/pubdoc/B/ISWSB- 74.pdf.

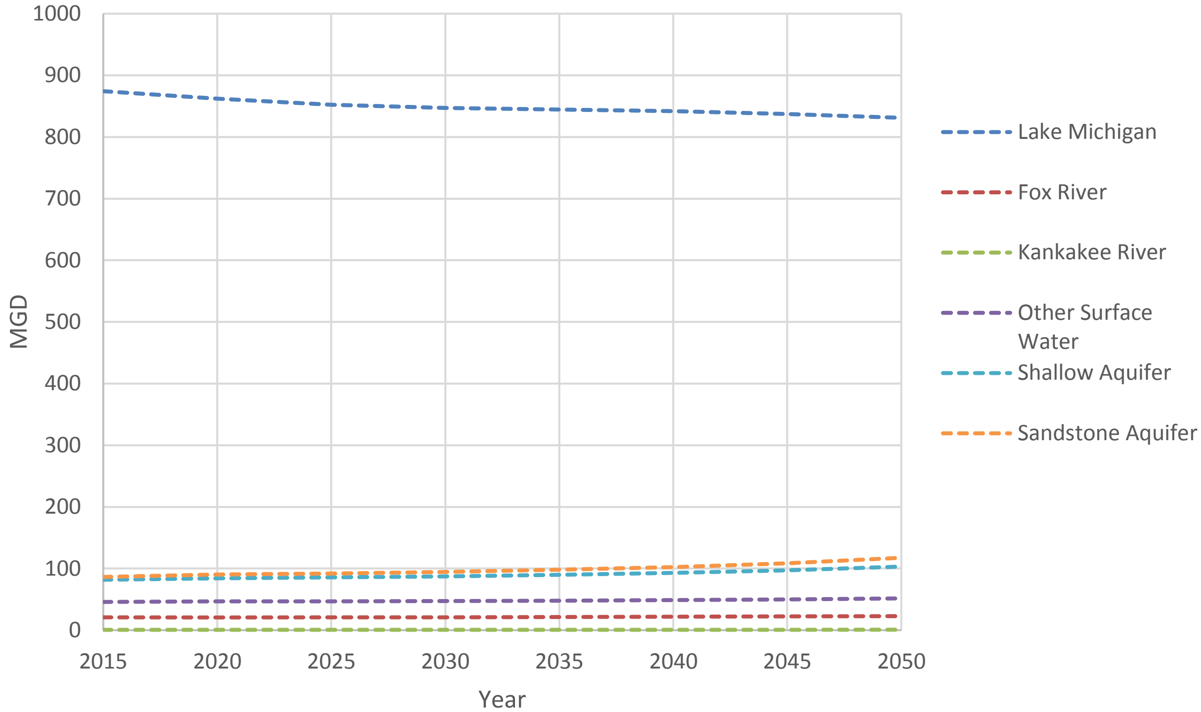
Figure 3.6. Primary water source by forecasted municipality, 2011



Notes: Primary water source was determined as the majority (greater than 50 percent) of withdrawals from all CWS and Industrial & Commercial Self-Supply facilities within community. Five communities – Hodgkins, McCook, Riverdale, Romeoville, and Thornton – have other surface water withdrawals that exceed CWS withdrawals. Hodgkins, McCook, Riverdale, and Thornton CWS rely on Lake Michigan while Romeoville CWS primarily depends on shallow groundwater.
Community level forecasts were generated for municipalities with a CWS providing water to the majority of the municipal area. Municipalities that are primarily served by private wells or smaller scale CWS providing water to a portion of the community are included in each county remainder, along with unincorporated lands.

Source: Chicago Metropolitan Agency for Planning, 2018

Figure 3.7. Regional water demand forecast by source,[a] (2011-50), MGD



[a] The domestic self-supply sector is not included here as the source data is not as refined as IWIP data for CWS and Industrial and Commercial self-supply.
Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Table 3.2. Percent change in withdrawals by source, 2011 and 2050

Water source	Total Use, MGD		Percent Change
	2011	2050	
Lake Michigan	908	830	-9%
Fox River	20	23	12%
Kankakee River	0.72	0.88	22%
Other River	43	52	20%
Shallow Aquifer	75	105	40%
Sandstone Aquifer	83	118	42%

Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Access to Lake Michigan water is a legally constrained resource with a set diversion rate that is approximately equivalent to 2.1 billion gallons of water per day.[32, 33] Approximately 50 percent of the allocation is currently used for domestic purposes[34] and the IDNR Lake Michigan Allocation Program has allocated 1,235 MGD to the year 2030.[35] Decreasing withdrawals among current communities using Lake Michigan could allow additional municipalities to gain access to Lake Michigan. However, it is important to note that climate change, and its anticipated increase in precipitation, may also increase the amount (percentage) of water that leaves the Lake Michigan basin as stormwater runoff, and thereby reduce the amount of the water allocation available for public water supply.[36] The amount that can be withdrawn from the Fox and Kankakee Rivers is also regulated. Each river segment has an estimated minimum low flow threshold to ensure enough water is flowing during drought conditions to protect and maintain aquatic life.[37] These thresholds are updated approximately every ten years in northeastern Illinois and the Kankakee River is currently being reassessed. Sustainable withdrawal rates from the shallow and sandstone aquifers vary by county.

Residential Public Water Supply Forecast

Three forecasts were generated for the residential public water supply forecast. First, a simple method is used to provide a reference forecast, allowing for observation of the impacts of adding demand drivers to the model.[38] The reference forecast assumes no further conservation and efficiency gains in the future. The reference forecast method holds unit water use (GPCD) constant at the baseline level. The reference forecast was then supplemented with a baseline forecast incorporating informed assumptions about the combined impact of demand drivers on unit use trends. Updated demand equations using historic data (from 2000-13) were developed for the residential public water supply sector and resulting coefficients from these models applied to unit use calculations for GPCD and incorporated into the baseline forecast. This section presents the results of each of the forecast types. The regression forecast was selected as the final forecast for the residential public water supply sector.

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[32] Wisconsin v. Illinois, 388 U.S. 426 (1967); 449 U.S. 48 (1980).

[33] CMAP, *Water 2050: Northeastern Illinois Regional Water Supply/Demand Plan*, 2010, http://www.cmap.illinois.gov/documents/10180/14452/NE+IL+Regional+Water+Supply+Demand+Plan.pdf/26911cec-866e-4253-8d99-ef39c5653757.

[34] CMAP ON TO 2050 strategy paper, "Water Resources," 2017, http://www.cmap.illinois.gov/onto2050/strategy-papers/water-resources.

[35] IDNR Lake Michigan Allocation Program will be updating the allocations in the Fall of 2018.

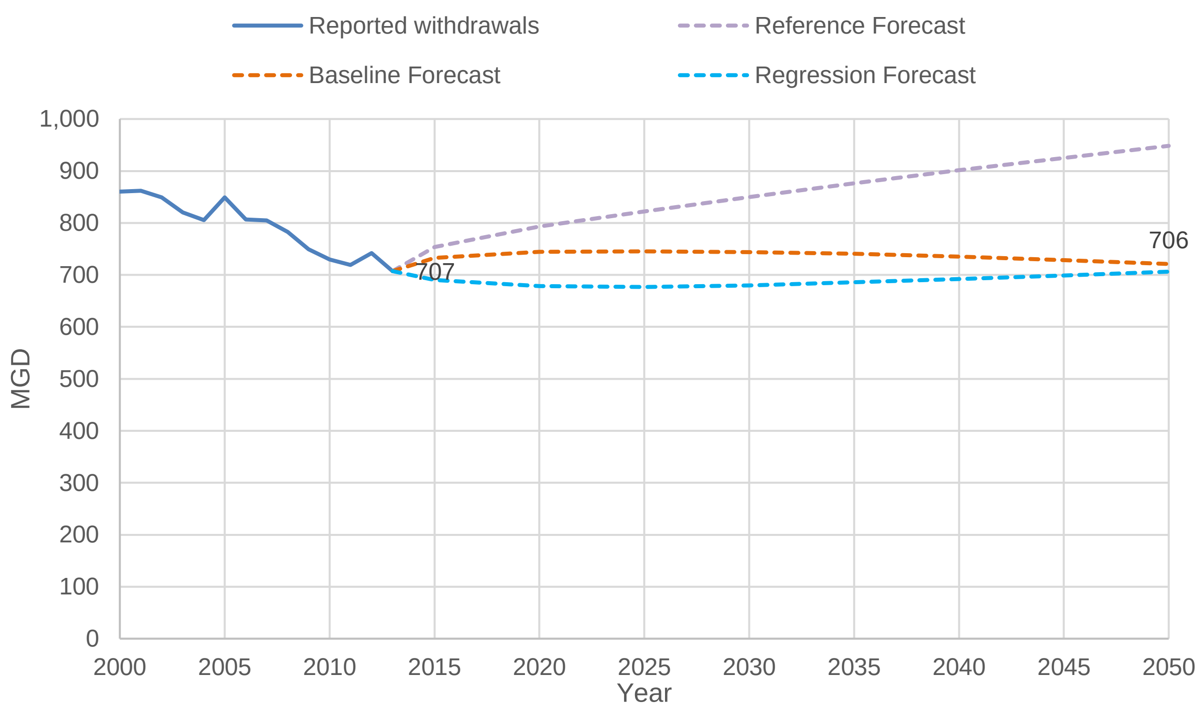
[36] "Guidance for Preparing Water System Improvement Plans," Lake Michigan Water Allocation Newsletter, Illinois Department of Natural Resources, September 2014, www.dnr.illinois.gov/WaterResources/Documents/LMO_Newsletter_2014.pdf.

[37] "7-Day 10-Year Flow Maps," Illinois State Water Survey, Prairie Research Institute, http://www.sws.uiuc.edu/docs/maps/lowflow/background.asp.

[38] This method equation is: baseline unit use (GPCD, GPED) * ON TO 2050 Socioeconomic Forecast (population, employment)

Figure 3.8 presents the reported water withdrawals and three forecasts for the residential public water supply sector. The reference forecast reveals that, in the absence of any water efficiency and conservation, water demand would increase through 2050 by 25 percent. The baseline forecast relaxes the assumption of constant GPCD by allowing for recent trends in demand drivers to continue, including a conservation trend of declining GPCD of 0.7 percent per year. Including these trends shows that the impact of increasing population growth on water demand is outweighed by water conservation and efficiency gains. This pattern likewise holds when the estimated regression demand equation coefficients are used to forecast demand. By 2050, total residential withdrawals are estimated to be 706 MGD, essentially the same as the 707 MGD withdrawn in 2013. **Figure 3.9** provides projected residential withdrawals in 2050 for each forecasted municipality using the regression forecast.

Figure 3.8 Residential public water supply, reported withdrawals (2000-13), reference, baseline, and regression forecast (2015-50), MGD



Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Figure 3.9. Projected residential withdrawals by forecasted municipality, 2050

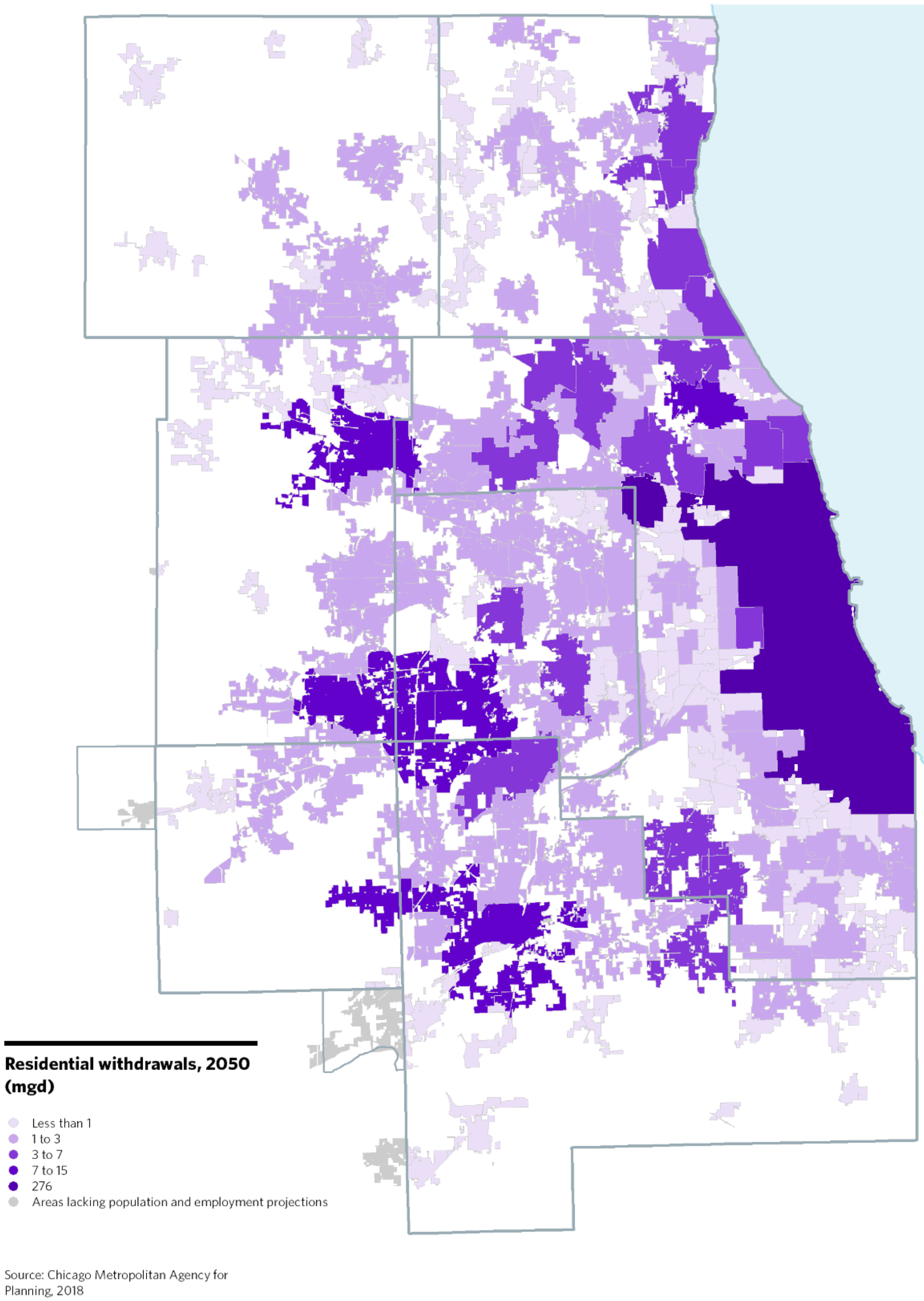
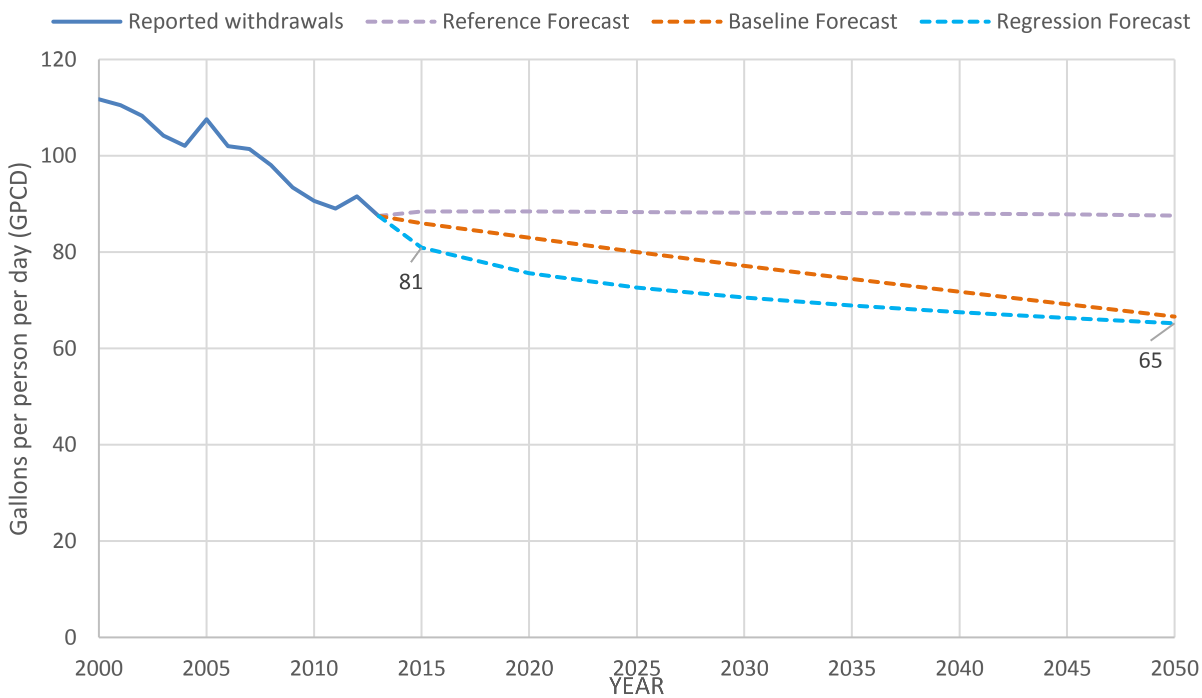


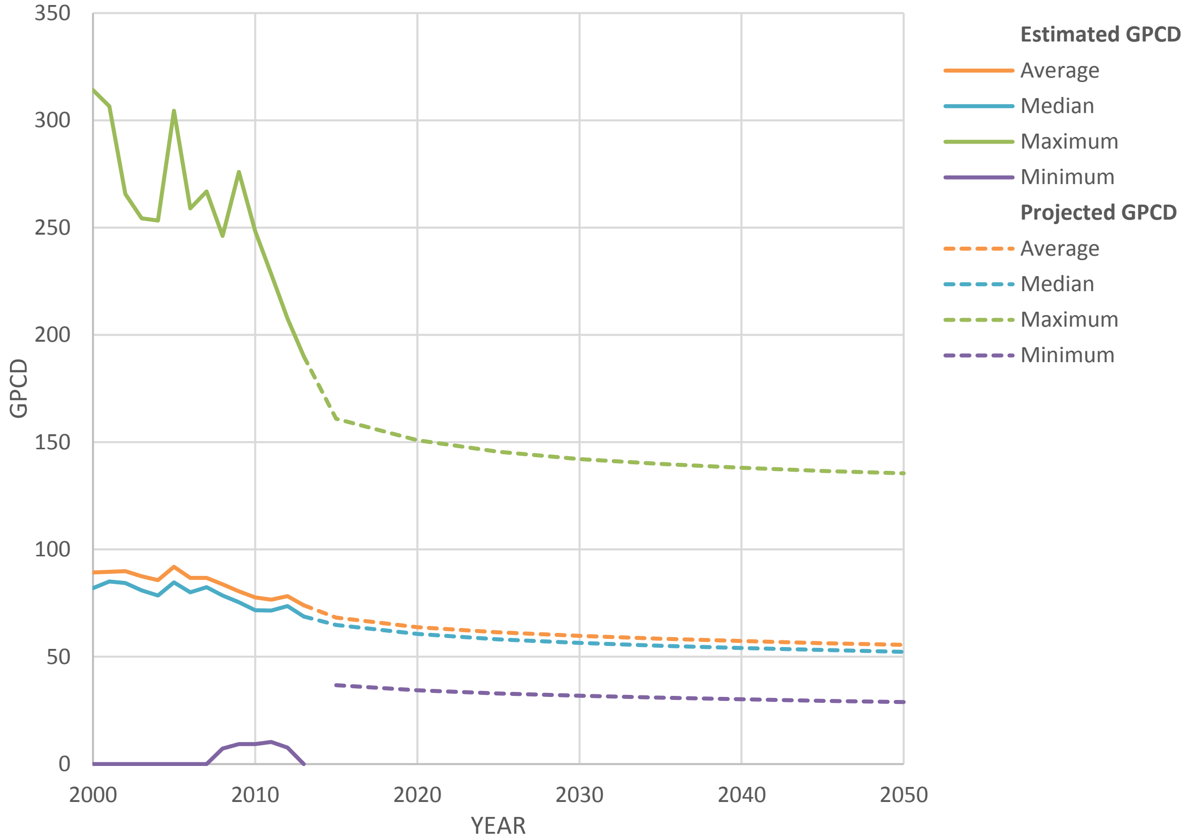
Figure 3.10 presents the estimated and projected GPCD values for each forecast type. By definition, GPCD for the reference forecast is held constant over time. When GPCD is allowed to follow historical trends in the baseline forecast, it declines about 15 gallons per day due to efficiency improvements, a trend that is borne out in the regression-based forecast of GPCD as well. **Figure 3.11** provides a summary of the characteristics of the GPCD data estimated and then projected using the regression forecast. The characteristics include the average, mean, and range of the data. **Figure 3.12** provides the projected GPCD in the year 2050 for each forecasted municipality using the regression forecast.

Figure 3.10. Residential public water supply, estimated (2000-13) and forecasted GPCD (2015-50)



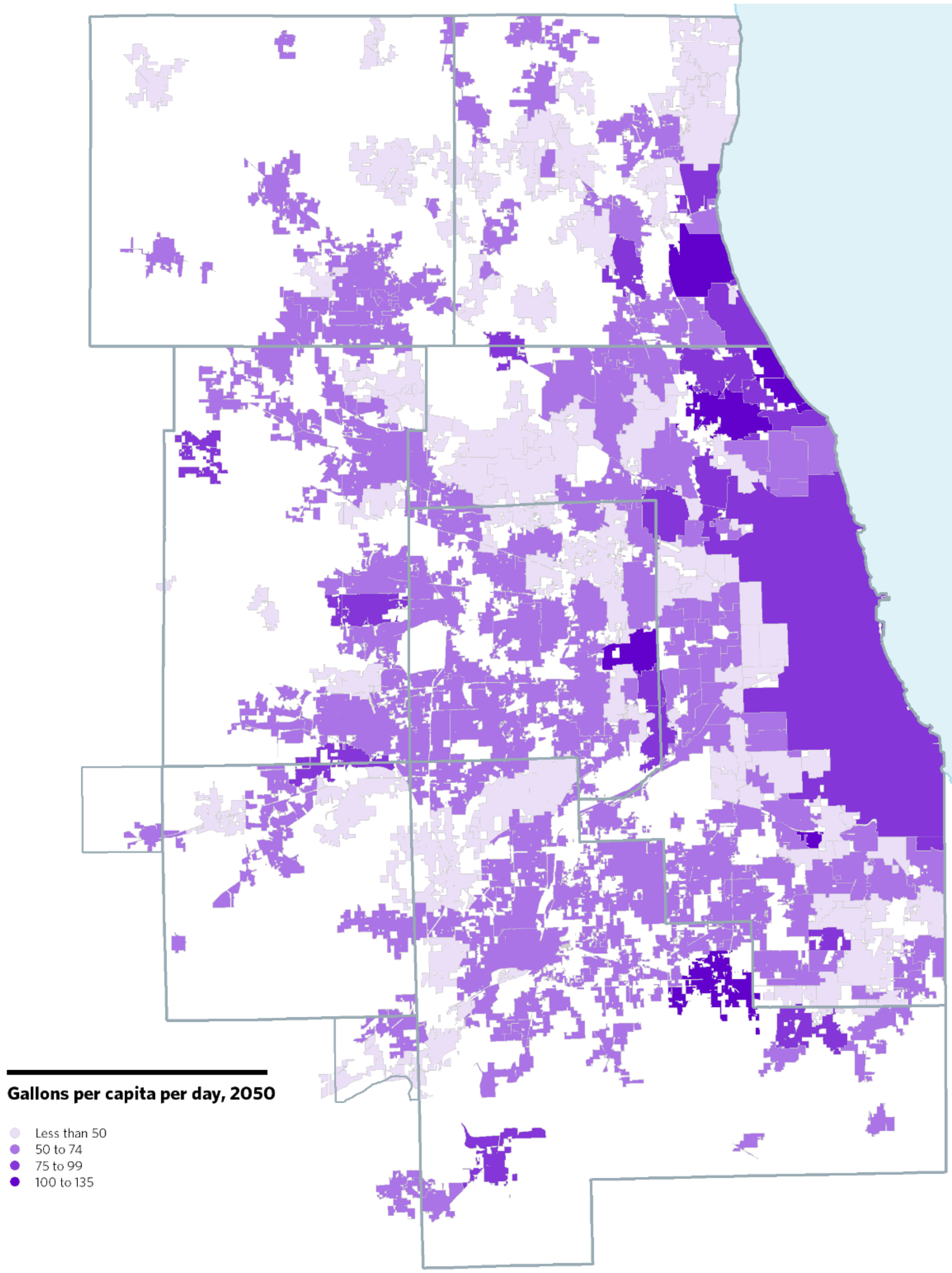
Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Figure 3.11. GPCD characteristics of residential public water supply, estimated (2000-13) and forecasted (2015-50)



Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Figure 3.12. Projected GPCD by forecasted municipality, 2050



Source: Chicago Metropolitan Agency for Planning, 2018

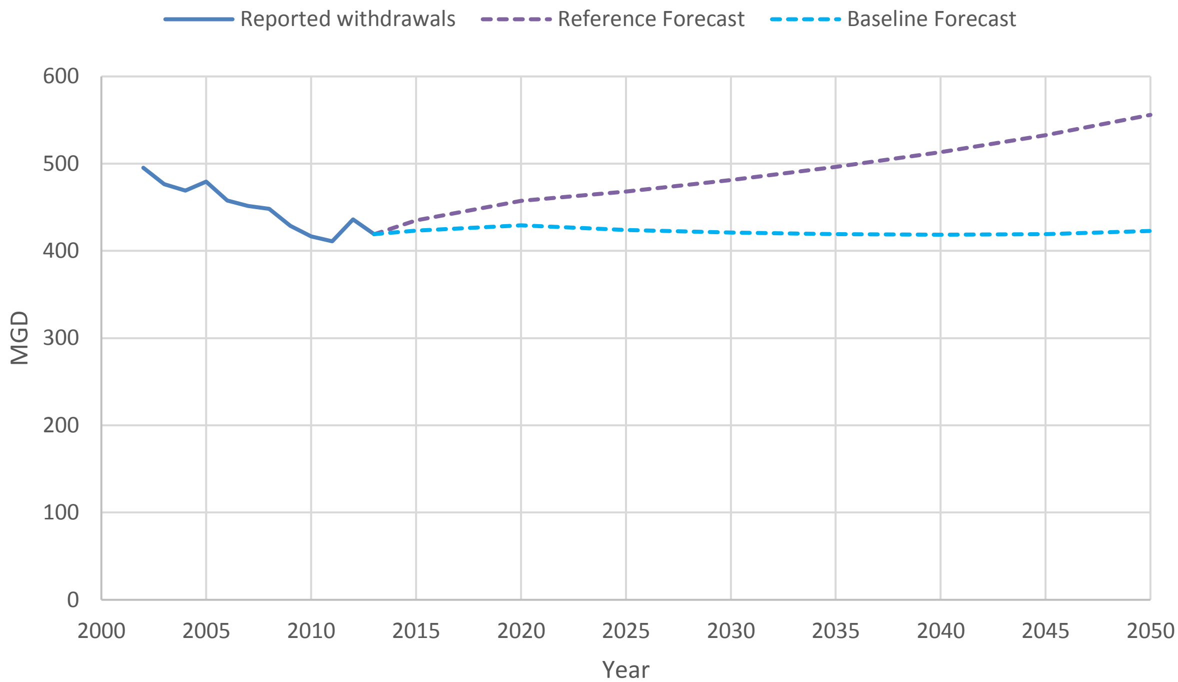
Non-Residential Water Supply Forecast

Two forecasts were generated for the non-residential water supply forecast. A simple method is used to provide a reference forecast, allowing for observation of the impacts of adding demand drivers to the model.[39] The reference forecast holds unit water use (GPED) constant at the baseline level, effectively assuming no further conservation and efficiency gains in the future. The reference forecast was then supplemented with a baseline forecast incorporating informed assumptions about the combined impact of demand drivers on unit use trends. This section presents the results of each of the forecast types. The baseline forecast was selected as the final forecast for the non-residential water sector.

Figure 3.13 presents the reported withdrawals and two forecasts for the non-residential water supply sector. The reference forecast reveals that, in the absence of any water efficiency and conservation, water demand would increase through 2050 by 32 percent. The baseline forecast relaxes the assumption of constant GPCD by allowing for recent trends in demand drivers to continue, including a conservation trend of declining GPCD of 0.7 percent per year. Including these trends shows that the impact of increasing employment growth on water demand is outweighed by water conservation and efficiency gains. By 2050, total non-residential withdrawals are estimated to be 421 MGD, essentially the same as the 419 MGD withdrawn in 2013. **Figure 3.14** provides projected non-residential withdrawals in the year 2050 for each forecasted municipality using the baseline forecast.

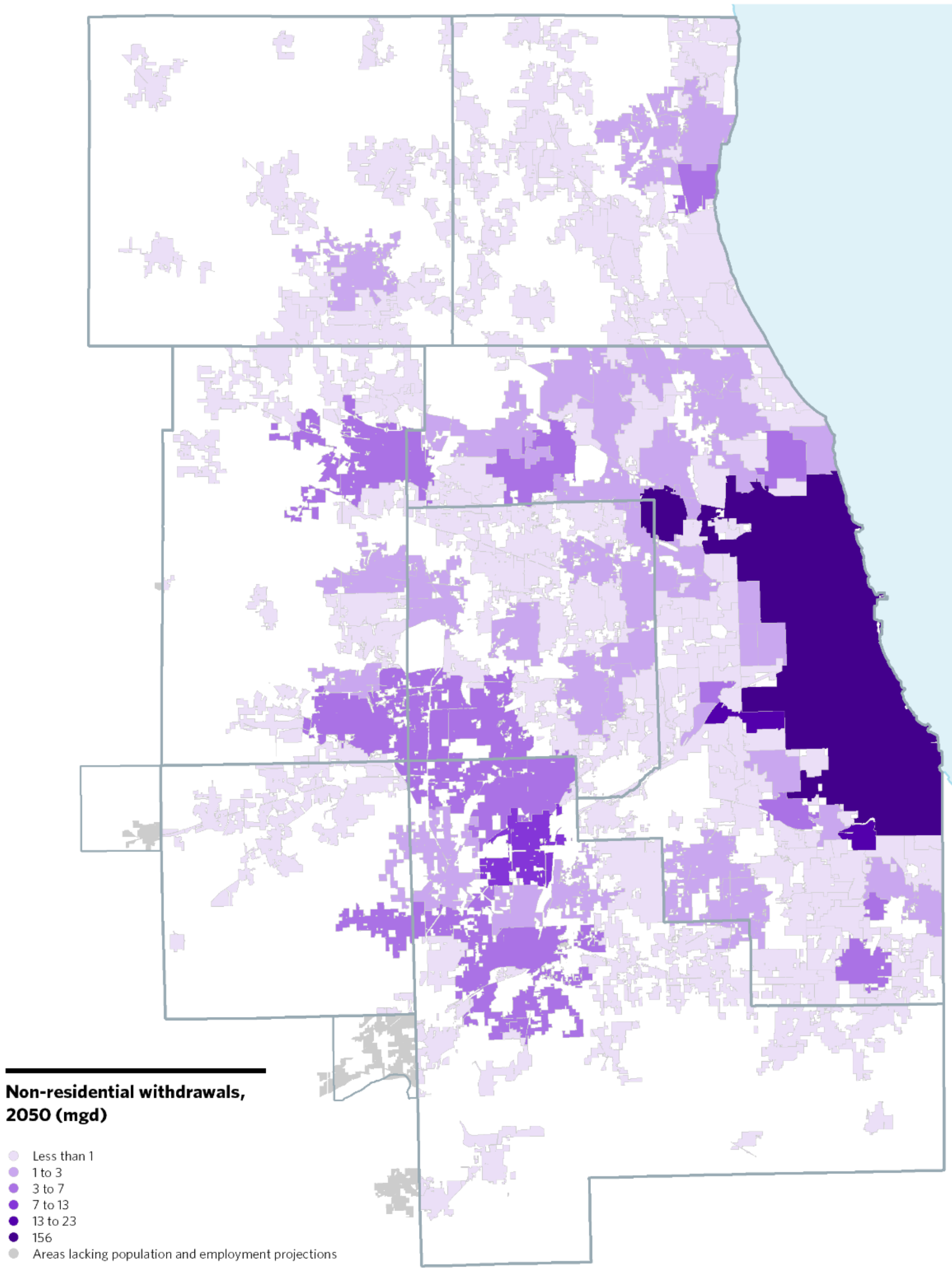
[39] This method equation is: baseline unit use (GPCD, GPED) * ON TO 2050 Socioeconomic Forecast (population, employment).

Figure 3.13. Non-residential public water supply and industrial and commercial self-supply, reported withdrawals (2002-13), reference and baseline forecast (2015-50), MGD



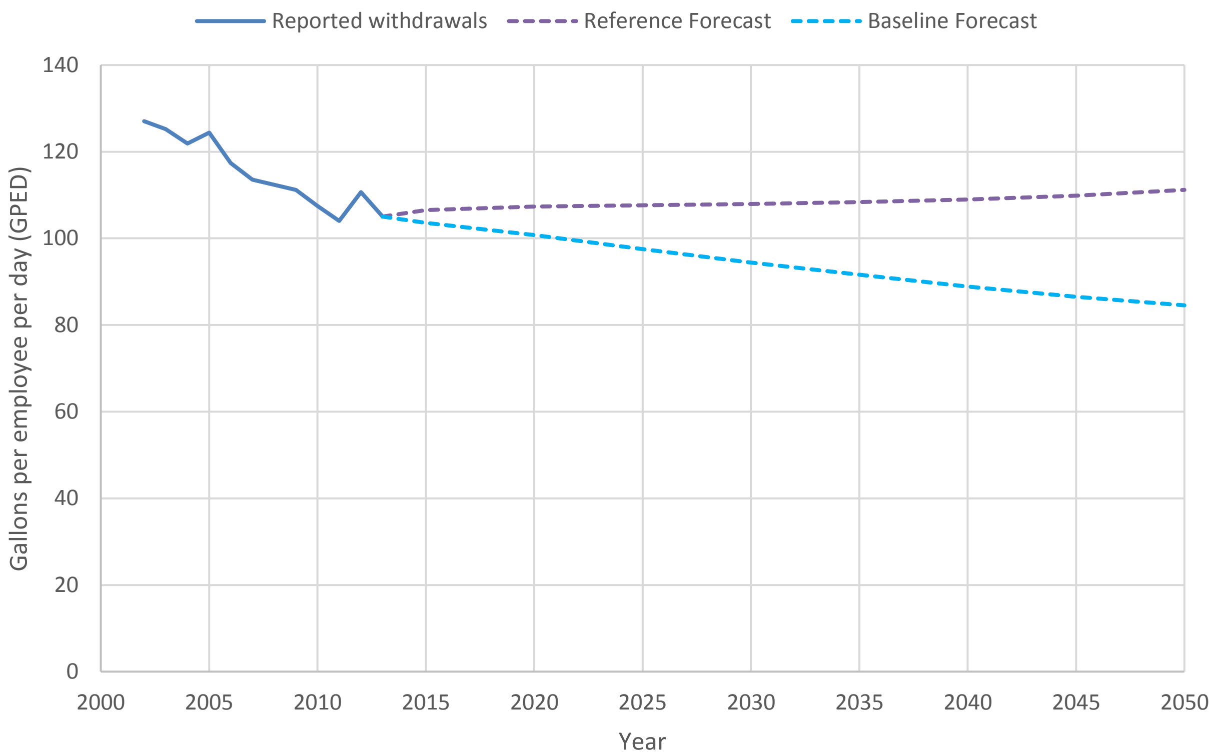
Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Figure 3.14. Projected non-residential withdrawals by forecasted municipality, 2050



Source: Chicago Metropolitan Agency for Planning, 2018

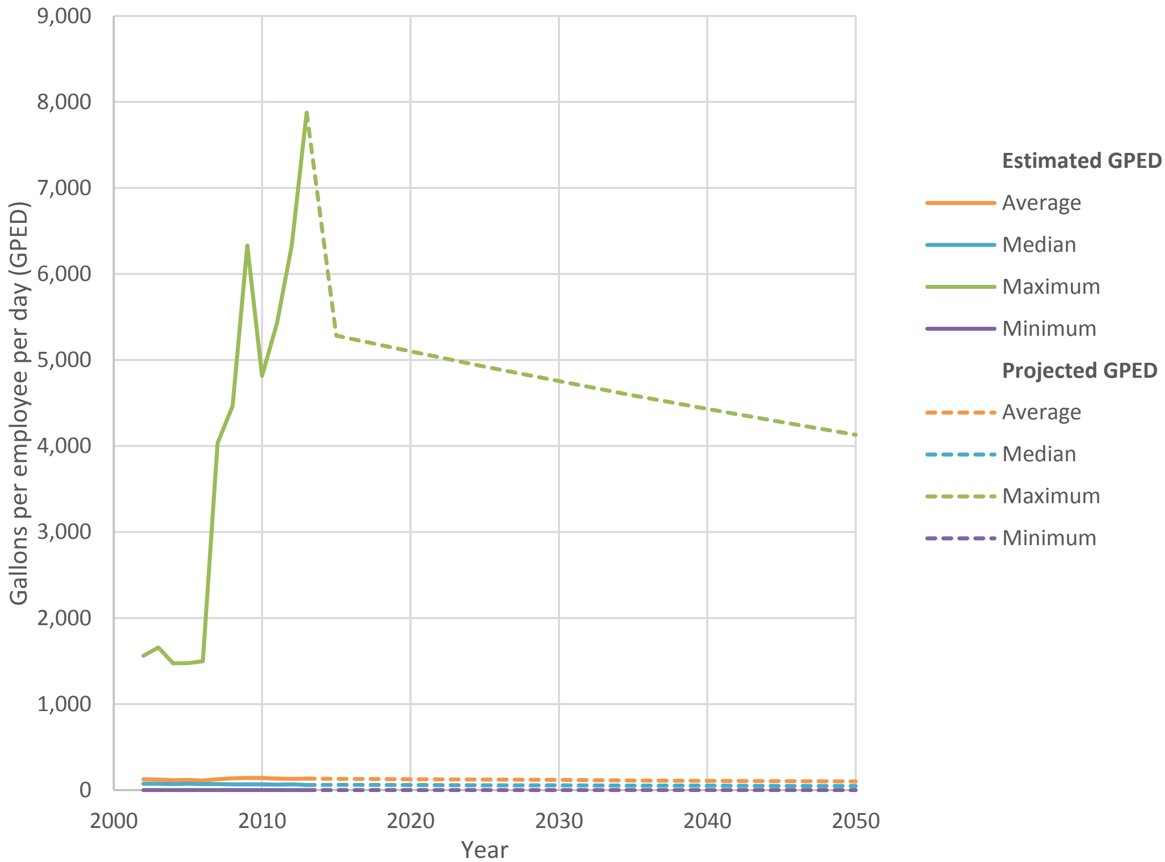
Figure 3.15. Non-residential public water supply and industrial and commercial self-supply, estimated GPED (2002-13), reference and baseline forecast GPED (2015-50)



Source: CMAP ON TO 2050 Regional Water Demand Forecast.

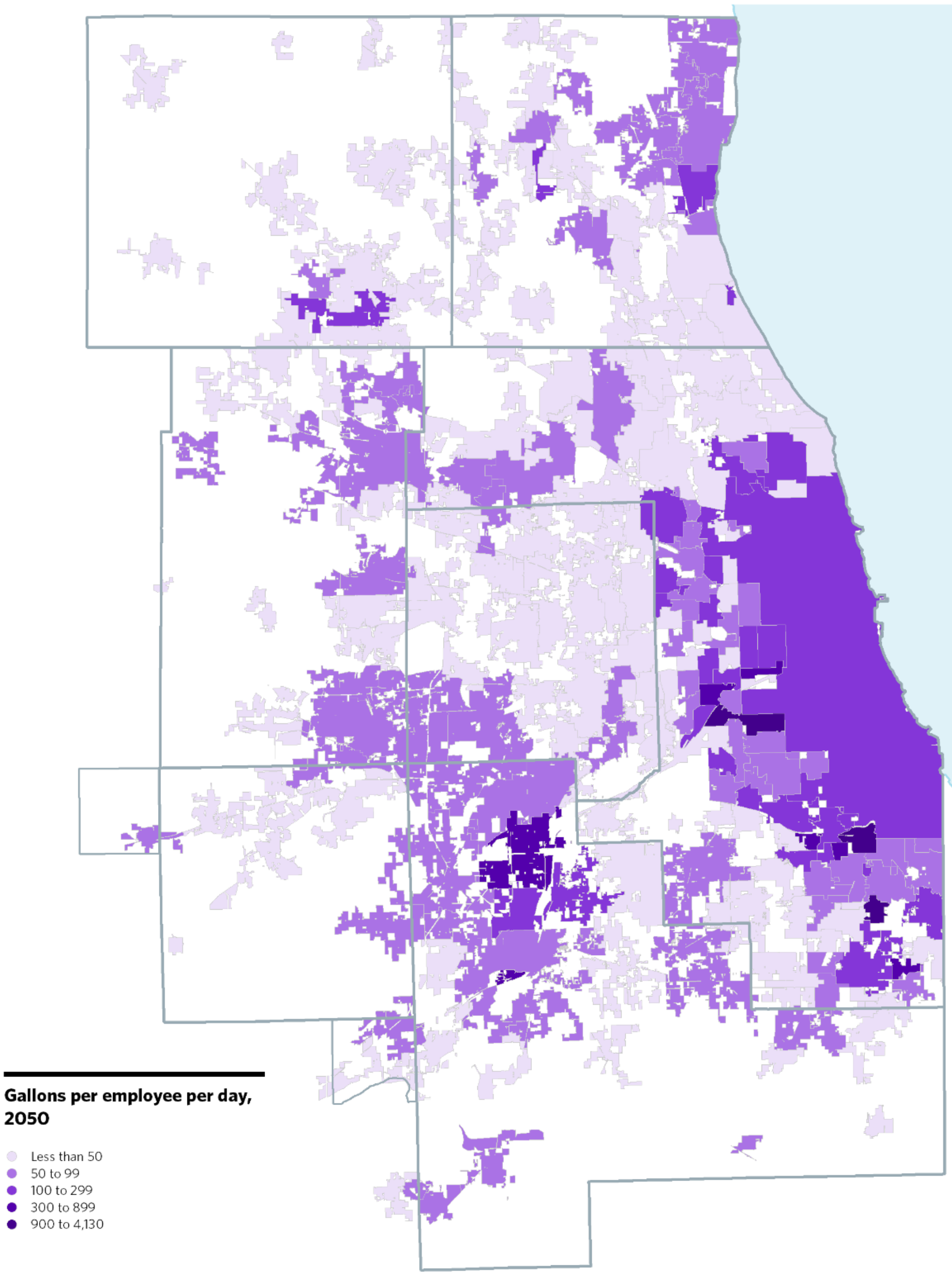
Figure 3.15 presents the estimated and projected GPED values for each forecast type. By definition, GPED for the reference forecast is held constant over time. When GPED is allowed to follow historical trends in the baseline forecast, it declines about 20 gallons per day due to efficiency improvement. **Figure 3.16** provides a summary of the characteristics of the GPED data estimated and then projected using the baseline forecast. The characteristics include the average, mean, and range of the data. **Figure 3.17** provides the projected GPED in the year 2050 for each forecasted municipality using the baseline forecast.

Figure 3.16. GPED characteristics of non-residential public water supply and industrial and commercial self-supply, estimated (2002-13) and forecasted (2015-50)



Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Figure 3.17. Projected GPED by forecasted municipality, 2050



Source: Chicago Metropolitan Agency for Planning, 2018

3.2 Domestic self-supply

Two forecasts were generated for the domestic self-supply forecast. A simple method is used to provide a reference forecast, allowing for observation of the impacts of adding demand drivers to the model.[40] The reference forecast holds unit water use (GPCD) constant at the baseline level, effectively assuming no further conservation and efficiency gains in the future. The reference forecast was then supplemented with a baseline forecast incorporating informed assumptions about the combined impact of demand drivers on unit use trends. This section presents the results of each of the forecast types.

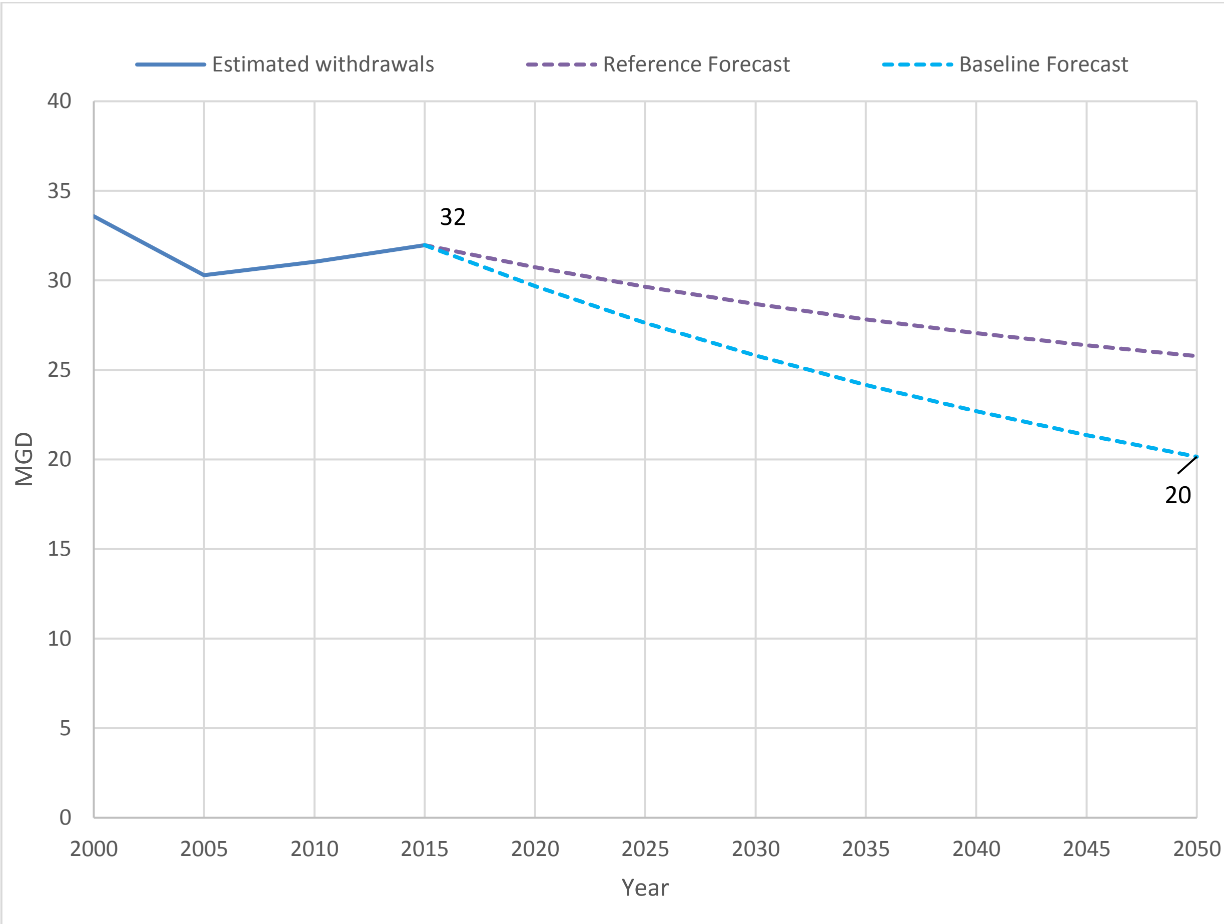
Figure 3.18 presents the estimated withdrawals and two forecasts for the domestic self-supply sector. Both forecasts assume declines in water use as the population on private residential wells is assumed to decline in the future. The reference forecast reveals that, in the absence of any water efficiency and conservation, water demand would decrease through 2050 by 20 percent because of this population decline. The baseline forecast relaxes the assumption of constant GPCD by allowing for recent trends in demand drivers to continue, including a conservation trend of declining GPCD of 0.7 percent per year. Including these trends leads to further declines in water demand through water conservation and efficiency gains. By 2050, total domestic self-supply withdrawals are estimated to be 20 MGD, representing a decline of 36 percent.

Figure 3.19 presents the estimated withdrawals and baseline forecast of the domestic self-supply sector by county. Will and Lake Counties have the largest populations on private residential wells. **Figure 3.20** presents the estimated and projected GPCD values for each forecast type. By definition, GPCD for the reference forecast is held constant over time. When GPCD is allowed to follow historical trends in the baseline forecast, it declines about 17 gallons per day due to efficiency improvements. **Figure 3.21** provides a summary of the characteristics of the GPCD data estimated and then projected using the baseline forecast. The characteristics include the average, mean, and range of the data.

For the domestic self-supply sector, population served data is reported in the U.S. Geological Survey (USGS) National Water Use Information Program. It is important to note that the population served by self-supplied domestic facilities are an estimate of the population not served by public supply. The population data was reviewed for accuracy; with several data points adjusted to remove variation that would be unlikely to occur within a 5-year period given regional growth trends. However, substantial questions remain regarding the initial population estimates, see section 4.2.

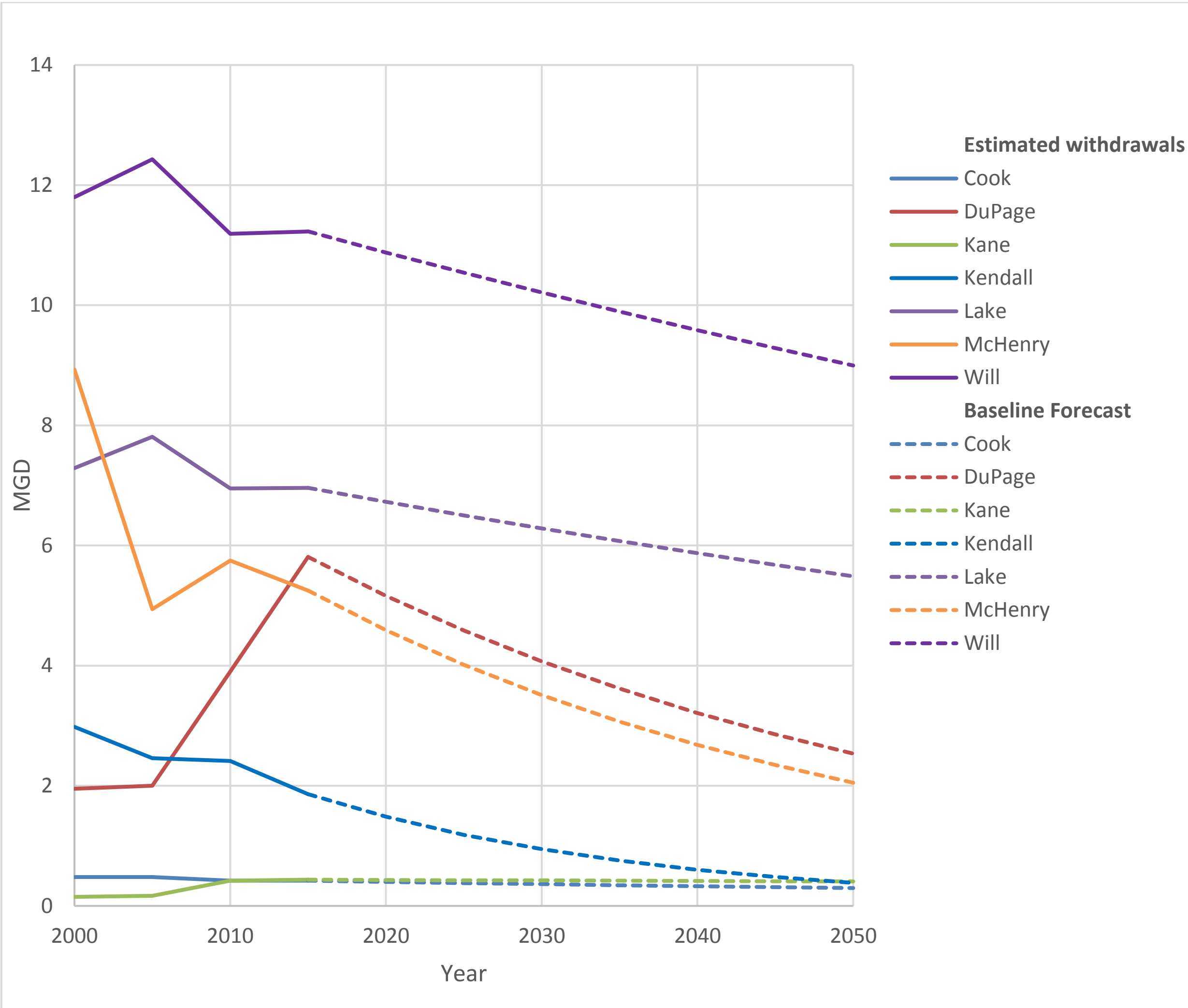
[40] This method equation is: baseline unit use (GPCD, GPED) * ON TO 2050 Socioeconomic Forecast (population, employment).

Figure 3.18. Domestic self-supply, estimated withdrawals (2000-15) and reference and baseline forecasts (2020-50), MGD



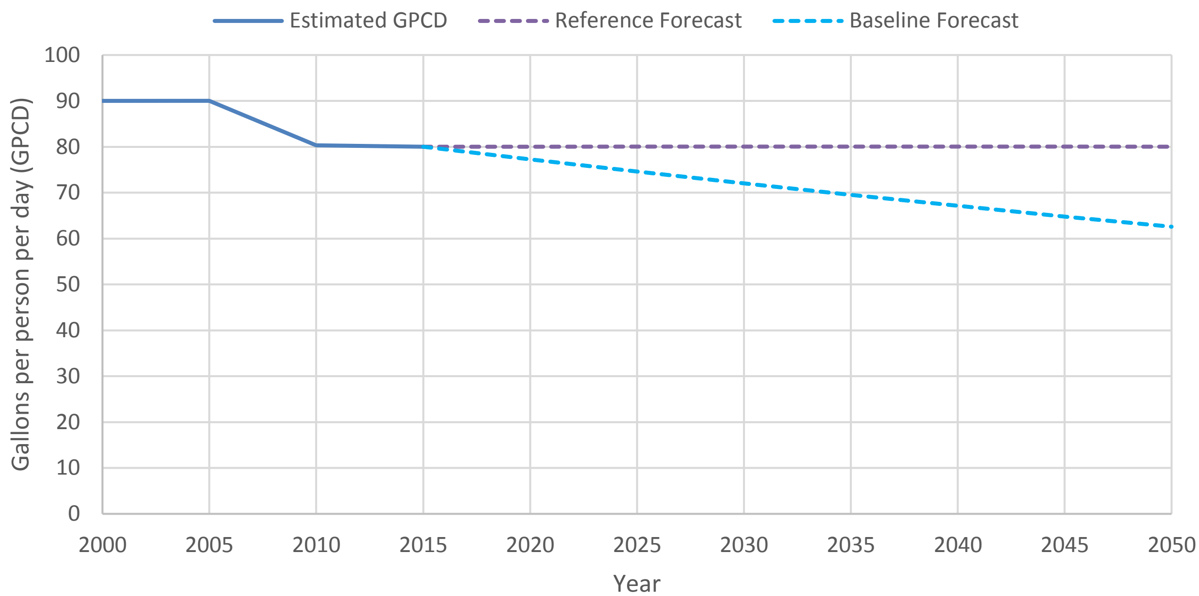
Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Figure 3.19. Domestic self-supply by county, estimated withdrawals (2000-15) and baseline forecast (2020-50), MGD



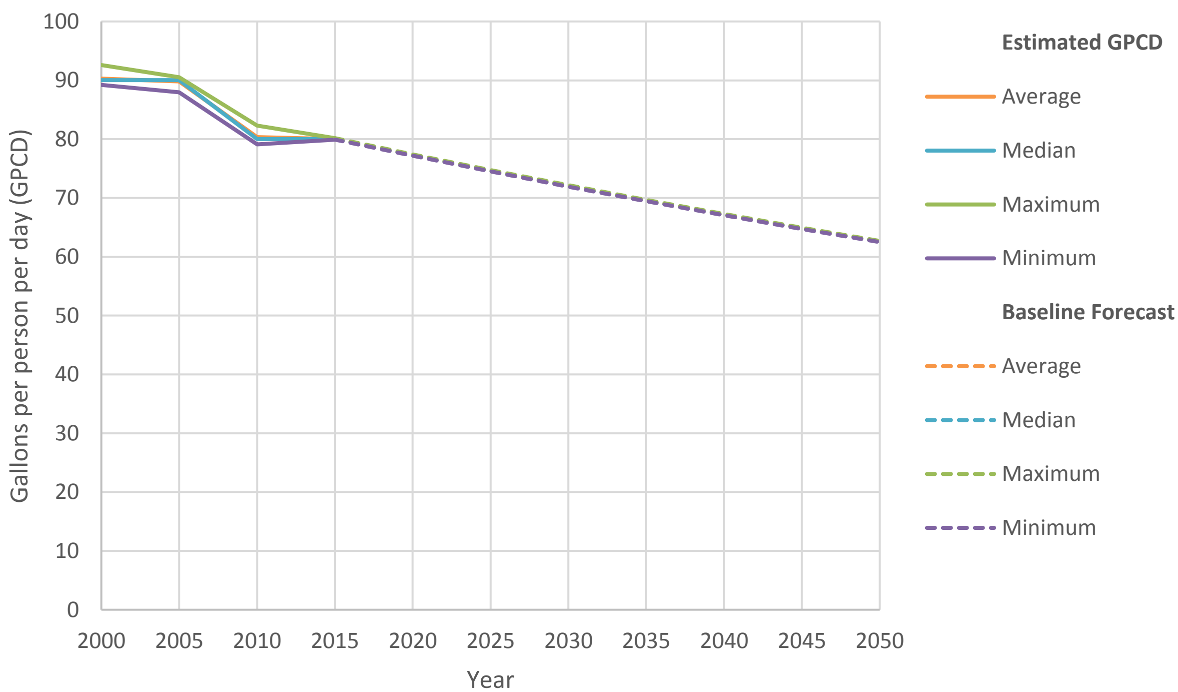
Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Figure 3.20. Domestic Self-Supply, estimated (2000-15), reference, and baseline forecast GPCD (2020-50)



Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Figure 3.21. GPCD characteristics of domestic self-supply, estimated (2000-15) and forecasted (2020-50)



Source: CMAP ON TO 2050 Regional Water Demand Forecast.

4. Data collection and processing

Developing a regional water demand forecast requires organizing and preparing data on water withdrawals, population and employment, and a variety of independent variables that influence water demand. This section describes the data collection and preparation process for the inputs into the forecasts for each of the sectors. The goal of this documentation is two-fold: one, to clearly articulate data transformation and assumptions that were made along the way and two, outline the steps for future updates to the forecast. **Table 4.1** provides a full list of the data used in the ON TO 2050 Regional Water Demand Forecast, including the source, geography, and time series of the data.

The steps described in this section developed the following items to be used in the forecast:

4.1 Water withdrawal data:
- Annual withdrawals for each forecasted community and county remainder, and county summary.
- Source mix of annual withdrawals for each forecasted community, county remainder, and full county.

4.2 Population and employment data:
- Past and projected population and employment values for each forecasted community and county remainder.
- Annual water unit use, calculated as residential water use per capita and non-residential water use per employee, for each forecasted community and county remainder.

4.3 Independent variables:
- Data collection and preparation steps to get the panel data ready for the regression analysis.
- Steps involved in determining the future projection values for the regression-based forecast.
- Grouping analysis for fixed effects.

4.4 Forecast equations:
- Development of baseline forecast equation.
- Regression forecast for the residential public water supply sector.

4.5 Future water demand calculations:
- Projected water unit use values using forecast equations.
- Generating municipal, county, and regional forecast results.

Table 4.1. Data used in the ON TO 2050 Regional Demand Forecast

Data	Source	Geography	Time Series
Public water supply withdrawals and distribution information	Illinois Water Inventory Program	Intakes/Wells	Annual, 2000-2013
Industrial and commercial self-supply withdrawals	Illinois Water Inventory Program	Intakes/Wells	Annual, 2000-2013
Public water supply withdrawals	Illinois Department of Natural Resources Office of Water Resources, Lake Michigan Allocation Program	Community water supplier and other facilities	Annual, 2000-2013
Domestic self-supply	U.S. Geological Survey National Water Information System: Water Use Data for Illinois	County	5-year increments, 2000-2015
Population served	IEPA Safe Drinking Water Information System: Drinking Water Watch	Community Water Suppliers	Various years, 2000-2014
Population	U.S. Census	Municipality/ Unincorporated County	Annual, 2000-2013
Population projections	CMAP ON TO 2050 Socioeconomic forecast	Local Area Allocation zone	5-year increments, 2015-2050
Total Employment	Longitudinal Employment and Household Dynamics		Annual, 2002-2015
Employment projections	CMAP ON TO 2050 Socioeconomic forecast	Local Area Allocation zone	5-year increments, 2015-2050
Service area boundaries	Individual Community Water Suppliers	Community Water Suppliers	Various
Power generation	Illinois State Water Survey	Intakes/Wells	Various
Temperature and precipitation	Illinois State Climatologist Office	Climate Division IL02	Monthly, 2000-2017
			Monthly normal, 1981-2010
Housing density	U.S. Census, Decennial U.S. Census, ACS	Municipality/ Unincorporated County	Annual, 2000-2015
	CMAP ON TO 2050 Socioeconomic forecast	Local Area Allocation zone	5-year increments, 2015-2050
Median household income	U.S. Census, Decennial U.S. Census, ACS	Municipality/ Unincorporated County	Annual, 2000-2015
	CMAP ON TO 2050 Socioeconomic forecast	Local Area Allocation zone	5-year increments, 2015-2050
Marginal residential price of water	Dziegielewski, et al;[a]	Community Water Supply System	2003
	IDNR Water Rates Survey		2005, 2010, 2015
	IISG Water Rates Survey		2008, 2012, 2013, 2016, 2018

[a] Dziegielewski, B., J.Kiefer, T.Bik (2004) Water Rates and Ratemaking Practices in Community Water Systems in Illinois: Project Completion Report Department of Geography Southern Illinois University Carbondale. Actual report only contains values for 2003.

4.1 Water withdrawal data

The forecast is based on annual water withdrawal data associated with community water suppliers and industrial and commercial self-supply available through the Illinois Water Inventory Program (IWIP) of the Illinois State Water Survey. Data on water withdrawals associated with domestic self-supply is available through the USGS in 5-year increments.

The data format is different between the three facility types -- community water suppliers, industrial and commercial self-supply, and domestic self-supply. For community water suppliers, IWIP collects annual data on water withdrawals, water withdrawals by customer class, well type,[41] aquifer codes for groundwater withdrawals, purchase network for wholesale distribution, and the name, address and identification number of facilities and associated wells and intakes (points) with coordinates[42] and identification number. For industrial and commercial self-supply, IWIP collects annual data on water withdrawals, well type, aquifer codes for groundwater withdrawals, and the name, address and identification number of facilities and associated wells and intakes (points) with coordinates and identification number. All IWIP data is self-reported by the facility operator. ISWS also reviews IWIP data against data collected through the Lake Michigan Allocation Program through the annual water use audit form, called the LMO-2. Like IWIP, LMO-2 data collects self-reported data. LMO-2 data includes annual data on water withdrawals, water use by customer class, general water source, purchase network for wholesale distribution, permittee names, and service population. In addition, the ISWS removes extreme outliers and conducts other interpretations in the in the self-reported data through a variety of steps.[43] For domestic self-supply, USGS estimates water withdrawal data derived from estimated population served data in 5-year increments by county through the National Water Use Information Program.[44] Source information distinguishes between groundwater and surface water withdrawals and lacks detail on individual wells.

Given the goal of providing a municipal-scale forecast for residential and non-residential withdrawals, a significant portion of this work involves spatially organizing water withdrawals by municipal boundary and categorizing withdrawals by customer class. **Table 4.2** provides a summary of the steps completed by facility type, which are described in more detail below. R/Python code is available upon request.

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[41] Well types include public supply groundwater, public supply surface water, individual self-supply groundwater, individual self-supply surface water, irrigation groundwater, irrigation surface water.

[42] Where a lambert x/y is not available, township/range/section/plot information is provided.

[43] Abrams, Daniel, Illinois State Water Survey, personal communication, January, 2018. This process primarily includes flagging and removing order of magnitude discrepancies in reporting. In some cases, modification of the self-reported purchase distribution network was made to coincide with IEPA data records, which was essential in converting water withdrawals to water usage data.

[44] U.S. Geological Survey, National Water Use Information Program, https://waterdata.usgs.gov/nwis/wu.

Table 4.2. Data preparation steps by facility type

Facility type	Preparation steps
Community water supply	Identifying municipal-scale community water suppliers Assigning facilities to municipal and county boundaries Determining residential and non-residential water withdrawals
Industrial and commercial self-supply	Removing power generation from I&C wells Assigning points to municipal and county boundaries
Domestic self-supply	Review withdrawal data for anomalies

Community water supply

Community water suppliers (CWS) are facilities that are publicly- or privately-owned that serve at least 25 people or maintain 15 residential service connections. A thorough review of IWIP's wholesale distribution network data provides more spatial details on where water is ultimately used. This reviewed network information is available starting in the year 2000, which in turn established the study period for the forecast to 2000 to 2013, the most recent year available. A number of steps were performed to prepare the data. CWS are identified in IWIP data by well type.[45]

Identify municipalities with municipal-scale community water suppliers

CWS service area boundaries are not collected by any state entity at this time, which makes it difficult to relate water withdrawals to demand factors (population and employment, income, housing density, etc.) of a given place. In the absence of service area boundaries, the project team identified municipalities where the majority of the population is likely being served by a single CWS. In this way, the withdrawals associated with that facility could be connected to the demand factors of that municipal area. All other municipalities, which may be served through private domestic wells and/or partially served by smaller scale CWS systems, as well as unincorporated areas are treated together in a county remainder.[46]

A number of steps were performed to isolate CWS providing water at a municipal-scale. A simple municipal name filtering exercise was used to pair municipalities with facilities likely servicing that area. A manual review was also conducted to pair facilities with slightly different naming conventions. Next, a comparison between IEPA Safe Drinking Water Information System (SDWIS) reported population served[47] and U.S. census population for each municipality

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[45] There are six well/intake types: Public supply groundwater (33), public supply surface water (34), Individual self-supply groundwater (35), individual self-supply surface water (36), irrigation groundwater (37), irrigation surface water (38). Community water suppliers are identified as public supply in IWIP data (codes 33 or 34).

[46] Individual domestic self-supply well locations are not known and could be located within municipalities served by a CWS system. Therefore, withdrawal data for the county remainders is composed only of withdrawals from smaller scale CWS and does not include domestic self-supply withdrawals, which are handled separately. As a result, the residential and non-residential forecasts likely create higher unit use values.

[47] SDWIS Drinking Water Watch also contains population served data at the time of reporting (not annual), which could include populations inside and outside of municipal boundaries.

from 2000 to 2014 identified facilities that were serving a majority of the municipal population. Where there was a significant difference between the U.S. census population and the SDWIS population served, further investigation was required to determine if municipal-scale service was being provided. Given the limited time to contact each facility, the project team focused on contacting 17 facilities where the SDWIS population served values were 25 percent above or below the census population.[48]

In addition, large private water suppliers -- Aqua Illinois, Utilities Inc, and Illinois American Water -- provided service boundary locations, which confirmed municipal-scale service.[49] For municipalities in the region that were still not assigned with a CWS, data checking was performed to confirm that the municipality was served via private wells or smaller scale community water supply systems.[50] In the end, 245 municipalities were identified as CWS facilities providing water service at the municipal scale **(Figure 4.1).** Additional issues were also uncovered and addressed through this process -- including lingering water withdrawals or population served values associated with water commissions serving multiple communities,[51] or geographically-based errors in annual water withdrawal reporting.[52]

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[48] Using contact information from IEPA's Drinking Water Watch website, the following facilities were contacted to confirm the scale of service provision: Beach Park, Brookfield-North Riverside Water Commission, Central Lake County JAWA, Fox Lake, Frankfort, Green Oaks, Hillside Berkeley Water Commission, Lakemoor, Lakewood, Montgomery, Mount Prospect, Northwest Water Commission, Pingree Grove, Prospect Heights, Romeoville, Round Lake Park, and West Suburban Water Commission.

[49] This was particularly helpful given that private water systems are often given unique names that do not necessarily correspond with the municipality they are located in.

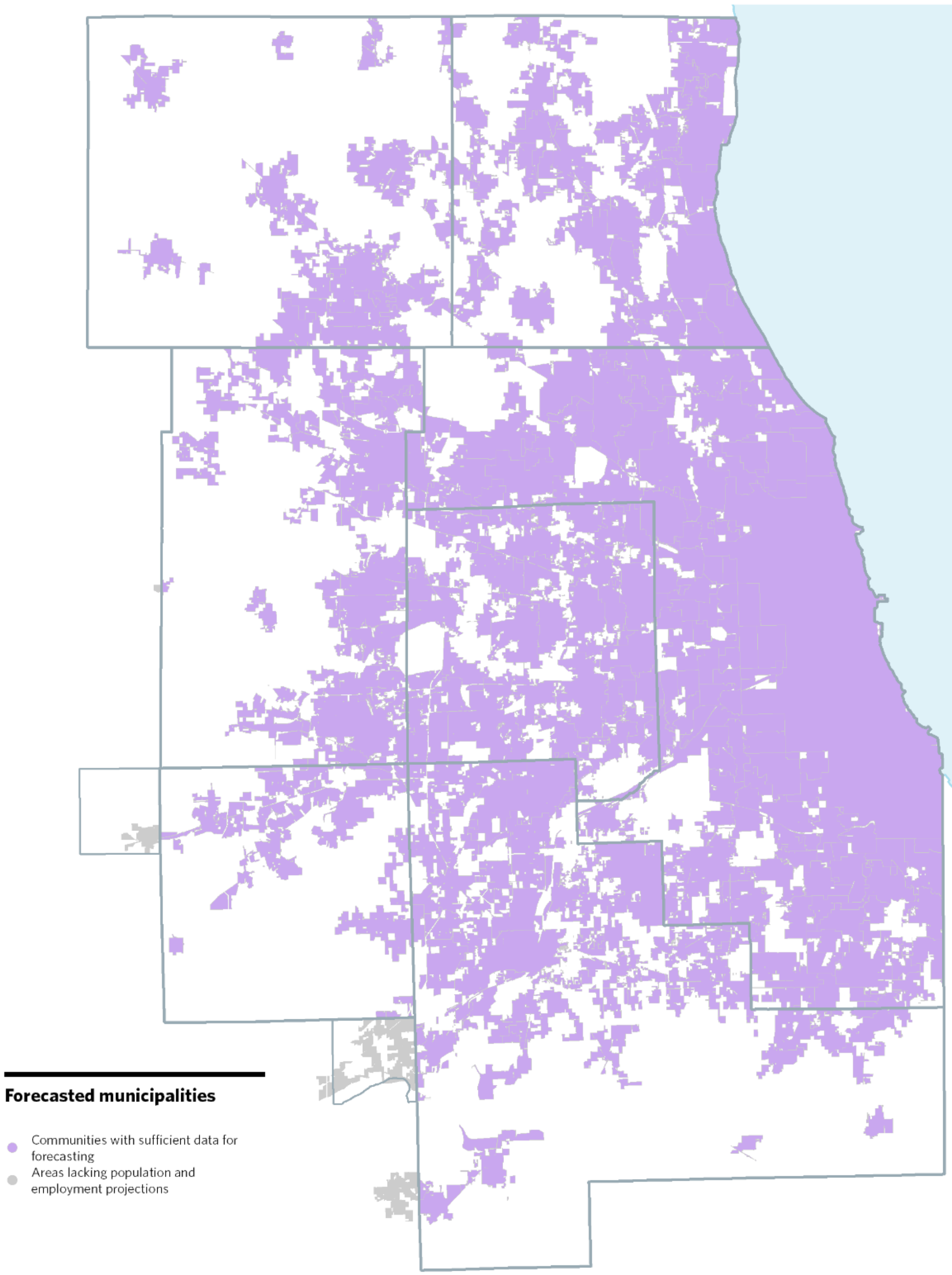
[50] The following municipalities were found to not have a municipal-scale CWS: Barrington Hills, Big Rock, Bull Valley, Campton Hills, Deer Park, Greenwood, Hawthorn Woods, Indian Creek, Inverness, Johnsburg, Kaneville, Kildeer, Lily Lake, Long Grove, McCullom Lake, Mettawa, Millbrook, Millington, North Barrington, Oakwood Hills, Old Mill Creek, Platville, Port Barrington, Prairie Grove, Ringwood, South Barrington, Spring Grove, Symerton, Third Lake, Trout Valley, Virgil, Wadsworth, Wayne, and Wonder Lake. Johnsburg may be served by a municipal-scale CWS with a portion served by Utilities Inc Whispering Hills facility. IWIP data has two facilities -- IL11190040 (Johnsburg 1) and IL11195080 (Johnsburg 2) but municipal staff could not be reached to determine the relationship of these facilities with the municipality. Godley does have a municipal-scale CWS, but this system started serving customers towards the end of the forecast study period and was not serving the majority of the municipal area. Other complications with the data and/or service area led to the omission of Braceville, Lisbon, and Orland Hills.

[51] IWIP's wholesale distribution network data has distributed water withdrawals to individual CWS throughout the region using purchasing records. However, withdrawals remained associated with four water commissions – Brookfield-North Riverside (serving Brookfield, North riverside, La Grange Park, Lyons), Central Lake County JAWA (serving Grayslake, Gurnee, Lake Bluff, Libertyville, Lindenhurst, Mundelein, Round Lake, Round Lake beach, Round Lake Heights, Round Lake Park, Vernon Hills, Volo, and Wauconda municipalities as well as the Grandwood Park, Knollwood, and Wildwood non-muni scale CWS), Hillside Berkeley Water Commission (serving Berkeley and Hillside), and the Northwest Water Commission (serving Arlington Heights, Buffalo Grove, Deerfield, Des Plaines, Palatine, and Wheeling). While remaining values could represent accounting errors, CMAP treated them as real values; remaining water withdrawals associated with commissions were proportionally reassigned to member communities from 2000-14.

[52] The West Suburban Water Commission (IL03195820) serves Justice, Willow Springs, and Hickory Hills. While water withdrawal data for Hickory Hills appears complete, values for Justice and Willow Springs were combined in the IWIP dataset and were reported inconsistently to IDNR's Lake Michigan Allocation Program. For the purposes of

this forecast, Justice and Willow Springs are treated as one entity. Future reporting improvements will allow separate forecasts to be generated for these two municipalities.

Figure 4.1. Communities with municipal-scale public water supply, 2000-13



Source: Chicago Metropolitan Agency for Planning, 2018

Assigning facilities to municipal boundaries

All CWS facilities were assigned to either a municipality or one of the seven county remainders. County remainders consist of unincorporated areas as well as municipalities that may be partially served by smaller scale CWS, industrial and commercial self-supply, and/or domestic self-supply. The step above, where 245 municipal-scale CWS were identified, addressed the majority of this task, accounting for 96.1 percent of use in 2013.[53] The remaining smaller scale CWS were assigned to one of the municipalities identified above or to the seven county remainders based on IWIP well or intake location data. CWS facilities can include multiple wells or intakes. In instances where a facility had wells or intakes in multiple geographies, the geography that contained 85 percent of the use totals was selected as the primary geography.

Determining residential and non-residential CWS withdrawals

ISWS provided total annual water withdrawals for all CWS, which had undergone additional internal data review processes to address gaps and outliers. Given that water demand factors for residential and non-residential uses are different, the forecast methodology requires the separation of residential and non-residential withdrawals. IWIP and LMO-2 data includes information on the annual quantities of water delivered to residential, commercial, and industrial customers in respective services areas. However, customer class deliveries reported to IWIP vary in calculation techniques, metering locations, and customer class designations among community water suppliers; because of these complexities, these data do not undergo the sam level of QA/QC by the ISIP program as point withdrawal data, As a result, the sum of residential and nonresidential withdrawals reported to IWIP general do not sum to the total water withdrawals.[54,55] Project time constraints prevented extensive data checking and verification. Given that total water withdrawals have undergone detailed review by IWIP staff, an average proportion of customer class subtotals was applied to the total water withdrawals to determine the residential and non-residential withdrawals.[56] The average proportion was determined on an annual basis for Lake Michigan permittees and a 10-year average for all other water suppliers. Using this technique, non-revenue water, or water loss, as well as other unallocated water use, is distributed to the two customer classes and is not treated separately.

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[53] Six of the municipalities identified for an individual forecast had portions of the community outside of the region. Given that only a portion of the withdrawals are distributed and used in the region, the past reported withdrawals values for these communities were reduced to reflect in-region values. The reduction was based on the proportion of the community's in region population or in-region employment.

[54] Benedykt Dziegielewski, 2009, "Residential Water Use in Northeastern Illinois: Estimating Water-use Effects of Infill Growth versus Exurban Expansion," Prepared for the Chicago Metropolitan Agency for Planning, Southern Illinois University Carbondale

[55] Abrams, Daniel, Illinois State Water Survey, personal communication, January, 2018.

[56] For Lake Michigan permittees, data from LMO-2 superceded IWIP reporting unless otherwise stated.

Industrial and commercial self-supply

Industrial and commercial water users that pump at a rate of 70 gallons per minute or greater from wells or surface water intakes are required to report annual water withdrawals to the State of Illinois.[57] Well types flagged as irrigation -- 37 and 38 -- include a wide range of non-residential uses, including manufacturing, golf courses, and car dealerships, and comprised approximately 11 percent of all industrial and commercial self-supply withdrawals in 2011. All of these were included in the non-residential forecast given that it would be hard to separate out purely irrigation-based withdrawals.

Remove surface water withdrawals associated with large-scale power generation

The previous regional water demand forecast included a separate, detailed demand assessment of water used in power generation. The amount of water used in power generation is dependent on electricity demand and the type of power generation. Water is primarily used for cooling; with more than 98 percent of withdrawals returning to a water body.[58] Given the limited time frame of this project, as well as the dominance of once-through cooling systems, the ON TO 2050 water demand forecast methodology does not include a separate analysis for this sector. Therefore, surface water withdrawal volumes used for power generation in the industrial and commercial self-supply withdrawal data needed to be removed as these volumes would distort the non-residential water demand forecast.[59]

ISWS provided two key datasets to identify withdrawals associated with power generation: self-reported data to IWIP on whether or not a given facility is used for power generation and a separate list of self-supply points with Standard Industrial Classification or SIC codes indicating power generation. All facilities reporting power generation to IWIP were reviewed and those points reporting surface water withdrawals over 10 MGD were removed. An additional four facilities with SIC codes indicating power generation were identified to have significant power generation and the corresponding surface water withdrawals from specific intakes were also removed. In addition, two surface water intakes reporting water for cooling were removed.

Assigning self-supply wells and intakes to municipal and county boundaries

Location information contained within IWIP point data was used to assign the facilities to one of the municipalities identified above or to the seven county remainders. In instances where a facility had wells or intakes in multiple geographies, the geography that contained 85 percent of the use totals was selected as the primary geography.[60] Location data was not available for 2 percent of the wells and intakes; these points were assigned to the relevant county remainder based on the facility identification code. A manual review of wells or intakes with withdrawals

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[57] Public Act 096-0222, http://www.ilga.gov/legislation/publicacts/fulltext.asp?Name=096-0222.

[58] Dziegielewski, B. and F.J. Chowdhury, 2008, "Regional Water Demand Scenarios for Northeastern Illinois: 2005-2050," Southern Illinois University Carbondale: Department of Geography and Environmental Resources.

[59] Any water withdrawals associated with groundwater wells were retained as this water was likely used for other purposes, not once-through cooling.

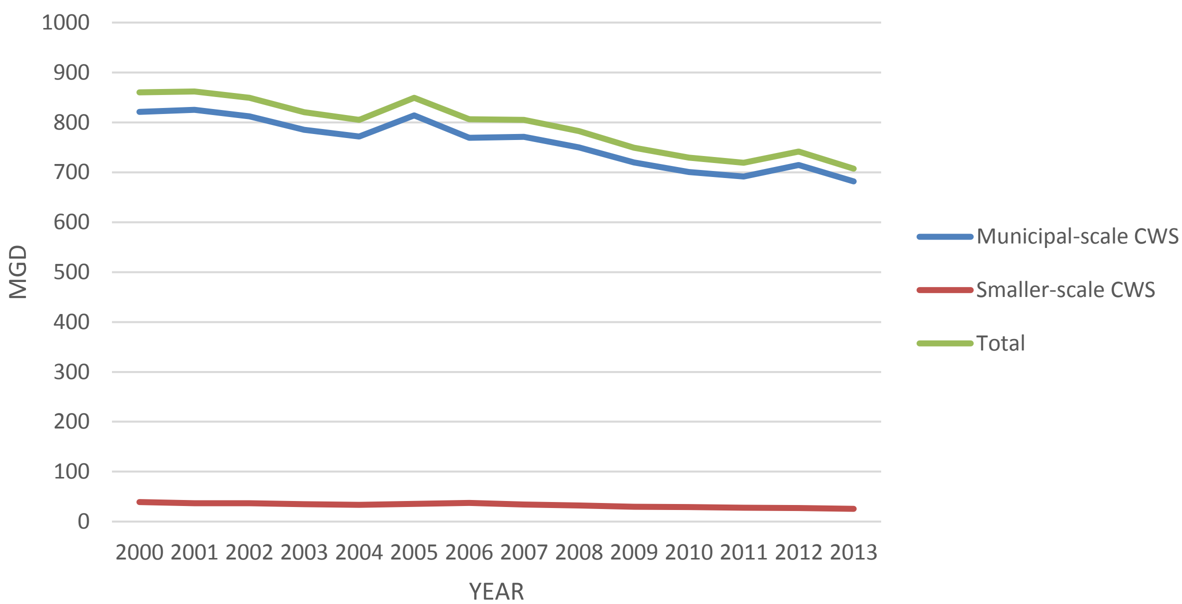
[60] The remaining 11 facilities were assigned manually based on internet research.

over 1 MGD was conducted to confirm the location via internet research. In addition, facilities with multiple wells or intakes were reviewed for locational consistency; wells that lacked locational data but were part of a system were assigned to a geography based on the location of the other points.

Organizing residential and non-residential withdrawals by geography

Throughout the process, annual residential and non-residential withdrawals were organized by the confirmed geography, with municipal scale CWS, smaller scale CWS,[61] and industrial and commercial self-supply kept separated. A total sum for residential and non-residential withdrawals was then calculated per year. Total residential water use was calculated as the sum of any residential water use coming from a municipal-scale CWS as well as any smaller scale CWS assigned to that geography (**Figure 4.2**). **Figure 4.3** shows the residential water use reported by forecasted community for 2011. Total non-residential water use was calculated as the sum of any non-residential water use coming from any CWS and then any water use attributed to an industrial and commercial self-supply facility assigned to that geography (**Figure 4.4**). **Figure 4.5** shows the non-residential water use reported by forecasted community for 2011.

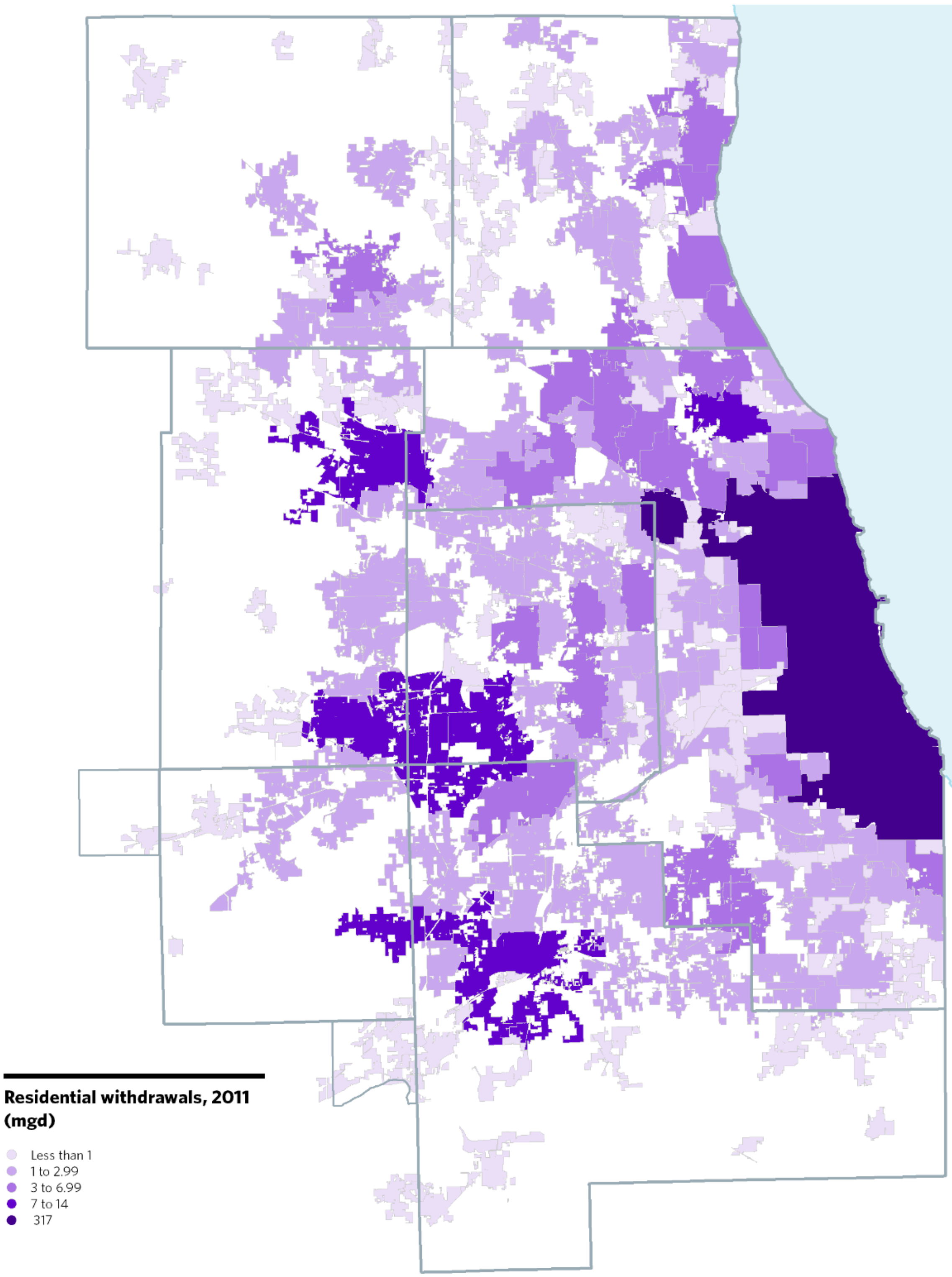
Figure 4.2 Total residential withdrawals, (2000-13), MGD



Source: CMAP ON TO 2050 Regional Water Demand Forecast.

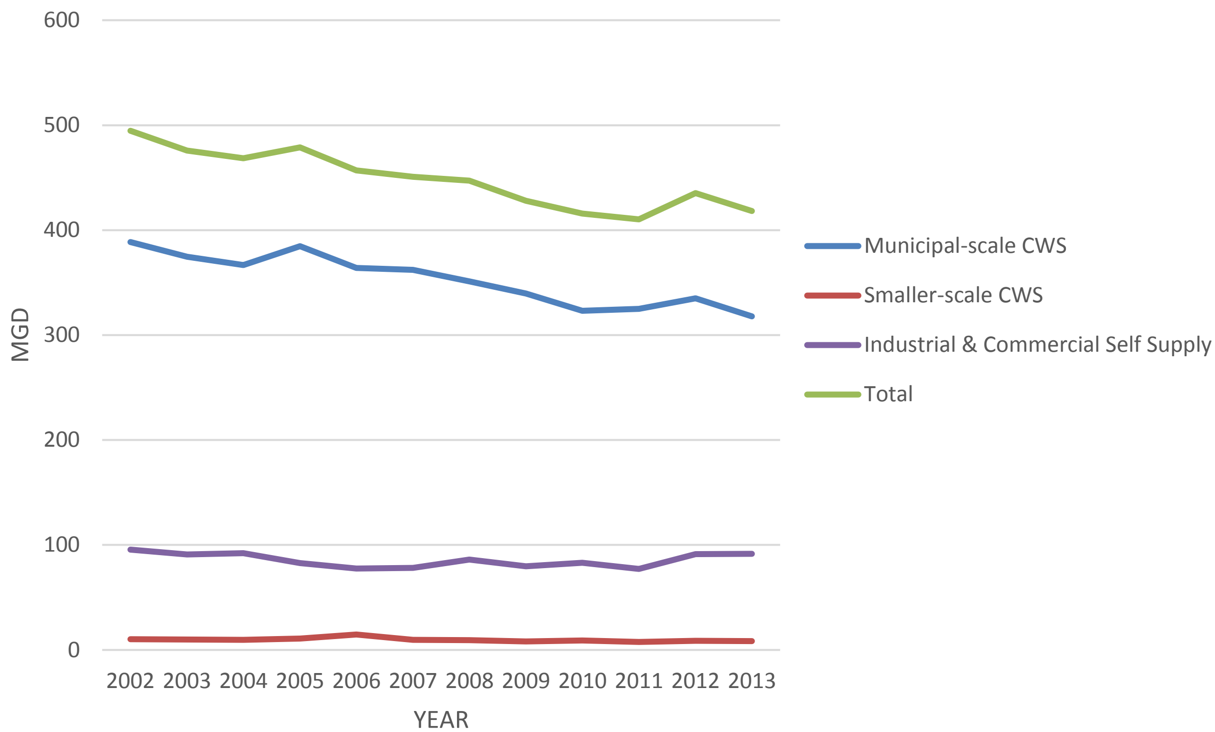
[61] Referred to as PWS in the regional water demand forecast database.

Figure 4.3 Reported residential withdrawals by forecasted municipality, 2011



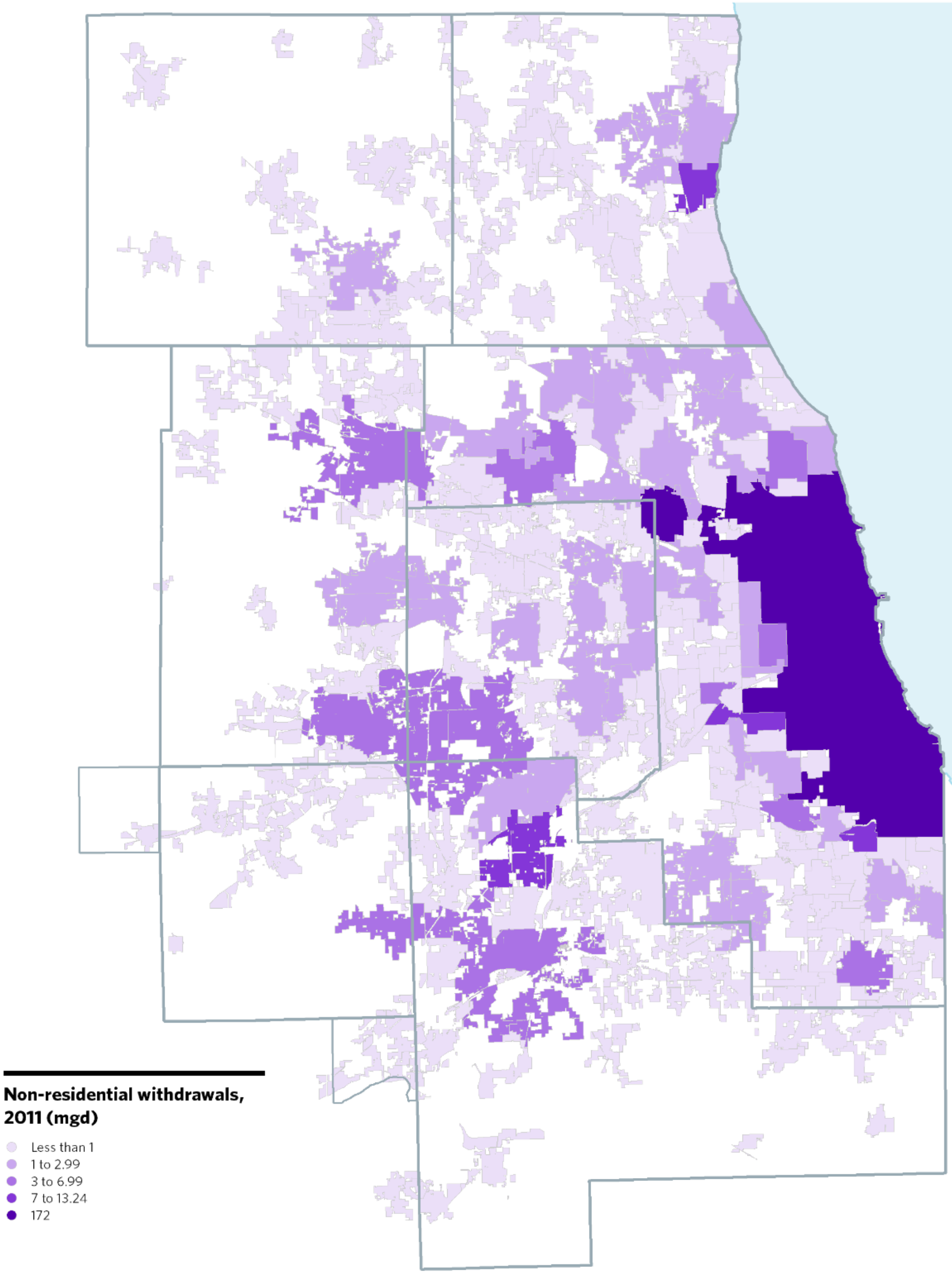
Source: Chicago Metropolitan Agency for Planning, 2018

Figure 4.4. Total non-residential CWS and I&C Self Supply withdrawals, (2000-13), MGD



Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Figure 4.5 Reported non-residential withdrawals by forecasted municipality, 2011



Source: Chicago Metropolitan Agency for Planning, 2018

Domestic self-supply

The USGS National Water Use Information Program compiles and publishes national water use data, including data on the domestic self-supply sector. The data is available from 2000 to 2015 in 5-year increments by county (**Table 4.3**). It is important to note that self-supplied domestic withdrawals are not required to report withdrawals to IWIP or the county departments of public health, which are the agencies involved in initial permitting. Therefore, the USGS estimates usage by multiplying an estimate of the population not served by public supply by an estimate for daily per capita use.[62] The withdrawal data was reviewed for accuracy; with several data points adjusted to remove variation that would be unlikely to occur within a 5-year period given regional growth trends. This was primarily determined by reviewing the estimated population served, see Section 4.2.

Table 4.3. Self-Supplied Domestic Withdrawals by County from 2000-15, MGD

County	2000	2005	2010	2015
Cook	0.48	0.48	0.42	0.42
DuPage	1.95	2	3.9[a]	5.81
Kane	0.15	0.17	0.42	0.44[b]
Kendall	2.98	2.46	2.41	1.86
Lake	7.29	7.81	6.95	6.96
McHenry	8.93	4.94	5.75	5.25
Will	11.8	12.43	11.19	11.23
Total	**33.58**	**30.29**	**31.04**	**35.89**

[a] Original value was 7.4, adjusted to reflect the middle value between 2005 and 2015.
[b] Original value was 4.36, adjusted decimal to better reflect recent trends
Source: USGS National Water Use Information Program.

Water withdrawals by source

Understanding future water demand by source is a critical element of the regional water demand forecast. Water source information is provided in the IWIP point data via a well type code[63] and an aquifer code.[64,65] However, a number of issues needed to be addressed to confirm the water source within the point data. First, the point data does not reflect the Lake Michigan wholesale distribution network within CWS; therefore, all Lake Michigan point data totals were

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[62] USGS National Water Use Information Program, Domestic Water Use, Data Sources, see https://water.usgs.gov/watuse/wudo.html

[63] There are six well types: Public supply groundwater (33), public supply surface water (34), Individual self-supply groundwater (35), individual self-supply surface water (36), irrigation groundwater (37), irrigation surface water (38)

[64] Aquifer codes consist of four digits, with the first two digits indicating the uppermost aquifer the well is open to while the last two digits signifying the lowermost aquifer the well is open to. For this forecast, any code where the last two digits signified the sandstone aquifer – either 60 or any number between 66-97 – were attributed to the sandstone aquifer. All others were designated as a shallow aquifer well.

[65] USGS reports that all domestic self-supply relies on groundwater sources, but information on withdrawals by aquifer type are not known. Therefore, the information on water withdrawals by source does not include withdrawals from the domestic self-supply sector.

replaced with ISWS processed LMO-2 totals. Additional CWS facilities lacked source information in the point data,[66] therefore, CMAP assigned source using a separate ISWS categorization[67] and knowledge gained through the CMAP LTA program. Surface water intakes do not currently contain the name of the source waters; therefore, CMAP assigned surface water sources based on proximity-based GIS analysis.[68] Surface water-based facilities that lacked coordinate data were manually assigned based on internet research to identify the location. For groundwater-based facilities composed of multiple wells and where some wells lacked source information, CMAP assigned the dominant aquifer code of the known wells to the missing data. For groundwater-based facilities composed of a single well with no aquifer code, these sources were manually assigned based on the dominant water source of nearby, un-related wells.

The forecast relies on withdrawal totals at the facility level, not the point data, because the facility data has undergone more extensive ISWS review. Therefore, the proportion of use by water source was derived from the point data and then the percentage was applied to facility level withdrawal totals. Some facilities rely on more than one water source and the proportion coming from each source can vary over time due to a variety of factors, including weather and infrastructure maintenance. To account for these variations, the methodology generates an average source mix from ten years of data (2003-13) and then uses that mix to project out future water demand by source. However, some municipal-scale CWS have made permanent transitions to different sources during the ten-year time period.[69] Municipal scale CWS were reviewed for any dramatic proportional changes within annual data (2003-13) and the time period used to generate the average source mix was reduced to account for updated water sources (**Table 4.4**). Permanent source switching in smaller scale CWS or industrial and commercial self-supply is not accounted for in this methodology.

[66] Coal City, Diamond, Minooka, Sandwich.

[67] Abrams, Daniel B. et all, 2015, "Changing Groundwater Levels in Sandstone Aquifers of Northern Illinois and Southern Wisconsin: Impacts on Available Water Supply," Illinois State Water Survey, Contract Report 2015-02.

[68] A buffer of one mile was placed on the proximity analysis.

[69] Abrams, Daniel B. et all, 2015, "Changing Groundwater Levels in Sandstone Aquifers of Northern Illinois and Southern Wisconsin: Impacts on Available Water Supply," Illinois State Water Survey, Contract Report 2015-02.

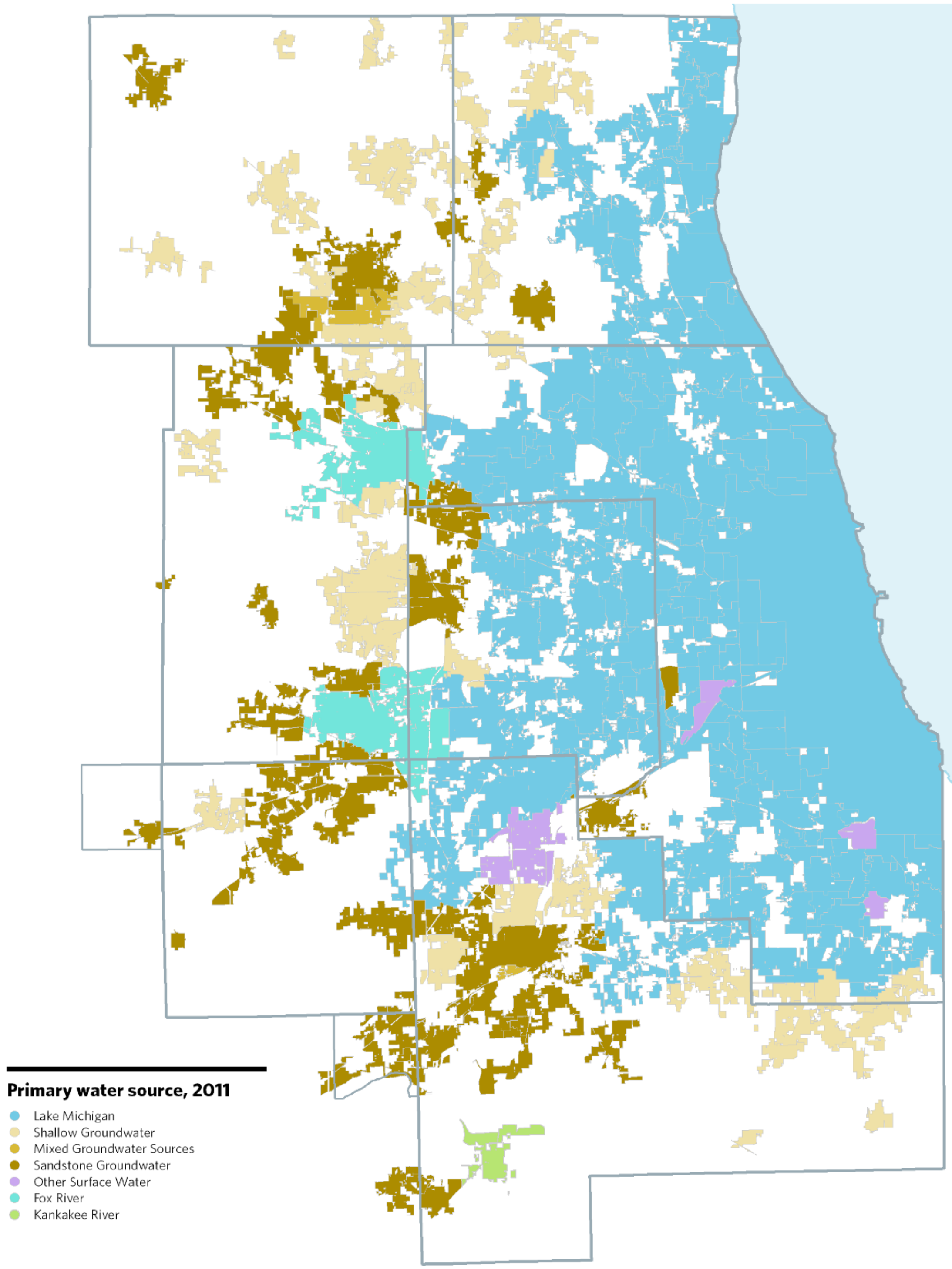
Table 4.4. Changing water supply sources among CWS, 2003-2013

Municipal-scale CWS	Source Change	Year of Change	Alternate Summary Years for Source Mix
Aurora	Fox River became dominant source	2008	2008-2013
Crystal Lake	Sandstone became dominant source	2013	2013
Elwood	Stopped using shallow groundwater	2005	2005-2013
Harvard	Sandstone became dominant source	2009	2009-2013
Mokena	Lake Michigan	2006	2006-2013
Plainfield	Lake Michigan	2005	2005-2013
Rockdale	Shallow became dominant source	2010	2010-2013

Source: CMAP ON TO 2050 Regional Water Demand Forecast

While communities and industrial and commercial facilities may switch sources in the future, predicting when and to what source is not possible through this effort. Therefore, the forecast assumes that communities and facilities will continue to rely on their current source. While the source mix generated for each community is more detailed, **Figure 4.6** illustrates the primary water source providing more than 50 percent of water used in the community.

Figure 4.6. Primary water source by forecasted community, 2011



Notes: Primary water source was determined as the majority (greater than 50 percent) of withdrawals from all CWS and Industrial & Commercial Self-Supply facilities within community. Five communities – Hodgkins, McCook, Riverdale, Romeoville, and Thornton – have other surface water withdrawals that exceed CWS withdrawals. Hodgkins, McCook, Riverdale, and Thornton CWS rely on Lake Michigan while Romeoville CWS primarily depends on shallow groundwater.
Community level forecasts were generated for municipalities with a CWS providing water to the majority of the municipal area. Municipalities that are primarily served by private wells or smaller scale CWS providing water to a portion of the community are included in each county remainder, along with unincorporated lands.

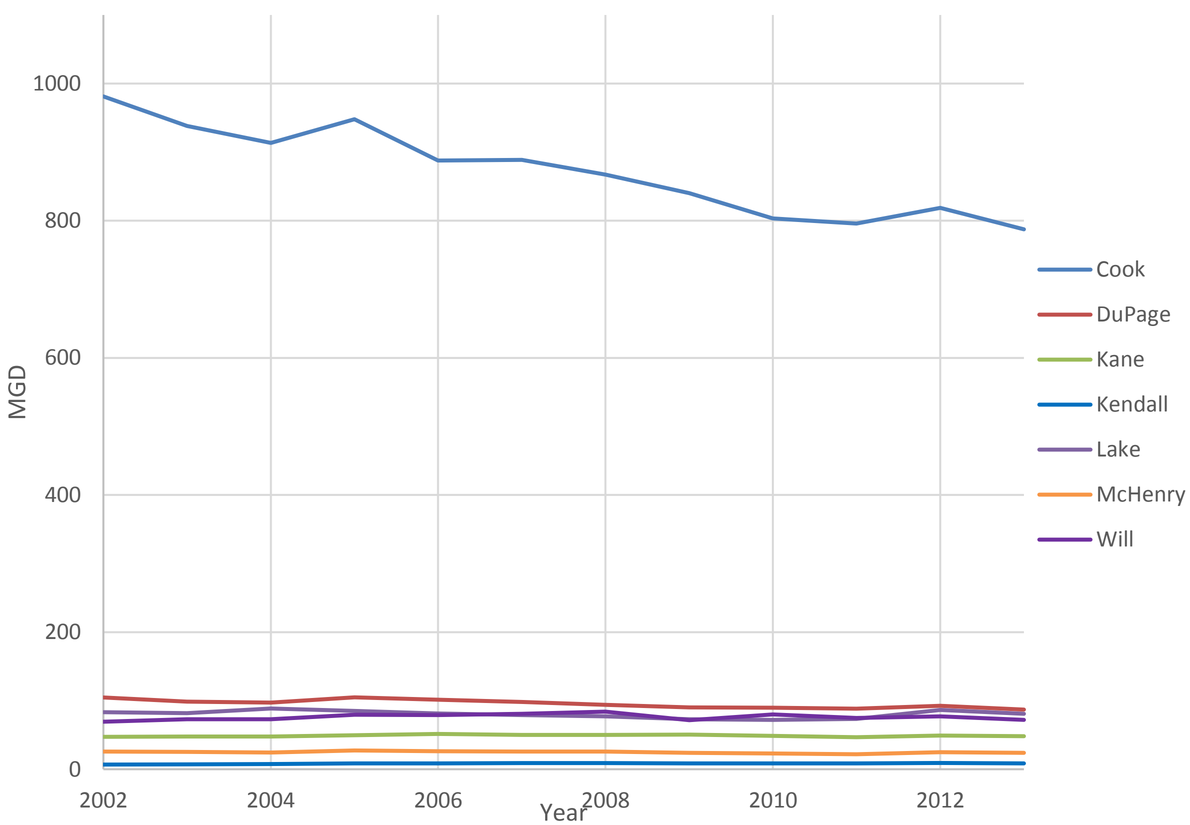
Source: Chicago Metropolitan Agency for Planning, 2018

Water withdrawals by county

Understanding future water demand by county is an important output of the regional water demand forecast. Several counties in the region have conducted detailed, county-level water supply plans; contrasting water demand against this information can inform local and regional planners about the sufficiency of water supply and encourage actions that conserve water, protect supply, and/or pursue alternative drinking water sources.

County information is provided in the IWIP point data via the facility identification number. **Figure 4.7** shows reported total withdrawals by county. For municipalities entirely within one county, the withdrawals can easily be assigned to that county. However, several communities straddle more than one county. In order to generate an estimate of water use by county, a proportion of water use within such communities was assigned to the respective county based on the location of population and employment (via local area allocation zones). Employment information was used for communities where the majority of water withdrawals serve non-residential uses; population in households was used for communities where the majority of water withdrawals serve residential uses.

Figure 4.7. Reported total withdrawals[a] by county, 2002-13



[a] Includes residential and non-residential withdrawals from public water supplies and industrial and commercial self-supply wells. County level withdrawals from domestic self-supply wells are presented in Table 3.3.
Source: CMAP ON TO 2050 Regional Water Demand Forecast.

4.2 Population and employment data

In order to calculate unit use of water over time, past population and employment data needed for each year of the study period for the forecasted geographies. This information is needed for the regression-based forecasts (see Section 4.4). In addition, unit-use for the year 2011 is needed as the base year for the forecasts. For all of the forecasts, projected population and employment from CMAP's ON TO 2050 Socioeconomic Forecast is a core data input. This section steps through the data collection of past population and employment data, the calculation of unit-use by population and employment, a grouping analysis to account for unknown factors contributing to different rates of water use (applied in the regression forecast), and the organization of the projected population and employment values.

Past population and employment

The U.S. Census and American Community Survey were used to provide population served values for each municipality.[70] Relying on U.S. Census data for population served has the added benefit of using the same population source utilized in the ON TO 2050 Socioeconomic Forecast. Municipal population came from the U.S. Census for 2000 and 2010 and the American Community Survey 5-year estimates for 2005-09 through 2012-16. Missing years (2000-06) were interpolated to produce an annual number.

Unincorporated areas and municipalities without a municipal-scale system are treated together in a remainder for each of the seven counties. The project team tested a variety of data sources to understand the population served for this area. Ultimately, since the water withdrawal data for this area is coming from one source -- smaller scale CWS -- the IEPA SDWIS population served for those facilities was used. These areas may have a higher likelihood of being served by domestic self-supply, which is addressed in a separate effort; so relying on the U.S. Census for population served could be misleading.

Total employment within a CWS service area is not collected via existing water withdrawal data. Instead, the project team relied on data from the Longitudinal Employer-Household Dynamics (LEHD) program to generate an annual total employment value for each municipality and the seven county remainders. LEHD data is available from 2002-2015 on an annual basis. Given that the ON TO 2050 Socioeconomic Forecast uses a different data source[71]

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[70] Past population data is collected with CWS withdrawal data. IEPA's SDWIS collects population served data on a rolling basis while the Lake Michigan Water Allocation Program collects population served data on an annual basis. However, conversations with the technical advisory committee and other stakeholders (NWPA Technical Advisory Committee) indicate that CWS operators generally track the number of service connections via billing systems, not the population served. Therefore, when asked to report on population served, municipal-scale CWS operators are thought to commonly rely on U.S. Census population data for the municipality. In addition, the municipal-based forecast includes water withdrawal values from both municipal-wide CWS as well as smaller scale CWS located within that geography. However, it is important to note that the municipal population could include residents who are not part of a CWS and are on private wells, which could result in lower estimated unit use values.

[71] CMAP, "ON TO 2050 Socioeconomic Forecast Appendix," 2018, http://www.cmap.illinois.gov/documents/10180/911391/FINAL+Socioeconomic+Forecast+Appendix.pdf/84809136-9d7e-6a9e-f406-ff43c73744eb

for generating total and sectoral employment, the relationship between the total LEHD employment for 2015 was compared to the ON TO 2050 Socioeconomic total employment projection for each community. In a separate file, past LEHD employment counts for 2011 were then adjusted based on this ratio for each community. This process reduced the potential for a dramatic change in employment between the past employment values and the projected employment through the ON TO 2050 Socioeconomic Forecast.

For the domestic self-supply sector, population served data is reported in the USGS National Water Use Information Program. The data is available from 2000 to 2015 in 5-year increments by county (**Table 4.5**). It is important to note that the population served by self-supplied domestic facilities are an estimate of the population not served by public supply. The population data was reviewed for accuracy; with several data points adjusted to remove variation that would be unlikely to occur within a 5-year period given regional growth trends. **Table 4.5** reflects adjusted values with original data noted. Further questions exist about the accuracy of the population estimates.

Table 4.5. USGS Estimated Self-Supplied County Population, 2000-15

County	2000	2005	2010	2015
Cook	5,380	5,303	5,195	5,239
DuPage	21,660	22,160	47,399[a]	72,636
Kane	1,620	1,930	5,309	5,449[b]
Kendall	33,060	27,324	30,096	23,274
Lake	80,980	86,812	86,912	86,970
McHenry	99,270	54,860	71,840	65,640
Will	131,070	138,093	139,830	140,315
Total	**447,920**	**392,650**	**431,626**	**448,572**

[a] Original value was 92,444, updated to reflect the middle value between 2005 and 2015.
[b] Original value was 54,498, updated to remove the last digit which was likely in error.
Source: USGS National Water Use Information Program.

Calculating unit use

Water unit use, calculated as residential water use per capita and non-residential water use per employee, is a core component of the forecasting process and is used in two different ways. First, the forecast requires water unit use for the most recent weather normal year in order to project out using the ON TO 2050 Socioeconomic forecast. Second, the regression-based forecasts require historical water unit use in order to understand the relationship between water use and factors that influence demand. This section steps through the process of deriving unit use for each of the three sectors. Along the way, additional data anomalies were discovered and addressed.

Deriving residential water use per capita for residential public water supply sector

Residential water use per capita was calculated for each year (2000-13) using the total annual residential water use divided by the annual population for each of the 245 municipalities and seven county remainders. Total residential water use was calculated as the sum of all CWS withdrawals assigned to that geography (Section 4.1) and total population derived from U.S. Census or SDWIS population served (see previous step). The resulting value is displayed as GPCD for each year. **Figure 4.8** shows the range of estimated GPCD across the forecasted communities. Estimates of GPCD for each county remainder may be artificially low because the population values include a significant, yet unknown population that is likely on private residential wells.

The results were reviewed for improbable values outside of the national average range of 60 to 90 GPCD or improbable variation between years as well as through an outlier analysis in preparation for the regression analysis (Section 4.4). For communities with questionable GPCD values, an alternative GPCD value was generated using IWIP values and customer class information instead of LMO-2 values and customer class information where available. Where deemed appropriate, the alternative GPCD replaced the previous GPCD value for portions or the entire study period.[72] For communities with unresolved outliers, problematic yearly values were removed[73] or the entire municipal-scale community water supply system was removed from the analysis.[74]

Deriving non-residential water use per employee for non-residential water supply sector
Non-residential water use per capita was calculated for each year (2002-13) using the total annual non-residential water use divided by the annual employment for each of the 245 municipalities and 7 county remainders. Total non-residential water use was calculated as the sum of all CWS and industrial and commercial self-supply withdrawals assigned to that geography (Section 3.1) and total employment derived from LEHD (see previous step). The resulting value is displayed as GPED for each year. **Figure 4.9** shows the range of estimated GPED across the forecasted communities. The results were reviewed for improbable values. Limited exploration could be conducted to verify the amounts given the lack of an alternative data source for comparison.

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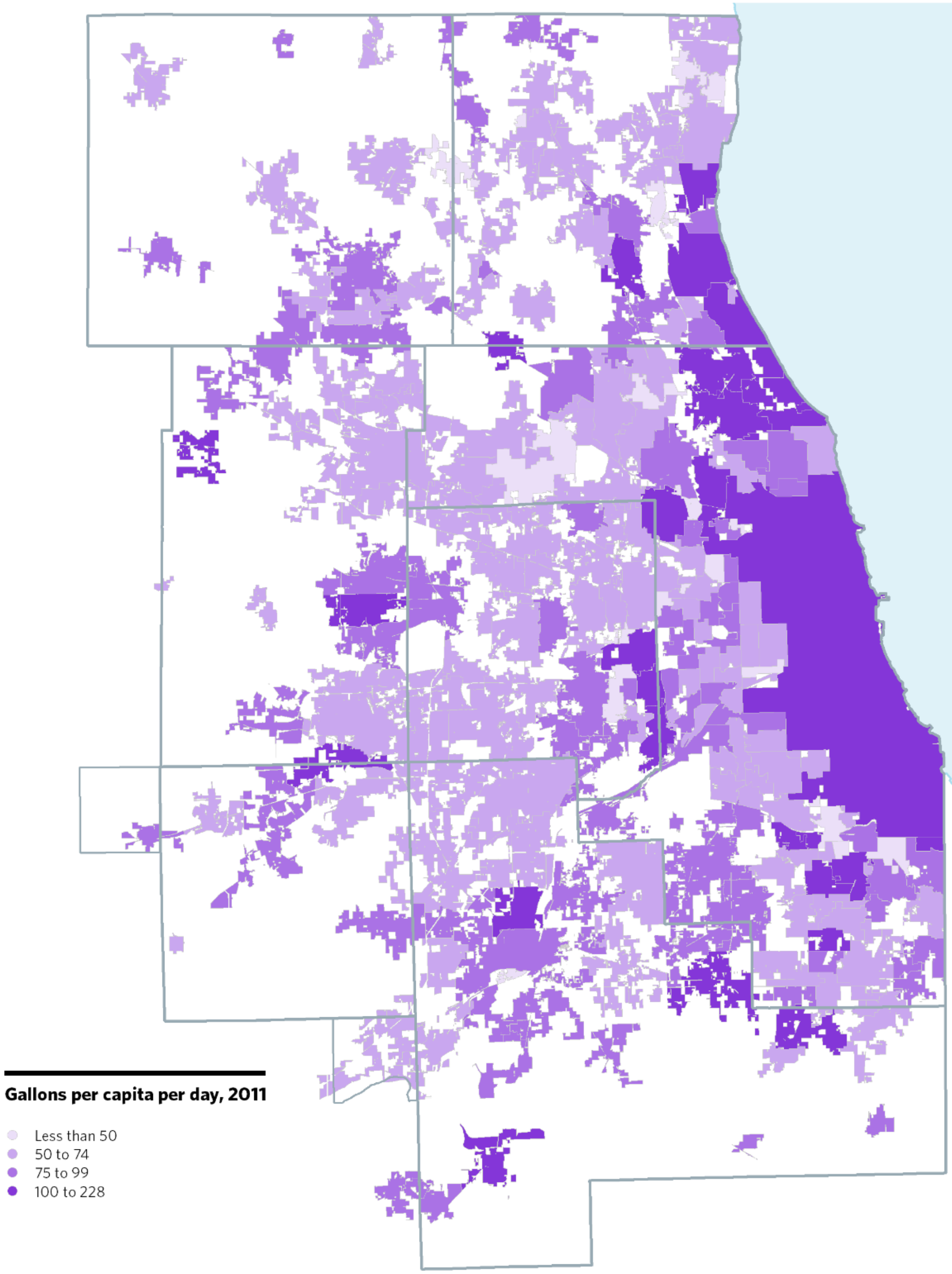
[72] The following municipal-scale CWS used IWIP data and customer class information despite LMO-2 data availability: Bolingbrook, Highwood, Hometown, and Schiller Park. GPCD values for Harvey were generated using LMO-2 data and IWIP customer class information. When LMO2 data was missing for a single year, IWIP values were used instead.

[73] The following GPCD values for the following municipalities were removed for the demand estimation process: Blue Island (omitted 2000), Homer Glen (omitted 2000), Oakbrook Terrace (omitted 2000), Pingree Grove (omitted 2000), Richmond (omitted 2000-02), Romeoville (omitted 2013), and Volo (omitted 2000-07).

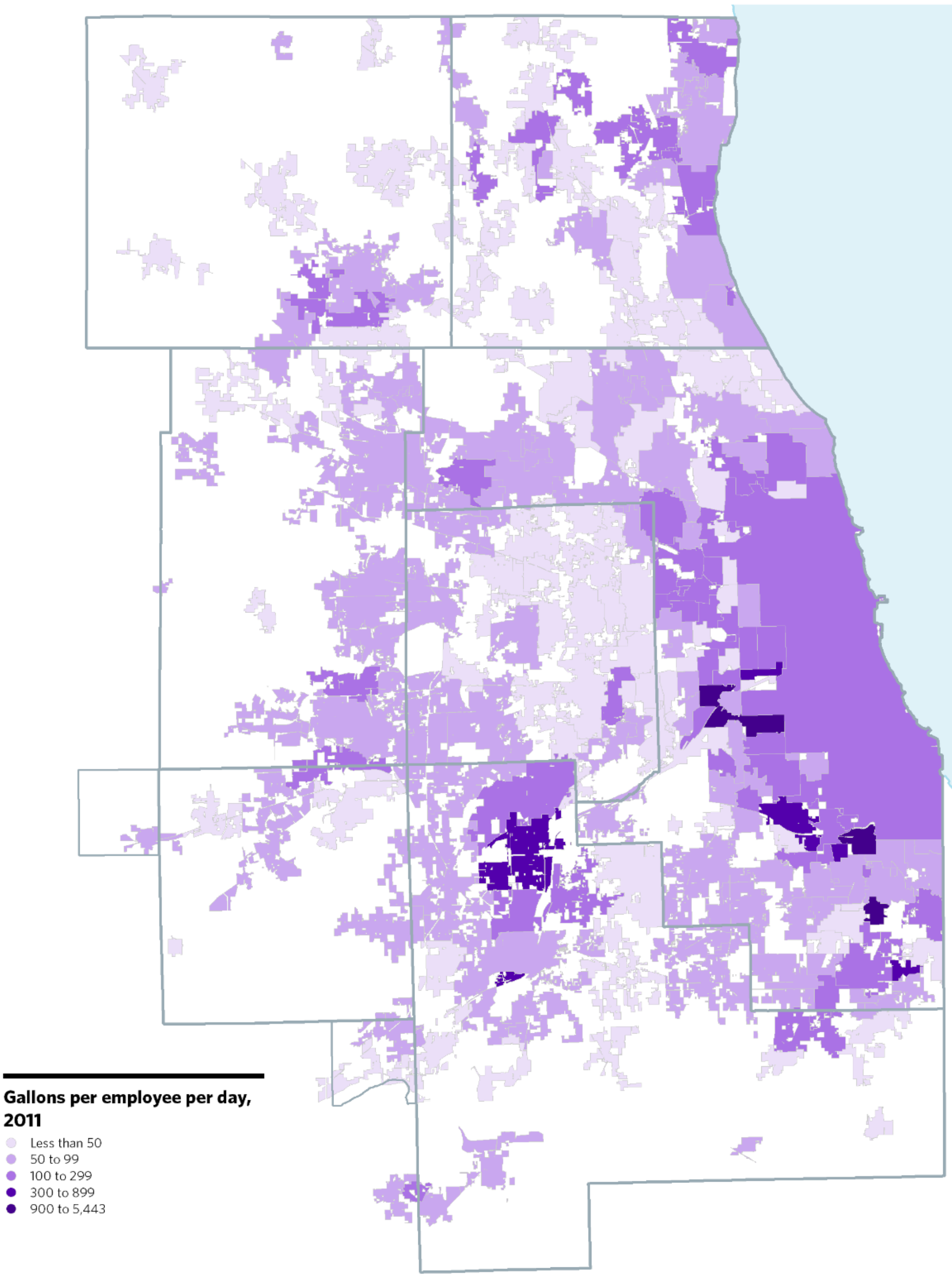
[74] Godley Public Water District was de-categorized as providing municipal-scale service. The lower GPCD values (under 4 GPCD) from 2000 to 2010 revealed that the system was not yet in place during the period of analysis. The water withdrawals and population are included in the county remainder.

Figure 4.8. Estimated GPCD by forecasted municipality, 2011



Source: Chicago Metropolitan Agency for Planning, 2018

Figure 4.9. Estimated GPED by forecasted municipality, 2011



Source: Chicago Metropolitan Agency for Planning, 2018

Deriving residential water use per capita for domestic self-supply sector
Residential water use per capita was calculated for the four years (2000, 2005, 2010, and 2015) using total water use divided by the population for each of the seven counties.[75] The resulting value is displayed as gallons per person per day (GPCD) for each available year (**Table 4.6**). It is apparent that USGS assumed the unit use values were 90 GPCD across the region in 2000 and 2005 and 80 GPCD across the region in 2010 and 2015.

Table 4.6. Residential water use per capital for domestic self-supply sector, GPCD

County	2000	2005	2010	2015
Cook	89.22	90.51	80.85	80.17
DuPage	90.03	90.24	82.28	79.99
Kane	92.59	87.95	79.11	80.01
Kendall	90.14	90.03	80.08	79.92
Lake	90.02	89.96	79.97	80.03
McHenry	89.96	90.05	80.04	79.98
Will	90.03	90.01	80.03	80.03
Regional GPCD[a]	**90.02**	**90.02**	**80.29**	**80.01**

[a] GPCD calculated from total use and total population of the domestic self-supply sector.
Source: CMAP analysis of USGS National Water Use Information Program

Future population and employment

The water demand forecast relies on the ON TO 2050 Socioeconomic Forecast for future population and employment projections. Created as part of CMAP's ON TO 2050 plan development, the socioeconomic forecast estimates the characteristics of the seven-county Chicago metropolitan region's population and employment in 2050.[76] The forecast estimates the 2050 age distribution, race/ethnicity, household size, and similar factors for the region's residents, as well projecting employment trends by sector in five-year intervals (2015-50). Overall, the forecast projects that the region will continue to grow, despite slow growth and some declines after the recent recession. By 2050, the region will have more than 10.8 million residents compared with 8.5 million in 2015. Employment will be just below the 5 million mark, growing from 4.08 million in 2015. More information on the methodology can be found in the ON TO 2050 Socioeconomic Forecast Appendix.[77]

[75] Annual GPCD data was not needed for the domestic self-supply sector as this sector is not forecasted using updated coefficients based on demand estimation.

[76] The Federal Highway Administration requires metropolitan planning organizations (MPOs), such as CMAP, to include a socioeconomic forecast in long-range plans. CMAP revisits its population and employment forecasts every four years in conjunction with the long-range plan schedule.

[77] CMAP, "ON TO 2050 Socioeconomic Forecast Appendix," 2018, http://www.cmap.illinois.gov/documents/10180/911391/FINAL+Socioeconomic+Forecast+Appendix.pdf/84809136-9d7e-6a9e-f406-ff43c73744eb.

It is commonly known that water service boundaries are not completely coterminous with municipal boundaries. Without a state- or regional-level dataset of CWS service boundaries,[78] all of the 245 municipalities identified to have community-wide CWS were assumed to have service areas consistent with the 2010 municipal boundaries used to construct the ON TO 2050 Socioeconomic Forecast.[79] Therefore, the population and employment projections for the municipality could be used as the demand drivers in the water demand forecast.[80] Future population and employment projections were also collected for each of the seven county remainders, which consist of unincorporated areas as well as municipalities that may be partially served by smaller scale CWS, industrial and commercial self-supply, and/or domestic self-supply.

Challenges with private residential wells

Private residential wells could be serving an unknown, yet potentially sizeable, portion of the population in municipalities and county remainders. Given significant data constraints and questions about how domestic self-supply withdrawal values are derived, the withdrawal values associated with the domestic self-supply sector were not assigned to a forecasted geography and are not included in the total forecast. Therefore, the forecast assumes that all populations in the forecasted geographies are being served by a community water supplier; despite the known prevalence of private residential wells. This results in lower GPCD values, which could be particularly significant in the county remainders where private residential wells are more prevalent.[81]

Population projections for the domestic self-supply sector were handled separately.[82] Feedback from stakeholders indicated that new permits for private residential wells have declined in

[78] The ON TO 2050 Socioeconomic Forecast provides population and employment data at the local level via a local area allocation process. The CMAP region is divided up into 16,442 travel model subzones which are roughly 160 acres each but are further divided by 2010 municipal boundaries into 21,977 Local Area Zones (LAZs). This format provides the opportunity to adjust the population forecast to better match the service area boundaries of the community water supply system if this data was more widely available.

[79] The ON TO 2050 Socioeconomic Forecast generates future population and employment projections for only those portions of a municipality that are within the 7-county Chicago region. Seven of the municipalities identified for an individual forecast had portions of the community outside of the region. The unit use values were calculated using total withdrawals and total population or employment for the municipal area and used in the forecast.

[80] This approach assumes that any new population growth within a municipal-scale CWS will connect to either the community-scale public water system or an existing smaller scale public water system and will not be served by private wells. This approach also assumes no service or municipal boundary expansion out to the year 2050 as annexations/service area boundaries are difficult to predict at a regional scale. New population growth forecasted for unincorporated areas adjacent to a municipality will be included in the county remainder, but could likely be served by an adjacent existing system.

[81] Attempts were made to include the county domestic self-supply withdrawals by associating these results with the county remainders; yet the GPCD values led to highly suspect amounts.

[82] The populations projected here are in addition to those included in the ON TO 2050 Socioeconomic Forecast.

recent years, especially after the recent recession. In addition, CMAP policy objectives within the ON TO 2050 Socioeconomic Forecast support infill and redevelopment; where it is assumed that additional residents would join an existing CWS and that residents with private residential wells within communities with existing CWS would transition to the public water supply system.[83] Therefore, the proportion of the population on domestic self-supply is anticipated to decline in the future for much of the region. However, recent trends for each county were independently reviewed. Tailored rates of change for each county were largely based on the median rate of change from 2000 to 2015 (**Table 4.8**).

Table 4.8. Projected population served by domestic self-supply, 2020-50.

County	Rate of change	Forecasted population						
		2020	2025	2030	2035	2040	2045	2050
Cook	-1.43%	5,164	5,090	5,017	4,945	4,875	4,805	4,736
DuPage	-8.00%	66,825	61,479	56,561	52,036	47,873	44,043	40,520
Kane	2.57%	5,589	5,733	5,880	6,031	6,186	6,345	6,508
Kendall	-17.35%	19,236	15,898	13,140	10,860	8,976	7,419	6,131
Lake	0.12%	87,070	87,170	87,271	87,371	87,472	87,573	87,674
McHenry	-9.45%	59,440	53,826	48,742	44,138	39,969	36,193	32,775
Will	0.35%	140,800	141,287	141,775	142,265	142,757	143,250	143,745

Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Communities with partial ON TO 2050 Socioeconomic Forecasts

Six of the municipalities identified for an individual forecast had portions of the community outside of the boundary of the ON TO 2050 Socioeconomic Forecast (**Figure 4.9**). Without a population and employment forecast for the remaining area, a full municipal-scale water demand forecast is not available at this time. However, data for each municipality remains in the forecast spreadsheets. Once full population and employment forecasts are obtained, the municipal forecasts could be individually updated. The forecast continues to include withdrawals associated with the population and employment growth that is anticipated for the portions of the community within CMAP's Socioeconomic Forecast area.

[83] In fact, the residential public water supply sector demands that any new population growth within the municipality by on the system.

Table 4.9. Communities with partial ON TO 2050 Socioeconomic Forecasts

Geographies
Channahon
Coal City
Diamond
Maple Park
Minooka
Sandwich

4.3 Independent variables

To complete the regression-based forecast, past data on independent variables (demand drivers) used in the regression analysis was collected for each forecasted geography. The independent variables selected to be included in the regression are listed in Table 2.3., and include: weather dummy variables, price, conservation trend, housing density, income variables, and grouping analysis dummy variables. In addition, future assumptions about each variable were informed by trend analysis and technical advisory committee input. This section steps through the data collection of past independent variable data, provides a brief summary of the variables, and discusses assumptions made about future values of demand drivers.

Weather

Weather, typically measured using temperature and precipitation, plays an important role in water use. While playing a more obvious role in short-term water demand due to seasonal variation, the Chicago region has experienced several major weather events that can be observed in the annual data, for example the droughts in 2005 and 2012, as well as polar vortex in 2013. Dummy variables for these years were included in the model to capture the impacts of these anomalies.

Organizing past data and future projections for independent variables

Informed by the last regional water demand forecast[84] as well as academic literature (Appendix A), independent variables were selected to explain the variability of unit use for the regression-based forecast (Section 2.2). This section describes the data collection and preparation steps to get the panel data ready for the regression analysis as well as the steps involved in determining the future projection values for the regression-based forecast. For the full data collection list, see **Table 4.1**.

Marginal price

The price variable was specified as the marginal price of water between 5,000 and 6,000 gallons of consumption, similar to the previous water demand forecast for the region. Annual data on water prices was collected for the years 2000-14 from several sources, including: IDNR Lake Michigan permittee water rate surveys, IISG water rate surveys, and water rate surveys

[84] Dziegielewski, B. and F.J. Chowdhury, 'Regional Water Demand Scenarios for Northeastern Illinois: 2005-2050,' 2008, Southern Illinois University Carbondale: Department of Geography and Environmental Resources.

conducted for the previous water demand forecast. Where data was missing, values were linearly interpolated to fill in missing values, and the resulting data set was reviewed for accuracy against initial data sources and feasibility of interpolated values. All prices were converted to $2011 dollars.[85]

A trend analysis was completed to determine the historical average annual percent change in marginal price for each municipality. These trends were then used to forecast future values of marginal price for use in the forecast. The marginal price of water was taken to be zero for county remainders, as the smaller scale CWS included in the county remainders do not typically set water rates for customers (for example, trailer parks, homeowners associations), but include water in other fees. A summary of the historic water price data is provided in **Table 4.10**.

Table 4.10: Average Marginal Price of Water 2000-13, $2011

Year	Average Price, $2011
2000	$ 4.35
2001	$ 4.18
2002	$ 6.81
2003	$ 5.23
2004	$ 6.04
2005	$ 5.07
2006	$ 3.10
2007	$ 2.95
2008	$ 2.24
2009	$ 2.14
2010	$ 4.60
2011	$ 4.74
2012	$ 4.43
2013	$ 6.57

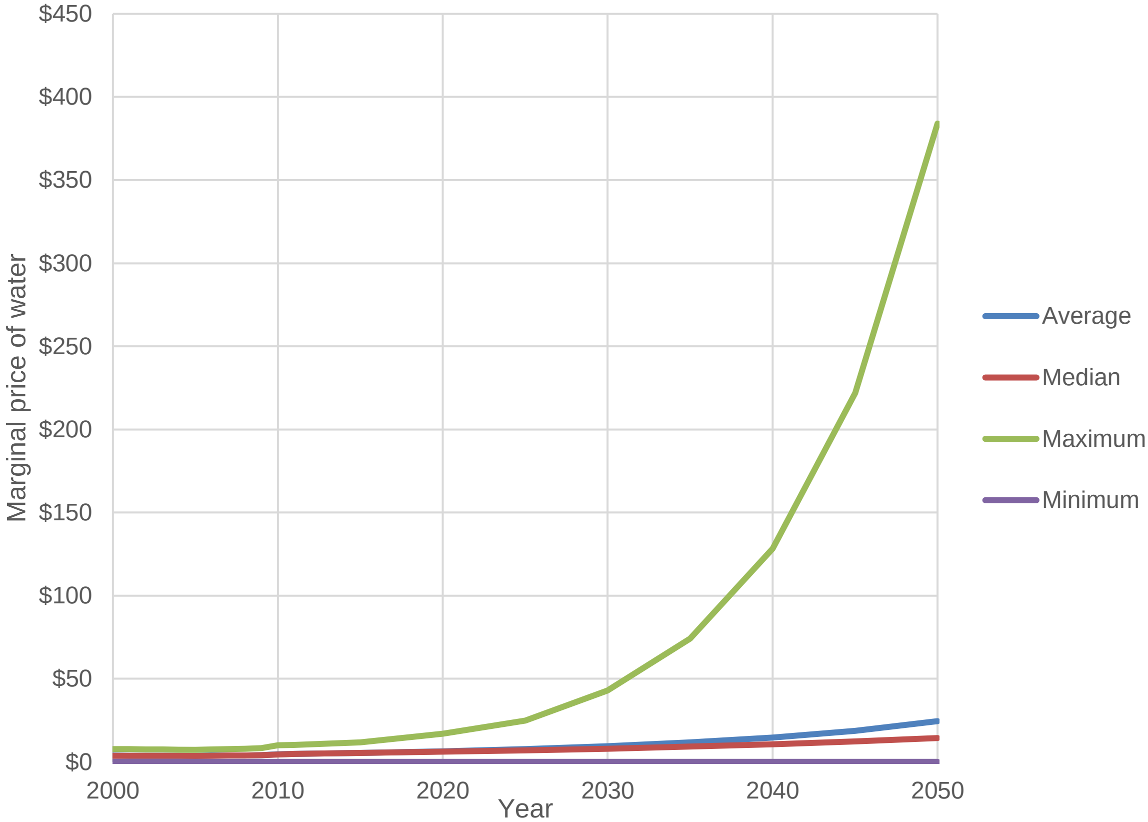
Source: Illinois-Indiana Sea Grant.

Figure 4.11 provides a summary of this recent data over time as well as the projections out to the year 2050. On average, the region has seen a 2.7 percent real price increase per year, although rate changes are highly variable across geography and time. For example, annual average price changes across communities in the region range from 2 percent decrease annually to an average increase of 14.7 percent annually. The assumption that the future rate of water price increases resembles the past, results in the exponential growth of a sub-set of water prices by 2050, indicated by the J-curve in **Figure 4.11**. While maintaining this pace of water price adjustments is not considered realistic, lacking project capacity to undertake further research into water price trend forecasting, assuming continuation of past trends was determined to be the best assumption to make for the overall forecast fit. An important note is that, while price

[85] Conversion to 2011 dollars was made by multiplying current year prices by the ratio of the CPI-U Index for the greater Chicago region. For example: water price in year 2002 dollars, was multiplied by CPI-U 2011/CPI-U 2002.

influences water demand, the impact is relatively inelastic, meaning a very large water price increase will result in a disproportionately small impact on demand. For example, a 10 percent increase in the price of water translates into approximately half a percent decrease in per capita water demand.

Figure 4.11. Marginal residential price of water, historic (2000-13) and projected (2015-50)



Note: Calculated as difference in the total water bill at 5,000 gallons and 6,000 gallons. Historic values are adjusted to 2011 inflation dollars. Lindenhurst was dropped from the figure to preserve the graphic scale.
Source: Dziegielewski, Kiefer, Bik, 2004;[86] IDNR, IISG, CMAP ON TO 2050 Regional Water Demand Forecast

Conservation

Separation of passive and active conservation in the water demand equation requires information on enactment of active conservation programs over the period covered by the historic data, and knowledge of the impact of passive conservation. Due to a lack of data on conservation programming across the region, it was therefore not possible to separate out passive conservation, occurring from the uptake of water efficiency devices as mandated by codes/standards, from active conservation programs, occurring from actively-run programs, such as Chicago's MeterSave program. Therefore, at the advice of the technical advisory

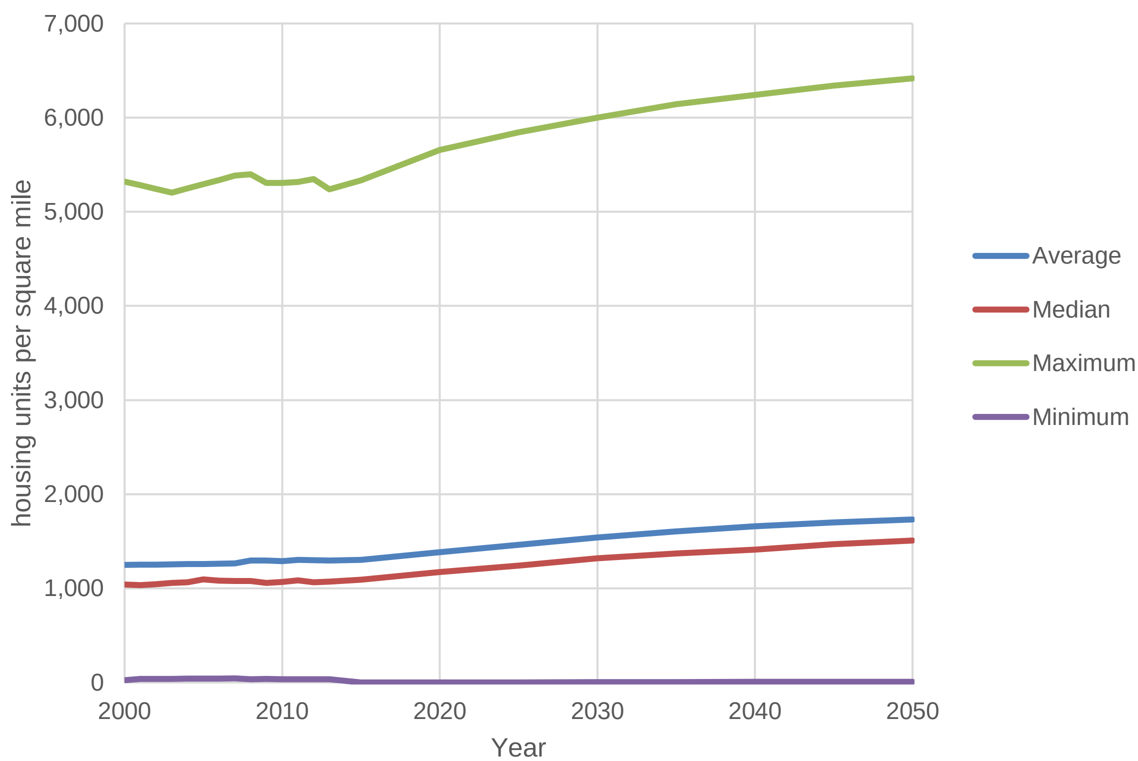
[86] Dziegielewski, B., J.Kiefer, T.Bik (2004) Water Rates and Ratemaking Practices in Community Water Systems in Illinois. PROJECT COMPLETION REPORT Department of Geography Southern Illinois University Carbondale. Actual report only contains values for 2003.

committee, and in keeping with a review of best demand forecasting practices, a conservation trend variable was included in the regression analysis. In this way, the regression-based water demand estimates based on historical water use information embed both passive and active conservation occurring over the period covered. The time trend variable is be used to capture trends in use not otherwise captured in the water demand equation.

Housing density

For each geography, housing density was calculated using housing units per square mile. The U.S. Census for 2000 and 2010 and the American Community Survey 5-year estimates for 2005-09 through 2012-16 provided the data on housing units. Missing years (2000-06) were interpolated to produce an annual number. The 2010 municipal boundary was used to generate the community size. **Figure 4.12** provides a summary of recent data over time as well as the projections out to the year 2050. Recent trends show the average housing density stable at 1,000 housing units per square mile. The ON TO 2050 Socioeconomic Forecast provides housing density projections in 5-year increments out to the year 2050. Overall, housing density is anticipated to increase by an average of 0.8 percent a year as the region carries out infill and redevelopment strategies as recommended in CMAP policy. By the year 2050, the average housing density is projected to increase to 1,700 housing units per square mile.

Figure 4.12. Housing density characteristics, historic (2000-13) and projected (2015-50)

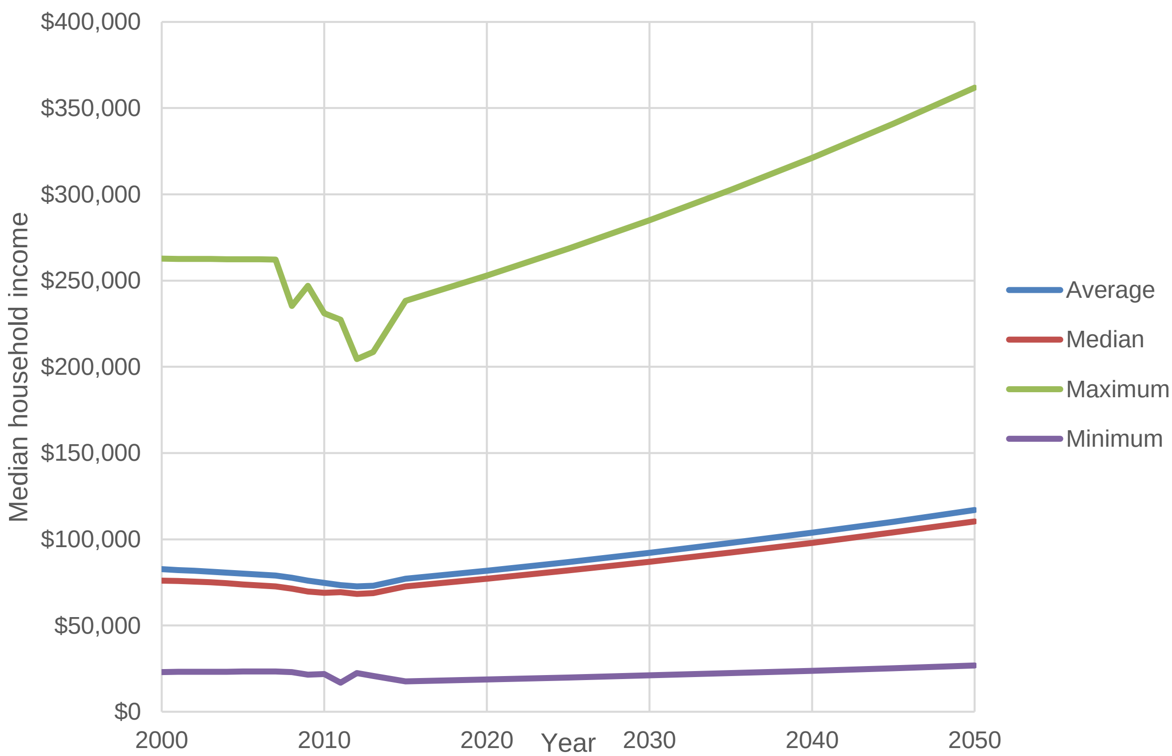


Source: CMAP analysis of U.S. Census, Decennial U.S. Census, ACS; ON TO 2050 Socioeconomic Forecast.

Median Household Income

For each geography, median household income was collected from the U.S. Census for 2000 and 2010 and the American Community Survey 5-year estimates for 2005-09 through 2012-16. Missing years (2000-06) were interpolated to produce an annual number. Annual values were then adjusted to 2011 dollars.[87] **Figure 4.13** provides a summary of recent data over time as well as the projections out to the year 2050. Recent historical declines in median household income are evident after the 2008 recession. The ON TO 2050 Socioeconomic Forecast provided a review of household income trends and projected that future median household incomes would increase 1.20 percent in real terms per year out to the year 2050.[88] This growth rate was applied to the 2011 median household income for each geography collected above to project out values in 5-year increments to the year 2050.

Figure 4.13. Median household income characteristics, historic (2000-13) and projected (2015-50)



Source: CMAP analysis of U.S. Census, Decennial U.S. Census, ACS; ON TO 2050 Socioeconomic Forecast.

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[87] Conversion to 2011 dollars was made by multiplying current year prices by the ratio of the CPI-U Index for the greater Chicago region. For example: water price in year 2002 dollars, was multiplied by CPI-U 2011/CPI-U 2002.

[88] Louis Berger, 2016, Chicago Region Socioeconomic Forecast Final Report, See Table 9-33. https://datahub.cmap.illinois.gov/dataset/89f66569-5f51-4c14-8b02-5ecc1ca00909/resource/a812de2f-d465-47f2-87df-0427e81da2cf/download/CMAPSocioeconomicForecastFinal-Report04Nov2016.pdf.

Grouping analysis

Because not all of the variation in water use across communities can be explained by the independent variables included in the regression-based forecast (Section 3.3), the regression-based forecast includes fixed effects to capture any remaining unexplained variation in water use across communities. Because this forecast has 253 forecasted geographies (245 municipalities and 7 county remainders), a grouping analysis was conducted for fixed effects. By including fixed effects, the average differences across cities in any observable or unobservable demand factors are controlled. Using a feature within ArcGIS' Spatial Statistics toolbox, the grouping analysis identifies groups of municipalities to maximize both within-group similarities and between-group differences.[89] The grouping analysis for the residential public water supply sector used two variables -- total residential water use and GPCD for 2011 -- for each community and generated seven distinct groups. Each county remainder was assigned to a separate group (**Figure 4.10**).

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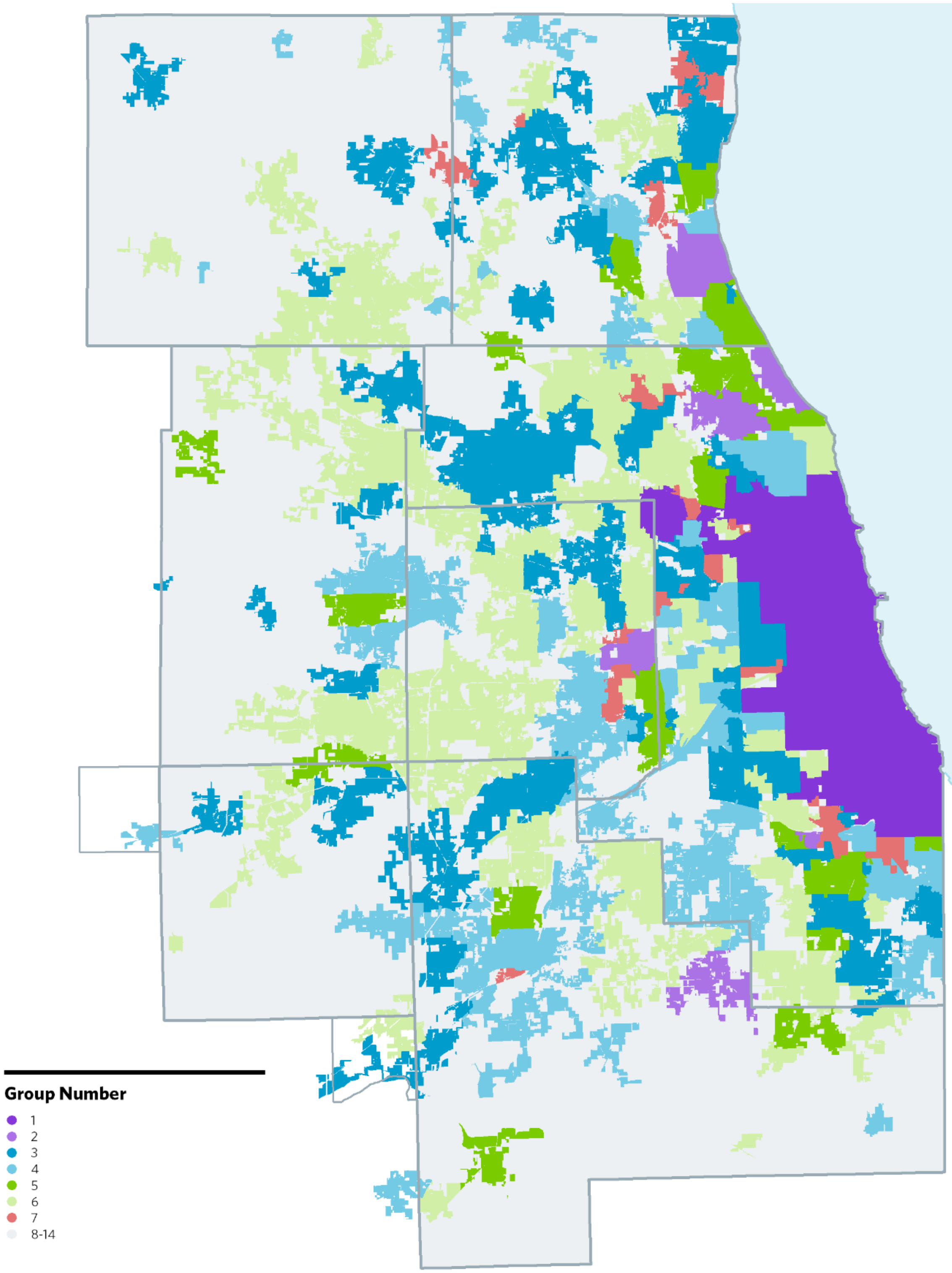
[89] Esri, ArcGIS Pro Tool Reference, Grouping Analysis, see http://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/how-grouping-analysis-works.htm.

Figure 4.10. Residential municipal-scale water supply sector groups



Source: Chicago Metropolitan Agency for Planning, 2018

4.4 Forecast equations

Both the baseline and regression based forecasts require additional research and analysis to generate the forecast equations. For the baseline forecast, it was necessary to make informed assumptions in relaxing the fixed GPCD and GPED assumption. For the regression based forecast, it is necessary to specify a functional format for estimation of the demand equation. This section describes development of the baseline forecast equation and the regression-based forecast equation. Given that the reference forecast holds unit use constant, it did not require additional research or analysis to construct.

Baseline forecast

The baseline forecast added in informed assumptions about the impact of demand drivers on unit use trends, based on consultations with water conservation and efficiency experts on the technical advisory committee. First, the baseline forecast retains the housing density assumptions inherent in the ON TO 2050 population forecast (for the residential sector) and the employment assumptions inherent in the ON TO 2050 employment forecast (for the non-residential sector). An additional assumption made in the baseline forecast not present in the reference forecast, however, is the continuation of the historic conservation trend assumption of 0.7 percent annually. Since the forecast was in five-year increments, the following equation was used:

0.7% annual decrease = GPCD(1-1.007)^5.*

The analysis used for the baseline forecast did not separate causal factors from one another, and so, this historic trend captures the influence of all factors influencing residential water uses. In considering this trend, water efficiency experts were consulted to ensure technical feasibility of future values.

Taking the upper end of the current technically feasible indoor GPCD value of 40 GPCD and adding 30 percent for outdoor water use yields a GPCD value of 52, lower than the forecasted 2050 GPCD value of over 60 using the historical conservation trend of 0.7 annually. The conservation and water efficiency experts that were consulted felt this was a very conservative and reasonable result as it presupposes absolutely no technical progress or behavior change to achieve, just the continuation of the natural fixture replacement rate. It is, of course, highly likely that there will be technical improvements in water efficiency (both indoor and outdoor) over the next 30 years, but these improvements are not possible to foresee with any degree of certainty and so, were not incorporated into the forecast.

Regression forecast

The regression forecast allows for more completely specifying the demand drivers to estimate the per unit water use. After the demand model is estimated, the resulting coefficients are used in the unit use forecasting calculation. The demand estimation used the software package R to perform multiple regression analysis fitted to historical water-use data for the period 2000-14 and for 245 communities and 7 county remainders. While equations were specified and data collected for both the residential and non-residential water sectors, due to project capacity limitations, only the residential sector equation was estimated and applied to the forecast. A multiple regression analysis was performed in the R software program to estimate the coefficients.

The model equation was specified as a double-log regression model. This is a method of using linear regression techniques with non-linear relationships (for example, an exponential relationship) by transforming the model (taking the natural log of both sides of the equation). The equation takes the form of a linear regression model where an increase in the value of an independent variable x by 1 unit results in y being multiplied by e to the B, which is done in the forecasting step. Expressing withdrawals in per capita terms reduces heterogeneity by normalizing the dependent variable across study sites.[90] Per unit water supply withdrawals were modeled as a function of several demand drivers in the residential sector, including marginal price of water, housing density, conservation trend, income, binary dummy variables for drought years (2005, 2012) and polar vortex year (2013), and binary grouping dummy variables.

The model specification for the regression demand equation was as follows:

$$\ln GPCD_{it} = \alpha_0 + \sum_j \beta_j \ln X_{jit} + \sum_l \delta_l D_{lit} + \varepsilon_{it}$$

where:
$GPCD_{it}$ = residential gallons per capita per day within geographical area i during year t
X_j = set of j explanatory variables for geographic area i during year t
D_l = set of l binary dummy variables designating community groupings, abnormal weather years
ε_{it} = random error
α, β, δ_l, = estimated parameters

Estimated regression coefficients are presented below in **Table 4.11**. The results show that 16 of the 20 variables are significant, as indicated by an asterisk. The signs of the income and price independent variables are in the expected direction and in keeping with previous studies on water demand. The expected signs for income is positive, and the expected signs for price, density, and conservation are negative. The sign of the 2012 drought and the 2013 polar vortex is, however, in the opposite direction as expected, as freezing pipes result in water leakage and higher levels of water withdrawals. Groups with negative coefficients include 3, 7, and 13, the remaining groups have positive coefficients.

[90] Dziegielewski, B. and F.J. Chowdhury, 2008, "Regional Water Demand Scenarios for Northeastern Illinois: 2005-50," Southern Illinois University Carbondale: Department of Geography and Environmental Resources.

Table 4.11. Regression Coefficients, for Residential Public Water Supply Sector

Independent Variables	Estimated Coefficients	T Ratio	Probability >|t|
(Intercept)	4.087048*	28.12	< 2e-16
log(Density)	0.002006	0.405	0.685288
log(Income)	0.030998*	2.839	0.004551
log(Marginal Price)	-0.04468*	-4.818	1.51E-06
log(Conservation)	-0.07006*	-10.238	< 2e-16
Weather 2005	0.078305*	5.739	1.03E-08
Weather 2012	-0.01514	-1.037	0.299904
Weather 2013	-0.06016*	-4.056	5.11E-05
Group 1*	0.605636	7.662	2.37E-14
Group 2*	0.980245	16.459	< 2e-16
Group 3	-0.04909	-0.862	0.388755
Group 4*	0.258116	4.548	5.61E-06
Group 5*	0.492377	8.574	< 2e-16
Group 6*	0.121491	2.144	0.032066
Group 7*	-0.41504	-7.136	1.17E-12
Group 8*	0.314279	4.007	6.29E-05
Group 9*	0.49855	6.387	1.92E-10
Group 10*	0.310918	3.999	6.48E-05
Group 11*	0.281115	3.61	0.000311
Group 12	0.12361	1.588	0.112345
Group 13*	-0.17267	-2.221	0.02643

* Indicates statistical significance at the .05 level or greater.
Source: CMAP ON TO 2050 Regional Water Demand Forecast.

Interpretation of the Coefficients

To interpret the coefficients on the continuous independent variables (price, income, density), if the value increases by one percent, we expect GPCD (the dependent variable) to change by β percent. The estimated elasticities of the price and income variables are consistent with economic theory. A one percent increase in marginal price of water is associated with a 0.04 percent decrease in per capita water demand; a one percent increase in median household income results in a 0.03 percent increase in per capita water usage. The conservation trend variable is an instantaneous time trend variable and so an estimated coefficient of -0.07 reflecting a declining trend in GPCD, equivalent to 7.26 percent annually.[91]

For the binary dummy variables, interpretation is somewhat less straight forward. For these variables, as the value switches from zero to one, the percent impact of the variable on GPCD (the dependent variable) is $100[\text{EXP}(\beta) - 1]$.[92] For example, the expected increase for Group one as compared to other groups is EXP(.605636) – 1, or 83 percent higher than other groups.

[91] As follows: β = ln (1+r) where β is the estimated coefficient and r is the annual growth rate. It follows that antilog (β) = (1+r) and that r = antilog(β) – 1. With an estimated coefficient of - 0.07006, therefore, r = antilog (0.07006) – 1 and so r = - 7.26%.

[92] The dummy variables reflect the mean effect of variables not included in the model.

Updated model coefficients were incorporated into the unit water use calculation for the water demand forecast for GPCD, as outlined in Section 2.1 above.

4.5 Future water demand calculations

With the baseline and regression forecast equations determined in Section 4.4, future values of unit use for each of the water sectors were calculated and then multiplied against future population and employment estimates.

Calculate future unit use for water sectors

With the forecast equations confirmed, the next step is to develop future values of unit use for each of the water sectors by forecast type. **Table 4.12** summarizes the equations and datasets used for each sector. For the residential and non-residential water supply sectors, the results were organized for each geography by sector and by forecast type in 5-year increments (2015 to 2050).

Table 4.12. Forecast equations for each sector and forecast type

Water sector	Forecast type	GPCDForecast equation
Residential Public Water Supply	Reference	2011 GPCD
	Baseline	GPCD $^{(n-5)}$ x $(1-0.007)^5$
	Regression	GPCD $= e^{\alpha_0+\sum_j \beta_j\, lnX_{jit}+\sum_l \delta_l D_{lit}} + e^{\varepsilon_{it}/2}$
Non-Residential Water Supply	Reference	2011 GPED
	Baseline	GPED $^{(n-5)}$ x $(1-0.007)^5$
Domestic Self-Supply	Reference	2015 GPCD
	Baseline	GPCD $^{(n-5)}$ x $(1-0.007)^5$

Generate municipal and county forecast results

The next step is to multiply the future unit use values (GPCD or GPED) by projected population and employment to generate estimates of future water withdrawals. For the residential and non-residential water supply sectors, the future unit use values for each geography were joined to LAZs assigned to that geography. LAZ assignments are based on 2010 municipal boundaries as defined by the U.S. Census. Using the software package R, the unit use values were multiplied against the LAZ level population and employment forecasts to generate total water use for each LAZ for each sector, forecast, and 5-year increment. LAZ level totals were then summarized by forecasted geography as well as by county. Summaries of population and employment totals were also generated to confirm values against the regional totals of the ON TO 2050 Socioeconomic Forecast. The domestic self-supply sector was treated separately, using the future population estimates developed in Section 4.2.

5. Future refinements and updates

Regular updates and refinements to the regional water demand forecast will help inform land use, transportation, and infrastructure investment decisions throughout the CMAP region. There are a number of ways to update the forecast in the coming years:

New IWIP data on annual withdrawals. Recent advancements in IWIP data collection now allow for online reporting by facilities, which will likely decrease the gap to the most recent dataset, allowing stakeholders to access more recent annual. This forecast relies on IWIP data from 2000 to 2013 and uses 2011 values as the primary input to the unit-use forecasts, since 2011 weather was most representative of the 30-year weather normal. The most recent, weather normal year occurred in 2016. When 2016 IWIP annual data is available, the existing regional water demand forecast could be updated with these values.

Complete forecasts for communities straddling the CMAP Socioeconomic Forecast area. Six of the municipalities identified for an individual forecast had portions of the community outside of the boundary of the ON TO 2050 Socioeconomic Forecast. The project team lacked time to work with each community to generate a population and employment forecast for the remaining municipal areas. Once full population and employment forecasts are obtained, the municipal forecasts could be individually updated.

Regression forecast for the non-residential water sector. Much less is understood about non-residential water demand than residential water demand. Although the non-residential regression equation was specified and the data collected (**Table 5.1**), this effort did not have the capacity to complete the regression estimation and associated forecast**.** Additional time and effort could, however, build upon the work started to complete this task.

2022 CMAP Socioeconomic Forecast. In four years, CMAP will release an updated population and employment forecast. These projections could be added to the existing regional water demand forecast, along with the latest IWIP annual data. At that time, rerunning the regression model to reflect recent withdrawals and changes in demand factors would be warranted.

2020 CMAP land use model. CMAP is currently building a regional land use model. Estimated to be complete in 2020, the land use model will ultimately drive the spatial distribution of the 2022 Socioeconomic Forecast. This presents an opportunity to transform the water demand forecast methodology to one that includes additional land use parameters. The integration of land-use planning with water planning is a recommendation emerging from water demand forecasting research. This research has found increased predictive capability of water demand models based on land use factors. The data requirements of this approach need to be explored and may require additional data collection.

Table 5.1. Non-residential water supply (CWS & Self-Supply) water demand estimation variables

Name	Definition	Cross Section Geography	Time series	Data Source (s)
Dependent Variable (s)				
GPED	Water Supply Withdrawals in Gallons Per Employee per Day (GPED) Calculated as Average Annual MGD divided by number of employees.	Municipality/ Unincorporated County	Annual 2001-2015	ISWS IWIP IDNR LMO-2 Longitudinal Employment and Household Dynamics (LEHD)
Independent Variables				
Price (-)	Marginal residential price of water Calculated as difference in the total water bill at 5,000 gallons and 6,000 gallons.	Municipality	Annual 2000-2014	Dziegielewski, Kiefer, Bik, 2004;93 IDNR, IISG
Sectoral Employment (%)	Sectoral Employment by 2-digit Standard Industrial Classification (SIC)/North American Industry Classification System (NAICS) calculated as annual compound growth rate in percent.94	Municipality/ Unincorporated County	Annual 2001-2015	Longitudinal Employment and Household Dynamics (LEHD)
Conservation trend* (-)	zero for 2000, 1 for 2001, 2 for 2002 etc.	n/a	Annual 2000-2014	Definitional
Unemployment	Unemployment rate	Municipality/ Unincorporated County	Annual 2000 - 2015	U.S. Census, Decennial U.S. Census, ACS
Dummy Variables	To account for county level fixed effects, drought years (2005, 2012), polar vortex years (2013-2014), geographical discrepancies, outliers	n/a		Cluster Analysis Definitional

Throughout this process, the project team recognized a number of opportunities to continue to enhance the format of annual water withdrawal data. CMAP is interested in continuing to partner with IWIP to ensure that water withdrawal data is collected in a way that helps both water supply and water demand analysis.

[93] Dziegielewski, B., J. Kiefer, T. Bik (2004) Water Rates and Ratemaking Practices in Community Water Systems in Illinois. Project completion report. Department of Geography Southern Illinois University Carbondale. Actual report only contains values for 2003.

[94] The main driver I&C Self-Supply Sector water demand is production output. Employment is used as a measure of output.

Appendix A: Best Practices in Water Demand Forecasting – Academic Literature Review

In order to reflect best practices in water demand forecasting, IISG conducted an academic literature review on forecast methodology and specific parameters to inform updates to the ON TO 2050 Regional Water Demand Forecast methodology. The following publications were reviewed:

1. Donkor, E.A., T.A. Mazzuchi, R. Soyer and J.A. Roberson. (2014). Urban Water Demand Forecasting: Review of Methods and Models. *Journal of Water Resources Planning and Management,* 140 (2). 146 – 159.
2. Dziegielewski, B and D.D. Baumann. (2011). Predicting future Demands for Water. In P. Wilderer (Ed.) *Treatise on Water Science* (pp. 163 – 188). Elsevier B.V.
3. House-Peters, L.A. and H. Chang. (2011). Urban Water Demand Modelling: Review of Concepts, methods, and Organizing Principles. *Water Resources Research,* 47, W05401.
4. Sebri, M. (2016). Forecasting Urban Water Demand: A Meta-regression Analysis. *Journal of Environmental Management,* 183. 777 – 785.
5. Singh, G., A. Goel, and M. Choudhary. (2015). An Inventory of Methods and Models for Domestic Water Demand Forecasting – A Review. *Journal of Indian Water Resources Society*, 35(3). 34 – 45.

1. Donkor, E.A., T.A. Mazzuchi, R. Soyer and J.A. Roberson. (2014). Urban Water Demand Forecasting: Review of Methods and Models. *Journal of Water Resources Planning and Management,* 140 (2). 146 – 159.

Type of demand studied: Urban water demand

Study Purpose: This study conducts a review of the literature on urban water demand forecasting (2000-2010). The purpose of the review is to determine forecasting methods applicable to decision-making at the utility level and to improve future forecasting.

Geography: Varies by study reviewed (global)

Data Disaggregation: Varies by study reviewed (residential, census tract, public, customer class)

Model Timeframe: Varies by study reviewed (annual, bimonthly, monthly, weekly, daily, hourly)

Variables, Definition, Data Source: Varies across the studies reviewed (time, seasonal/drought dummy, weather variables, price, population density, building size, lot size, household size, income, population/per capita demand, employment, occupancy rate, conservation measures, sub-sector size, day of week, monthly bill, GNP. Inflation, greenery coverage, etc.). the authors note that the periodicity and horizon of the forecast, as well as the forecast purpose (peak day, total daily, monthly, annual) determine the variables included in the analysis.

Data Type: The review focuses on time-series data.

Model Specification/ Estimation Method: The models and methods vary across the studies reviewed. The authors provide an inventory of forecasting methods and models, including: judgmental / qualitative methods; unit water demand analysis; univariate time series; moving average/exponential smoothing models; stochastic process models; time-series regression model; scenario-based approaches and decision support systems; artificial neural networks; and composite models.

The review finds that time series regression has been used extensively, in combination with neural network and/or univariate time series models, as it is generally considered more accurate for short term forecasting. There is a little research on the efficacy of neural network on medium and long term forecasting. The demand periodicity tends to be daily/annual, and short term demand is found to be more influenced by weather variables while mid-to long term demand is more influenced by socioeconomic variables.

Study Findings: The author concludes that many of the reviewed articles do not take into account the possibility of operationalizing models at the utility level, so that there is a need to consider how easy it is for utilities to gather, maintain, and analyze data in the model and to keep models as simple as possible. In particular, auto regression variable selection can be arbitrary, and needs to be better justified. Post-evaluation of models is needed to assess performance. No generalized forecasting model has been developed, and there is not accepted industry standard for water demand forecasting.

2. **Dziegielewski, B and D.D. Baumann. (2011). Predicting future Demands for Water. In P. Wilderer (Ed.) *Treatise on Water Science* (pp. 163 – 188). Elsevier B.V.**

   Type of demand studied: Urban water demand

   Study Purpose: This article outlines water demand forecasting data requirements and methods. asic concepts, definitions, and techniques of water demand forecasting (both theoretical and empirical) are reviewed and an example of a regional multisector forecast is provided (from northeast Illinois)

Geography: This article addresses all spatial scales of forecasting, though the example provided is regional.

Data Disaggregation: This article addresses all levels of data aggregation/disaggregation, the example provided is sectorial (public supply, power generation, industrial and commercial, agricultural and irrigation, domestic self-supplied)

Model Timeframe: not explicitly discussed, timeline relevant to water-supply planning (so, long term).

Variables, Definition, Data Source: The article provides a review of the variables used in municipal and residential water use studies (population, water price, income, housing, family composition, weather, other) and their definitions/specifications; as well as a review of the water use coefficients for Industrial, Commercial, and Institutional use by U.S. Department of commerce Standard Industrial Classification (SIC) codes (construction; transportation and public utilities; finance, insurance, and real estate; services; public administration). For the illustrative case summary (northeastern Illinois) a list of explanatory variables and elasticity estimates is provided (See Water 2050 methods).

Data Type: The article discusses use of all data types (time-series, cross-sectional, pooled). Data in the provided case study is pooled.

Model Specification/ Estimation Method: The article discusses various model specifications (multiple regression time trend forecasting, water requirement forecasts), functional forms (linear, log-log, semi-log), as well as use of the Institute for Water Resources Municipal And industrial Needs (IWR-MAIN) forecasting software.

Study Findings:

- A credible forecast involves: a high-level of data disaggregation, use of econometric models based on economic theory, and credible forecasting assumptions.
- Credible forecasts are based on an examination of disaggregate historical water use data, for at least 15 – 20 years, as well as collection of data on independent variables
- Useful forecasts are based on appropriate model specifications and accurate elasticity estimates, whose expected signs and magnitude are informed by economic theory and physical relationships.

- Credible forecasts are based on forecasting assumptions such as official/consensus population forecasts, economic growth forecasts, and information on other explanatory variables.
- Uncertainty and post-forecast analysis should be addressed, so that the forecast is understood/accepted by decision-makers.

3. **House-Peters, L.A. and H. Chang. (2011). Urban Water Demand Modelling: Review of Concepts, methods, and Organizing Principles. *Water Resources Research,* 47, W05401.**

Type of demand studied: Urban Water Demand

Study Purpose: This study assesses advances in urban water demand forecasting over the past 30 years, though a coupled human/natural system lens. The goal is to assess the capacity of more advanced, complex, technological methods to more accurately estimate water demand.

Geography: Varies by study reviewed (global)

Data Disaggregation: Varies by study reviewed

Model Timeframe: Varies by study reviewed. The author notes that there are two types of demand forecasting – short term (used for operational and management decisions) and ling-term (used for planning and infrastructure decisions).

Variables, Definition, Data Source: Varies across the studies reviewed. The author includes a table of explanatory variables used 1) temporal water demand analysis (temperature, precipitation, wind speed, evapotranspiration, water price, rate structure, population growth) and 2) spatial water demand analysis (family/hh size, education, percent Hispanic, house square footage, number of bedrooms, outdoor space size, pool, garden, proportion of single family households, housing type, normalized difference of vegetation index, urban heat island, conservation policy).

Data Type: Varies by study reviewed. The author includes a discussion of studies using a temporal scale methods (time series analysis) as well as studies using spatial scale methods (geographically weighted regression (GWR)).

Model Specification/ Estimation Method: Varies by the study reviewed which discusses the characteristics and limitations of each method.

Study Findings:

- Early urban water demand forecast methods are fundamentally aspatial, using simple econometric / times series modelling / linear multivariate regression, which has limited data requirements and minimal computing capacity.
- Increasing data availability, computing power, and technology has enabled more sophisticated model development incorporating spatial analysis methods.
- Despite advances, limitations remain. More advanced methods are data and computing intensive – there is a need for middle-road forecasting method development that uses more simple modelling (that still integrates spatially explicit land information into water demand modelling) so that water managers can use the models.

4. **Sebri, M. (2016). Forecasting Urban Water Demand: A Meta-regression Analysis.** ***Journal of Environmental Management,*** **183. 777 – 785.**

Type of demand studied: Urban water demand

Study Purpose: this research builds upon Donker et al (2014) by using a meta-analytic (quantitative) literature review of 23 empirical urban water demand forecasting studies. The purpose is to identify factors causing variation in the accuracy of forecasts.

Geography: Varies by study reviewed (global)

Data Disaggregation: Varies by study reviewed (residential, customer class, municipal)

Model Timeframe: Varies by study reviewed (annual, quarterly, monthly, weekly, daily, hourly)

Variables, Definition, Data Source: Varies across the studies reviewed. The meta-analysis itself used mean absolute percentage error (MAPE) as the dependent variable, which is a statistical metric indicating forecast accuracy, and independent variables include: demand periodicity (annual, quarterly, monthly, weekly, daily, hourly); forecast horizon (short, medium, long); forecasting method (Artificial Neural Network (ANN), Box-Jenkins, seemingly unrelated equations (SUR), Hybrid (ANFIS), Multi-Linear Regression model (MLR): model specification)lag, lag length, weather information, other control variables (number of explanatory variables), and other study characteristics (sample size, developed country, publication year).

Data Type: The review focuses on time-series data.

Model Specification/ Estimation Method: The models and methods vary across the studies reviewed. For the meta-analysis itself, three estimation techniques used were ordinary least Squares (OLS), Weighted Least Squares (WLS), and Random Effect maximum Likelihood (REML).

Study Findings:

- Forecast accuracy is influenced by demand periodicity, forecast horizon, forecast method, model specification, and study specific factors (such as sample size, publication year, developed v. developing county)
- Forecast accuracy is greater in the short run and the medium run than in the long run.
- Forecast accuracy is affected by the econometric method employed (with artificial neural networks, support vector regression, and hybrid models more accurate than multiple linear regression).
- Including weather makes the forecast less accurate.

5. **Singh, G., A. Goel, and M. Choudhary. (2015). An Inventory of Methods and Models for Domestic Water Demand Forecasting – A Review. *Journal of Indian Water Resources Society*, 35(3). 34 – 45.**

Type of demand studied: Urban water demand

Study Purpose: The purpose of this review study is to summarize water demand forecasting methods and models used in the published literature from 1970 to 2013. The types of models are described and comparted in terms of their purpose, advantages, and disadvantages.

Geography: Varies by study reviewed (global)

Data Disaggregation: Varies by study reviewed

Model Timeframe: Varies by study reviewed (long term (annual), medium term, short-term (monthly, weekly, daily, hourly)

Variables, Definition, Data Source: The variables vary across the studies reviewed. The authors note that model variables can be broadly divided into two categories, socioeconomic and climate. Explanatory variables are listed for each study reviewed (including for example, evaporation, temperature, rainfall, housing units, marginal price, employment, income, monthly bill, GNP, population, households, inflation, humidity, density, building size, drought dummies, subsector size, peak demand, lagged demand, wind velocity, reservoir level).

Data Type: Not discussed in the article.

Model Specification/ Estimation Method: Varies by study reviewed. The study discusses the range of methods used in water demand forecasting in the past 30 – 40 years, which includes both long term water demand forecasting methods (extrapolative of time series method; univariate time series method; econometric and stochastic method (regression, multinomial logit, etc.); end-use methods; scenarios based (decision support system) methods; IWR-MAIN software based method) and medium to short term forecasting (artificial neural network, hybrid methods, fuzzy logic, genetic algorithms). A summary of the advantages and disadvantages of each method is provided.

Study Findings:

- Choice of water demand forecasting method/model depends on the forecasting period, periodicity, available data and forecast variables
- ANN, dynamic/hybrid models perform best for short term to medium term forecasting
- Econometric models, end-use method, combined with simulation / scenario based forecasting is best for long-term forecast.

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The Chicago Metropolitan Agency for Planning (CMAP) is our region's comprehensive planning organization. The agency and its partners developed and are now implementing ON TO 2050, a new long-range plan to help the seven counties and 284 communities of northeastern Illinois implement strategies that address transportation, housing, economic development, open space, the environment, and other quality-of-life issues. See www.cmap.illinois.gov for more information.

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