Executive Summary

In January 2006, Governor Rod Blagojevich signed Executive Order 2006-01 calling for a comprehensive program of state and regional water-supply planning in the State of Illinois. The order charges the Illinois Department of Natural Resources (IDNR) with the responsibility of developing financial and technical support for two regional water supply planning committees in their development of water-supply plans for two priority regions in the state. The two areas, identified through work done by the Illinois State Water Survey (ISWS), were chosen as areas of potentially limited water-supply availability and substantial population and economic growth. The two pilot regions are eleven counties in Northeastern Illinois and fifteen counties in East-Central Illinois. As a first step in planning, each region is to estimate current and future water withdrawals. This report describes the water-demand study that estimates current and future withdrawals for the East-Central Illinois Region.

Regional water-supply planning in East-Central Illinois is focusing on the Mahomet Aquifer system and the Sangamon River watershed (Figure A). This study presents future water-demand scenarios for geographical areas which encompass groundwater withdrawal points and surface water intakes in the 15-county regional planning area of East-Central Illinois. The region under study includes the Illinois counties of Cass, Champaign, DeWitt, Ford, Iroquois, Logan, Macon, Mason, McLean, Menard, Piatt, Sangamon, Tazewell, Vermilion, and Woodford.

The Mahomet Aquifer Consortium (MAC) is facilitating the planning effort in the region and has formed a local planning committee with representatives of various stakeholder groups. In East-Central Illinois, the following groups are represented on the Regional Water Supply Planning Committee (RWSPC): Agriculture; County Government; Electric Generating Utilities; Environment; Industries; Municipal Government; the Public; Rural Water Districts; Small Business; Soil and Water Conservation; Water Authorities; and Water Utilities.

The four major water sectors are public water supply (PWS), self-supplied thermoelectric power generation (PG), self-supplied commercial and industrial (C&I), and self-supplied irrigation and agriculture (IR&AG). A chapter is provided for each sector that describes the method and

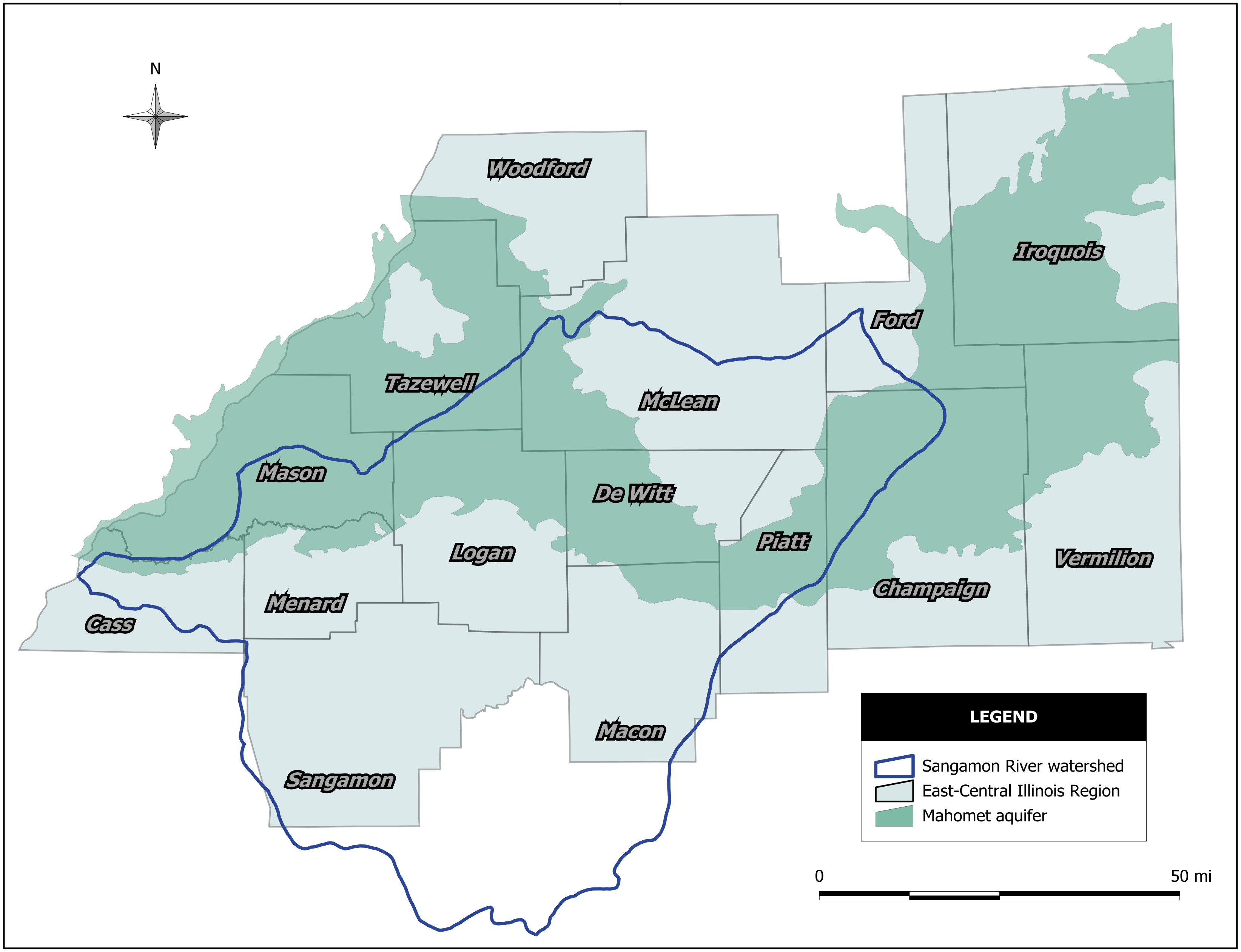

Figure A: The fifteen-county East-Central Water Supply Planning Region in Illinois.

estimates of water demand. In addition, a chapter is included that describes the potential impacts of climate change on water withdrawals for each water sector.

For each of the water sectors, we generated three water demand scenarios organized into separate geographical study areas within the region. The scenarios were defined by varying assumptions regarding the future values of demand drivers and explanatory variables. The three scenarios represent water withdrawals under baseline (BL Scenario) as well as under less and more resource intensive (LRI & MRI) demand conditions. The scenarios do not represent forecast or predictions, nor do they set upper and lower bounds of future water withdrawals. Different assumptions or conditions could result in withdrawals that are within or outside of this range. The purpose of the scenarios is to capture future water withdrawals under three different sets of future conditions.

The future water withdrawals generated from this work will be used by the ISWS, using groundwater and surface water modeling, to analyze the impacts of withdrawing water from specific withdrawal points to meet the demand scenarios. The data generated from this demand study will be delivered to the ISWS at the level of withdrawal points, meaning future water withdrawals will be determined for all existing wells and surface water intakes. Although withdrawal-point data are not included in this report, the data will be available upon request from the ISWS for the public water supply sector. The withdrawal-point data for the commercial and industrial and power generation sectors will not be available to the public due to confidentiality agreements.

Historical data

The project team at Wittman Hydro Planning Associates (WHPA) and Ben Dziegielewski at Southern Illinois University Carbondale (SIUC), in collaboration with the Illinois State Water Survey (ISWS) and Illinois State Geological Survey (ISGS) prepared data sets on historical withdrawals, which were subsequently used in developing water-use relationships for future scenarios. Data used to specify explanatory variables and their future values came from several sources.

Except for Lake Michigan, the State of Illinois does not require permits for the withdrawal of water, nor does it require reporting of the amounts of water withdrawn. Since data was not available from a mandatory State reporting source, data used came from several other sources. The principal source of data on historical water withdrawals is the Illinois Water Information Program (IWIP) of the Illinois State Water Survey (ISWS), a voluntary water withdrawal reporting program established in 1978. Additional data were obtained from the National Water Use Inventory Program (NWUIP) of the U.S. Geological Survey. A summary of the historical water withdrawals by sector is provided in Table A.

Table A: Reported historical water withdrawals in million gallons per day (MGD) for each water sector, 1985-2005.

Water Sector	1985	1990	1995	2000	2005
Public water supply	109.63	121.37	129.61	134.01	137.03
Self-supplied domestic	12.73	11.48	11.57	11.47	8.86
Power generation	–	1,568.8	1,095.5	1,067.7	1,315.35
Commercial & industrial	79.48	74.33	78.1	77.99	84.79
Irrigation & agriculture	37.78	51.39	96.89	103.48	236.82
TOTAL	239.62	1,827.37	1,411.67	1,394.65	1,782.85

We obtained other data from state and federal agencies, most often from routinely collected statistics available from libraries or in electronic format on agency websites. The techniques for developing future water demand varied by sector and included multiple regression and mass balance estimation. These techniques provide future water demand numbers as a function of demand drivers (i.e., population, employment, power generation, irrigated acreage for the respective demand sectors) and variables which influence average rates of water demand (i.e., weather conditions, price of water, income, employment mix).

Future water withdrawals

The techniques for developing estimates of future withdrawals were dictated by the type of water-withdrawal data and the corresponding data on independent or explanatory variables that were available for each water-demand sector. The two principal techniques which were used in this report are the unit-use coefficient approach and multiple regression. The unit-use coefficient method was used for the irrigation and agriculture sector, power generation, and domestic supply. Multiple regression was used for the PWS and C&I sectors. Table B shows the demand drivers and independent variables used for each of the water sectors.

Weather variables

As evidenced in Table B, weather is one of the most important determinants of water demand. Specific weather variables are used in the estimation of future withdrawals in PWS, C&I, and AG&IR sectors. Consequently, in order to estimate future water withdrawals, the weather variables (i.e., precipitation, temperature, and cooling degree days) must also be estimated. Weather data

Table B: Drivers of water demand and elasticities of explanatory variables used to estimate water withdrawals in East-Central Illinois.

Demand sector	Demand driver	Independent variables	Elasticity/ coefficient
Public supply	Population served	Air temperature	1.4222
		Precipitation	-0.1140
		Employment fraction	0.6381
		Price of water	-0.2226
		Median household income	0.3244
		Conservation trend	-0.0026
Power generation	Gross electric generation	2005 rate of water usage (gal/kWh)	0.93-591.1
Commercial & industrial	Employment	Cooling degree-days	0.5297
		Precipitation	-0.2766
		Conservation trend	-0.1262
		Health services empl. (%)	0.0618
		Retail empl. (%)	0.0740
		Manufacturing empl (%)	0.0098
		Percent self-supplied	0.0324
Irrigation & agriculture	Irrigated acres	Rainfall deficit (inches)	1.0000
	Livestock counts	Unit coefficients (gal/animal)	0.03-35.0
Domestic self-supplied	Population	Unit coefficient (gal/per capita)	82.0

Note: Elasticity values describe the degree to which a change in an explanatory variable changes water demand.

may be dealt with in a variety of ways when looking into the future. One approach is to "predict" future weather by using the climatic normals, as calculated by the National Center for Climatic Data (NCDC). Climatic normals are defined as the "statistical average over a time period usually consisting of three consecutive decades." The current climatic normals are defined as the average for the period 1971-2000. The averaging of the past weather data means that no inter-annual variation is taken into account in the water demand models (Figure B). In effect, this assumes that the average weather from the historical 30-year period can be used to estimate the future demand. On the one hand this approach firmly connects the forecast to the historical record. On the other hand, by representing the future as the average of the 30-years of record we lose the extremes that cause much of the variation in demand.

It was decided by the ISWS and technical committee of the RWSPC that the demand models would use climatic normal data as the future weather variables. The climatic normal method was chosen so that the general trend of water demand could be understood. By using normal weather data in the future, the annual variation, as seen the historic reported withdrawals, is not seen in the future estimates. Because normal climatic data were used in estimating future water withdrawals, for any given year in the future (or the past) the water demand estimates will not match the actual water withdrawn. This is particularly true of extreme years, such as 2005, where in some parts of the region the temperature and precipitation were considerably different from normal weather. What is revealed by this study is the *average* water withdrawals from 2010 to 2050.

Another implication of using normal weather data to estimate future water withdrawals, is that the future looks different than the past. In most of the future withdrawal graphs shown in this report there is a linear-type increase from 2010 to 2050 (Figure C). But, the historical data show variation from year to year; an increase in withdrawals one year and a decrease the next. The fluctuation in the historical data is due, in part, to the variation in weather patterns from year to year and study area to study area. A good example of this is 2005. Because 2005 was relatively hotter and drier than other years (particularly in some study areas), the water withdrawals for that year are higher than expected compared to normal historical growth. When 2005 reported data are compared to the model generated data which is calculated with normal (1971-2000) weather data, 2005 reported data are often higher than future withdrawal estimates. This is because of the anomalous weather pattern that year. What you see often in the graphs reported in this report is a decrease from reported 2005 values to the estimated 2010 withdrawals (Figure C). This is not a modeling error or under-prediction, this is due to the drought conditions evident in 2005. For this reason, this report often compares future withdrawal estimates to 2005 values generated by the model using normal (1971-2000) weather data. The following terms are used throughout the

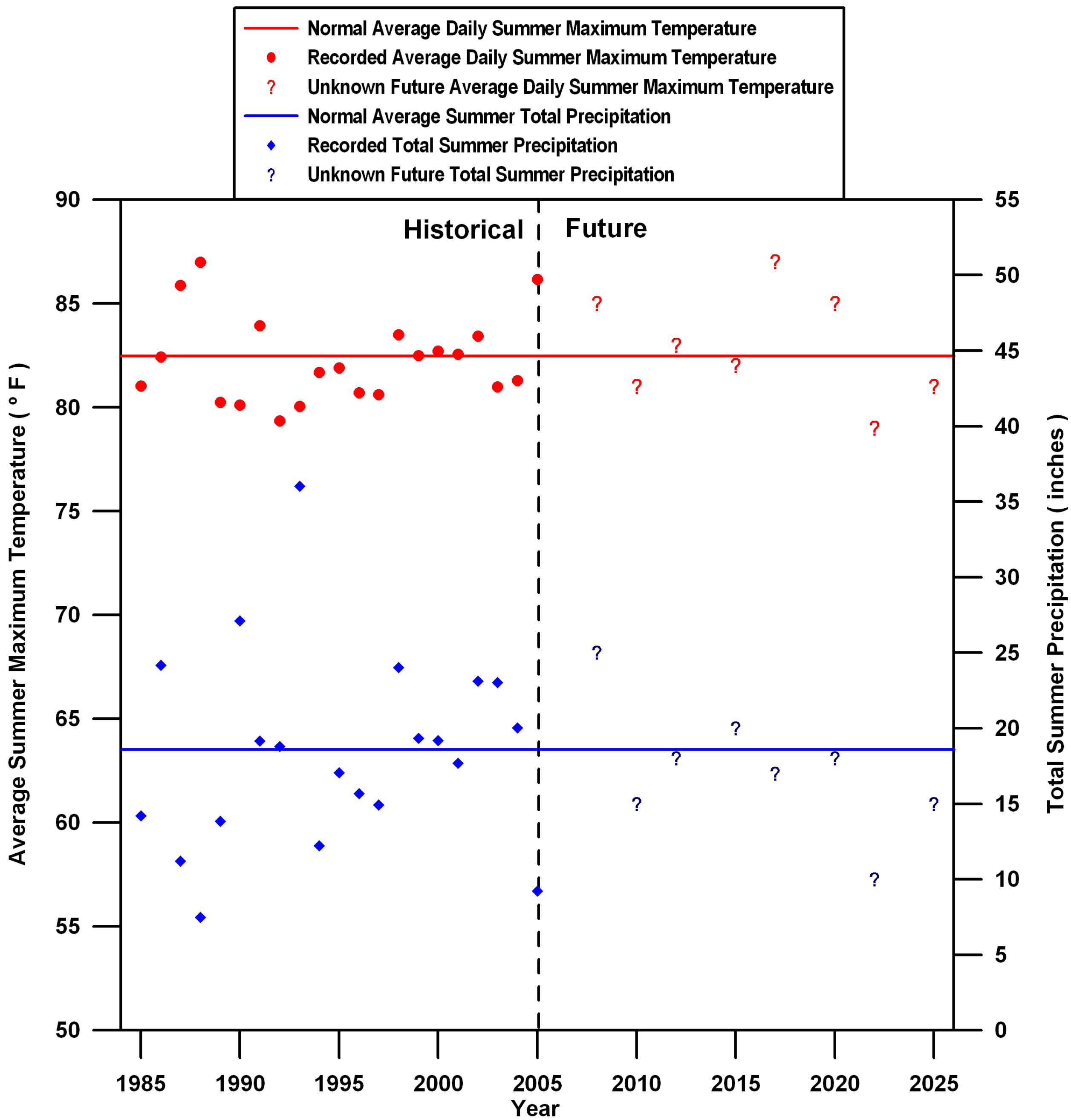

Figure B: Example of normal versus recorded weather data.

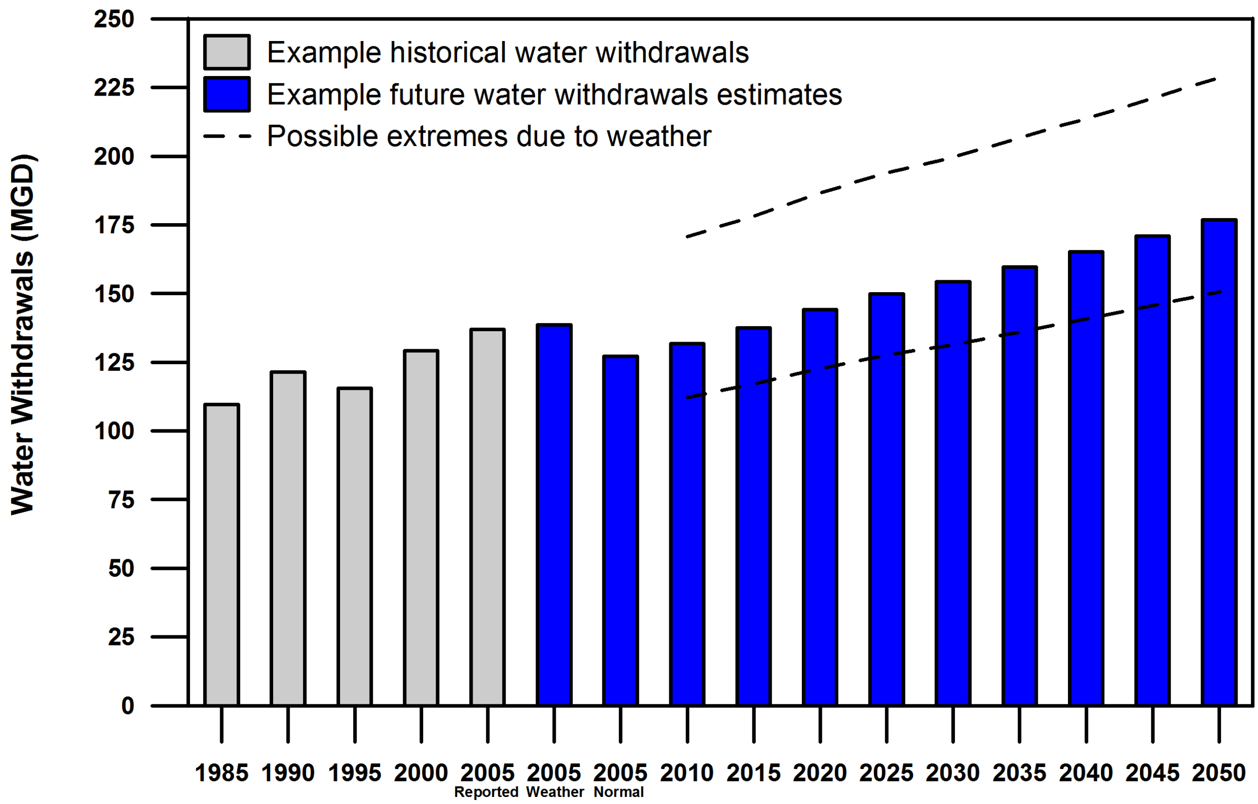

Figure C: Example of the effects of using climatic normal temperature and precipitation.

report.

2005 Normal 2005 model generated value using normal (1971-2000) weather data.

2005 Reported 2005 value reported from the original data source; not a modeled value.

2005 Weather 2005 model generated value using actual weather data from 2005.

As Figure C also shows with the dashed line, on any given year, the water withdrawals may be higher or lower than the estimated withdrawals due to natural variation in the weather in the future. This is important to remember when looking at graphs of future estimates throughout this report.

Public and self-supplied domestic water supply sector

The public and self-supplied domestic water supply sector includes the water withdrawals for domestic residential and community use and/or consumption. This sector includes the water withdrawals that are 1) treated and served to the public from a central location, such as a water utility, and 2) self-supplied domestic withdrawals which involves a homeowner with a private well that provides water to his/her own property.

For all other water sectors in this study, water withdrawal is examined only on a county level. For the public supply sector, additional study areas were selected for each county in order to more accurately estimate water withdrawals in these areas. A total of 26 municipalities were selected (Figure D). In addition, PWS water withdrawals were estimated in the 15-county rural areas which represent the balance of county areas outside the 26 selected municipalities.

Public water supply water withdrawals

The future public water supply (PWS) water withdrawals were estimated using multiple regression. The general purpose of multiple regression is to learn about the relationship between several independent variables (*e.g.* temperature, income, etc.) and a dependent variable (*e.g.* per capita water withdrawals). For the public water supply sector, a log-linear model was created to capture the relationship between per capita water demand and six independent variables. The six variables used were temperature, precipitation, marginal price, median household income, employment/population ratio, and conservation trend. The resulting equation was then used to estimate the future water withdrawals.

Water withdrawals were estimated for the three scenarios; BL, LRI, and MRI. The three future scenarios are designed to capture a range of future conditions of water demand for public supply water withdrawals which would result in lower and higher values of future water withdrawals by this sector based upon various specific assumptions (Table C).

The results for public water supply scenarios is shown in Figure E and Table D. Under the baseline scenario, the total public supply withdrawals are projected to increase from 127.2 MGD in 2005 (Normal) to 176.9 MGD in 2050 (Table D). This represents an increase of 49.6 MGD or 39.0 percent. Under the LRI scenario the withdrawals would increase to 153.5 MGD by 2050. This represents an increase of 14.0 MGD or 20.6 percent. Under the MRI scenario the withdrawals would increase to 185.4 MGD by 2050. This represents an increase of 58.1 MGD or 45.7 percent.

Self-supplied domestic water withdrawals

The self-supplied domestic water withdrawals were estimated using a unit-use coefficient method. For this calculation, the number of people in each county that supply their own water via private wells was multiplied by an average daily use (82 gallons per day per person). The self-supplied

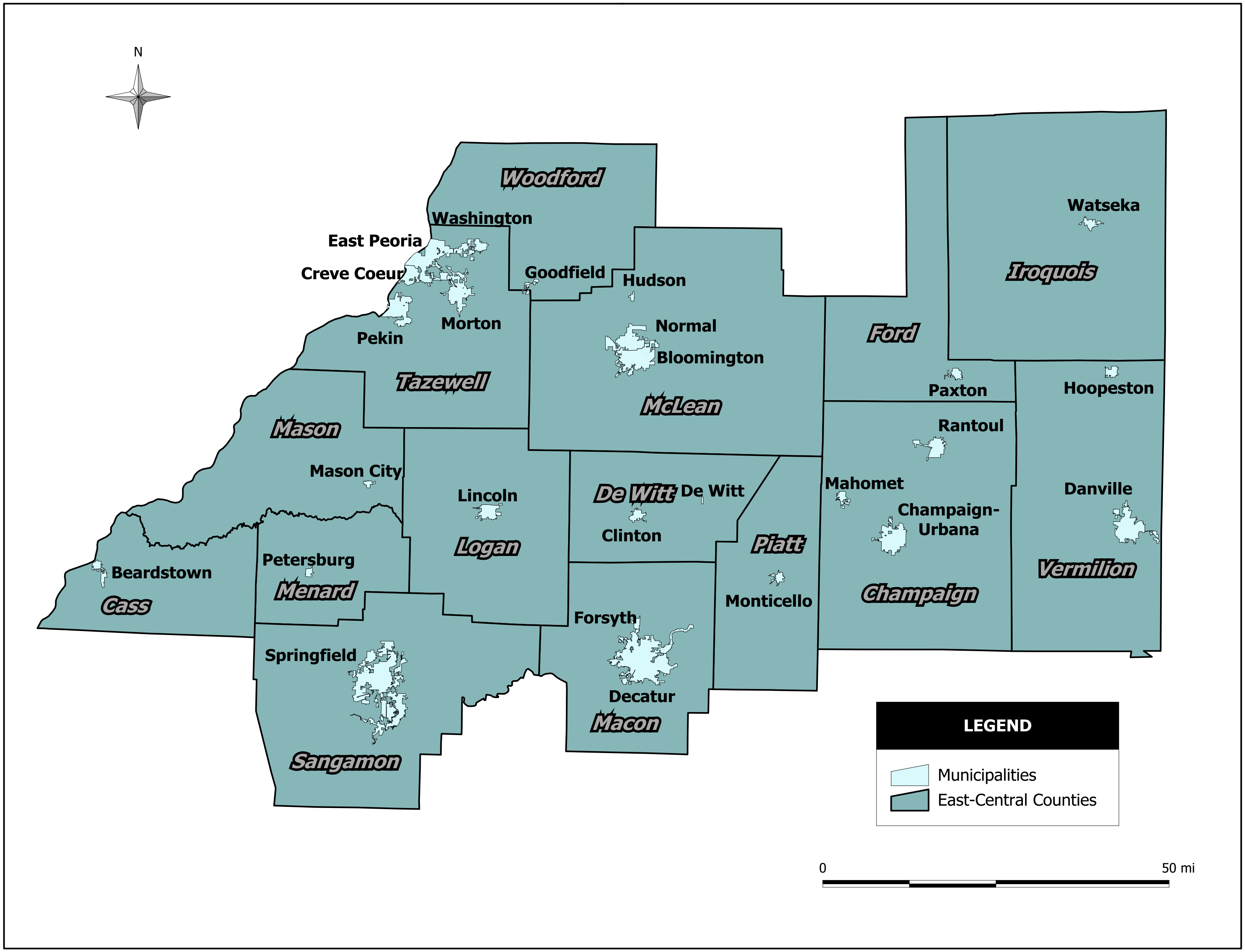

Figure D: Map of 26 public water supply study areas modeled in addition to the 15 counties within the East-Central Region.

Table C: Factors affecting future water demands in the public water supply sector in East-Central Illinois for each of scenarios.

Factor	Scenario 1- Baseline (BL)	Scenario 2- Less Resource Intensive (LRI)	Scenario 3 – More Resource Intensive (MRI)
Total population	DCEO projections	DCEO projections	DCEO projections
Median household income	Existing projections of 0.7 %/year growth	Existing projections of 0.5 %/year growth	Higher growth of 1.0%/years
Water conservation	Gradually reduced to 10% of the historical trend by 2050	Gradually reduced to 10% of the historical trend by 2050	Historical trend removed
Future water prices	Prices held at 2005 level in real terms	Conservation oriented future price increases (1.5%)	Prices held at 2005 level in real terms
Weather (air temperature and precipitation)	30-year normal (1971-2000)	30-year normal (1971-2000)	30-year normal (1971-2000)

Table D: Public water supply results for the baseline (BL), less resource intensive (LRI), and more resource intensive (MRI) scenarios.

Year	Population served	BL withdrawals (MGD)	LRI withdrawals (MGD)	MRI withdrawals (MGD)
2005 (Weather)	946,821	138.9	138.9	138.9
2005 (Normal)	946,821	127.2	127.2	127.2
2010	978,207	131.9	129.9	132.6
2015	1,012,168	137.6	133.5	139.1
2020	1,050,932	144.2	137.8	146.5
2025	1,081,997	149.9	141.0	153.1
2030	1,101,919	154.3	142.9	158.4
2035	1,129,372	159.7	145.6	164.9
2040	1,156,613	165.2	148.2	171.4
2045	1,184,582	171.0	150.8	178.2
2050	1,213,300	176.9	153.5	185.4
Difference from 2005 (Normal) to 2050				
Unit	266,479	49.6	26.3	58.1
Percent (%)	28.1	39.0	20.6	45.7

MGD = million gallons per day

2005 (Weather) = modeled 2005 withdrawals using actual weather data.

2005 (Normal) = modeled 2005 withdrawals using normal weather data.

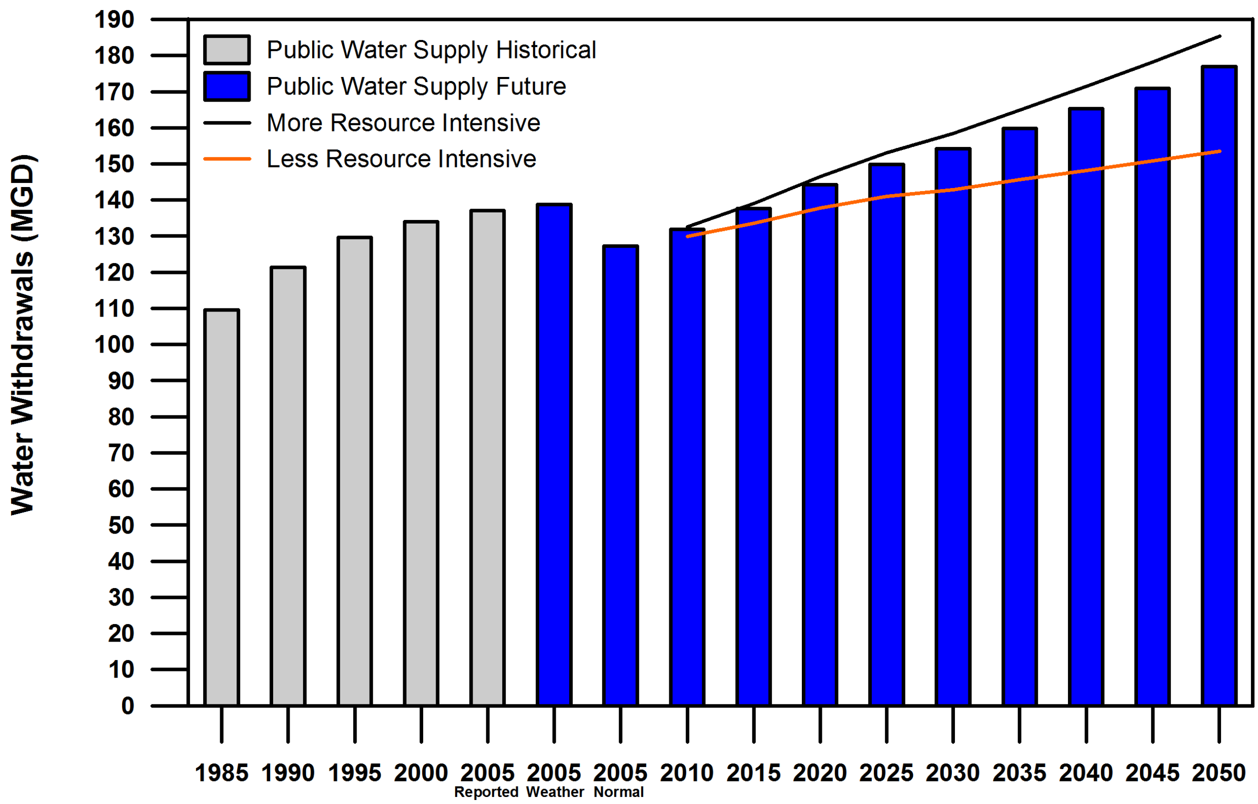

Figure E: Future water withdrawals for the public water supply sector.

Table E: Total withdrawals for the self-supplied domestic water sector, 2005-2050.

Year	Total self-supplied domestic population	Total self-supplied domestic withdrawals (MGD)
2005	108,076	8.9
2010	121,510	10.0
2015	125,363	10.3
2020	129,539	10.6
2025	132,847	10.9
2030	135,267	11.1
2035	137,249	11.3
2040	140,237	11.5
2045	143,290	11.7
2050	146,421	12.0
Difference from 2005 to 2050		
Unit	38,345	3.1
Percent (%)	35.5	35.5

Assumed water withdrawal rate of 82 gallons per person per day.

domestic population was calculated by subtracting the future total population served by a PWS system within a county from the future total county population. The total self-supplied domestic population is expected to increase by 38,345 people from 108,076 in 2005 to 146,421 in 2050 (Table E). The withdrawals are projected to increase from 8.9 MGD in 2005 to 12.0 MGD in 2050 (Figure F). This represents an increase of 3.1 MGD or 35.5 percent.

Power generation sector

Water withdrawn by power plants is classified by the United States Geological Survey (USGS) as thermoelectric generation water use. It represents the water applied in the production of heat-generated electric power. The heat sources may include fossil fuels such as coal, petroleum, natural gas, or nuclear fission. The main use of water at power plants is for cooling. Nearly 90 percent of electricity in the United States is produced with thermally-driven, water-cooled generation systems which require large amounts of water.

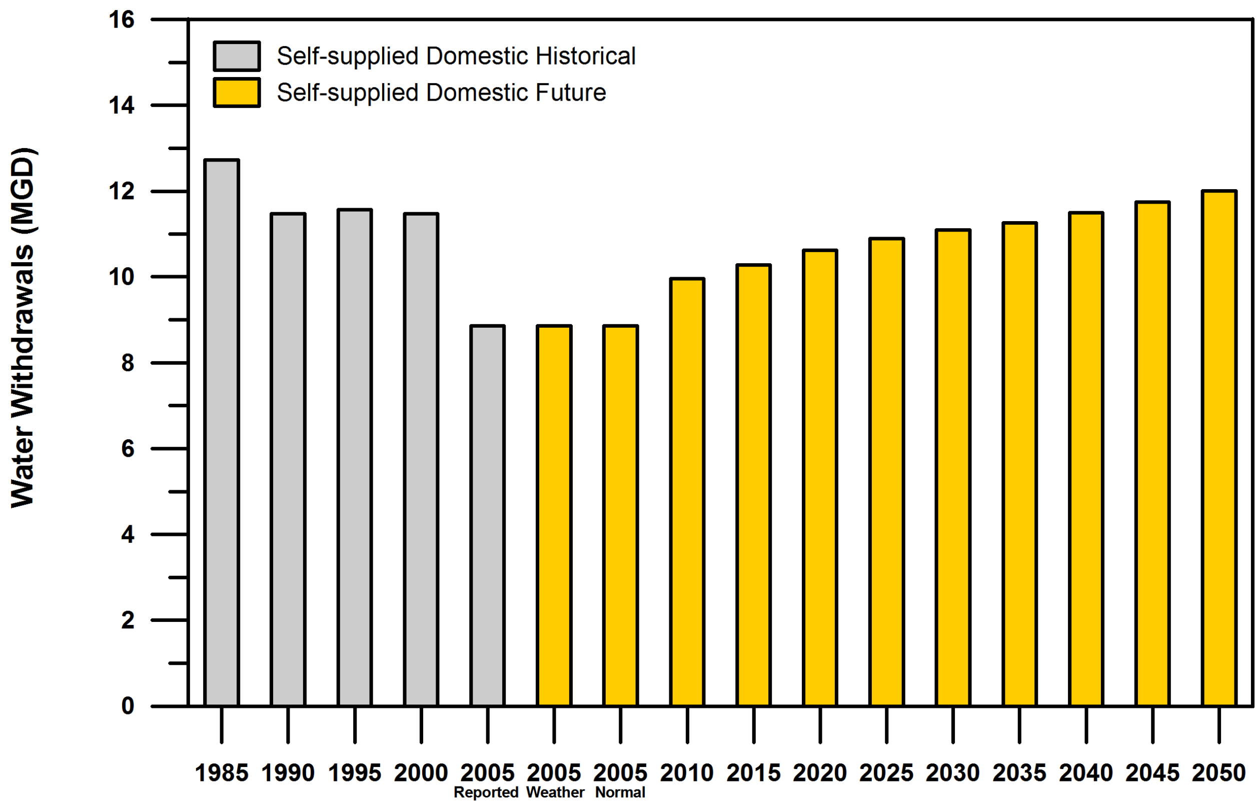

Figure F: Future water withdrawals for the self-supplied domestic sector.

The USGS National Water Use Information Program reported significant thermoelectric withdrawals from six power plants in five of the fifteen counties in East-Central Illinois. Although relative to the other water sectors, the volume of water withdrawals for power generation is large, it is important to note that much of the water is returned to the source and is available for re-use by others.

The plants in the region are separated into two groups: once-through open cycle and closed-loop make-up water intake plants. Once-through flow plants pump water directly to the condensers and almost immediately return it back to the river or lake. Closed-loop make-up water plants withdraw water to replace losses and blowdown in cooling towers and/or water losses from perched lakes or ponds. This division of plants provides for a better consistency in representing non-consumptive and consumptive water withdrawals for power production. Water withdrawn by once-through plants is considered non-consumptive use since nearly all water withdrawn is returned to the source. Because of evaporative losses in cooling towers, withdrawals by closed-loop make-up water plants represent a sum of both consumptive and non-consumptive use and are comparable with withdrawals by the industrial/commercial and agricultural sectors.

There is no accurate or predictable correlation between local demand for power and local generation, either now or in the future, due to the nature of the electric power market. Increasing future electric demand may not be met by the six plants currently within the study area. The demand may be met with power generated outside the study area, or with power generated inside the study area by alternate means, such as gas turbines, wind turbines, solar, etc. For this study, we were unable to correlate demand for electricity within the region to electricity production. Additionally, we were unable to correlate regional and national demand for electricity to production in the region due to the lack of data. So for the three scenarios, specific assumptions were made that related to how the existing and new plants would be run. For example, in the LRI scenario it was assumed that the oldest generating units would become prohibitively expensive to run and would, therefore, be put on standby. In the MRI scenario, a new closed-loop plant was added in Woodford County (Table F).

A straightforward unit-coefficient method was used in this study to derive future quantities of water withdrawals. This method represents cooling water demand as the product of total gross generation at the plant and the unit rate of water required in gallons per kilowatt-hour (gal/kWh). For each of the six power generation plants, the 2005 rate of water usage (gal/kWh) was applied to future years under the three scenarios along with the scenario assumptions. Additionally, one of the existing plants is expected to be replaced in 2010 with a new closed-loop plant.

Under the baseline scenario, between 2005 and 2050, total withdrawals would decline by 39.8

Table F: Factors affecting future water demands for power generation in East-Central Illinois for each of scenarios.

Factor	Scenario 1- Baseline (BL)	Scenario 2- Less Resource Intensive (LRI)	Scenario 3 – More Resource Intensive (MRI)
Power generation	No new power plants within study area	Older generating units put on standby	New power plant in study area with cooling towers

Note: The demand for electricity does not correlate to electricity production within the East Central Region.

MGD or 3.0 percent (Table G and Figure G).

In the LRI scenario, the older Havana (Units #1-5) and Vermilion (Units #1-2) units are put on stand by between 2020 and 2040 (Table G). Overall, between 2005 and 2050, total withdrawals would decline by 97.6 MGD or 7.4 percent.

In the MRI scenario, the assumed addition of one clean coal plant with closed-loop cooling would increase make-up water demand by 66.8 MGD in 2030 (Table G). The sum effect would be that the total withdrawals would decline by 26.9 MGD or 2.0 percent between 2005 and 2050.

It is important to note that while the thermoelectric power generation sector requires large quantities of water, the overall consumptive use of water is small. In once-through cooling systems, as much as 99 percent of water withdrawn can be returned back to the source. Closed-loop systems with cooling towers require smaller withdrawals (on average approximately 5 percent or less of the volumes withdrawn by once through cooling systems), however, between 30 to 70 percent of that smaller volume could be consumed due to evaporation.

Commercial & industrial sector

The commercial and industrial (C&I) sector represents water withdrawals that are self-supplied or purchased (*i.e.*, water delivered by a public water supply) to commercial, industrial, and other nonresidential establishments. The industrial sub-sector includes "water used for industrial purposes such as fabrication, processing, washing, and cooling, and includes such industries as steel, chemical and allied products, paper and allied products, mining, and petroleum refining." The commercial sub-sector includes water used for "motels, hotels, restaurants, office buildings, other commercial facilities, and institutions" (Avery, 1999).

Table G: Electric power generation and water withdrawals for the baseline (BL), less resource intensive (LRI), and more resource intensive (MRI) scenarios in East-Central Illinois.

Year	BL Scenario		LRI Scenario		MRI Scenario	
	generation (MWh/year)	withdrawals (MGD)	generation (MWh/year)	withdrawals (MGD)	generation (MWh/year)	withdrawals (MGD)
2005	25,624,970	1,315.4	25,624,970	1,315.4	25,624,970	1,315.4
2010	26,709,115	1,275.5	26,709,115	1,275.5	26,709,115	1,275.5
2015	26,709,115	1,275.5	26,709,115	1,275.5	26,709,115	1,275.5
2020	26,709,115	1,275.5	26,404,463	1,263.4	26,709,115	1,275.5
2025	26,709,115	1,275.5	26,397,671	1,252.4	26,709,115	1,275.5
2030	26,709,115	1,275.5	26,390,879	1,241.4	30,979,615	1,342.4
2035	26,709,115	1,275.5	25,978,997	1,228.8	30,979,615	1,342.4
2040	26,709,115	1,275.5	25,972,205	1,217.8	30,979,615	1,342.4
2045	26,709,115	1,275.5	25,972,205	1,217.8	30,979,615	1,342.4
2050	26,709,115	1,275.5	25,972,205	1,217.8	30,979,615	1,342.4
Difference from 2005 to 2050						
Unit	1,084,145	-39.8	347,235	-97.6	5,354,645	26.9
Percent %	4.2	-3.0	1.4	-7.4	20.9	2.0

MWh/year = mega watt hour per year; MGD = million gallons per day

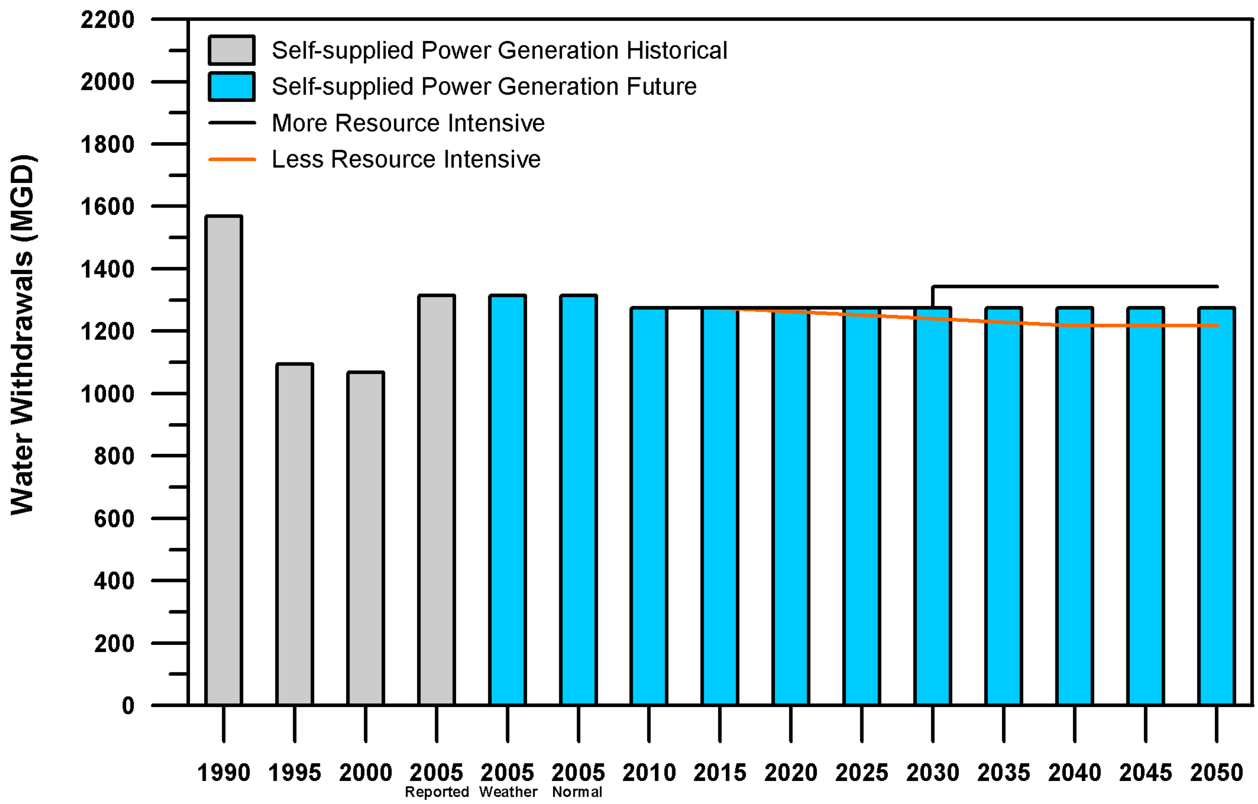

Figure G: Future water withdrawals for the power generation sector.

The future C&I water withdrawals were estimated using multiple regression. The general purpose of multiple regression is to learn about the relationship between several independent variables (*e.g.* temperature, cooling degree days, etc.) and a dependent variable (*e.g.* per capita water withdrawals). For the commercial and industrial sector, a log-linear model was created to capture the relationship between per employee water withdrawals and total county employment, annual cooling degree days, total precipitation during summer (May 1 through September 30), percent of employment in health services, percent of employment in retail trade, percent of employment in manufacturing, percent of self-supplied commercial and industrial water demand, and a conservation trend variable. The resulting equation was then used to estimate the future water withdrawals.

Because of the nationwide growth in ethanol production and the increase in the number of ethanol facilities, ethanol facilities were used to represent any new large industrial users of water for the East-Central Illinois region. While ethanol production is currently the anticipated new water demand, it is understood by the authors that ethanol may not be the only new industrial user and may not reach the anticipated growth rate. Therefore, in this study, demands created by future ethanol facilities are used to understand how a large new water demand may impact the region. For the purposes of this report, is was assumed that eight new ethanol facilities would be built within the region. The water use associated with these new large industrial users was assumed to be the rates of water use for ethanol production.

Water withdrawals were estimated for the three scenarios; BL, LRI, and MRI. The three future scenarios are designed to capture a range of future conditions of water demand for C&I withdrawals which would result in lower and higher values of future water withdrawals by this sector based upon various specific assumptions (Table H).

The estimated future water demands under each of the three scenarios for the entire 15-county study area are summarized in Table I and Figure H. Under the baseline scenario, self-supplied commercial and industrial (including mining) withdrawals are projected to increase from 63.7 MGD in 2005 to 137.5 MGD in 2050. This represents an increase of 73.8 MGD or 115.9 percent. The total self-supplied withdrawals in 2050 will be 21.3 MGD lower under the LRI scenario and 41.0 MGD higher under the MRI scenario as compared to the BL scenario results.

Irrigation & agriculture sector

The irrigation and agriculture (IR&AG) sector includes self-supplied withdrawals of water for irrigation of cropland and golf courses as well as water for livestock. The IR&AG sector represents a significant component of total water demand especially in the counties with large proportions of

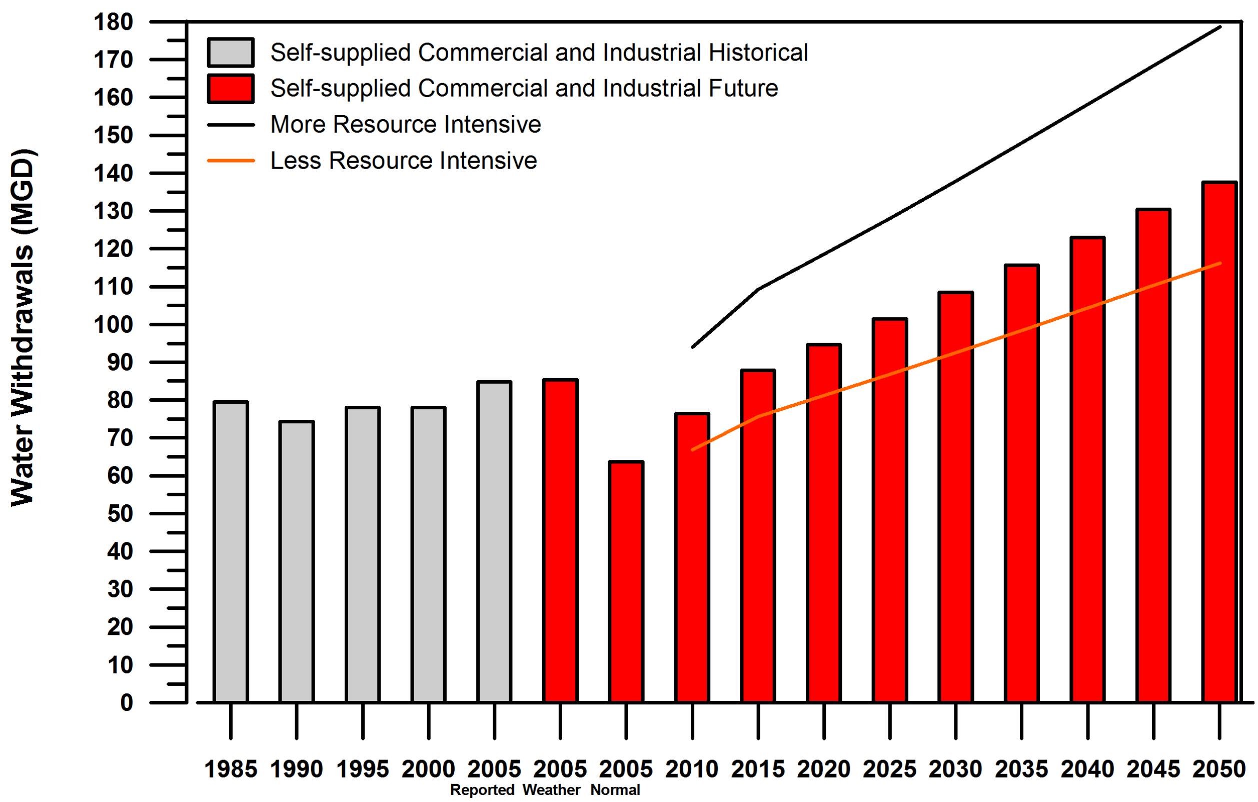

Figure H: Future water withdrawals for the commercial and industrial sector.

Table H: Factors affecting future the commercial and industrial water demands in East-Central Illinois for each of scenarios.

Factor	Scenario 1- Baseline (BL)	Scenario 2- Less Resource Intensive (LRI)	Scenario 3 – More Resource Intensive (MRI)
Employment population	IDES projections	IDES projections	IDES projections
New ethanol facilities	4 gallons of water per gallon EtOH produced	3 gallons of water per gallon EtOH produced	5 gallons of water per gallon EtOH produced
Mix of commercial/ industrial activities	IDES projections	IDES projections	IDES projections
Water conservation	Continuation of historical trend	30% higher than historical trend	50% lower than historical trend
Weather (cooling degree days and precipitation)	30-year normal (1971-2000)	30-year normal (1971-2000)	30-year normal (1971-2000)

land in irrigated cropland.

Water withdrawals for livestock use were estimated using a unit-use coefficient method. For this calculation, the type and number of animals in each county was multiplied by an average daily use. Estimates of future livestock numbers were generated based on baseline rates of growth projected by the U.S. Department of Agriculture Economic Research Service (USDA).

Water withdrawals for irrigation were calculated using the ISWS / USGS method of multiplying the number of irrigated acres times the annual rainfall deficit. The rainfall deficit is assumed to be the amount of water that is applied to cropland or golf courses to supplement precipitation in the growing season. For future years, the estimates of water irrigation are based on normal (average 1971-2000) rainfall deficit which depends on the distribution of weekly precipitation during the summer irrigation season (May through August). The rainfall deficit for each county was estimated for each irrigation season from 1985 to 2005 using the ISWS/USGS method.

Data on irrigated cropland are collected and reported by the U.S. Department of Agriculture. For future estimates of irrigated cropland, it was assumed that irrigated cropland for all counties (except Mason, Tazewell, and Cass counties) would increase at the region-wide historical rate of 1.05 percent per year. For Mason, Tazewell, and Cass counties the Imperial Valley Water Authority, local Farm Services Agencies, and Farm Bureau personnel provided estimates of the future amount

Table I: Results for commercial and industrial sector for the baseline (BL), less resource intensive (LRI), and more resource intensive (MRI) scenarios for East-Central Illinois, 2005-2050.

Year	Employment population	BL withdrawals (MGD)	LRI withdrawals (MGD)	MRI withdrawals (MGD)
2005 (Weather)	530,114	85.3	85.3	85.3
2005 (Normal)	530,114	63.7	63.7	63.7
2010	548,769	77.8	67.8	94.0
2015	567,424	87.9	75.7	109.2
2020	586,079	94.7	81.2	118.6
2025	604,734	101.4	86.7	128.0
2030	623,389	108.4	92.5	137.8
2035	642,044	115.7	98.4	147.9
2040	660,699	123.0	104.4	158.2
2045	679,354	130.4	110.4	168.4
2050	698,009	137.5	116.2	178.5
Difference from 2005 (Normal) to 2050				
Unit	167,895	73.8	52.5	114.8
Percent (%)	31.7	115.9	82.4	180.2

MGD = million gallons per day

2005 (Weather) = modeled 2005 withdrawals using actual weather data.

2005 (Normal) = modeled 2005 withdrawals using normal weather data.

Table J: Factors affecting future agriculture and irrigation water demands in East-Central Illinois for each of scenarios.

Factor	Scenario 1- Baseline (BL)	Scenario 2- Less Resource Intensive (LRI)	Scenario 3 – More Resource Intensive (MRI)
Irrigated land*	Regional irrigated cropland growth rate (1.05% per year)	75% of irrigated cropland growth rate (0.79% per year)	125% of irrigated cropland growth rate (1.31% per year)
Livestock	Baseline USDA growth rates	Baseline USDA growth rates	Baseline USDA growth rates
Weather (air temperature and precipitation)	30-year normal (1971-2000)	30-year normal (1971-2000)	30-year normal (1971-2000)

*Growth rates do not apply to Mason, Tazewell, and Cass counties; these growth rates are discussed in Chapter 5.

of irrigated acres.

Water withdrawals were estimated for the three scenarios; BL, LRI, and MRI. The three future scenarios are designed to capture a range of future conditions of water demand for IR&AG withdrawals which would result in lower and higher values of future water withdrawals by this sector based the specific assumptions summarized in Table J.

The estimated future irrigated acres and water withdrawals under each of the three scenarios for the entire 15-county study area are summarized in Table K and Figure I. Under the baseline scenario, irrigation and agriculture withdrawals are projected to increase from 139.4 MGD in 2005 to 186.5 MGD in 2050. This represents an increase of 47.0 MGD or 33.8 percent. Under the LRI scenario the withdrawals would increase to 177.2 MGD by 2050. This represents an increase of 37.8 MGD or 27.1 percent. Under the MRI scenario the withdrawals would increase to 195.8 MGD by 2050. This represents an increase of 56.4 MGD or 40.4 percent.

Impacts of climate change and drought

Climate change refers to significant changes in climate parameters, like precipitation, temperature, and wind, that would last for long periods of time, like a decade or longer. Climate change may result from any individual or a combination of natural factors (i.e., change in sun intensity or

Table K: Summary of irrigated acres and irrigation and agriculture water withdrawals for the baseline (BL), less resource intensive (LRI), and more resource intensive (MRI) scenarios in East-Central Illinois.

Year	BL Scenario		LRI Scenario		MRI Scenario	
	irrigated acres	withdrawals (MGD)	irrigated acres	withdrawals (MGD)	irrigated acres	withdrawals (MGD)
2005 (Weather)	–	236.8	–	236.8	–	236.8
2005 (Normal)	180,255	139.4	180,255	139.4	180,255	139.4
2010	210,274	162.4	200,459	155.0	220,094	169.7
2015	222,602	171.9	211,977	163.9	233,241	179.8
2020	234,834	181.3	223,418	172.7	246,276	189.9
2025	236,082	182.5	224,444	173.8	247,760	191.3
2030	237,207	183.6	225,378	174.7	249,089	192.5
2035	238,196	184.5	226,214	175.5	250,245	193.6
2040	239,042	185.3	226,946	176.2	251,214	194.5
2045	239,739	186.0	227,572	176.8	251,986	195.2
2050	240,284	186.5	228,091	177.2	252,558	195.8
Difference from 2005 to 2050						
Unit	60,029	47.1	47,836	37.8	72,303	56.4
Percent %	33.3	33.8	26.5	27.1	40.1	40.4

MGD = million gallons per day

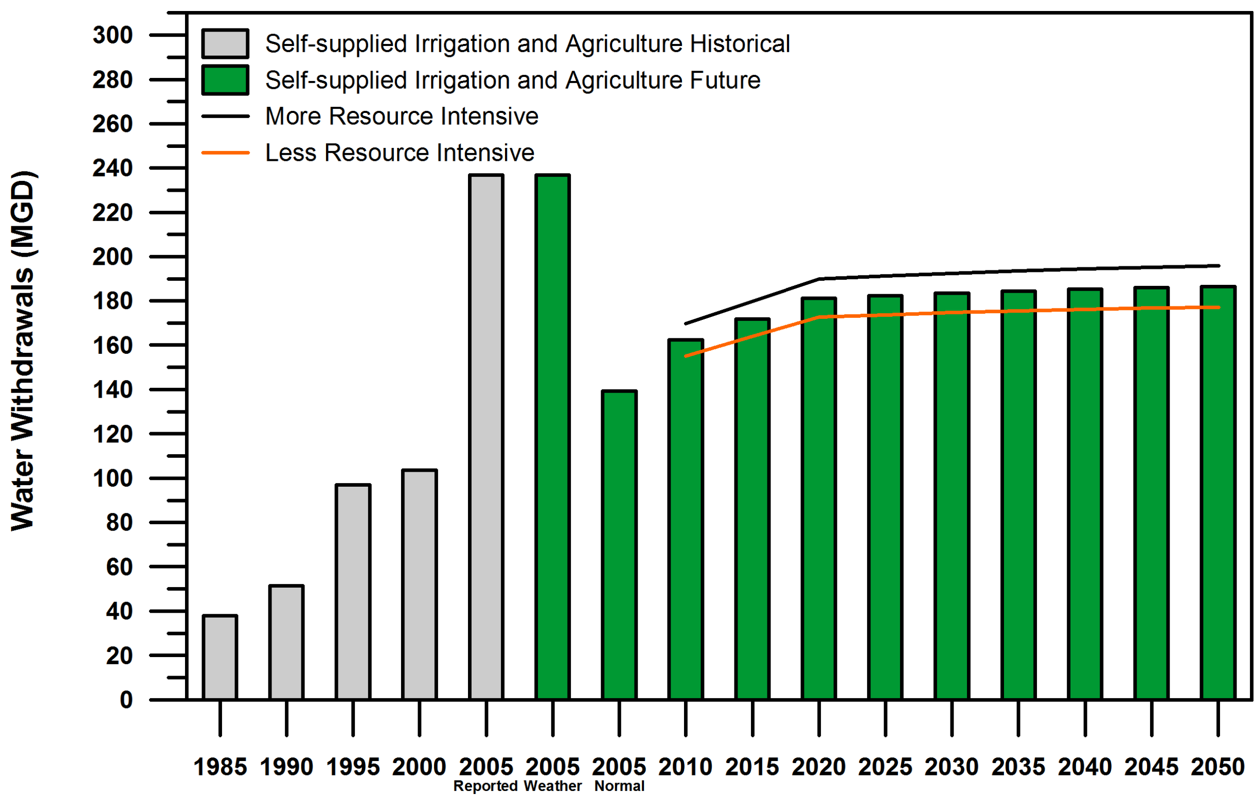

Figure I: Future water withdrawals for the irrigation and agriculture sector.

changes in Earth's orbit around the sun), natural processes (i.e., changes in ocean circulation, and volcanic eruptions), or human activities that impact atmosphere composition (i.e., burning of fossil fuels) or land surface (i.e., urbanization, deforestation, and desertification).

With the increase of greenhouse gases and rising global average temperature, many climate models have been developed throughout the world to model future changes in climate. The ISWS used the outputs from many of these existing global climate model runs to download climate scenarios specifically for Illinois to 2050. These include a possible average annual temperature departure from the 1971-2000 long-term normal of up to $+6^{\circ}F$ in Illinois. and a possible Illinois departure from 1971-2000 normal annual precipitation in a range from -5 inches to +5 inches per year.

Future water withdrawals will be affected by the anticipated changes in temperature and precipitation. The changes in annual temperature and precipitation also result in changes during the growing season. We assume the temperature increase of $6^{\circ}F$ will also apply to the summer growing season. We assume that the distribution of precipitation will range from +2.5 inches to -3.5 inches during the growing season. The effects of these changes will vary by water sector depending on the sensitivity of water demand to air temperature and precipitation. The specific assumptions about the changes in weather variables are discussed separately for each of the major water sectors in Chapter 6. The effect of climate change on water withdrawals for each water demand sector are summarized in Table L. The model suggests that if temperature increases, then water withdrawals will also increase. The effect is even greater when temperature increases and precipitation decreases. Conversely, if precipitation increases and temperature does not, water withdrawals may decrease.

Another type of climate impact on water demand is the effect of periodic droughts. In the future, in addition to possible changes in mean annual temperature and precipitation, it can be expected that periodic droughts will occur. While the severity and duration of future droughts is not known, their impact on water demand in the pubic supply sector can be determined by examining historical droughts. The most severe historical droughts in Illinois took place in the 1930s and 1950s. These were multi-year droughts which were associated with growing season precipitation deficits during the driest year of approximately 40 percent below normal.

For purposes of this analysis, it was assumed that during future droughts the normal (1971-2000) precipitation for the growing season would be reduced by 40 percent to represent a worst-case historical drought. Table M shows the results for average day water demand in each water sector under the conditions of a worst-case historical drought. The total water withdrawals for all sectors (except power generation) would increase by 106 MGD relative to the baseline scenario

Table L: Effects of possible climate change on water withdrawals (in MGD)

Weather scenario/ sector	2005 (Normal) withdrawals (MGD)	2030 withdrawals (MGD)	2050 withdrawals (MGD)	Change from BL in 2050
Baseline (BL) scenario				
Public-supply	127.2	154.3	176.9	–
Self-supplied C&I	63.7	108.1	137.5	–
Irrigation and agriculture	139.4	183.6	186.5	–
All sectors (w/o power)	330.3	446.0	500.9	–
$+6^{\circ}F$ temperature only				
Public-supply	127.2	163.2	195.6	18.7
Self-supplied C&I	63.7	119.5	175.7	38.2
Irrigation and agriculture	139.4	189.1	196.9	10.4
All sectors (w/o power)	330.3	483.2	579.6	78.7
$+2.5$” precipitation only				
Public-supply	127.2	152.1	174.4	-2.5
Self-supplied C&I	63.7	105.2	133.3	-4.2
Irrigation and agriculture	139.4	154.6	157.0	-29.5
All sectors (w/o power)	330.3	411.9	464.7	-36.2
-3.5” precipitation only				
Public-supply	127.2	157.8	181.0	4.1
Self-supplied C&I	63.7	102.6	144.8	7.3
Irrigation and agriculture	139.4	217.4	220.8	34.3
All sectors (w/o power)	330.3	489.2	546.6	45.7
$+6^{\circ}F$ temperature, $+2.5$” precipitation				
Public-supply	127.2	161.1	193.0	16.1
Self-supplied C&I	63.7	126.9	181.3	43.8
Irrigation and agriculture	139.4	160.5	167.9	-18.6
All sectors (w/o power)	330.3	448.5	542.2	41.3
$+6^{\circ}F$ temperature, -3.5” precipitation				
Public-supply	127.2	167.1	200.3	23.4
Self-supplied C&I	63.7	137.7	197.2	59.7
Irrigation and agriculture	139.4	223.1	231.4	44.9
All sectors (w/o power)	330.3	527.9	628.9	128.0

Table M: Effects of drought on water withdrawals (in MGD) in East-Central Illinois.

Weather scenario/ sector	2005 (Normal) withdrawals (MGD)	2030 withdrawals (MGD)	2050 withdrawals (MGD)	Change from BL in 2050
Baseline (BL) scenario				
Public-supply	127.2	154.3	176.9	–
Self-supplied C&I	63.7	108.1	137.5	–
Irrigation and agriculture	139.4	183.6	186.5	–
All sectors (w/o power)	330.3	446.0	500.9	–
Drought year (40 percent precipitation deficit)				
Public-supply	127.2	163.5	187.5	10.6
Self-supplied C&I	63.7	123.2	156.7	19.2
Irrigation and agriculture	139.4	259.0	263.0	76.5
All sectors (w/o power)	330.3	545.7	607.2	106.3

estimated with normal weather information. This means that on any given year, a drought could cause an increase of approximately 100 MGD.

Summary of results

The baseline scenario estimates the total water withdrawal to increase by 8.1% by the year 2050, from 1,654.6 MGD in 2005 to 1,788.4 MGD (Table N). Water withdrawals are expected to increase in all water demand sectors, except power generation (Table N). The power generation sector decreases water withdrawals in the baseline scenario because of the replacement of the Lakeside Plant with a new Dallman 4 Plant in Sangamon County which uses less water. Because power generation withdraws close to 80% of this total, it is useful to look at the changes in water withdrawals without including the power sector.

The water demand sectors, other than power generation, when totaled, increase by 173.6 MGD (51%) from 2005 to 2050 in the baseline scenario. This number is reduced to 119.7 MGD (35%) in the LRI scenario and increased to 232.5 MGD (69%) in the MRI scenario. These values underscore the importance of analyzing water demand and planning for the future. When the water demand increases are input into the groundwater and surface water supply models by the ISWS, the region will have a greater understanding of the demand placed on the regional water supply and the

Table N: Summary of water withdrawals in East-Central Illinois (in MGD).

Scenario/ Sector	2005 Normal (MGD)	2050 Modeled (MGD)	Change from 2005 (Normal) - 2050 (MGD)	Change from 2005 (Normal) - 2050 (%)
Baseline Scenario (BL)				
Public Supply	127.24	176.88	49.64	39.0
Self-supplied C&I	63.70	137.51	73.81	115.9
Self-supplied domestic	8.86	12.01	3.15	35.6
Irrigation and agriculture	139.40	186.46	47.06	33.8
Subtotal (w/o power)	339.20	512.86	173.66	51.2
Power generation	1,315.35	1,275.54	-39.81	-3.0
TOTAL	1,654.55	1,788.40	133.85	8.1
Less Resource Intensive Scenario (LRI)				
Public Supply	127.24	153.50	26.26	20.6
Self-supplied C&I	63.70	116.17	52.47	82.4
Self-supplied domestic	8.86	12.01	3.15	35.6
Irrigation and agriculture	139.40	177.21	37.81	27.1
Subtotal (w/o power)	339.20	458.89	119.69	35.3
Power generation	1,315.35	1,217.78	-97.57	-7.4
TOTAL	1,654.55	1,676.67	22.12	1.3
More Resource Intensive (MRI)				
Public Supply	127.24	185.36	58.12	45.7
Self-supplied C&I	63.70	178.52	114.82	180.2
Self-supplied domestic	8.86	12.01	3.15	35.6
Irrigation and agriculture	139.40	195.77	56.37	40.4
Subtotal (w/o power)	339.20	571.66	232.46	68.5
Power generation	1,315.35	1,342.37	27.02	2.1
TOTAL	1,654.55	1,914.03	259.48	15.7

C&I = Commercial and industrial water sector; w/o = without;

Note: All withdrawal values reported in million gallons per day (MGD) potential impacts to the resource and the region.

The total withdrawals for each county are shown in Table O. To compare the relative amounts withdrawn in each county in 2050, the percent of each demand sector are shown graphically in Figure J. DeWitt, Mason, Tazewell, and Sangamon counties all have withdrawals over 150 MGD. These large withdrawals are primarily due to the power generation plants within those counties. Ford, Iroquois, Logan, Menard, Piatt, and Woodford counties are all expected to have withdrawals less than 10 MGD.

Figure J shows that public water supply is the primary withdrawal sector in Champaign, McLean, Macon, and Vermilion counties, whereas irrigation and agriculture are the primary withdrawals in Cass, Mason, and Menard counties. Commercial and industrial water withdrawals are focused within Macon and Tazewell counties. Self-supplied domestic remains a very small portion of each county.

Uncertainty - data limitations, drought, and modeling

Like all modeling efforts, the process of modeling future water withdrawals and the withdrawals presented in this report have uncertainty associated with them. But, the importance of the regional water supply planning effort necessitates progress now, even with this uncertainty. Throughout this project, we have been confronted with three main types of uncertainty; data quality, drought, and modeling. These uncertainties are described below.

Data limitations

The water withdrawal data used in this regional water demand analysis were extracted from the Illinois Water Inventory Program (IWIP) of the ISWS. The IWIP database is a record of annual withdrawals for each of the reporting high capacity water users in the state. Every year, facilities are sent a questionnaire about the previous year's annual water withdrawals. Participation, while for some sectors is high (90% of participating facilities in 2005), is voluntary. Additionally, the water withdrawals for commercial, industrial, and power generation facilities are considered confidential and not available to the public. These characteristics of the database lead to problems with data quality:

- Under reporting - not all facilities report every year and/or some facilities never report.
- Not all water sectors are included - irrigation is not reported in the database.

Table O: Future withdrawals for each county, by demand sector, for the year 2050 (in MGD) for the baseline scenario.

County	Public water supply (MGD)	Domestic (MGD)	Power generation (MGD)	Commercial & industrial (MGD)	Irrigation & agriculture (MGD)	Total (MGD)
Cass	2.32	0.44	–	3.16	15.84	21.76
Champaign	33.62	2.56	–	9.74	6.15	52.07
DeWitt	1.83	0.4	810.44	0.03	0.94	813.64
Ford	2.25	0.25	–	6.54	0.92	9.96
Iroquois	3.3	0.96	–	1.48	3.25	8.99
Logan	3.99	0.71	–	2.82	2.08	9.59
Macon	31.33	0.21	–	26.59	0.41	58.54
Mason	0.95	0.55	105.00	7.48	108.26	222.24
McLean	24.07	1.55	–	2.07	2.15	29.85
Menard	1.04	0.02	–	0.00	3.09	4.16
Piatt	1.42	0.46	–	1.56	0.49	3.94
Sangamon	31.74	1.54	331.46	7.93	1.64	374.31
Tazewell	25.39	0.12	25.88	62.05	39.14	152.59
Vermilion	10.52	0.66	2.76	6.04	0.72	20.71
Woodford	3.08	1.58	–	0.02	1.39	6.06
Total	176.88	12.01	1,275.54	137.51	186.46	1,788.40

All data reported in million gallons per day (MGD).

All sectors, except public water supply, are self-supplied

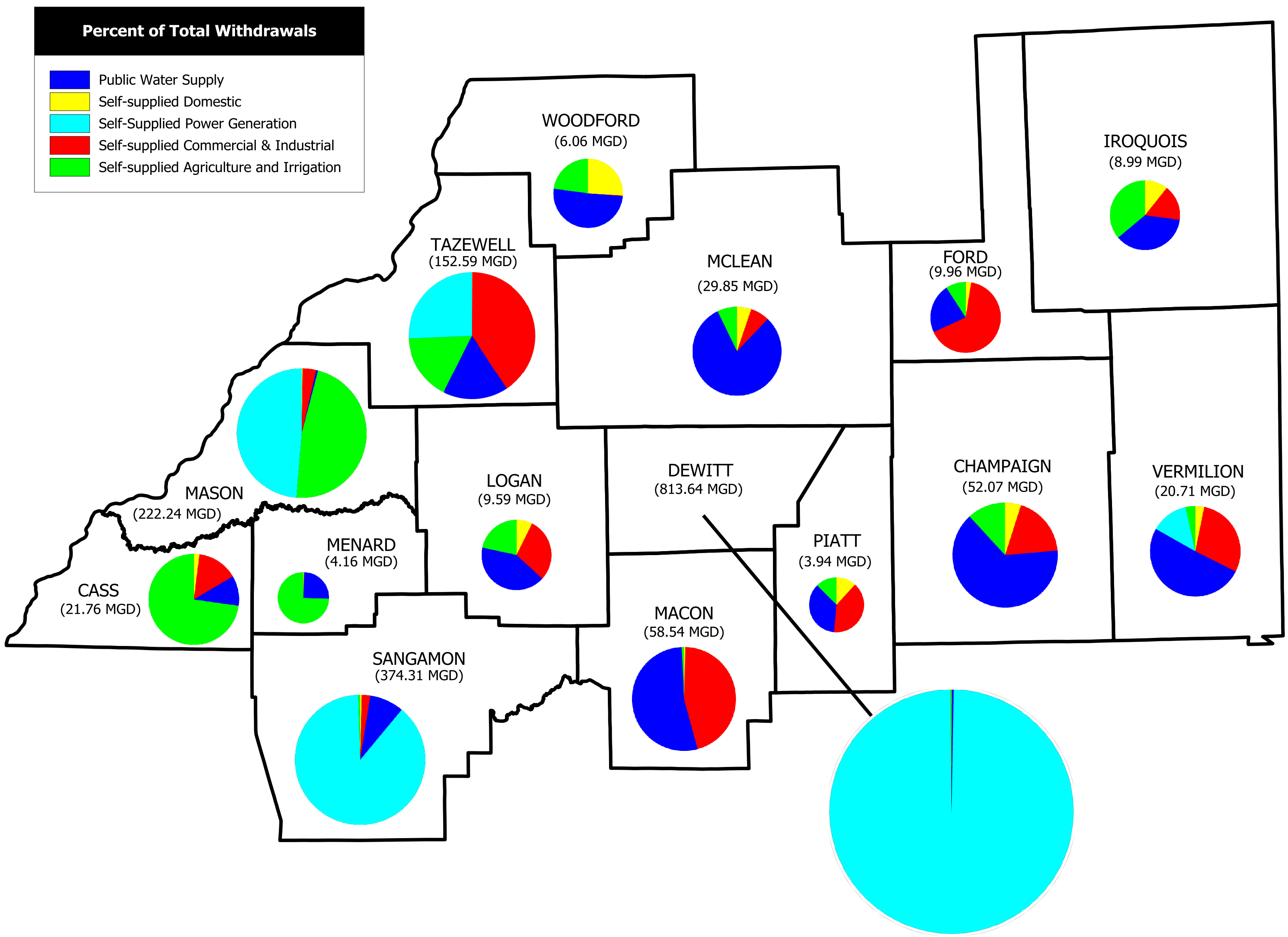

Figure J: County water withdrawals in East-Central Illinois in 2050 by demand sector for the baseline scenario.

- Facilities report annual withdrawals - this does not reflect the way water is actually withdrawn throughout the year; people and facilities use more water in the summer.
- Facilities do not all report the same way - some facilities report how much water was withdrawn from the source, others report how much water was sold to customers, some facilities report how much water was produced.

The future estimates that can be made with this data are limited by their temporal scale and the degree to which total withdrawals are represented in the record. For example, the annual values of water withdrawals limits our estimates to annual water withdrawals. We are not able to predict water withdrawals for any month or season. It is important that the reader recognize the fact that this limitation is a natural consequence of the way the data are currently being reported. Annual calendar year reporting makes it more difficult for a water withdrawal model to capture the true nature of the water demand relationships. Data regarding monthly withdrawals would improve the quality of the database.

The water withdrawal inventory only includes data that are reported voluntarily by the water user. This creates a bias in the database because voluntary reporting may inadvertently screen for a better representation of water users who are already required to maintain this information such as public water suppliers and power plants. Commercial water users can legally claim that their water withdrawals are proprietary information and even if it is reported, it may not be publicly available. Irrigation withdrawals, like commercial water users, are not required to be reported.

Implications The modeling analysis described in this report is based on the relationship between annual reported water withdrawals and a set of factors that are known to affect annual water withdrawals, such as regional population, income, price, precipitation, etc. However, inasmuch as the water demand model reflects an association between a set of fairly well-understood demographic and climatological factors with water withdrawals, there is substantial embedded uncertainty in all of our predictions because of the character of the water withdrawal data described above. In short, the model relates spatially distributed climate data and demographic information to relatively imprecise annual water withdrawal data. Improving water withdrawal data should improve future water withdrawal scenario results.

Consideration of drought

One of the confounding aspects of this project is that our work is being done to estimate future water withdrawal trends – but we are not considering future inter-annual variation in weather and the potential effects of drought (except in sensitivity analysis). As our team has presented the models and the analysis for technical review this has raised questions about the objectives of the work and the perceived need for a "worst case" analysis that considers future water shortages. Droughts and floods will occur over the next 5 decades but the timing, frequency and duration of these events cannot be predicted. Rather than focus attention on these extreme events the purpose of our demand modeling is to anticipate changes in water withdrawals that may happen because of fairly well-understood drivers of water demand; demographic changes (growth), price fluctuation, or the implementation of conservation practices. An illustration of the difference between the analysis of regional trends and the effects of a drought are shown in Figure K.

Another problem with the consideration of drought in the 15-county area is that drought response is normally handled by local infrastructure planning. Changes in local infrastructure may include additional wells, alternative water supplies and conservation planning. In some combination, these techniques can be coordinated to accommodate the spikes in demand for the relatively short duration of the dry spell. For example, in water systems that rely on surface water (these are inherently more vulnerable to drought conditions) some groundwater sources or alternative water supplies is one of the most common approaches to drought planning.

The 2005 water withdrawal data demonstrated how a short-duration drought could affect regional water withdrawals. This increase can be considered a "drought buffer" that needs to be added to the potentially increasing water withdrawals anticipated because of regional economic and demographic change.

Implications

1. Droughts are not being modeled in this project. Instead we have focused our attention on the general increases in water withdrawals that can be expected to occur in the next 50 years. The sensitivity analysis is used to understand the possible implications of drought.

2. Preparations for dry years have traditionally been done at the local level. Additional wells, alternative sources, wholesale agreements to share with neighboring water suppliers, and conservation are all appropriate measures for water systems to consider.

3. Long-term increases in water withdrawals are expected and these are being anticipated by the 15-county water demand model.

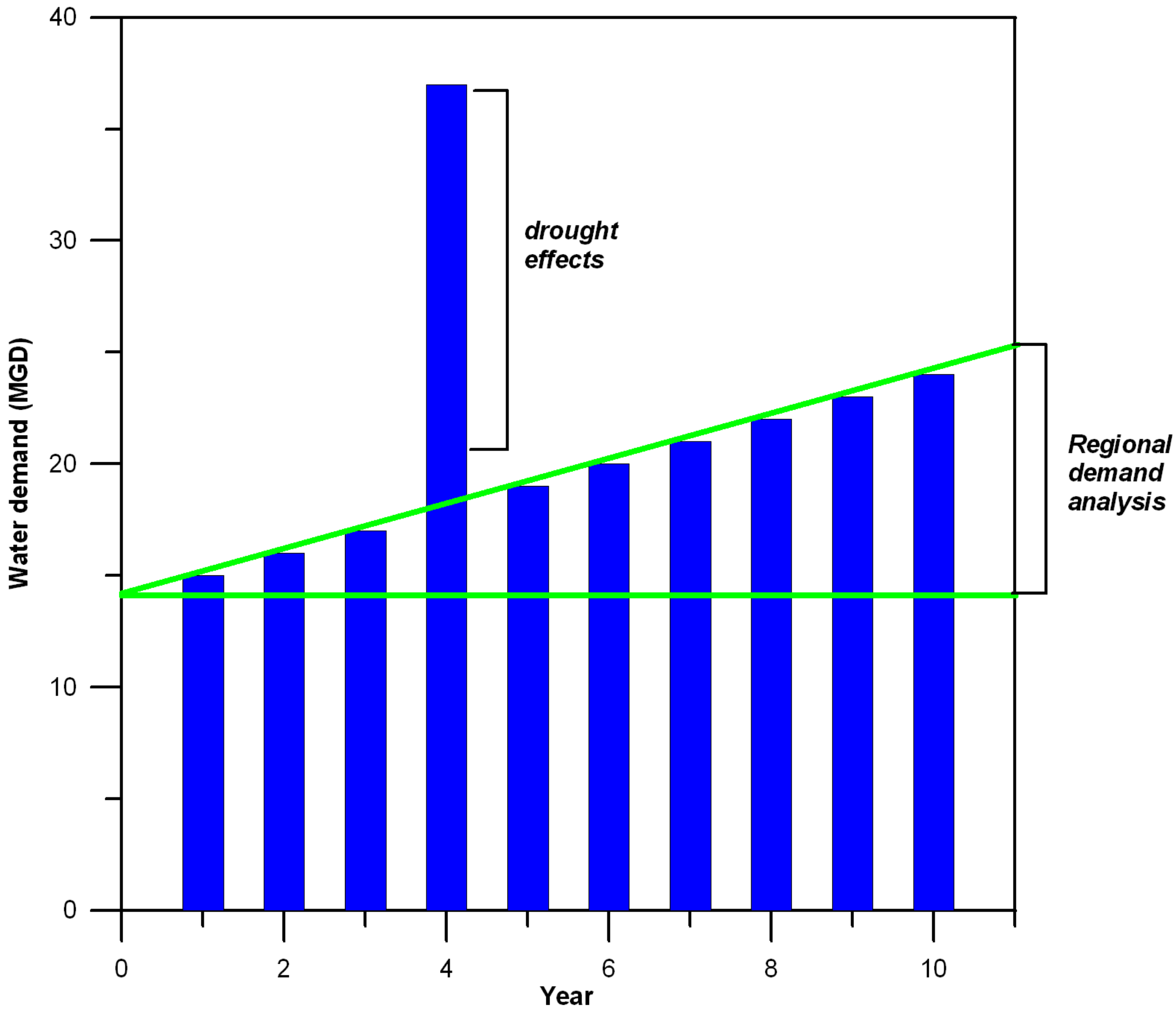

Figure K: Example of potential drought effects.

Uncertainty of future demands

It is important to recognize the uncertainty in determining future water demands in any study area and user sector. This uncertainty is always present and must be taken into consideration while making important planning decisions on future water conservation and supply requirements. Generally, the uncertainty associated with the analytically derived future values of water demand can come from a combination of the following distinct sources.

1. Random error: The random nature of the additive error process in a linear (or log-linear) regression model which is estimated based on historical data guarantees that future estimates will deviate from true values even if the model is specified correctly and its parameter values (i.e., regression coefficients) are known with certainty.

2. Error in model parameters: The process of estimating the regression coefficients introduces error because estimated parameter values are random variables which may deviate from the true values.

3. Specification error: Errors may be introduced because the model specification may not be an accurate representation of the "true" underlying relationship.

4. Scenario error: Future values for one or more model variables cannot be known with certainty. Uncertainty may be introduced when projections are made for the water demand drivers (such as population, employment or irrigated acreage) as well as the values of the determinants of water usage (such as income, price, precipitation and other independent variables). For example, 97% of the variability in public water supply withdrawals are explained by the population served. Therefore, variations in future water demand would result from different population change scenarios.

The approach used in this study is uniquely suited for dealing with the last source of error – the scenario error. By defining three alternative scenarios the range of uncertainty associated with future water demands in the study area can be examined and taken into consideration in planning decisions. A careful analysis of the data and model parameters was undertaken in other to minimize the remaining three sources of error.

Conclusion

This study examined the future water demand on a geographic region. However, it didn't address the ability of the water resources in that region to supply the estimated demand or the impact of the increased demand on the ecological or hydrological resources. Water demand estimates are important to understanding how different areas are using water and how fast and where the region is growing. What these estimates do not reveal is if the regional water sources, both surface water and groundwater, can supply and sustain the demand placed upon them. But, as these water withdrawals are utilized in the water supply modeling analysis performed by the ISWS, the RWSPC will be able to plan for the future and ensure that all water users within the region have a safe and secure water supply.