Chapter 4

Self-supplied Commercial and Industrial (C&I)

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4.1 Background

The commercial and industrial (C&I) sector represents water withdrawals that are self-supplied or purchased (*i.e.*, water delivered by a public supply system) 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"[Avery, 1999]. The commercial sub-sector includes water used for "motels, hotels, restaurants, office buildings, other commercial facilities, and institutions" [Avery, 1999].

This chapter focuses on *self-supplied* water withdrawals by industrial and commercial (or institutional) establishments within the 15-county study area in East-Central Illinois. However, for analytical purposes both self-supplied and publicly delivered supplies are considered in order to correlate future water demand in this sector with the projections of the main driver variable – total employment in each of the 15 counties.

4.2 Multiple regression method

The general purpose of multiple regression is to learn more about the relationship between several independent variables (e.g. cooling degree days, precipitation, etc.) and a dependent variable (e.g. per employee water withdrawals). Multiple regression can establish that a set of independent variables explains a proportion of the variance in a dependent variable at a significant level (through a significance test of R^2), and can establish the relative predictive importance of each of the independent variables. The relative importance is shown via the sign and magnitude of the resulting coefficients or elasticities. The general multiple regression method is described in greater detail in Chapter 1.

4.2.1 Commercial and industrial water-demand relationships

Water withdrawals and purchases for C&I purposes are most often explained in economic terms, where water is treated as a factor of production. Ideally, econometric models of C&I water demand could be developed based on outputs, the price of water, and other inputs. Unfortunately, such data are rarely collected at the county level or are not publicly available because of their proprietary nature. An alternative approach that has been commonly used is to use unit-use demand coefficients to estimate water demand based upon the size and type of products or services produced by the firm. Because the size of the firm is frequently represented by its number of employees, total water demand estimates for the C&I sector are frequently calculated in terms of the quantity of water per employee for a specified type of business enterprise.

The type of firm can be determined by its SIC code, a system that is now converted into the North American Industry Classification System (NAICS). Several SIC/NAICS codes, especially those in the manufacturing sector, are commonly associated with high-levels of water demand. The ready availability of data on the number of employees by SIC/NAICS codes at the county level has led to the widespread use of sectoral employment as the primary independent variable in C&I water demand studies [Davis et al., 1987].

The variability of self-supplied C&I water demand for different SIC/NAICS codes tends to be very high and therefore is difficult to model at the aggregate level of water-demand data. Table 4.1 compares the reported self-supplied C&I withdrawals for the 15 counties in the study area. The last column in Table 4.1 shows the water demand per employee which were obtained by dividing the self-supplied withdrawals by the reported total employment in self-supplied firms. Often times, the C&I facilities do not provide the number of employees in their firm when they report their water withdrawals which is part of the variability seen in the water demand per employee. The per employee water demand ranges from 35 gallons per employee per day (GPED) in Iroquois County to 504,691 GPED in Ford County. Because it would difficult to develop water-demand models which explain such great variability, the combined total self-supplied and purchased C&I water withdrawals were used as the dependent variable in deriving water-demand relationships.

Table 4.2 shows the data on per employee water demand at the county level for total self-supplied and total C&I water demand in 2005. The per-employee rates of total water demand (self-supplied and purchased) show much less variability (from 7 gallons per employee per day (GPED) to 792 GPED) than per-employee rates of self-supplied withdrawals in the subset of self-supplied firms as shown in Table 4.1. For this reason the total self-supplied and purchased C&I water demand is modeled.

A log-linear model similar to the public-supply model was applied to capture the relationship between average water demand per employee (for combined self-supplied and delivered water) and independent variables. The independent variables included two weather variables, annual cooling degree days and total precipitation from May 1 through September 30, and three variables representing the structure of employment within each county. The employment structure was captured as the percentage of employment in the 2-digit SIC/NAICS categories health services, retail trade, and manufacturing. Also, a variable was included in the data to provide a measure of the allocation of publicly supplied and self-supplied C&I water demand in each county. The percent of self-supplied C&I withdrawals variable was calculated as the quantity of self-supplied

Table 4.1: County-level estimates of self-supplied commercial and industrial water demand in 2005.

County	Self-supplied withdrawals (MGD)	Employment in self-supplied establishments	Water demand per employee (GPED)
Cass	1.83	2,300	796
Champaign	5.54	2,117	2,617
DeWitt	$2E^{-5}$	23	0.9
Ford	3.03	6	504,691
Iroquois	0.02	704	35
Logan	1.00	no data	–
Macon	15.73	842	18,677
Mason	5.58	75	74,428
McLean	0.01	17	391
Menard	0.00	30	0
Piatt	1.09	45	24,241
Sangamon	5.06	19	266,503
Tazewell	43.20	5,192	8,321
Vermilion	2.70	380	7,095
Woodford	0.00	10	0
Total/Ave.	84.79	1,760	7,210 (Ave.)

Source: Illinois Water Inventory Program, Illinois State Water Survey, 2007.

MGD = million gallons per day. GPED = gallons per employee per day.

Table 4.2: County-level self-supplied and purchased commercial and industrial water withdrawals in 2005.

County	Total county employment	Self-supplied withdrawals (MGD)	Public-supply deliveries to C&I (MGD)	Total C&I withdrawals (MGD)	Water demand per employee (GPED)
Cass	7,324	1.83	0.10	1.93	263
Champaign	98,084	5.54	5.65	11.19	114
DeWitt	8,023	0.00	0.27	0.27	34
Ford	6,994	3.03	0.44	3.47	496
Iroquois	15,923	0.02	0.34	0.36	23
Logan	12,718	1.00	0.34	1.34	106
Macon	50,203	15.73	4.85	20.58	410
Mason	7,175	5.58	0.10	5.68	792
McLean	84,570	0.01	1.36	1.36	16
Menard	6,751	0.00	0.05	0.05	7
Piatt	8,858	1.09	0.15	1.24	140
Sangamon	101,526	5.06	7.99	13.05	129
Tazewell	66,606	43.20	7.24	50.44	757
Vermilion	35,850	2.70	3.38	6.07	169
Woodford	19,509	0.00	0.26	0.26	13
Total/Ave.	530,114	84.79	32.50	117.29	231(Ave.)

MGD = million gallons per day; GPED = gallons per employee per day; Ave. = average

Sources: Illinois Water Inventory Program, Illinois State Water Survey, 2007; US Geological Survey 2005 provisional data; and County Business Patterns and Illinois Department of Employment Security, 2007.

C&I withdrawals divided by the sum of self-supplied and delivered C&I water. The conservation trend variable was included to account for unspecified changes that are likely to influence water withdrawals over time, and that represent general trends in efficiency in production processes and technologies.

4.3 Historical data

Water withdrawals and independent variables for each county in the region were analyzed for the historical period to establish the mathematical relationship between independent variables and withdrawals. Data were gathered for the historical years 1985, 1990, 1995, 2000, and 2005. A description of the data and the sources from which data were obtained is provided in the following sections. Individual counties are the geographical areas of analysis for this sector.

4.3.1 Historical water withdrawals

Total C&I water withdrawals are comprised of two datasets 1) self-supplied C&I facilities that own their water supply system and 2) C&I facilities that purchase water from public suppliers. Data on self-supplied C&I withdrawals for both surface water and groundwater sources were obtained directly from the Illinois Water Inventory Program (IWIP) of the Illinois State Water Survey (ISWS). Data on water delivered to C&I establishments by public suppliers were obtained from U.S. Geological Survey (USGS).

Self-supplied C&I facilities voluntarily report annual water withdrawals to the ISWS (Table 4.3). For the entire 15-county study area in East-Central Illinois, total self-supplied commercial and industrial withdrawals (including mining) range between 74 – 85 MGD from 1985 to 2005. All of the historical data was used as reported from the ISWS, with one exception. In 2001, the City of Decatur's public water supply system sold one of its water treatment plants to Archer Daniels Midland (ADM), a local industry. Prior to 2001, Decatur sold water to ADM. The sale of the treatment plant in 2001 was evidenced in the IWIP historical withdrawals as an increase in water withdrawals for Macon County of approximately 15 MGD in 2005. This increase in withdrawals for 2005 creates an "artificial" increase in per employee water withdrawals for Macon County as compared to other years. Conversely, in the Public Water Supply (PWS) Sector (Chapter 2), there is a large decrease in the withdrawals in 2005. Because the model is designed to capture only changes in withdrawals that relate to the eight independent variables, not the change of large volumes of water from one sector to another, we removed this change from the historical data. This was done by adding ADM's withdrawals to Macon County in the amount of water that was sold to ADM in 1985, 1990, 1995, and 2000. The historical withdrawals (1985, 1990, 1995, and 2000) were removed from PWS and added to the withdrawals in the C&I Sector. Including ADM withdrawals in C&I for all historical years better enables the model, which is based upon the historical data, to capture the other changes in water withdrawals. The modification in the historical withdrawals data is noted in the graphs and tables throughout the report.

The data in Table 4.3 shows some variability of the reported withdrawals across the data years at the county level. The variability of the reported withdrawals can be partially attributed to the voluntary method in which the self-supplied withdrawals are inventoried. Although participation by known facilities is common, it should be noted that in any given year the database *may* be underestimating total withdrawals because of non-reporting by known facilities and lack of participation by unidentified facilities. For example, In Sangamon County the increase between 1995 and 2000 is due to one large facility reporting withdrawals only in 2000 and 2005 and no previous years. The non-reporting facility may either be an existing business that did not report in the past or a new business. The variability in Tazewell County is a result of the facilities reporting differing amounts of withdrawals in any given year and the addition of facilities throughout the time period. The reduction in withdrawals for Champaign County in 1995 as compared to 1990 withdrawals are a result of one large facility closing. In Macon County the gradual decline in water withdrawals is due in part to one large facility reducing total withdrawals over the years. The variability in other counties may also be due to the addition or subtraction of facilities, changes due to weather, some facilities no reporting or variability in production from year to year.

4.3.2 Total county employment

County-level total employment data were obtained from the Illinois Department of Employment Security (IDES) (2007) for 1985, 1990, 1995, 2000, and 2005. The IDES reports the number of people employed on a monthly basis and reports the average number of people employed annually. Since employment is generally not seasonal, the annual average number of people employed for each county are used.

Total county employment is used to convert total water withdrawals into gallons per employee per day (GPED). The model uses GPED as the dependent variable, or the left-hand side of the equation. GPED is calculated by dividing total water withdrawals by total county employment.

Table 4.3: Historical self-supplied commercial and industrial water withdrawals as reported to Illinois State Water Survey.

County	1985 MGD	1990 MGD	1995 MGD	2000 MGD	2005 MGD
Cass	0.77	1.99	1.59	2.00	1.83
Champaign	8.97	10.87	7.60	5.33	5.54
DeWitt	0.00	0.01	0.00	0.00	0.00
Ford	0.05	0.02	0.79	2.66	3.03
Iroquois	0.10	0.05	0.05	0.10	0.02
Logan	0.07	0.21	0.06	0.13	1.00
Macon *	19.52	20.81	19.30	17.17	15.73
Mason	8.98	7.56	4.83	4.87	5.58
McLean	0.65	0.04	0.06	0.01	0.01
Menard	0.00	0.00	0.00	0.00	0.00
Piatt	1.18	0.80	0.81	0.90	1.09
Sangamon	1.58	1.92	1.26	5.06	5.06
Tazewell	34.37	27.06	39.08	37.41	43.20
Vermilion	3.23	2.99	2.65	2.37	2.70
Woodford	0.00	0.01	0.01	0.00	0.00
Total	79.48	74.33	78.1	77.99	84.79

*Water withdrawals for Macon County has ADM pumpage added for 1985-2000; see Section 4.3.1 for explanation. MGD = million gallons per day.

Source: Illinois Water Inventory Program, Illinois State Water Survey, 2007.

4.3.3 Independent variables

Water withdrawals are driven, or controlled, by certain influencing factors called independent variables. A substantial data collection and processing effort was required to prepare appropriate independent variables for the development of water-withdrawal relationships. The dependent variable was defined as gross water withdrawals (self-supplied withdrawals plus water purchased from public water suppliers). Seven independent variables were used to explain the variability of water withdrawals across study areas. These six variables were chosen based upon a previous study of Illinois water withdrawals [Dzielgielewski et al., 2005] in which approximately 20 variables were tested to determine if they significantly affected water demand. A discussion of the data and source information for each of the variables listed below is found in the sections following this section:

- total annual cooling degree days;
- total precipitation from 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 C&I water withdrawals; and
- a conservation trend.

4.3.3.1 Weather variables - cooling degree days and precipitation

Cooling degree days and precipitation are both important drivers of water demand. Cooling degree days are calculated by subtracting 65 from a day's average temperature so that on any day where the average temperature is above $65°F$ the day is said to have as least one cooling degree day. For example, if the average temperature for the day is $80°F$ and we subtract $65°F$ from $80°F$, the day has 15 cooling degree days. Cooling degree days are positively correlated to water demand, meaning that an increase in cooling degree days results in an increase in water withdrawals.

The total summer precipitation (May 1 through September 30) is also used as an independent variable in the model. So for each county, the total summer precipitation was collected and analyzed in the model. Precipitation is negatively correlated to water withdrawals, meaning an increase in precipitation results in a decrease in water demand.

The correlation of weather to water withdrawals indicates that climate change will impact water withdrawals in the region. Although, we do not account for it in our three scenarios, we do examine the possible effects of climate change and drought in Chapter 6. Please refer to this chapter for more discussion about climate change and the impacts to water withdrawals.

The data for the weather variables, total annual cooling degree days and total summer (May 1 through September 30) precipitation, were obtained from Dr. Jim Angel, State Climatologist, ISWS. Data from 29 stations in the 15-county region were organized and summarized. The station number and location of the weather stations used for this study are listed in Appendix D.

The weather variables assigned to each county were the average of all the stations in that particular county. If there were no stations in a county or no data from the existing station, data from a surrogate station were used. Typically, the surrogate station used was the nearest station to the county where no data existed. The surrogate stations were chosen with the advice of the State Climatologist.

4.3.3.2 Percent health services employment, percent retail trade employment, and percent manufacturing employment

The employment structure within in a county is related to water withdrawals. For example, if a county has a high percent of people employed in the manufacturing sector, it also has high water withdrawals. Employment data for 2-digit Standard Industrial Classification (SIC) codes were obtained from County Business Patterns [United States Census Bureau, 2005] and different employment sectors were tested to see if they were significant. Three variables representing employment structure within each county are used in the model. Employment structure is captured as the percentage fraction of employment in 2-digit SIC categories for health services, retail trade, and manufacturing. The percentages are calculated from the total employment of the county.

4.3.3.3 Percent self-supplied commercial and industrial withdrawals

County-level estimates of self-supplied C&I water withdrawals from both surface and groundwater sources were obtained from ISWS for 1985, 1990, 1995, 2000 and 2005. Data on self-supplied C&I water withdrawals were added to the public deliveries to C&I establishments in order to obtain total water withdrawals and purchases by the C&I sector. The percent of self-supplied C&I withdrawals variable was calculated as the quantity of self-supplied C&I withdrawals divided by the sum of the publicly supplied and self-supplied C&I water.

4.3.3.4 Conservation trend

An additional variable was included to account for unspecified changes that are likely to influence water withdrawals over time and that represent general trends in water conservation behavior. Water demand per employee can be expected to change over time and the conservation trend variable is intended to capture water demand changes due to gains in efficiency in production processes and technologies. The conservation trend variable was specified as zero for 1985, 5 for 1990, 10 for 1995, 15 for 2000, and 20 for the year 2005.

4.4 Commercial and industrial multiple regression model

The final regression model for the C&I sector is shown in Table 4.4 and Figure 4.1. Based upon previous water demand research and modeling efforts, the estimated elasticities (or coefficients) of the independent variables in the structural model have the expected signs and magnitudes. For example, it is expected that the summer precipitation coefficient will be negative which indicates that as precipitation increases, water demand decreases. The expected signs and magnitude of the independent variables were used as one indicator of model validity.

Besides the structural coefficients, two types of binary variables were tested during model development. County binaries were added to the model to account for county specific characteristics that were not accounted for by other variables in the model. Outlier binary variables were added to the model to account for county/year observations that are far outside the expected range of variables. A detailed description of the model development procedure and a complete set of estimated coefficients including binary county intercepts and binary spike variables is included in Appendix D.

The estimated coefficients represent constant elasticities of the independent variable with respect to per employee water demand. For example, the constant elasticity of annual cooling degree days indicates that, on average, a one (1.0) percent increase in the number of cooling degree days increases per employee water demand by 0.53 percent. The negative constant elasticity of summer precipitation variable indicates that, on average, a one (1.0) percent increase in summer precipitation decreases per employee water demand by 0.28 percent. Figure 4.1 is used to graphically indicate the relative impact each variable will have on the modeled per employee water demand compared to other variables in the model.

The last row of Table 4.4 shows the model statistics. These statistics indicate that the model explained 94 percent of time-series and cross-sectional variance in log-transformed per employee water demand. Please refer to the list of key terms for explanation of the other statistical values

Table 4.4: Structural portion of the regression model for commercial and industrial water demand in East-Central Illinois.

Variables	Estimated regression coefficient	t-Ratio	Probability >|t|
Intercept	-1.1465	-0.34	0.73
Annual cooling degree days (ln)	0.5297	1.20	0.24
Summer precipitation (ln)	-0.2766	-1.13	0.26
Health services employment (%)	0.0618	3.25	0.00
Retail employment (%)	0.0740	4.34	<.0001
Manufacturing employment (%)	0.0098	1.30	0.2
Self-supplied C&I demand (%)	0.0324	18.58	<.0001
Conservation trend (ln)	-0.1262	-1.70	0.09
N = 75, R^2= 0.94, R^2Adj = 0.92, Root MSE = 0.41, Mean of Response= 4.6			

shown.

The regression models were used to generate both historical and future GPED withdrawals in each of the 15 counties. Figure 4.2 shows the model versus reported historical water withdrawals. The figure shows that, as expected, there is scatter around the line which indicates that the model predicts GPED accurately for most data points. The model predicted the GPED withdrawals best when the the GPED withdrawals were below 400 GPED as shown by most of these points falling on or near the line. Most of the withdrawals fall below 400 GPED.

Table 4.5 compares the model-generated 2005 values versus the 2005 reported values. As a region, the model versus the reported difference in 2005 withdrawals was -0.55 MGD. The differences between the model generated and reported values are relatively small, since in some cases where the differences for the 2005 data year were large additional calibrations of model intercepts were performed. The calibrated 2005 intercepts were retained in preparing estimates of future water withdrawals.

4.5 Future data

The model described in Section 4.4 established the relationship between water withdrawals and water demand variables. Assuming that this relationship remains the same in the future, the model is used with the future water demand variables to estimate water withdrawals in the future. The

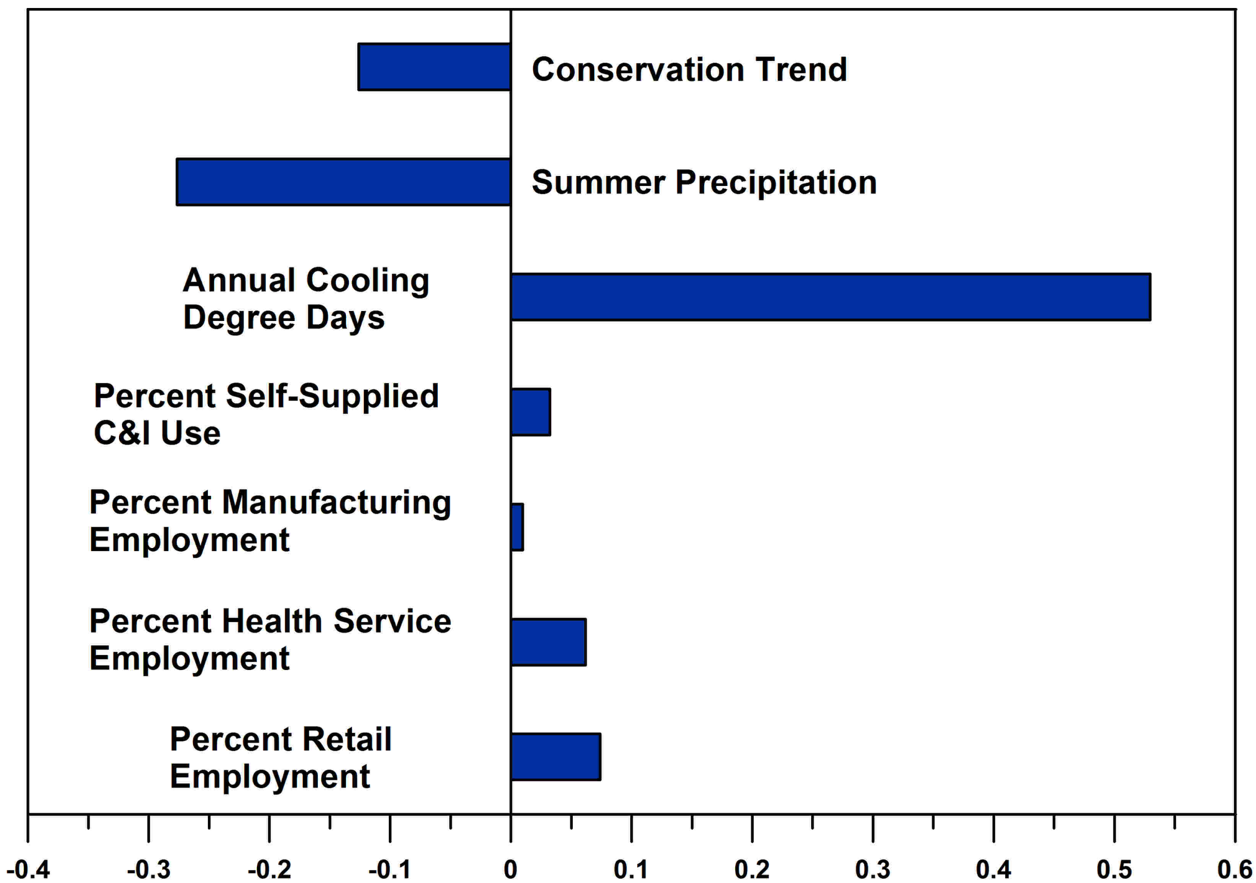


Figure 4.1: Structural model for commercial and industrial sector in East-Central Illinois.

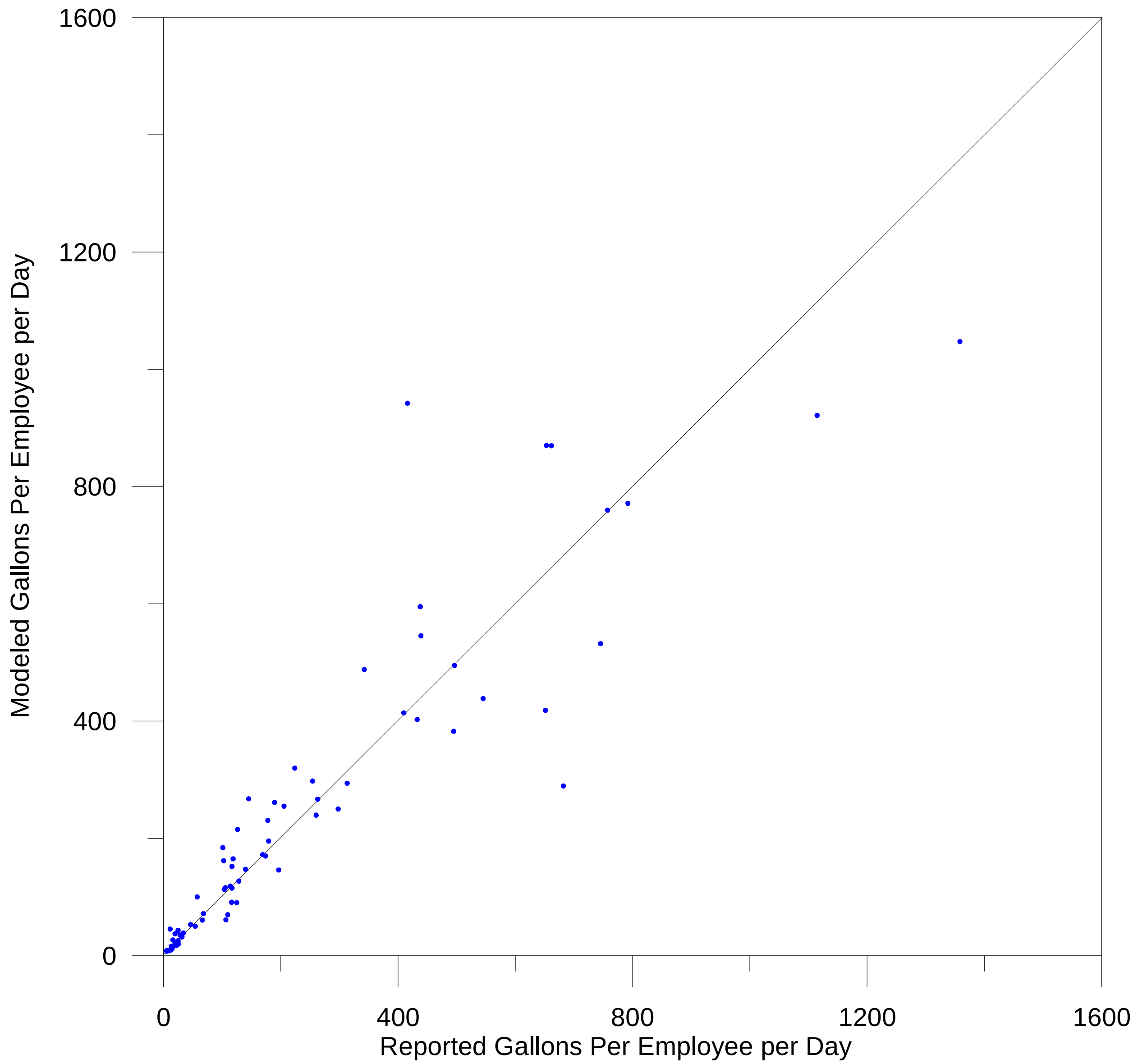


Figure 4.2: Reported versus modeled gallons per employee per day.

Table 4.5: Comparison of model-generated and reported water withdrawals in 2005 for self-supplied commercial and industrial sector.

County	Model-generated withdrawals* (MGD)	Reported withdrawals (MGD)	Difference (MGD)
Cass	1.87	1.83	-0.04
Champaign	5.74	5.54	-0.20
DeWitt	0.00	0.00	0.00
Ford	3.02	3.03	0.01
Iroquois	0.02	0.02	0.00
Logan	1.10	1.00	-0.10
Macon	15.89	15.73	-0.16
Mason	5.44	5.58	0.14
McLean	0.01	0.01	0.00
Menard	0.00	0.00	0.00
Piatt	1.15	1.09	-0.06
Sangamon	5.01	5.06	0.05
Tazewell	43.35	43.20	-0.15
Vermilion	2.74	2.70	-0.04
Woodford	0.00	0.00	0.00
East-Central Illinois	85.33	84.79	-0.55

*Model-generated withdrawals are estimated using actual 2005 weather data.

MGD = million gallons per day.

Source: Illinois Water Inventory Program, Illinois State Water Survey, 2007.

following sections describe how employment and the water demand variables are estimated to the year 2050.

4.5.1 Future employment population

The main driver of future water demand in the C&I sector is the future level of production of goods and services as measured by total employment. The future output of goods and services will also depend on labor productivity; the total future employment should be adjusted for productivity. The long-term growth in labor productivity in Illinois between 1977 and 2000 was 1.3 percent per year as reported by the U.S. Bureau of Labor Services of the U.S. Department of Labor [USBLS, 2000]. However, no information was available on the projections of future growth in productivity and, for the purpose of this study, a long-term rate in productivity increase was assumed to be 1.0 percent per year. The assumption of 1.0 percent per year makes the estimates of future self-supplied C&I withdrawals conservative. Higher future increases in productivity would translate into higher physical output per employee and result in higher withdrawals.

Future employment projections were obtained from IDES out to the year 2014. This study assumes that future employment trends will continue as projected by IDES to the year 2050 (2007). Table 4.6 and Figures 4.3 – 4.10 shows the historical and future total employment for each of the 15 counties in the study area. Between 2005 and 2050, total employment is projected to increase by 167,895 employees or by 32 percent. The employment population is used to generate water withdrawals in the future by multiplying the model derived GPED amounts by the employment to obtain MGD for the county.

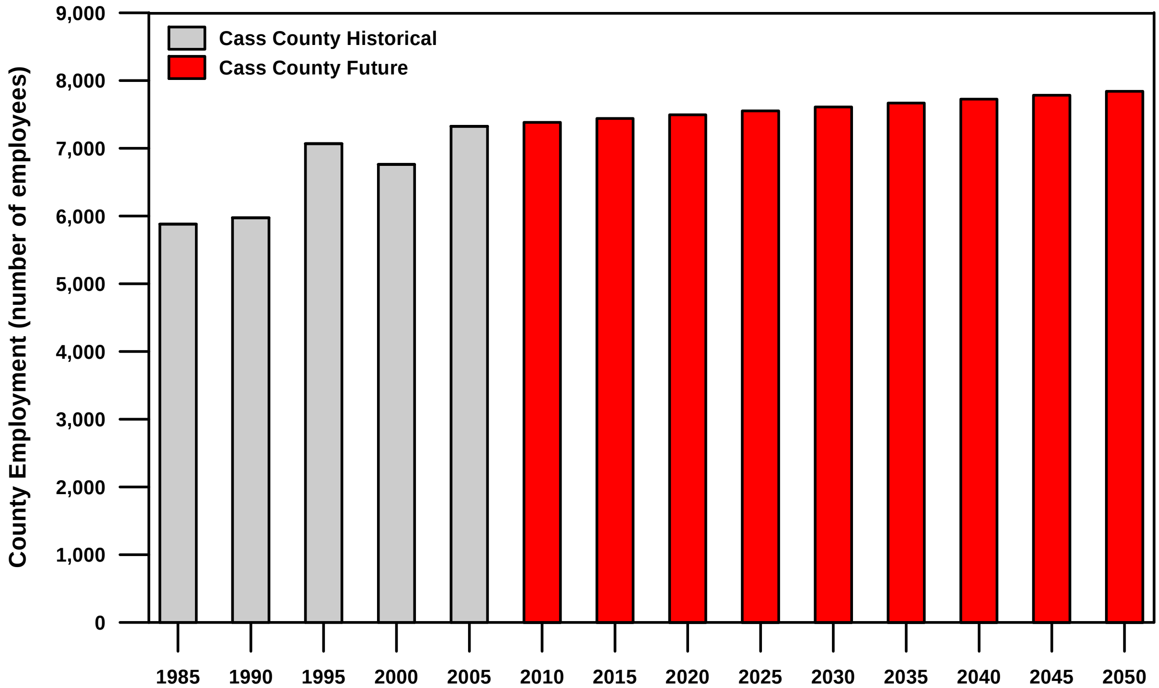
Table 4.6: 2005 total employment, 2050 total employment projections, and number of employees added per year.

County	2005 employment[1]	2050 employment	Employees added per year[2]
Cass	7,324	7,842	11.5
Champaign	98,084	134,921	818.6
DeWitt	8,023	9,063	23.1
Ford	6,994	7,485	10.9
Iroquois	15,923	17,705	39.6
Logan	12,718	14,230	33.6
Macon	50,203	67,375	381.6
Mason	7,175	8,453	28.4
McLean	84,570	121,781	826.9
Menard	6,751	7,296	12.1
Piatt	8,858	9,511	14.5
Sangamon	101,526	137,148	791.6
Tazewell	66,606	89,489	508.5
Vermilion	35,850	39,981	91.8
Woodford	19,509	25,733	138.3
Total	530,114	698,009	3,731

[1]Source: County Business Patterns and Illinois Department of Employment Security, 2007; [2]Source: Illinois Department of Employment Security, 2007

4.5.2 Future values of independent variables

The future values of the seven independent variables (i.e., annual cooling degree days, May through September precipitation, percent health services employment, percent retail trade employment, percent manufacturing employment, percent self-supplied C&I demand, and conservation trend) will determine the future rates of per employee water demand in the C&I sector in each study area. In preparing future C&I withdrawals, future values of the independent variables have to be projected. A description of the projections is provided below.



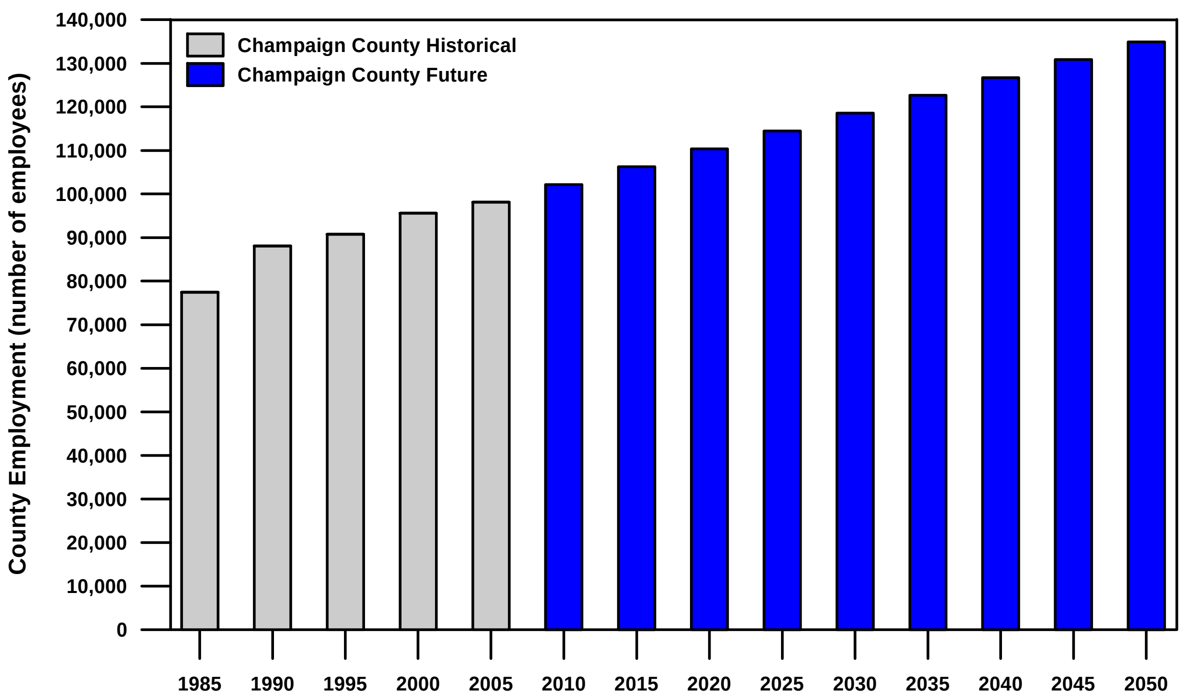
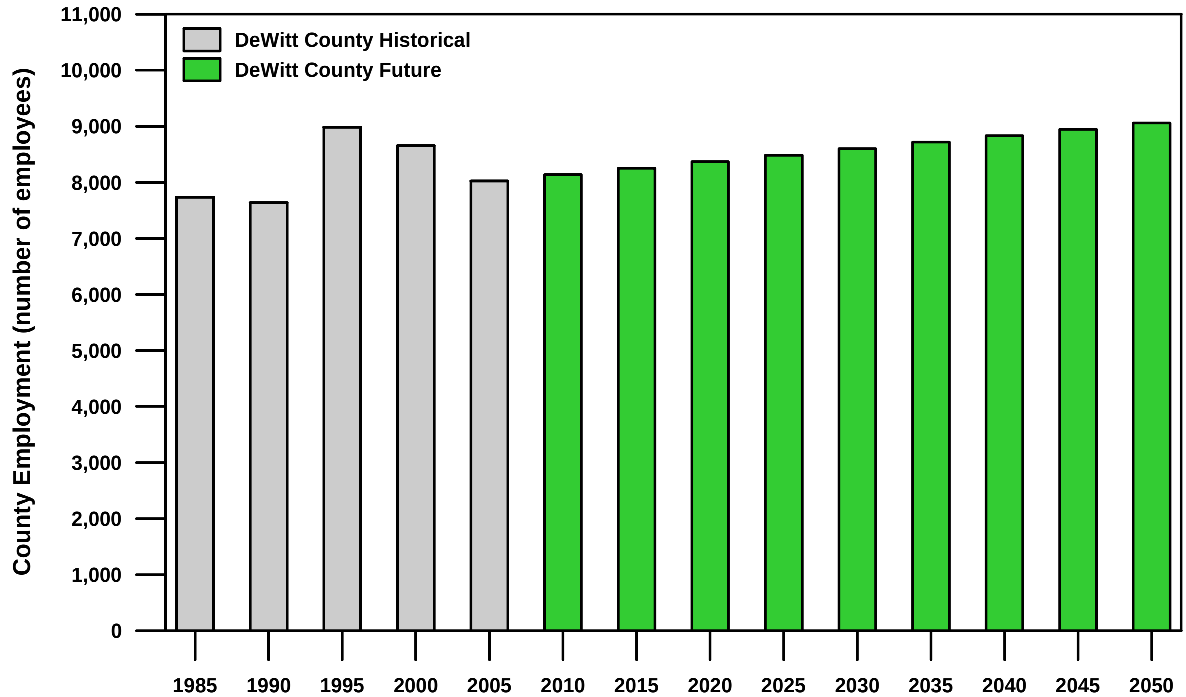


Figure 4.3: Historical and future employment populations for Cass and Champaign counties in East-Central Illinois.



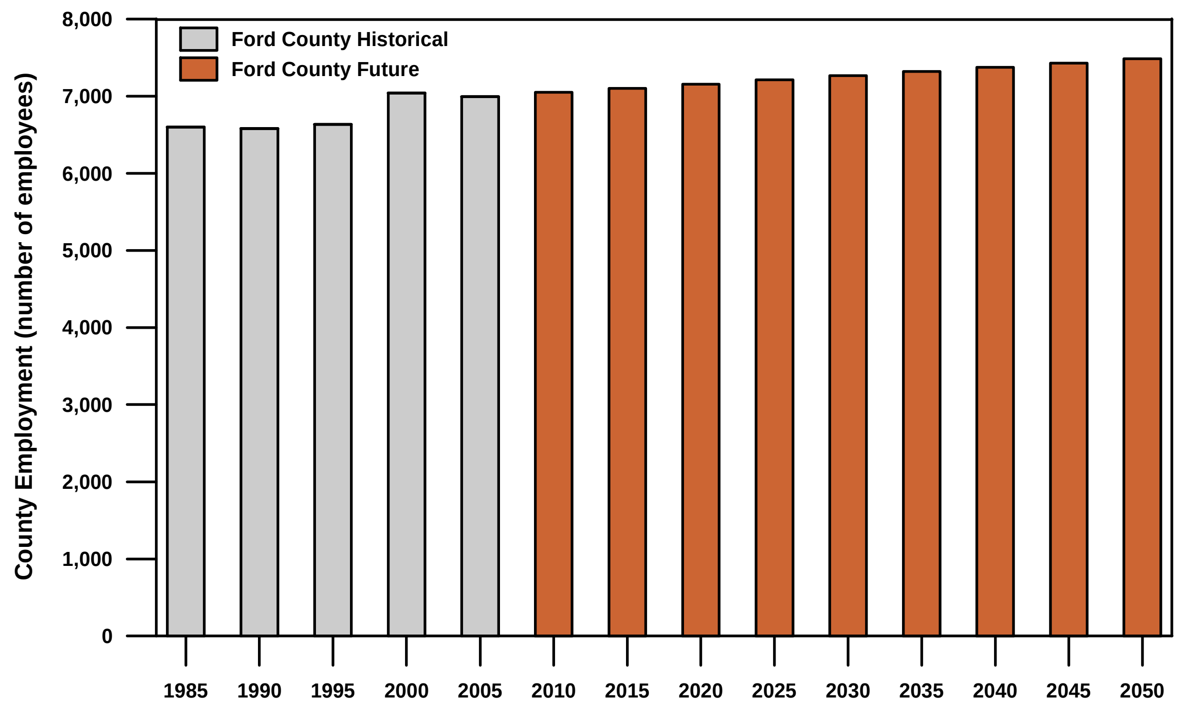


Figure 4.4: Historical and future employment populations for DeWitt and Ford counties in East-Central Illinois.

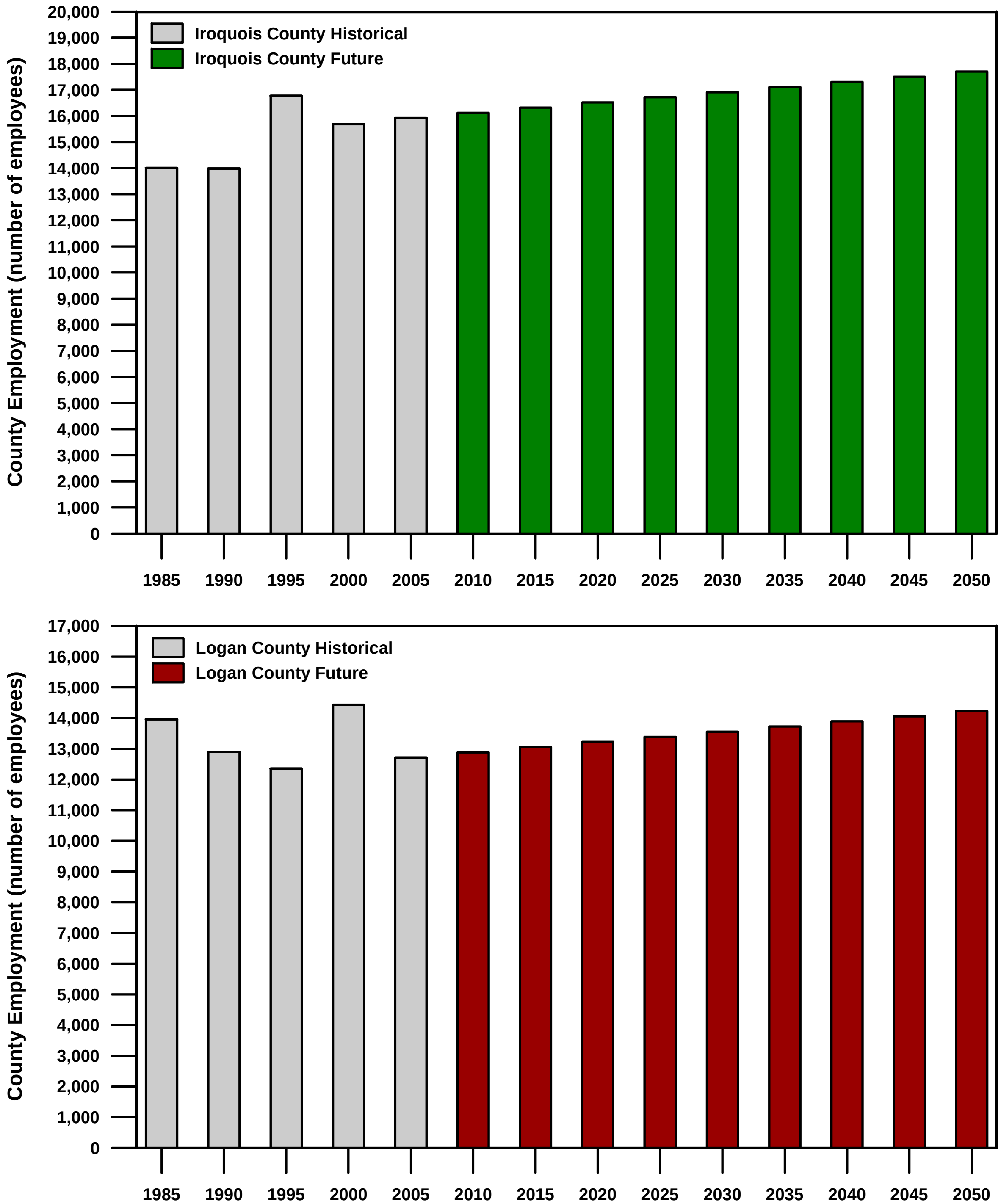


Figure 4.5: Historical and future employment populations for Iroquois and Logan counties in East-Central Illinois.

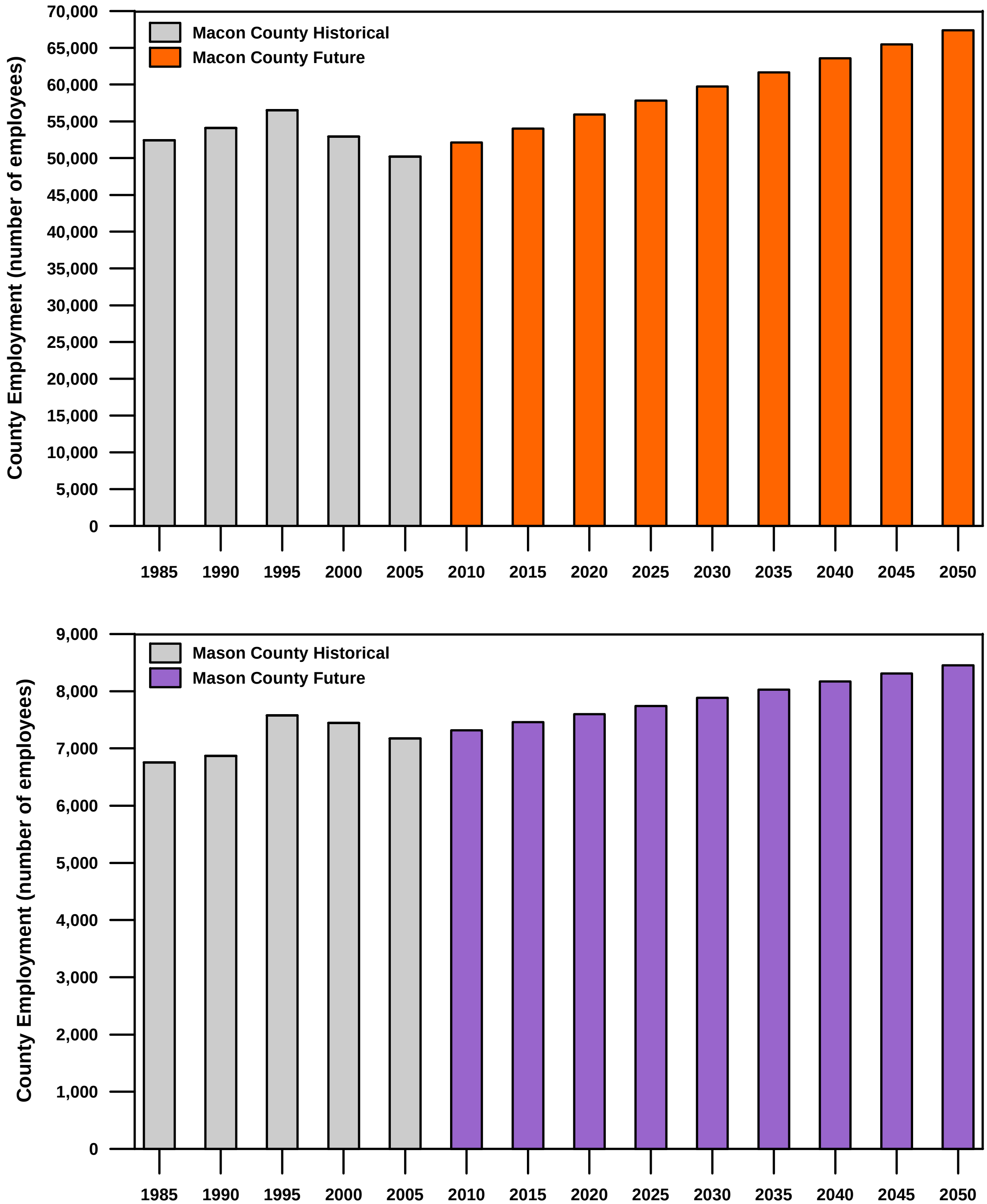


Figure 4.6: Historical and future employment populations for Macon and Mason counties in East-Central Illinois.

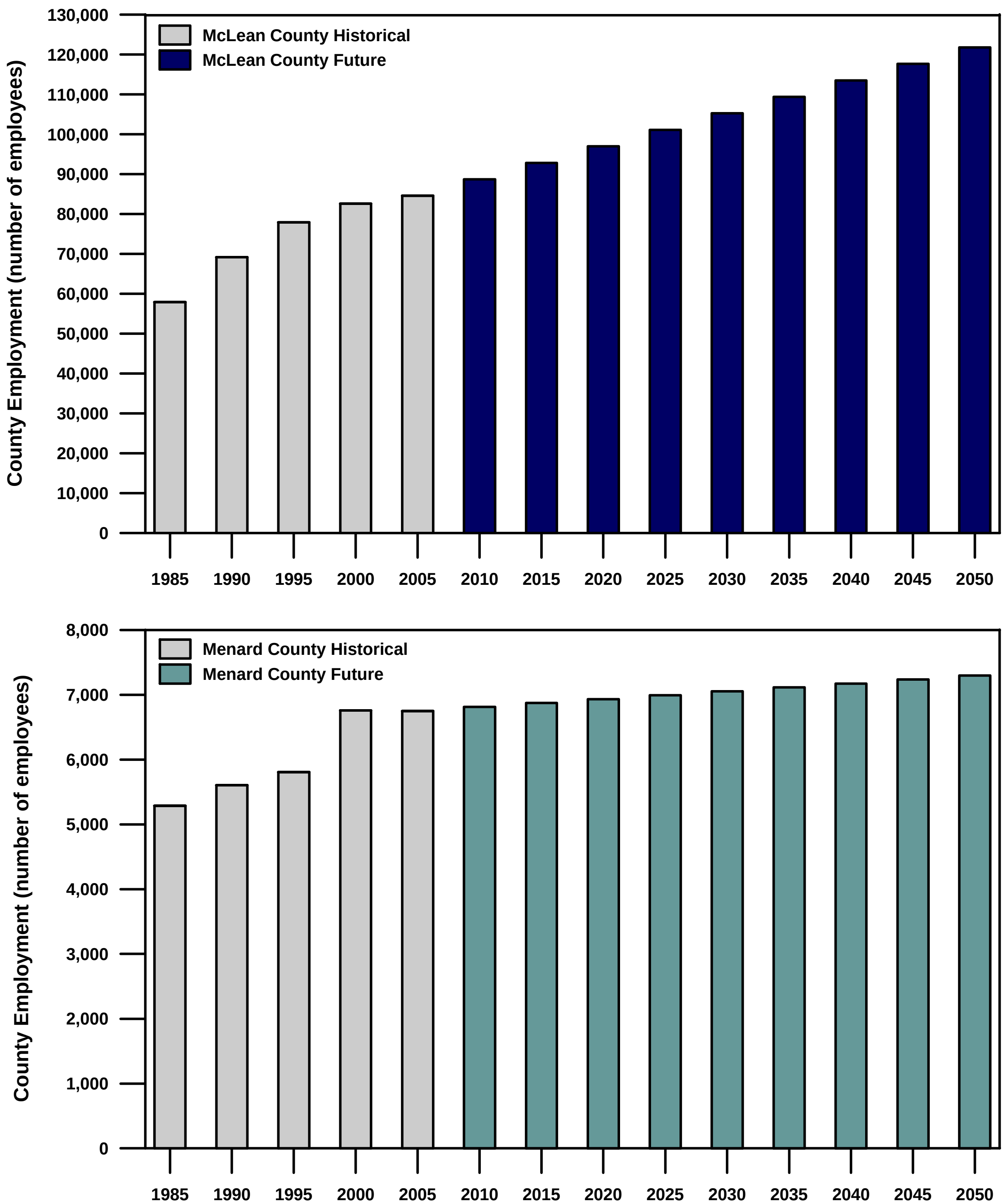


Figure 4.7: Historical and future employment populations for McLean and Menard counties in East-Central Illinois.

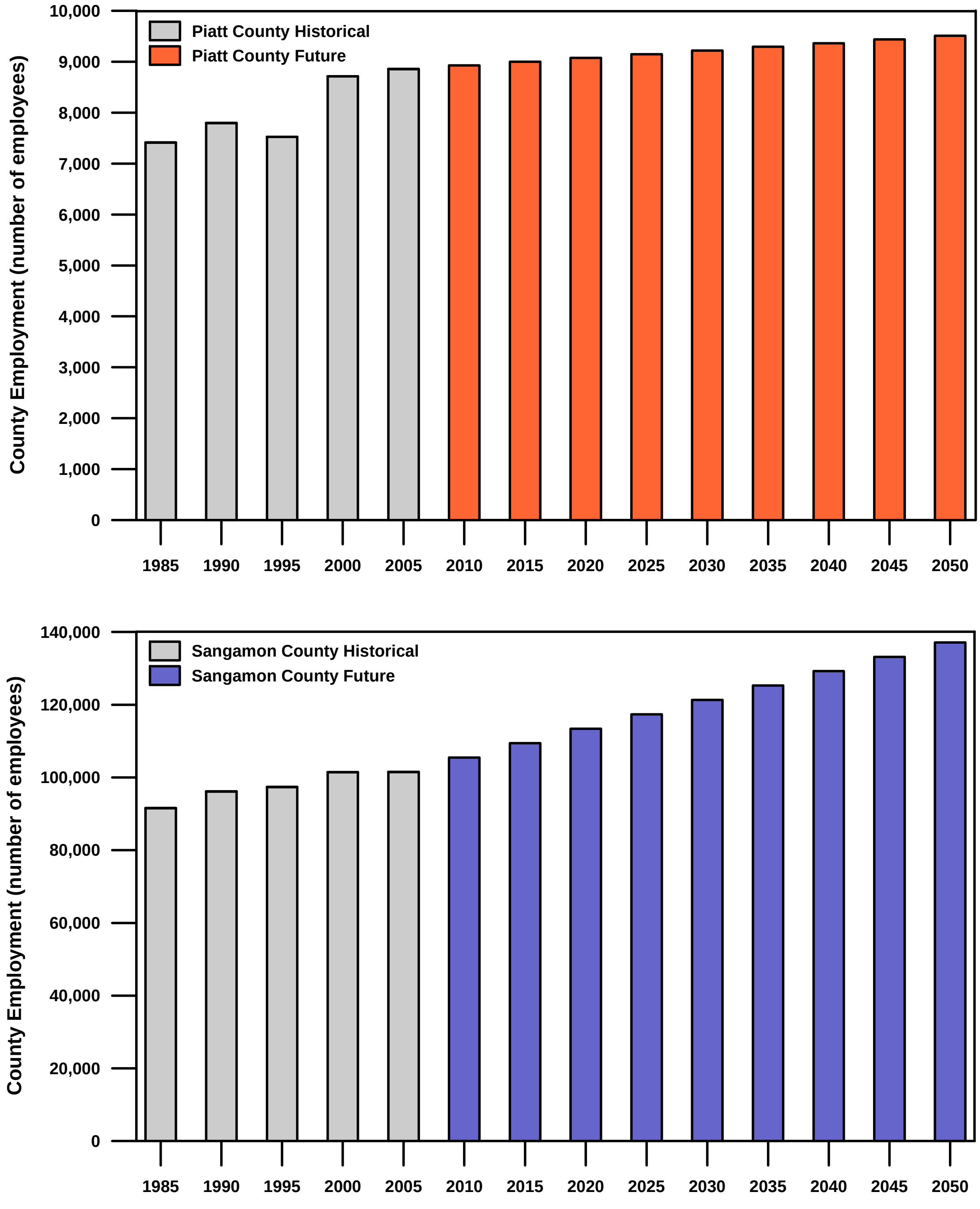


Figure 4.8: Historical and future employment populations for Piatt and Sangamon counties in East-Central Illinois.

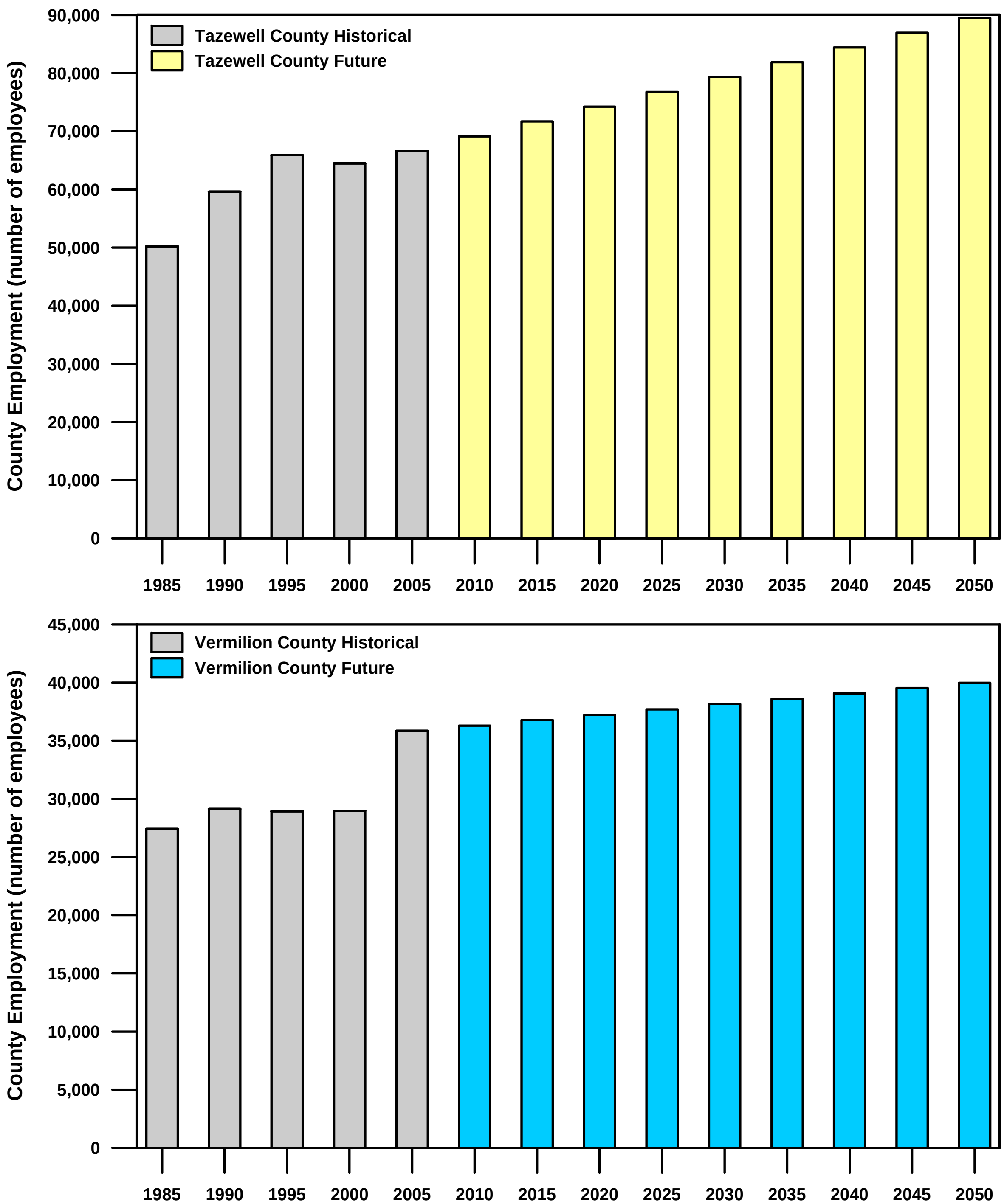


Figure 4.9: Historical and future employment populations for Tazewell and Vermilion counties in East-Central Illinois.

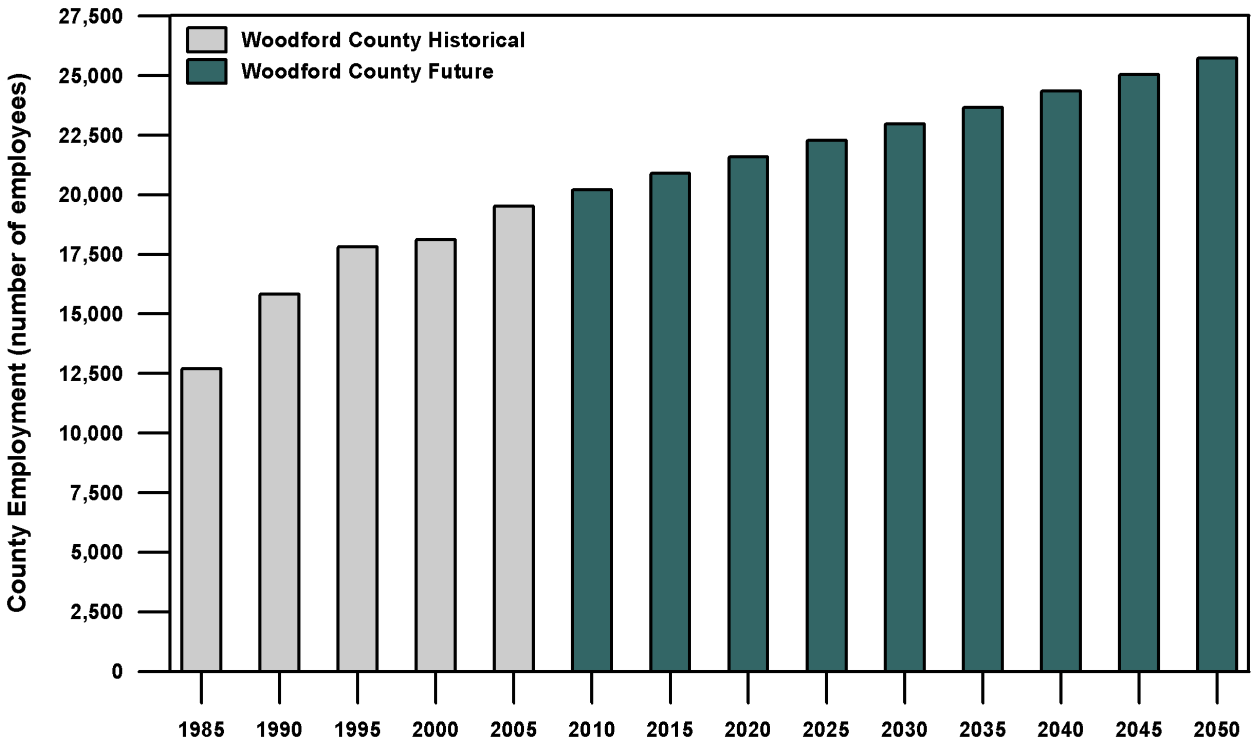


Figure 4.10: Historical and future employment populations for Woodford County in East-Central Illinois.

4.5.2.1 Weather variables - cooling degree days and precipitation

Some of the most important determinants of water demand are related to weather. Consequently, in order to estimate future water withdrawals, the weather variables (i.e., annual cooling degree days and summer precipitation) must also be estimated. Weather data may be dealt with in a variety of ways when looking into the future. One approach is to use the climatic normals, as calculated by the National Center for Climatic Data (NCDC), as future weather. Climatic normals are defined as the "statistical average over a time period usually consisting of three consecutive decades" [Owenby et al., 2006]. The current climatic normals are defined 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. In effect, this assumes that the normal weather from the historical 30-year period will be similar to the future weather and 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 (Figure 4.11).

A second method for estimating weather data in the future is to use stochastic models. Stochastic modeling would allow us to create a dataset of fictional weather data that is statistically the same as the historic data (i.e., the mean, mode, and median would be the same numbers in both the historical data and the future, fictional data). The statistical properties of the weather would vary the same in the future as it has in the past. But, again, this approach does not accurately predict water withdrawals for a given year due to the fictional weather.

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 because, although, it is understood that either method of estimating future weather variables may be inaccurate for any given year in the future, 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 but the overall average withdrawals may be estimated. 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.

For these reasons, the future values of weather variables (i.e., annual cooling degree-days and summer precipitation) are assumed to be normal values, or the average values from 1971-2000. The cooling degree days and rainfall data is 1971-2000 normal data from each of the 29 stations within the 15-county region. The normal data vary for each county based upon the weather stations within the county. This means that the values used for each future year represent average values

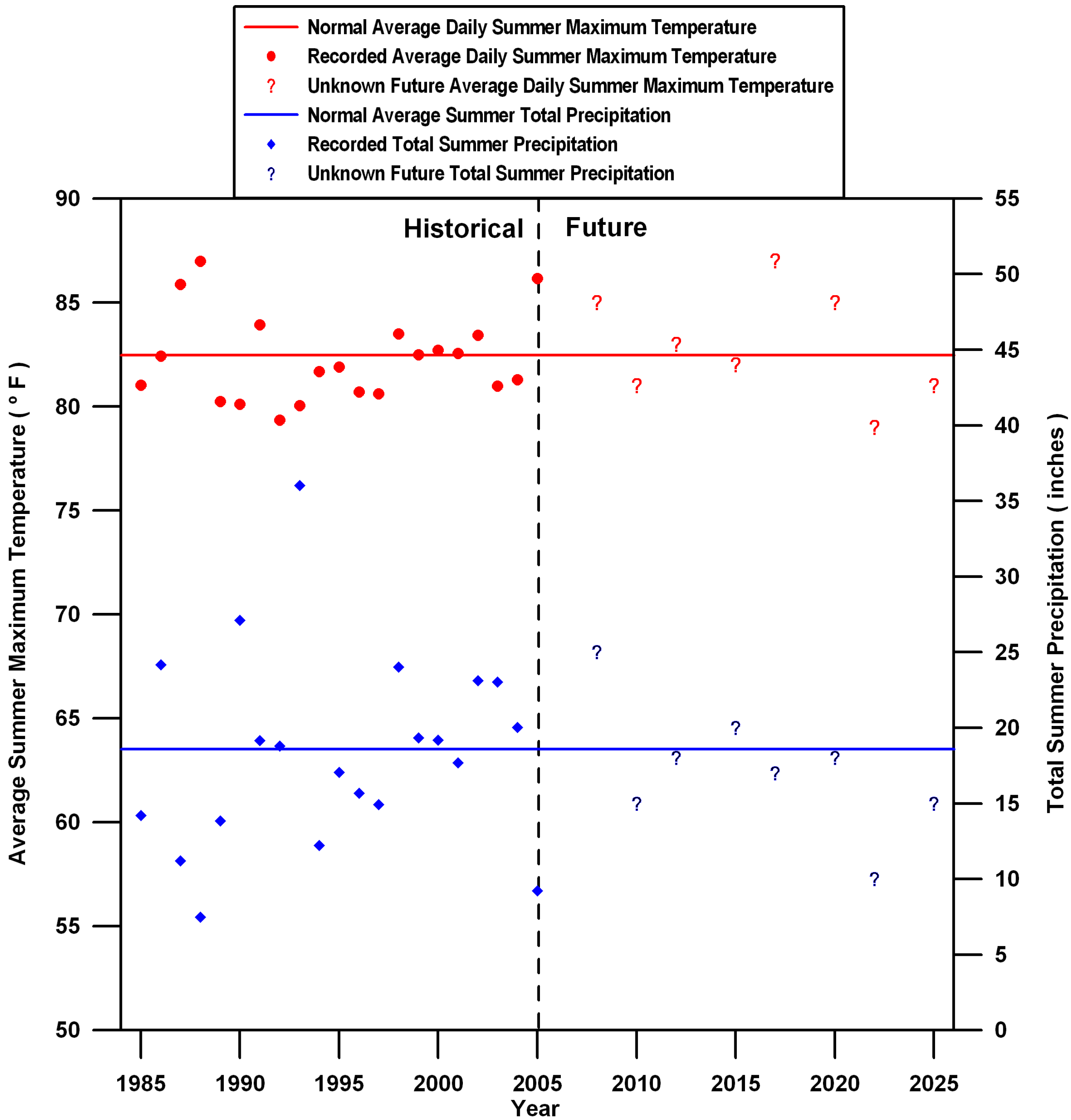


Figure 4.11: Example of inter-annual variation in temperature and precipitation compared to climatic normals.

from each of the weather stations for the 30-year period from 1971 to 2000. Higher or lower annual cooling degree days will result in higher or lower per employee water demand. Similarly, higher or lower total summer precipitation will result in lower or higher per employee water demand.

4.5.2.2 Percent health services, retail trade, and manufacturing employment

Future growth rates for employment in the three SIC/NAICS categories health services, retail trade, and manufacturing were obtained from IDES. The most recent projections are from 2004 - 2014. This study assumes that shares of each SIC/NAICS category will continues as projected by IDES to the year 2020. From 2025 through 2050 the growth rates in each category were linearly decreased by 25 percent. The growth rates were decreased due to uncertainty of extrapolating trends from 2014 out to 2050. Table 4.7 shows the IDES projected growth rates for the three employment categories.

4.5.2.3 Percent self-supplied commercial and industrial demand

Since the percentage fraction of self-supplied C&I water is used as one of the independent variables, the future values of the self-supplied share of water had to be determined. The historical fractions of the self-supplied C&I withdrawals are shown in Table 4.8.

The future values were assumed after examination of the historical shares of self-supplied withdrawals by comparing the historical averages for the entire data period 1985-2005 and the most recent period 1995-2005. The future shares of self-supplied withdrawals were set as rounded percentage (to the nearest 5 percent) of total C&I demand (i.e., the sum of both self-supplied and delivered by public systems). These assumed percentage fractions were also used in calculating self-supplied withdrawals from the future estimates of total C&I water demand.

4.5.2.4 Conservation trend

The conservation trend variable was included in the future to account for unspecified changes that are likely to influence water withdrawals over time, and that represent general trends in water conservation behavior. The conservation trend variable is intended to capture water demand changes due to gains in efficiency in production processes and technologies. The conservation trend variable was specified as 25 for 2010, 30 for 2015, 35 for 2020 and so on, ending with 65 for the year 2050.

Table 4.7: Projected 2004-2014 annual compound growth rates for health services, retail trade, and manufacturing employment.

County	Health services growth rate (%)	Retail trade growth rate (%)	Manufacturing growth rate (%)
Cass	1.85	0.22	-0.61
Champaign	1.41	0.29	-0.57
DeWitt	1.30	0.52	-0.10
Ford	1.26	0.04	-1.26
Iroquois	1.29	0.18	-1.01
Logan	1.59	0.10	-1.81
Macon	1.11	0.67	-0.19
Mason	1.88	0.20	-1.51
McLean	2.32	0.49	-2.28
Menard	1.81	0.18	-1.59
Piatt	1.21	0.00	-0.93
Sangamon	1.29	0.33	-0.97
Tazewell	2.19	0.52	-0.09
Vermilion	1.13	0.24	-0.78
Woodford	1.71	0.66	-0.50

Source: Illinois Department of Employment Security, Economic Information and Analysis Division, 2007. Note: in the model the growth rates were decreased by 25 percent from 2025 to 2050 due to the uncertainty of extrapolating the projections to 2050.

Table 4.8: Historical and assumed percent of self-supplied commercial and industrial withdrawals.

County	1985	1990	1995	2000	2005	Assumed 2010-2050
Cass	75.6	97.2	88.7	94.3	95.9	95.0
Champaign	56.3	65.1	57.6	48.0	49.5	50.0
DeWitt	2.5	5.4	0.1	0.1	0.0	5.0
Ford	11.2	6.4	66.8	86.0	87.2	90.0
Iroquois	28.8	32.3	20.7	24.5	6.9	25.0
Logan	3.8	13.6	4.4	8.6	74.7	75.0
Macon	89.5	70.6	78.0	74.9	76.4	80.0
Mason	97.9	98.8	97.6	98.9	98.2	95.0
McLean	16.4	1.9	3.8	0.3	0.5	15.0
Menard	0.0	0.0	0.0	0.0	0.0	5.0
Piatt	89.4	85.8	85.1	88.0	88.1	90.0
Sangamon	29.9	18.8	11.8	48.5	38.8	40.0
Tazewell	91.8	91.7	91.0	85.1	85.7	85.0
Vermilion	39.5	39.4	40.9	41.6	44.4	45.0
Woodford	1.6	2.7	2.9	1.0	0.0	5.0

Source: historical percent self-supplied calculated using data from Illinois Water Inventory Program, Illinois State Water Survey, 2007. 2010-2050 value assumed, using historical data as guidance.

4.6 Scenarios

The three scenarios define future conditions which would result in different levels of self-supplied C&I water demand. The specific assumptions used in each scenario are described below.

4.6.1 Water intensive facilities

C&I water withdrawals are anticipated to increase as new water intensive industries move into the East-Central Illinois region. In order to understand how estimated future demands will or will not be met by the existing supply, the future withdrawals need to be assigned to a specific withdrawal points. To account for new industries within the region at specific withdrawal points, ethanol facilities are used to represent new 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. In the 1990s peaking electric plants were the anticipated new water intensive industry. However, the electric peaking plants did not reach the anticipated maximum density. Ethanol production plants are the new electric peaking plants in that they are expected to be a booming industry yet their future is uncertain. Therefore, in this study, demands created by future ethanol facilities are used to understand how a new water demand may impact the region.

Water intensive facilities, such as ethanol production plants, are expected to increase total withdrawals throughout the East-Central Illinois region in the future. Ethanol use in automobiles in the United States increased from 1,630 million gallons in 2000 to 3,904 million gallons in 2005 [EIA, 2007]. Much of the ethanol used is produced in the Midwest. Already Illinois is ranked number three, behind Iowa and Nebraska, in ethanol facility capacity [Nebraska, 2007]. Based on 2006 survey results, ethanol plants use 2.65 - 6.10 gallons of fresh water to produce a gallon of ethanol [Wu, 2008]. The average of dry and wet mills were 3.45 and 3.92, respectively[Wu, 2008]. The ISWS and technical committee of the RWSPC assumed that 4.0 gallons of water per gallon of ethanol (gal/gal ethanol) produced for the baseline scenario, 3.0 gal/gal ethanol for the less resource intensive, and 5.0 gal/gal ethanol for more resource intensive. Because of the rapid growth and water withdrawals of these facilities and/or other similar industries, these withdrawals need to be accounted for in future scenarios.

There are currently three (3) ethanol facilities within the region. An additional 16 ethanol facilities have obtained air permits from the Illinois EPA. Since water withdrawal permits are not required in the State of Illinois, except for Lake Michigan, the air permits were used to determine the number of potential ethanol facilities and expansions of existing facilities within the region. In

Table 4.9: Existing and proposed water intensive industries (represented by ethanol production plants) included in the East-Central Illinois regional water demands.

County	City	Status	Permitted production (MGY)	Year included in study
Champaign	Champaign	proposed	125	2010
Cass	Beardstown	proposed	60	2015
Ford	Gibson City	proposed	118	2010
Iroquois	Gilman	proposed	118	2010
Logan	Hartsburg	proposed	110	2015
Macon	Decatur	existing	290	historical
Mason	Havana	proposed	115	2015
McLean	Chenoa	proposed	110	2015
Tazewell	Pekin	2 existing	190	historical
		2 expansions	165	2010
Vermilion	Danville	proposed	118	2010

MGY = million gallons per year of ethanol. Source: Illinois EPA Bureau of Air, 2007.

many instances the proposed facilities were located in the same town or very near one another, so only one ethanol plant was added per county if there were no existing facilities within the county. For each of the scenarios it was assumed that water withdrawals for a total of eight (8) new facilities would be added with four (4) new facilities by 2010 and four (4) additional facilities by 2015. Two (2) existing facilities are expected to expand their ethanol producing capacities (Figure 4.12 and Table 4.9). In 2010 estimated water withdrawals were included for the expansions in Tazewell County and new facilities in Champaign, Ford, Iroquois, and Vermilion counties; in 2015 water withdrawals were included for new facilities in Cass, Mason, McLean, and Logan counties.

4.6.2 Scenario 1 - Baseline (BL)

The baseline (BL) scenario defines future conditions in terms of recent trends in demand drivers and independent variables. The main demand driver is total county employment. The assumptions pertaining to the values of independent variables and other parameters are described below.

1. Total county employment will follow the 2004-2014 projection trends, which were obtained from IDES, until 2050.

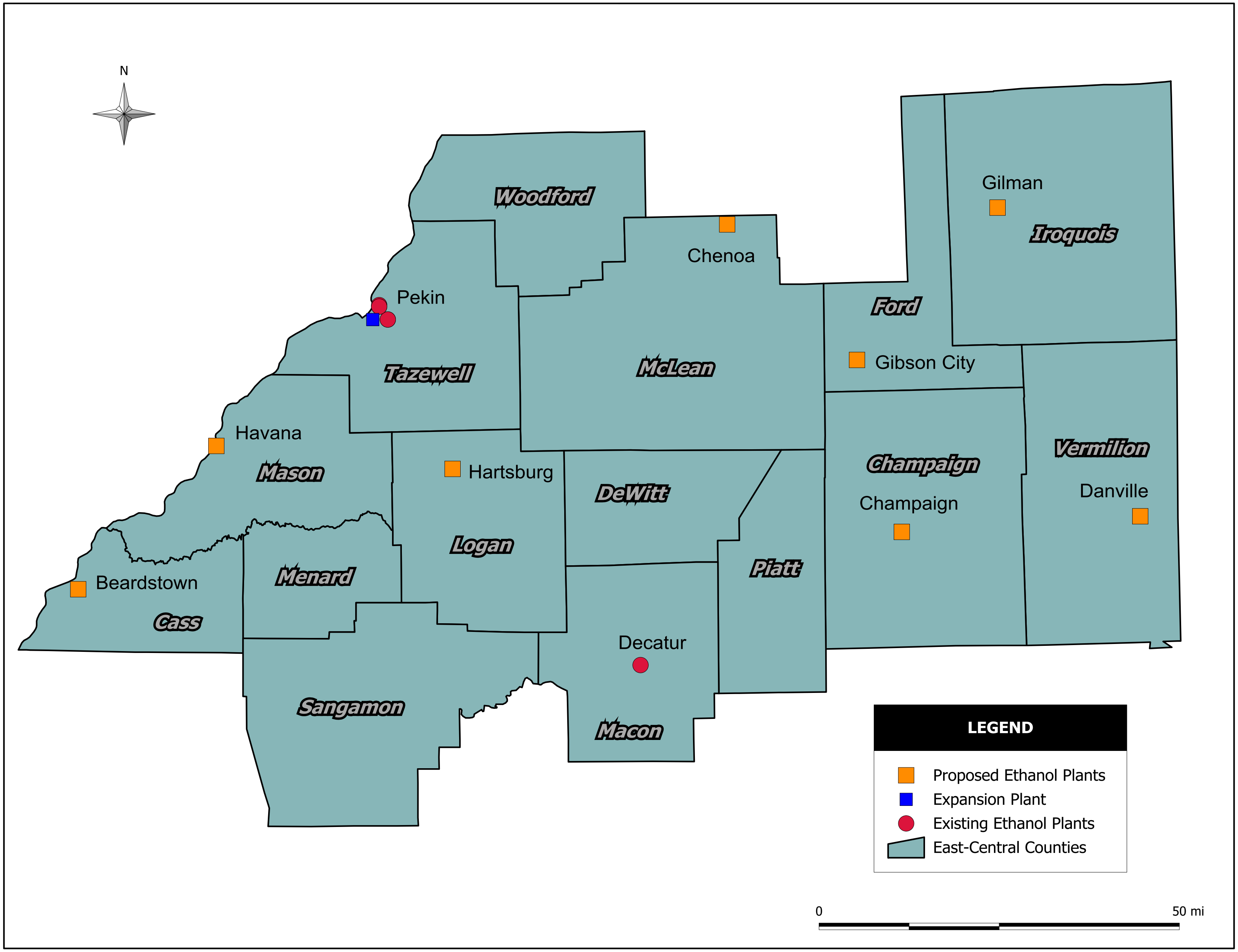


Figure 4.12: Existing and proposed water intensive industries in the East-Central Illinois region. *Note: Water intensive industries are represented by ethanol production facilities due to the need to tie water withdrawals to specific locations. Ethanol facilities were chosen as a surrogate because they are currently the most well-known and understood growing industry for this region.*

2. Fractions of employment in health services, retail trade, and manufacturing will follow growth rates, as projected by IDES, until 2020 (Table 4.7). From 2025 to 2050 the growth rates for each sector will linearly decline by 25 percent.

3. Self-supplied C&I water demand for each county will be the percentage levels shown in the last column of Table 4.8.

4. Future conservation will follow the estimated historical trend of annual reduction of approximately 0.2 MGD per year (when all other variables would be held constant).

5. Annual cooling degree-days and total May 1 to September 30 precipitation will remain at normal weather values.

6. New industrial facilities (represented by ethanol production plants) will use 4.0 gallons of water for each gallon produced.

7. Productivity will increase by 1.0 percent per year.

4.6.3 Scenario 2 - Less resource intensive (LRI)

The less resource intensive (LRI) scenario defines conditions which would result in lower self-supplied C&I water withdrawals. The specific assumptions pertaining to the values of independent variables and other parameters are described below.

1. Total county employment will follow the 2004-2014 projection trends, which were obtained from IDES, until 2050.

2. Fractions of employment in health services, retail trade, and manufacturing will follow growth rates, as projected by IDES, until 2020 (Table 4.7). From 2025 to 2050 the growth rates for each sector will linearly decline by 25 percent.

3. Self-supplied C&I water demand for each county will remain at the percentage levels shown in the last column in Table 4.8.

4. Future conservation will increase by 30 percent compared to the estimated historical trend.

5. Annual cooling degree-days and total May 1 to September 30 precipitation will remain at normal weather values.

6. New industrial facilities (represented by ethanol production plants) will use 3.0 gallons of water for each gallon produced.

7. Productivity will increase by 1.0 percent per year.

4.6.4 Scenario 3 - More resource intensive (MRI)

The more resource intensive (MRI) scenario defines conditions which would result in higher self-supplied C&I water withdrawals. The specific assumptions pertaining to the values of independent variables and other parameters are described below.

1. Total county employment will follow the 2004-2014 projection trends, which were obtained from IDES, until 2050.

2. Fractions of employment in health services, retail trade, and manufacturing will follow growth rates, as projected by IDES, until 2020 (Table 4.7). From 2025 to 2050 the growth rates for each sector will linearly decline by 25 percent.

3. Self-supplied water demand for each county will remain at the percentage levels shown in the last column in Table 4.8.

4. Future conservation will decrease by 50 percent compared to the estimated historical trend.

5. Annual cooling degree-days and total May 1 to September 30 precipitation will remain at normal weather values.

6. New industrial facilities (represented by ethanol production plants) will use 5.0 gallons of water for each gallon produced.

7. Productivity will increase by 1.0 percent per year.

4.7 Results

The estimated future water demands under each of the three scenarios for the entire 15-county study area are summarized in Tables 4.10, 4.11, and 4.12. Under the baseline scenario, self-supplied commercial and industrial (including mining) withdrawals are estimated to increase from 63.7 MGD in 2005 to 137.5 MGD in 2050. This represents an increase of 73.8 MGD or 116 percent. The total self-supplied withdrawals in 2050 will be 21.3 MGD (29%) lower under the

LRI scenario and 41.0 MGD (56%) higher under the MRI scenario as compared to the BL scenario results. Figure 4.13 shows the self-supplied withdrawal results for all three scenarios.

Figures 4.14–4.21 show the county results for the baseline scenario. Thirteen of the fifteen counties will withdrawal 10 MGD or less for self-supplied commercial and industrial uses by the year 2050. Macon and Tazewell counties will have the largest withdrawals for self-supplied C&I, withdrawing 27 and 62 MGD, respectively. Counties where new water intensive industries may locate will see an increase in water demand of approximately 1 MGD due to these new facilities. For Tazewell county, this increase is minimal compared to the overall expected growth in C&I water demands. For Iroquois and McLean counties almost all of their demand for estimated future self-supplied C&I withdrawals are created from new water intensive industries. However, currently, these two counties have virtually zero demand for self-supplied C&I. The regional summary (Chapter 7) will compare the self-supplied C&I withdrawals to other sectors.

4.7.1 Groundwater and surface water withdrawals

The data generated from this demand study will be delivered to the ISWS as digital data at the level of withdrawal points, meaning future water withdrawals will be determined for all existing wells and surface water intakes. The allocation of the future self-supplied C&I demands between groundwater and surface water withdrawals is generally assumed to remain at the 2005 level for each study area. The exception to the generalization is for those counties where additional industrial users were assumed to locate or expand: Cass, Champaign, Ford, Iroquois, Logan, Mason, McLean, Tazewell, and Vermilion counties. It is assumed that the new industrial facilities will use 100 percent groundwater and therefore, the percent groundwater used will increase and the percent surface water will decrease in those nine counties. Table 4.13 shows the estimated percentages of surface water and groundwater for each county. The withdrawal-point data for the commercial and industrial sector will not be available to the public due to confidentiality agreements and the proprietary nature of the data.

Table 4.10: Baseline scenario results for commercial and industrial sector for East-Central Illinois, 2005-2050.

Year	Per employee withdrawals (GPED)	Self-supplied C&I withdrawals (MGD)
2005 (Weather)	224.5	85.3
2005 (Normal)	170.4	63.7
2010	195.5	77.8
2015	208.9	87.9
2020	218.5	94.7
2025	227.3	101.4
2030	236.3	108.4
2035	245.2	115.7
2040	253.8	123.0
2045	261.7	130.4
2050	269.0	137.5
Difference from 2005 (Normal) to 2050		
Unit	98.6	73.8
Percent (%)	57.9	115.9

GPED = gallons per employee per day; MGD = million gallons per day.

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

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

Table 4.11: Less resource intensive scenario results for commercial and industrial sector for East-Central Illinois, 2005-2050.

Year	Per employee withdrawals (GPED)	Self-supplied C&I withdrawals (MGD)
2005 (Weather)	224.5	85.3
2005 (Normal)	170.4	63.7
2010	171.1	67.8
2015	181.1	75.7
2020	188.6	81.2
2025	195.5	86.7
2030	202.5	92.5
2035	209.5	98.4
2040	216.2	104.4
2045	222.4	110.4
2050	228.0	116.2
Difference from 2005 (Normal) to 2050		
Unit	57.6	52.5
Percent (%)	33.8	82.4

GPED = gallons per employee per day; MGD = million gallons per day.

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

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

Table 4.12: More resource intensive scenario results for commercial and industrial sector for East-Central Illinois, 2005-2050.

Year	Per employee withdrawals (GPED)	Self-supplied C&I withdrawals (MGD)
2005 (Weather)	224.5	85.3
2005 (Normal)	170.4	63.7
2010	240.4	94.0
2015	259.5	109.2
2020	273.8	118.6
2025	287.1	128.0
2030	300.5	137.8
2035	313.7	147.9
2040	326.5	158.2
2045	338.6	168.4
2050	349.6	178.5
Difference from 2005 (Normal) to 2050		
Unit	179.2	114.8
Percent (%)	105.2	180.2

GPED = gallons per employee per day; MGD = million gallons per day

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

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

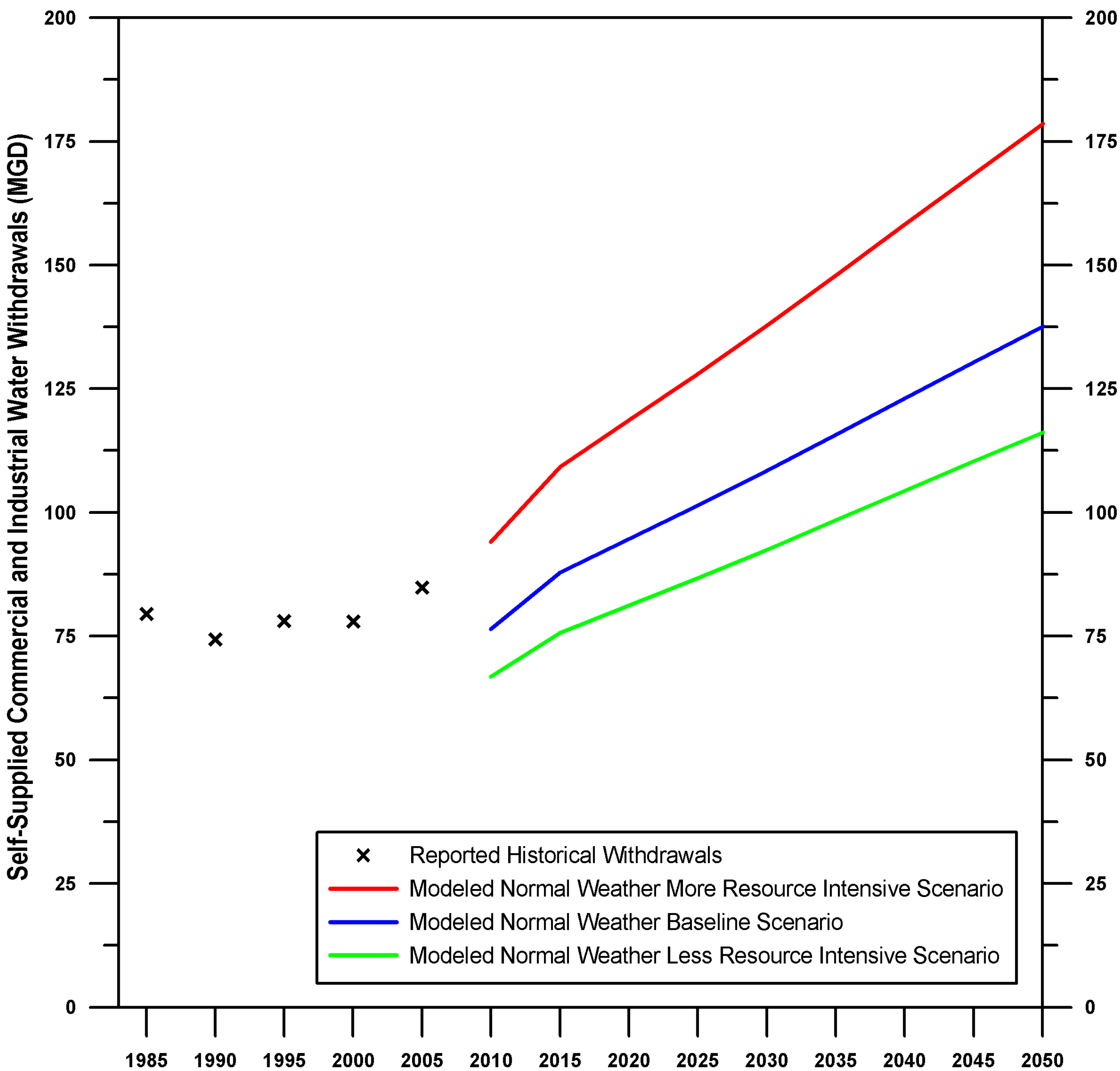


Figure 4.13: Historical and future self-supplied commercial and industrial withdrawals for the baseline scenario, the less resource intensive scenario, and the more resource intensive scenario for East-Central Illinois.

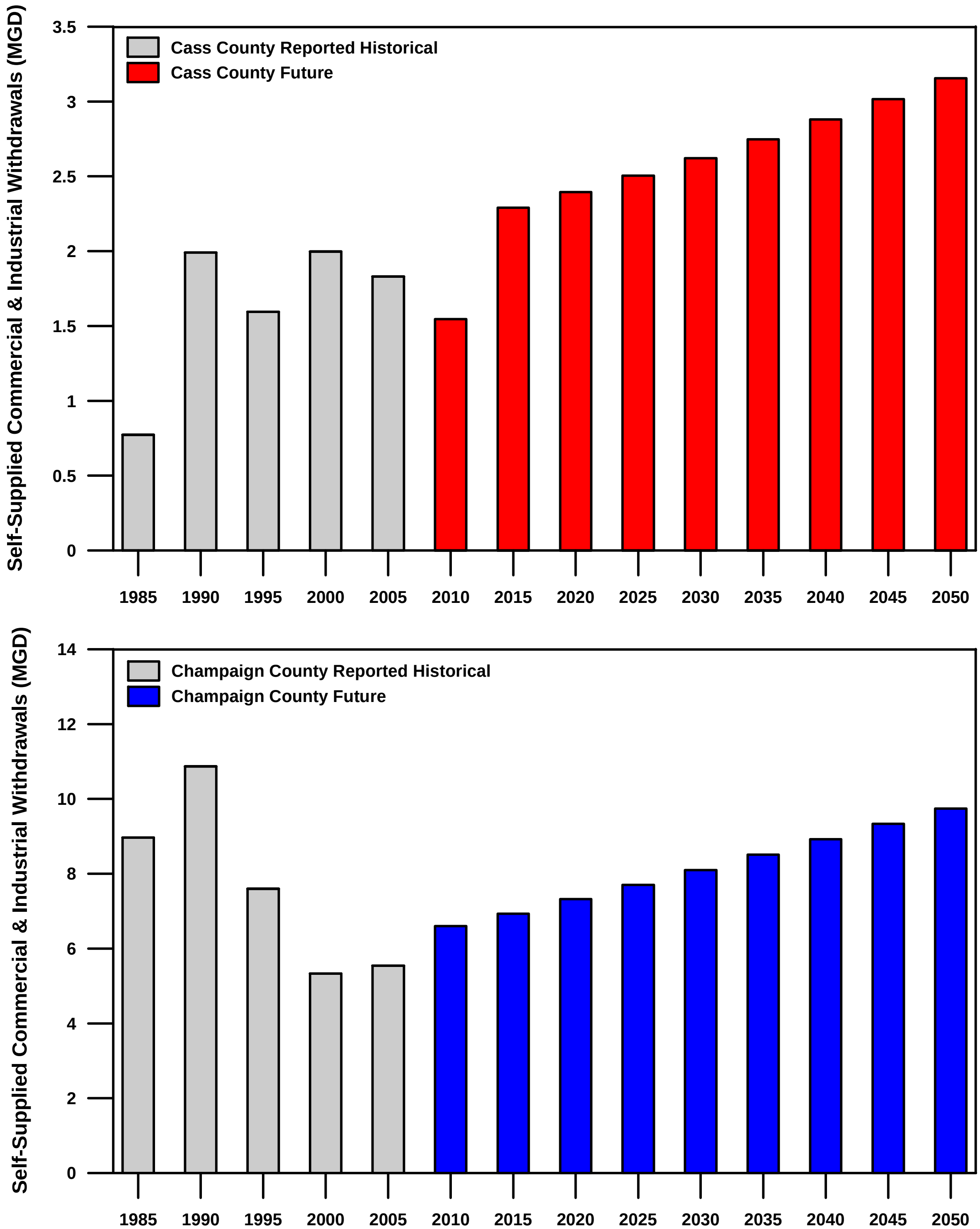


Figure 4.14: Self-supplied commercial and industrial historical and future water withdrawals for Cass and Champaign counties in East-Central Illinois. Note: New water intensive industry added in Champaign County in 2010 and in Cass County in 2015.

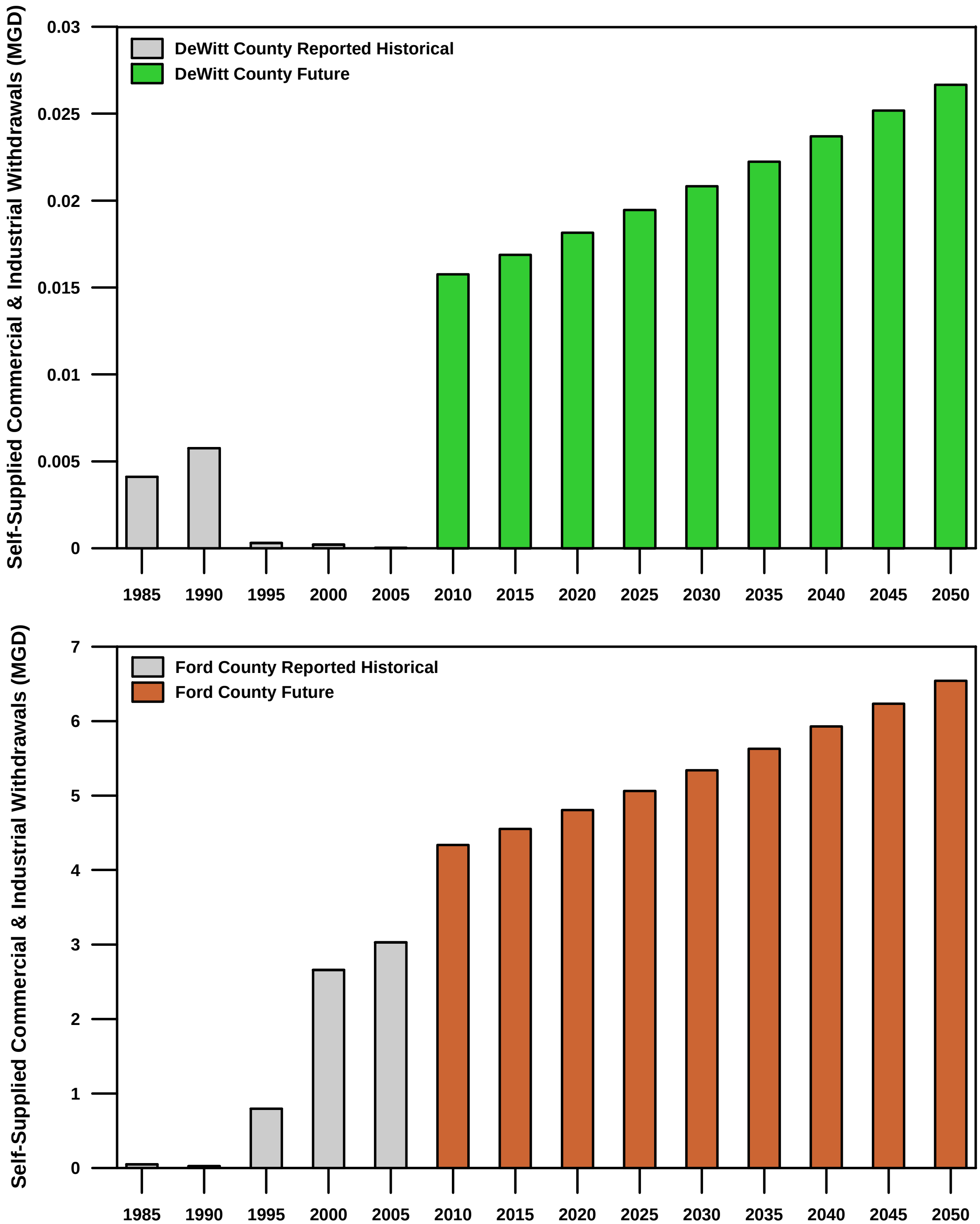


Figure 4.15: Self-supplied commercial and industrial historical and future water withdrawals for DeWitt and Ford counties in East-Central Illinois. Note: New water intensive industry added in Ford County in 2010.

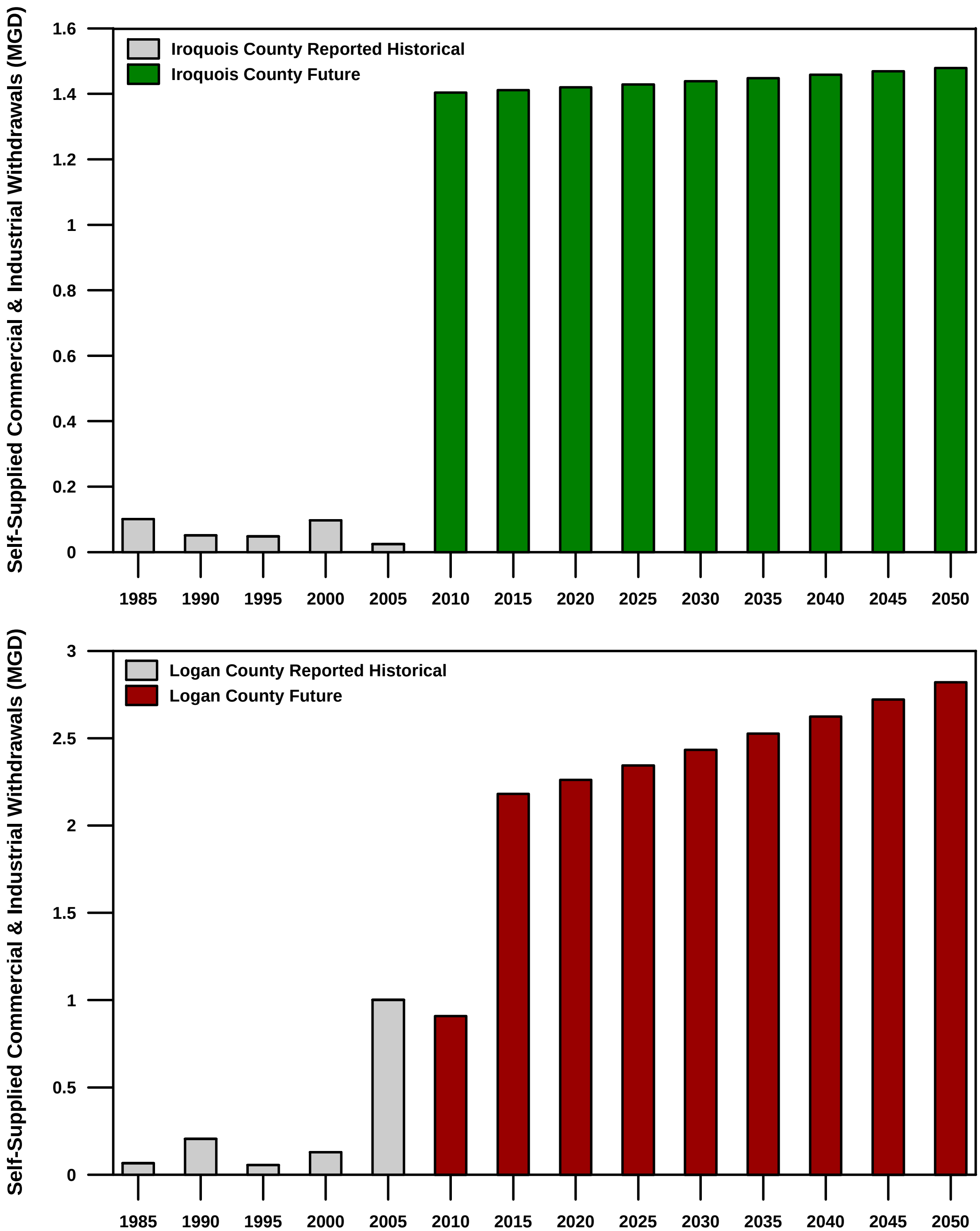


Figure 4.16: Self-supplied commercial and industrial historical and future water withdrawals for Iroquois and Logan counties in East-Central Illinois. Note: New water intensive industry added in Iroquois County in 2010 and in Logan County in 2015.

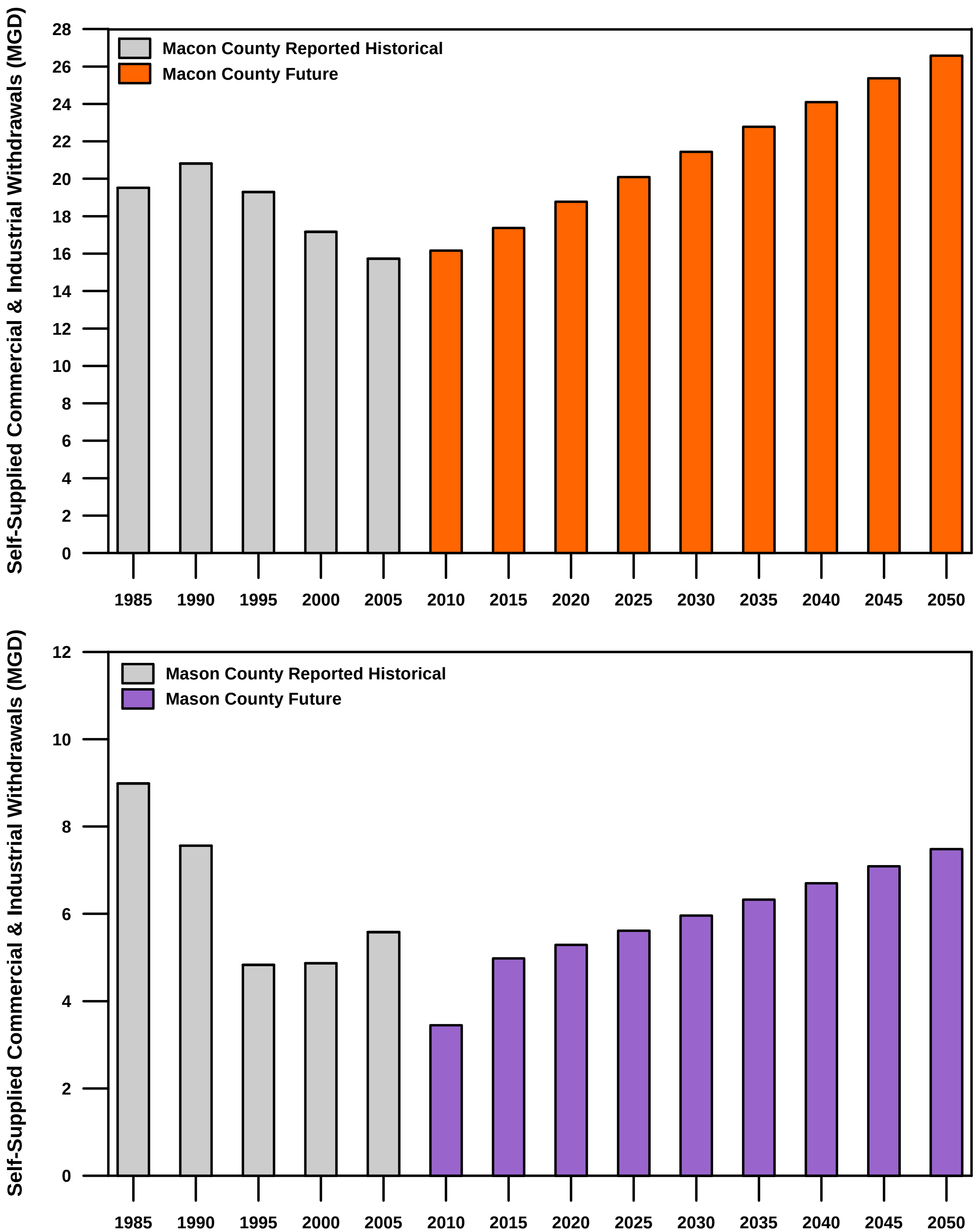


Figure 4.17: Self-supplied commercial and industrial historical and future water withdrawals for Macon and Mason counties in East-Central Illinois. *Note: 1985-2000 water withdrawals for Macon County has ADM withdrawals added; see Section 4.3.1 for explanation.* Note: New water intensive industry added in Mason County in 2015.

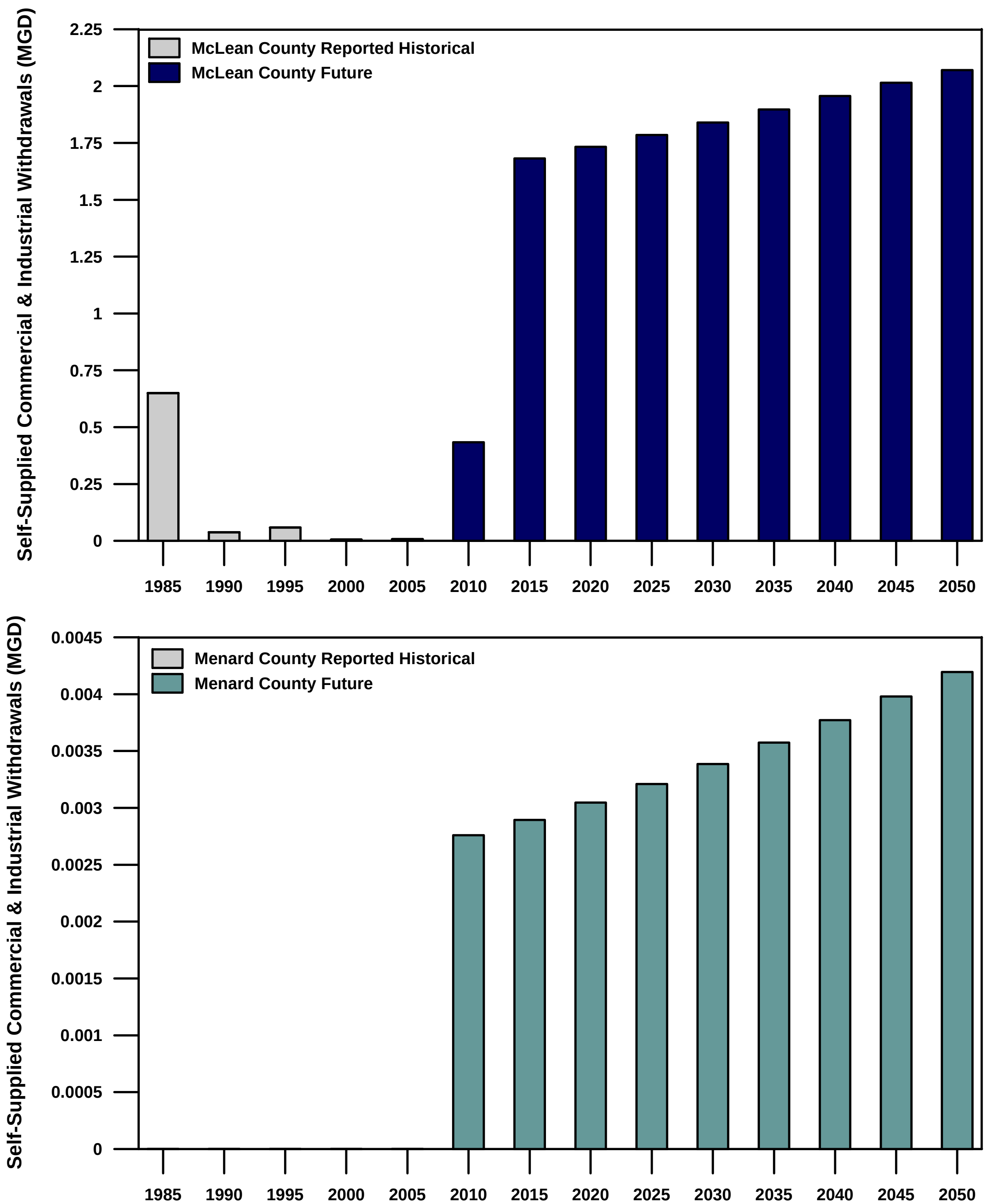


Figure 4.18: Self-supplied commercial and industrial historical and future water withdrawals for McLean and Menard counties in East-Central Illinois. Note: New water intensive industry added in McLean County in 2015.

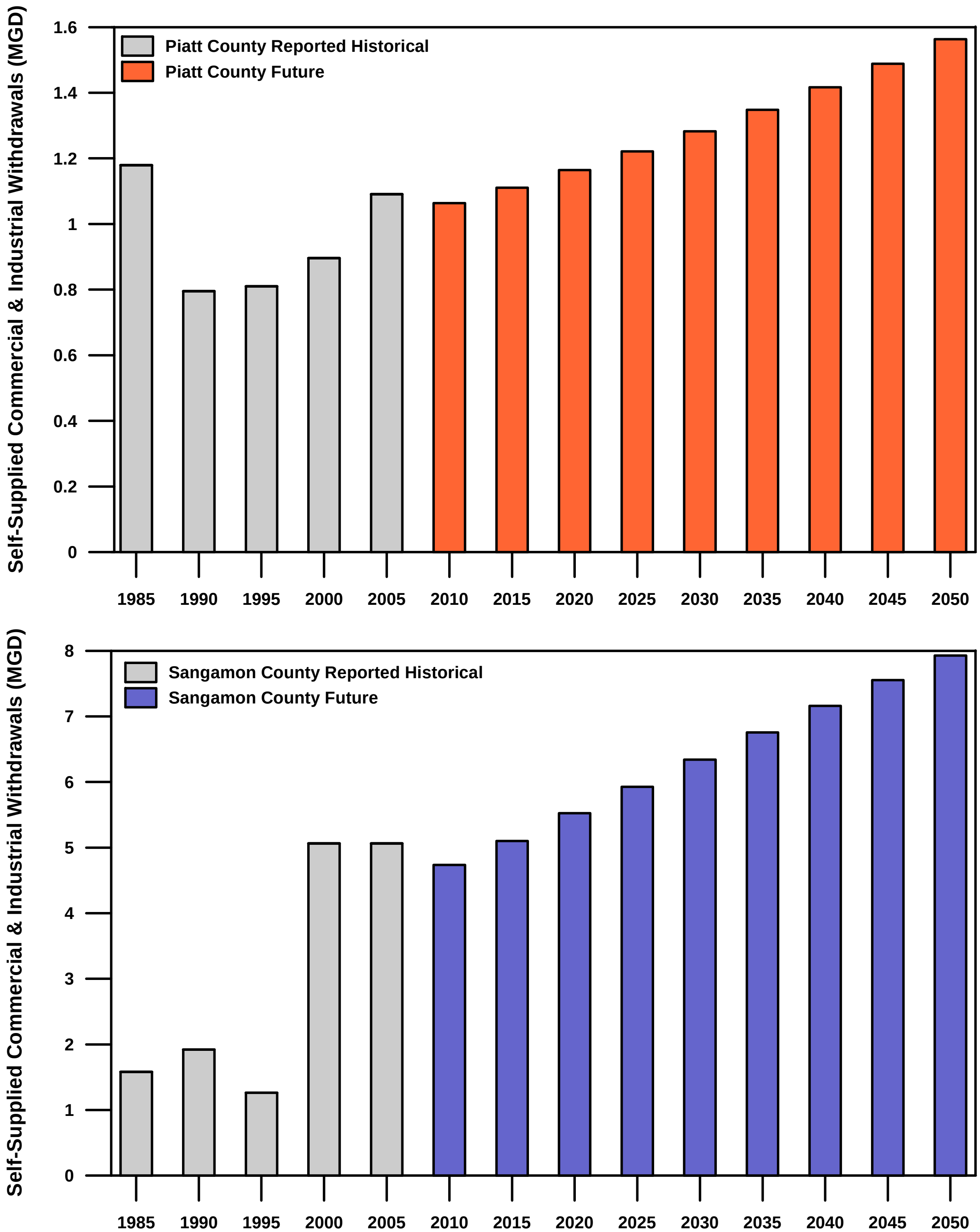


Figure 4.19: Self-supplied commercial and industrial historical and future water withdrawals for Piatt and Sangamon counties in East-Central Illinois.

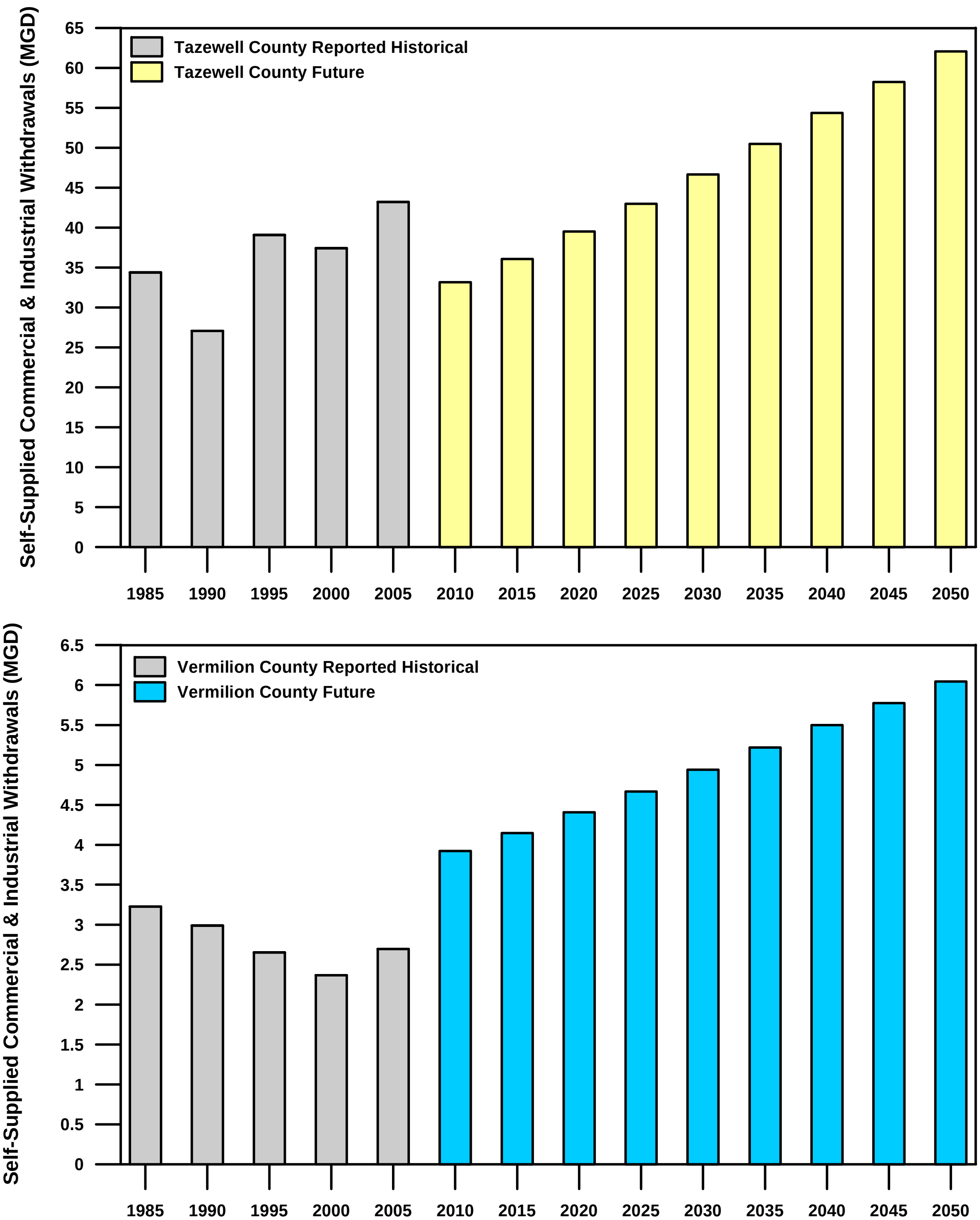


Figure 4.20: Self-supplied commercial and industrial historical and future water withdrawals for Tazewell and Vermilion counties in East-Central Illinois. Note: Expansion of water intensive industry added in Tazewell County in 2010 and new water intensive industry added in Vermilion County in 2010.

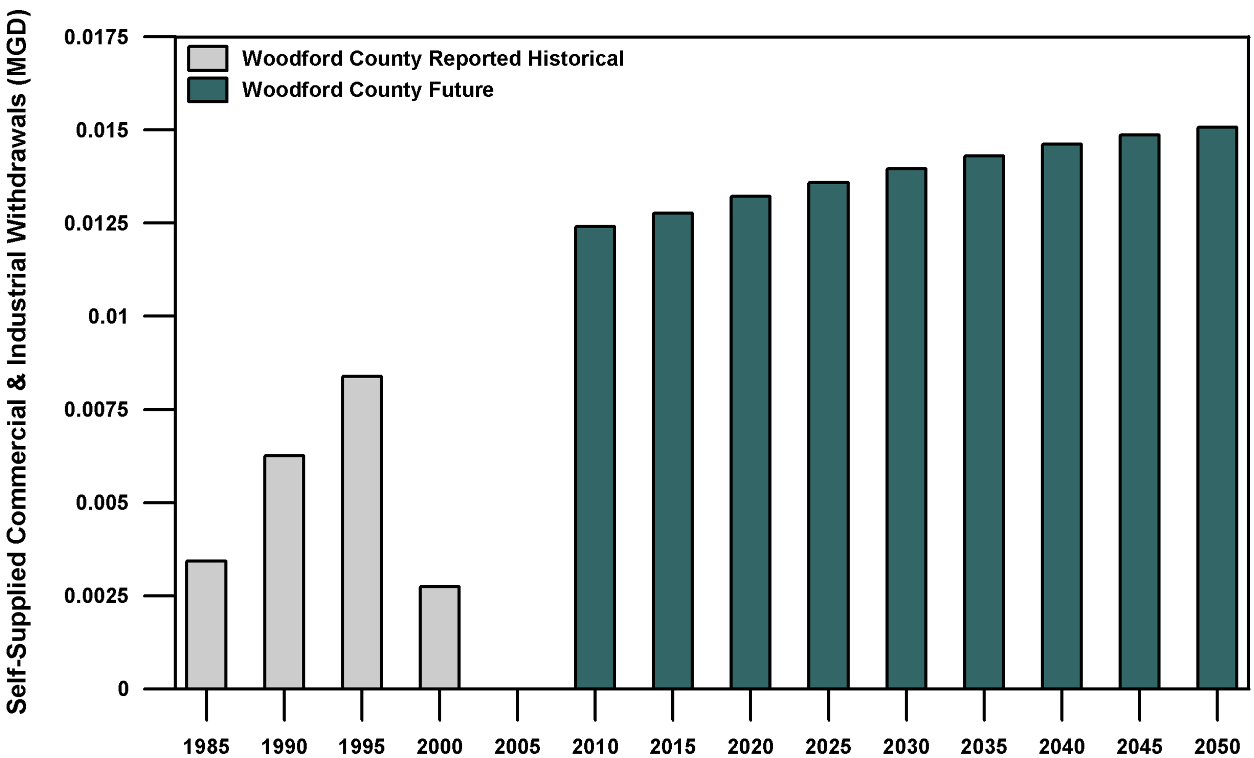


Figure 4.21: Self-supplied commercial and industrial historical and future water withdrawals for Woodford County in East-Central Illinois.

Table 4.13: Percent of total withdrawals that are groundwater and surface water.

County	Groundwater (%)	Surface Water (%)
Cass	100.0	0.0
Champaign	58.7	41.3
DeWitt	100.0	0.0
Ford	19.8	80.2
Iroquois	100.0	0.0
Logan	51.7	48.3
Macon	7.8	92.2
Mason	100.0	0.0
McLean	100.0	0.0
Menard	100.0	0.0
Piatt	100.0	0.0
Sangamon	79.8	20.2
Tazewell	38.3	61.7
Vermilion	100.0	0.0
Woodford	100.0	0.0

Source: Illinois Water Inventory Program, Illinois. State Water Survey, 2007.