Chapter 1

Introduction

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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 fifteen counties in East-Central Illinois and eleven counties in Northeastern Illinois (Figure 1.1). 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 1.2). The planning region includes fifteen counties: 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 East-Central Illinois region and has formed a local planning committee with representatives from 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 RWSPC hired Wittman Hydro Planning Associates, Inc. (WHPA) to conduct the water demand study for the region. This report describes the data, methods, and models used to estimate future water withdrawals for the fifteen-county water supply planning region in East-Central Illinois up to the year 2050. The report provides a summary of the historical and future groundwater and surface water withdrawals for four different water-demand sectors: 1) public water supply and self-supplied domestic, 2) self-supplied thermoelectric power generation, 3) self-supplied commercial and industrial, and 4) self-supplied agriculture and irrigation. All sectors, except public water supply, are self-supplied, meaning the users in the sector do not buy the water they use but rather have a system (a well or surface water intake) that directly supplies the water from the source to the user. For simplicity, this report may not always use the descriptor "self-supplied".

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

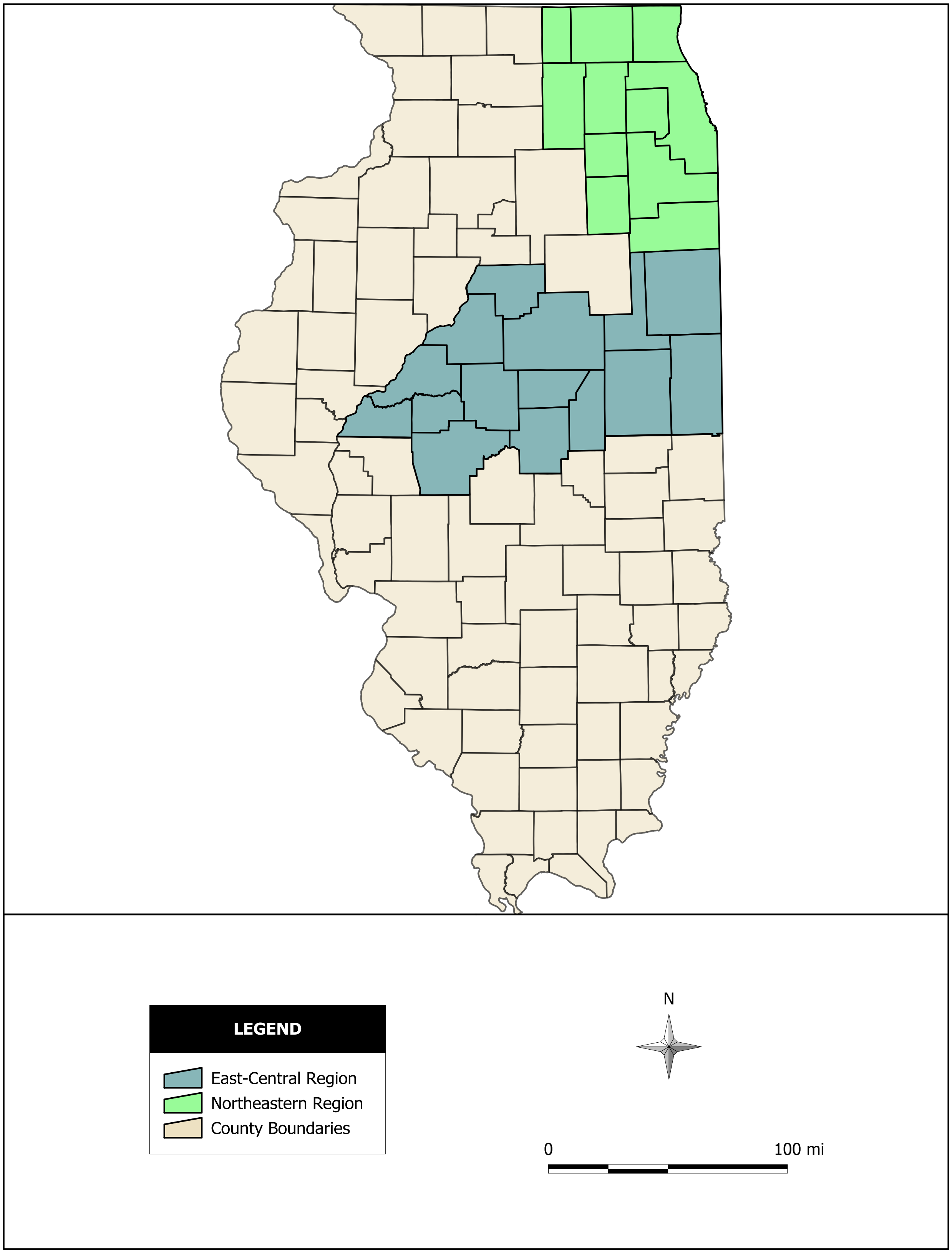

Figure 1.1: The two priority planning regions in Illinois identified through work by the Illinois State Water Survey.

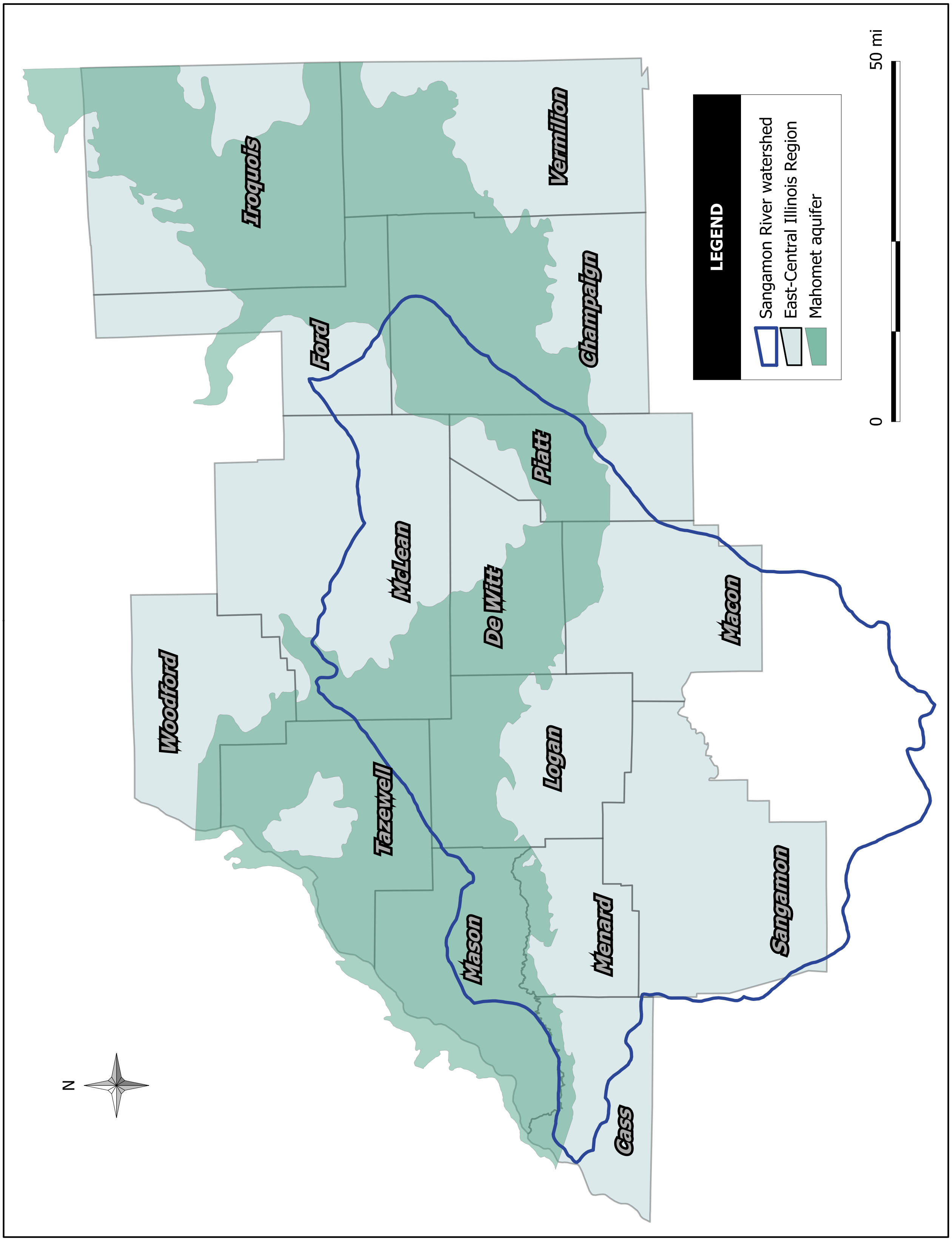

Figure 1.2: The 15-county East-Central Water Supply Planning Region in Illinois.

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 is 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.

1.1 Purpose

The purpose of this study is to examine water demand on a regional basis and provide information to the East-Central RWSPC to begin the water-supply planning process. Future water withdrawals were estimated with a regional approach. We collected historical data on all water suppliers/users in the region, created regional models for each sector based upon the aggregated historical data, and used the models to estimate future withdrawals. Individual models for each city, industry, county were not created. For this reason, the regional model will be different than existing models for individual cities, counties, etc.

Additionally, future withdrawals were estimated for three specific scenarios. Each of these scenarios includes a set of assumptions that will differ from the assumptions in other existing models. For example, in the public water supply model baseline scenario, median household income was increased 0.7% per year. This income assumption has a direct effect on the estimate of future water withdrawals. Other models may use other reasonable assumptions to estimate future demand. Therefore, care should be used when comparing this regional model with other water demand models that were built for different purposes and at different scales.

The future withdrawals are estimated averages, which means that for any given year the authors do not expect to predict the precise amount of water withdrawn. The intent of this study is to understand the general water demand trends for the region. These estimates should be used for planning purposes only; they should be understood as the average estimates over the period of interest.

1.2 Objective

The objective of this study is to estimate current and future water withdrawals, both groundwater and surface water, for the 15-county East-Central Illinois planning region. The future withdrawals are estimated in five year increments to the year 2050. The future water withdrawals are developed for four water-demand sectors on a county level, for three scenarios.

1.3 Methodology

The methodology consists of the following five basic steps for each of the water-demand sectors. These steps are described below.

1. Collect historical water-withdrawals and water-demand variable data.
2. Conduct public outreach and obtain data specific to study areas.
3. Develop mathematical relationships between water withdrawals and water-demand variables.
4. Develop three future water-withdrawal scenarios.
5. Prepare water-withdrawal estimates.

1.4 Historical water-withdrawals and water-demand variable data

Historical data sets for the major water sectorsin the 15-county study area were collected to develop the statistical water-demand relationships used to estimate future water withdrawals.

1.4.1 Water-demand sectors

The four major sectors (or categories) of water withdrawals modeled in the study are:

1. public water supply (PWS) and self-supplied domestic (private domestic wells) sector. This sector also includes water supplied by a PWS to some commercial or industrial users.
2. self-supplied thermoelectric power generation (PG) sector.
3. self-supplied commercial and industrial (C&I) sector.
4. self-supplied irrigation and agricultural uses (IR&AG) sector.

1.4.2 Data years

The historical data sets assembled for each sector include the data years: 1985, 1990, 1995, 2000, and 2005. These years were chosen because many of the socio-economic data needed to establish statistical relationships between water-withdrawals and independent variables are only available in 5 or 10 year increments.

1.4.3 Study areas

Historical water withdrawals of all sectors, other than the PWS sector, are studied at the county level. For the PWS sector, the study areas include a total of 26 water service areas of the high-growth municipalities and 15 county rural areas which represent the balance of county areas outside of the 26 municipalities and water districts (Figure 1.3 and Table 1.1). The criteria used to select these areas are described in more detail in Chapter 2.

1.4.4 Water-withdrawal data

For each water-demand sector, water withdrawals between for 1985, 1990, 1995, 2000, and 2005 were collected from the ISWS, the United States Geological Survey (USGS), or estimated based upon these data sources. Water withdrawal data are expressed in million gallons per day (MGD). For some sectors the withdrawal data are converted into water demand per capita, per employee, per acre or per kilowatt-hour. More detail about the historical water-withdrawal data is provided in the discussions of each water-demand sector in Chapters 2-5 of this report.

1.4.5 Independent variable data

The historical data on water withdrawals in each sector were supplemented with corresponding data on independent variables for each study area and demand sector. Water withdrawals are associated with demand drivers like population or employment and independent variables such as price of water, income, air temperature, as well as other factors which influence the amount of water demand. The independent variable data include:

- resident population and population served;
- employment (ratio of employment to population, total employment, percent of employment in specific employment sectors);
- median household income;

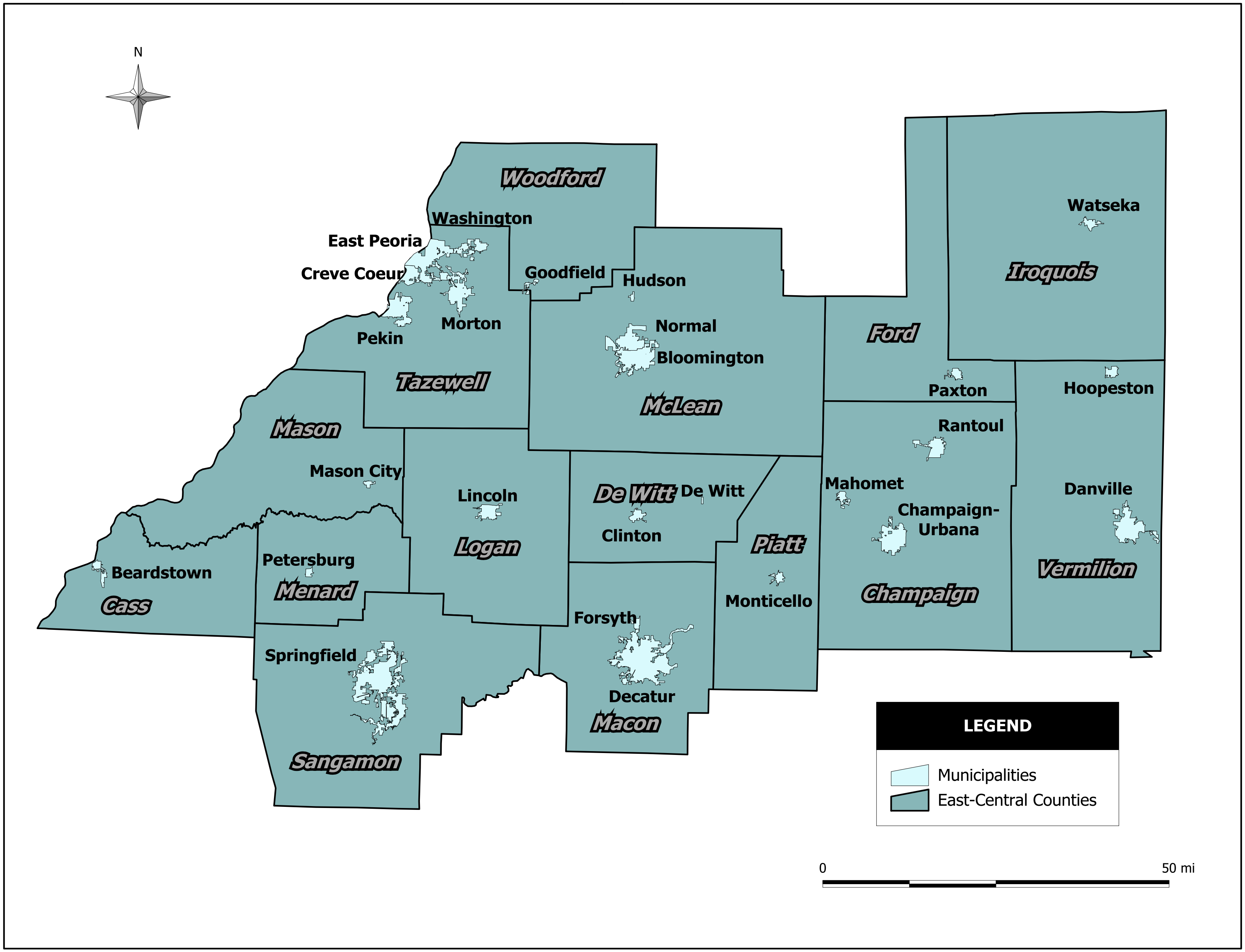

Figure 1.3: Map of 41 public water supply study areas in East-Central Illinois. The study areas include 26 municipalities and 15 county rural areas which represent all public water suppliers outside the 26 municipalities.

Table 1.1: The 26 municipal public water supply study areas and their population growth [Census, 2000]. *Note: These 26 study areas are in addition to the 15-county study areas representing the public water suppliers outside these high-growth areas.*

County	PWS Study Area	Percent Growth (1990-2000)	Population (2000)
Cass	Beardstown	9.4	5,766
Champaign	Rantoul	-25.3	12,857
Champaign	Mahomet	57.2	4,877
Champaign	Champaign/Urbana	6.3*	103,913
DeWitt	DeWitt	54.1	188
DeWitt	Clinton	0.6	7,485
Ford	Paxton	5.5	4,525
Iroquois	Watseka	4.5	5,670
Logan	Lincoln	-0.3	15,369
Macon	Decatur	-2.4	81,860
Macon	Forsyth	90.9	2,434
Mason	Mason City	10.1	2,558
McLean	Hudson	50.1	1,510
McLean	Normal	13.4	45,386
McLean	Bloomington	24.7	64,808
Menard	Petersburg	1.7	2,299
Piatt	Monticello	12.9	5,138
Sangamon	Springfield	5.9	111,454
Tazewell	Creve Coeur	-8.3	5,448
Tazewell	Morton	10.1	15,198
Tazewell	Washington	7.3	10,841
Tazewell	East Peoria	5.9	22,638
Tazewell	Pekin	5.0	33,857
Vermilion	Hoopeston	1.6	5,965
Vermilion	Danville	0.2	33,904
Woodford	Goodfield	51.1	686

*Percent growth for Champaign, Illinois; Population is 2000 U.S. Census data.

- marginal price of water;
- thermoelectric power generation (type of system and gross power generated);
- air temperature (annual average, growing season average, and average maximum during the growing season)
- precipitation (annual average and growing season total)
- cooling degree days
- irrigated acres
- rainfall deficit

1.5 Public outreach

After the historical data were collected, WHPA solicited input from the public and water users/ purveyors from each sector. The purpose of this outreach portion of the project was to ensure that the data used in the scenario analysis reflect the experience of the public. To this end, the data and methodology were presented to the stakeholders in the region. Persons from each sector were invited to at least one meeting at which relevant data were presented. At the meetings, stakeholders had an opportunity to comment on and discuss the independent variables used to determine water withdrawals.

The stakeholders were asked to provide data on any known future changes within their sector and/or county. If specific data were obtained, WHPA incorporated the data into the future scenarios. For example, the City of Springfield will be replacing their Lakeside electrical generating plant with a new Dallman 4 electrical generating plant. This information is included in the power generation sector. Where stakeholders were unable to provide specific information, WHPA listened to their opinions and views and took them into consideration. However, these views and opinions were not included in the final withdrawal scenarios unless additional data were available to substantiate the views/opinions.

Invitations were sent to over 1,400 contacts within the 15-county region. The contact list included stakeholders from each county, including, but not limited to:

- city officials (*e.g.,* planners, managers, mayors, board members, city clerk)
- public water-suppliers

- commercial and industrial users
- thermoelectric power generators
- local engineers
- irrigators / farmers
- water authorities
- agricultural representatives
- media contacts (*e.g.,* reporters)
- state and federal agencies (*e.g.,* USDA, NRCS, EPA, ISGS, ISWS)[1]

Four multi-county meetings were scheduled in August, 2007 (Table 1.2). Each public meeting targeted specific counties in the water-supply region, but the information provided at each meeting was general enough that persons from other counties could attend. The agenda and meeting summaries from these meetings are provided in Appendix A.

In addition to the four multi-county meetings, WHPA met individually with the 26 PWS study areas. At these meetings, data for the municipality were discussed and revised accordingly. City planners, mayors, city-council members, water department/water company personnel, and other relevant groups were invited to the municipal meetings

1.6 Mathematical relationships between water-withdrawal and water-demand variables

The techniques for developing estimates of future withdrawals were dictated by the type of water-withdrawal data and the corresponding data on explanatory variables that were available for each water-demand sector. The two principal techniques used in this report are the unit-use coefficient approach and multiple regression. The unit-use coefficient method is used for irrigation and agriculture, power generation, and domestic supply sectors. Multiple regression is used for the public water supply and commercial and industrial sectors.

[1]USDA = United States Department of Agriculture; NRCS = Natural Resources Conservation Service; EPA = United States Environmental Protection Agency; ISGS = Illinois State Geological Survey; ISWS = Illinois State Water Survey

Table 1.2: Schedule and information for the four multi-county public outreach meetings held in August 2007.

Date	Time	Location	Targeted Counties
8/20/07	1:00 PM	Rantoul Public Library Community Room 106 West Flessner St. Rantoul, IL 61866	Champaign, Ford, Iroquois, and Vermilion counties
8/21/07	1:00 PM	Tremont United Methodist Church 112 W. Pearl St. Tremont, IL 61568	McLean, Tazewell, and Woodford counties
8/22/07	1:00 PM	St. Paul's Lutheran Church 121 N Pearl St. Havana, IL 62644	Cass, Mason, Menard, and Sangamon counties
8/23/07	1:00 PM	Vespasian Warner Public Library Revere Ware Room 310 N. Quincy St. Clinton, IL 61727	DeWitt, Logan, Macon, and Piatt counties

1.6.1 Unit-use coefficient method

The general approach to developing future water withdrawals can be described as:

$$Q_{\text{cit}} = N_{\text{cit}} \cdot q_{\text{cit}} \tag{1.1}$$

where:

Q_{cit} =water withdrawals in sector c of study area i in year t;

N_{cit} =number of users (demand drivers) such as population, employment, or acreage; and

q_{cit} =average rate of water demand in gallons per capita-day, gallon per employee-day, etc.

Unit-use approaches are based upon the assumption that q_{cit} will remain constant over time and future water demand will be proportional to the number of users N_{cit}. For example, in the self-supplied domestic sector the average water withdrawal rate is 82 gallons per person per day, so water withdrawals are directly proportional to the self-supplied domestic population in each county. Likewise, future withdrawals are calculated by multiplying estimates of future population by this unit-use coefficient (i.e., per capita rate of water withdrawals).

1.6.2 Multiple regression method

Modeling of water demand usually concerns the average rate of water withdrawal, q_{cit} , which is expected to change over time. Water-withdrawal relationships can be expressed in the form of equations, where this average rate of water withdrawal is expressed as a function of one or more independent (explanatory) variables. A multivariate context best relates to actual water-demand behaviors, and multiple regression analysis can be used to determine the relationship between water demand and each independent variable. The functional form (e.g., linear, multiplicative, exponential) and the selection of the independent variables depend on the category of water demand. For example, public water supply withdrawals can be estimated using the following linear model:

$$PS_{it} = a + \sum_j b_j X_{jit} + \varepsilon_{it} \tag{1.2}$$

where

PS_{it} = per capita public supply water withdrawals within geographical area i during year t;

X_{jit} = a set of independent variables (e.g., air temperature, precipitation, price of water, median household income and others), which are expected to explain public supply withdrawals; and

ε_{it} = random error.

The coefficients a and b_j can be estimated by fitting a multiple regression model to historical water-withdrawal data.

The models used in this study are specified as double-log (i.e., log-linear models). Additional variables serve to fit the model to the data and also isolate observations which are likely to be outliers:

$$lnPS_{it} = \alpha_o + \sum_j \beta_j lnX_{jit} + \sum_k \gamma_k lnR_{kit} + \sum_l \delta_l D_{lit} + \sum_m \rho_m S_{mit} + \varepsilon_{it} \tag{1.3}$$

where:

PS_{it} = per capita public supply water withdrawals within geographical area i during year t (in gallons per capita per day);

X_j = a set of independent variables;

R_k = ratio (percentage) variables such as ratio of employment to population;

D_l = indicator (or binary) variables designating specific public water supply systems which assume the value of one (1) for observations for the system and zero (0) otherwise;

S_m = indicator spike variables designating individual observations in the data;

ε_{it} = random error; and

α, β, γ, δ,and ρ are the parameters to be estimated.

A large number of econometric studies of water withdrawals have been conducted during the last 50 years. Haneman (1998) summarized the theoretical underpinnings of water-demand modeling and reviewed a number of determinants of water demand in major economic sectors. Useful summaries of econometric studies of water demand can be found in Boland et al. (1984). Dziegielewski et al. (2002a) reviewed a number of studies of aggregated sectoral and regional demand. A substantial body of work on model structure and estimation methods was also performed by the USGS (Helsel and Hirsch, 1992).

1.6.3 Model estimation and validation procedures

Several procedures were used to specify and select the water-demand models for this study: 1) models included variables that had been identified by previous research, 2) the variables had regression coefficients that were statistically significant, 3) the variables were within a reasonable range of *a priori* values and with expected signs, 4) the explanatory power of the model was reasonable, as measured by the coefficient of multiple determination (R^2), and 5) the absolute percent error of model residuals was not excessive. This modeling approach and estimation procedure were originally developed and tested in the study of geographically aggregated water withdrawal data conducted by Dziegielewski et al. (2002a, 2002b).

Additional information on analytical methods, models, and assumptions is included in the chapters and appendices which describe the analysis of water withdrawals and development of future water-withdrawal scenarios for each major sector.

1.7 Future water-withdrawal scenarios

For each of the water sectors, the water-demand drivers and/or variables were varied to simulate three different scenarios of water demand in the future: baseline, less resource intensive, and more resource intensive. The scenarios were defined by different sets of assumed conditions regarding the future values of demand drivers and independent variables. The general characteristics of each scenario are described below. A more detailed description of the scenarios and variables assumptions for each water sector are provided in the respective chapters.

The purpose of the scenarios is to capture future water withdrawals under three different sets of conditions. The three scenarios do not represent forecasts or predictions, nor do they set upper and lower bounds of future water demand. Different assumptions or conditions could result in withdrawals that are within or outside of the range represented by the three scenarios.

1.7.1 Scenario 1 - Baseline (BL)

The basic assumption of this scenario is that the recent trends in population growth and and other independent variable patterns will continue. With respect to population growth the baseline is represented by the official forecasts of population and employment in the 15-county planning area. The official forecast prepared by Illinois Department of Commerce and Economic Opportunity and Illinois Department of Economic Security includes the total number of residents and jobs for the region [DCEO, 2005 and IDES, 2007]. The population projections are based on technical analysis of demographic trends in the region.

The BL scenario does not rely on a simple extrapolation of recent historical trends in total or per capita (or per employee) water demand into the future. Instead, the future unit rates of water demand are determined by the water demand model as a function of the key independent variables. The "recent trends" assumption applies only to future changes in the independent variables. Accordingly, the BL scenario assumes that the independent variables such as income and price will follow the recent historical trends or their official or available forecasts. This scenario also assumes that recent trends in the efficiency of water usage (mostly brought about by the effects of plumbing codes and fixture standards, as well as actions of water users) will continue. The conservation trend on water use in the historical data is estimated as a part of the regression model.

1.7.2 Scenario 2 - Less resource intensive (LRI)

In the less resource intensive scenario, overall water demand is reduced compared to the BL scenario. Industrial withdrawals of water would decrease as some less water-intensive industrial activities continue to expand or locate in the study area. The efficiency assumptions include more water conservation (e.g., implementation of additional cost-effective water conservation measures by urban and industrial users). Other water demand parameters such as income and price are assumed to shift to levels which result in lower water demand (*i.e.*, lower income, higher prices for water). Irrigated acres are assumed to increase more slowly than in the BL scenario.

1.7.3 Scenario 3 - More resource intensive (MRI)

In the more resource intensive scenario, overall water demand is increased compared to the BL scenario. Industrial withdrawals of water would increase as some water-intensive industrial categories locate or expand in the study area. The price of water is assumed to remain unchanged in real terms, which implies that future price increases will only offset the general inflation. A higher rate of growth of median household income is also assumed. Additional discussion of sector-specific assumptions for each scenario is included in the chapters which describe estimates of water demand in each sector.

1.8 Water-withdrawal estimates

After the water-demand relationships are calculated via the unit-use coefficient or regression method, the future water-withdrawal estimates are prepared using the three scenarios described above for each sector. Water withdrawals are estimated in total million gallons per day for every five years until the year 2050. 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 is 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.

1.9 Normal weather and impacts of using normal weather in future scenarios

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., precipitation, temperature, and cooling degree days) must also be estimated. Weather data 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" [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. Figure 1.4 shows historical recorded data for temperature and precipitation compared to the climatic normals. The future data (shown as ?) shows that the future weather is not predictable and how it may vary in relation to the climatic normals used in this study. In effect, this assumes that the average weather from the 30-year historical 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 the variation in demand, as evidenced in the historical dataset.

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 in the historic reported withdrawals due to weather, 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. 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 1.5). 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

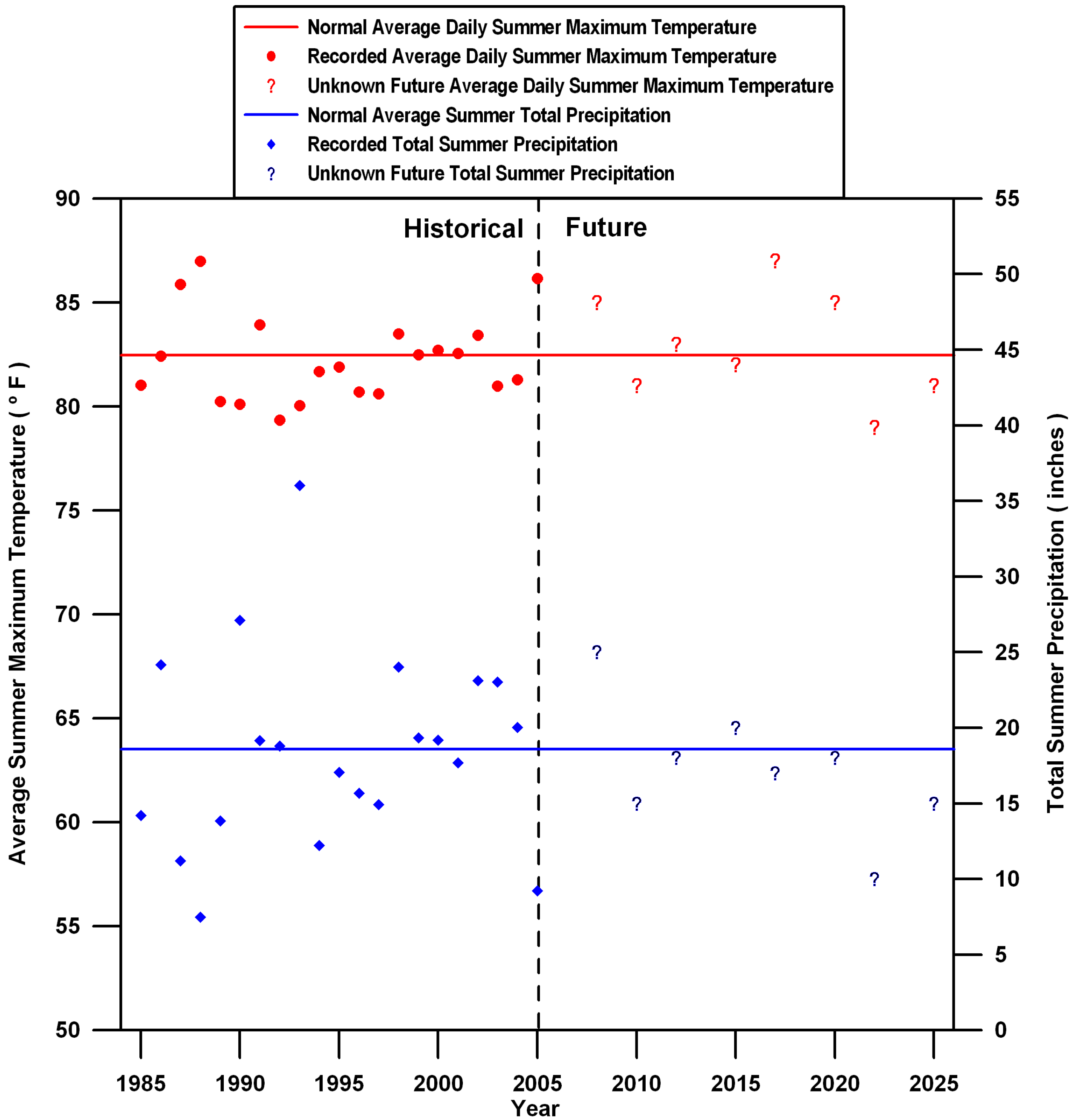

Figure 1.4: Example of inter-annual variation in temperature and precipitation compared to climatic normals.

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 1.5). 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 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 1.5 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.

1.10 Uncertainty - data quality, 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.

1.10.1 Data quality

The water withdrawal data used in this regional aquifer 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

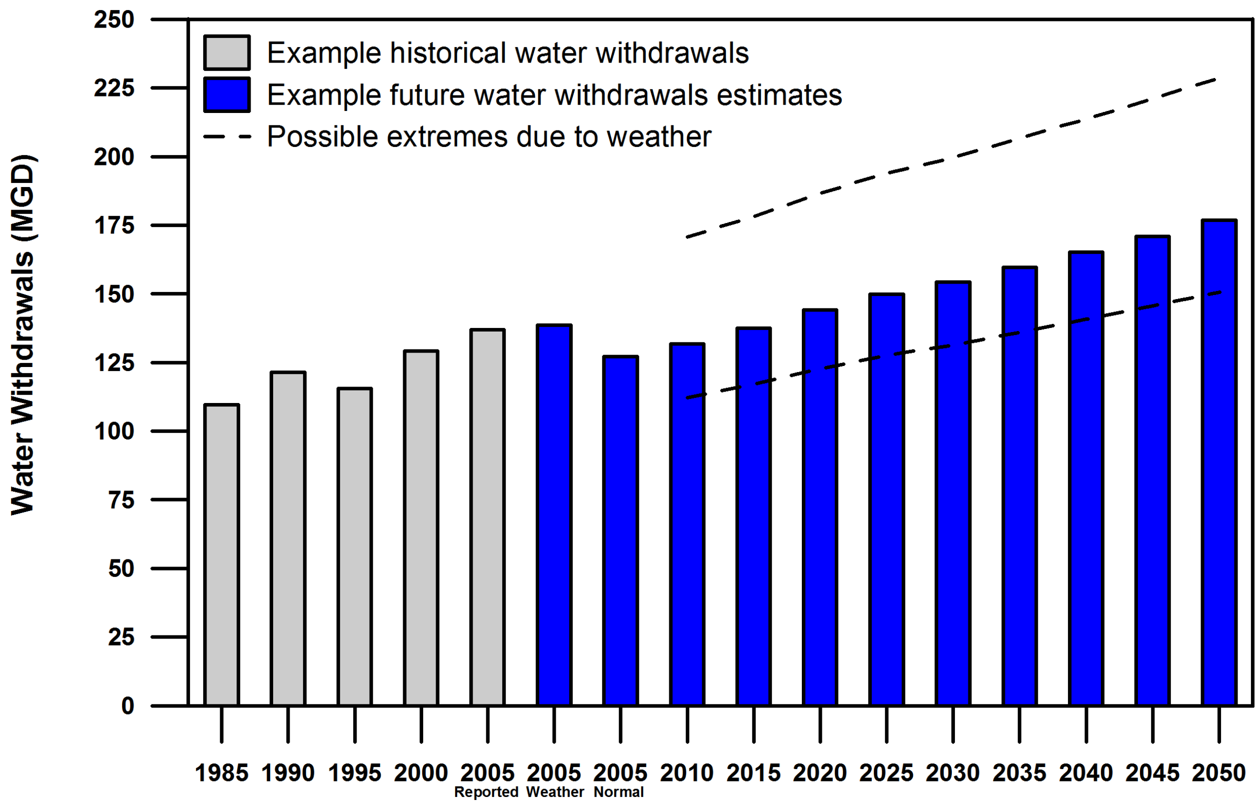

Figure 1.5: Example of the effects of using climatic normal temperature and precipitation.

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.
- 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 increase 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.

1.10.1.1 Implications of data quality

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. There is no way to improve predictions of future water withdrawals without improving the existing water withdrawal data.

1.10.1.2 Data recommendations

There are three steps that need to be taken to improve our understanding of regional water withdrawals and how it may change in the future:

1. make water withdrawal reporting mandatory for all users;
2. have water users report monthly withdrawal;
3. institute a metering/verification program to better define the relationship between reported and actual water withdrawals.

These changes would allow the community to manage demand and determine whether the estimated future water withdrawals in this report reflect actual conditions in the field.

1.10.2 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 1.6.

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

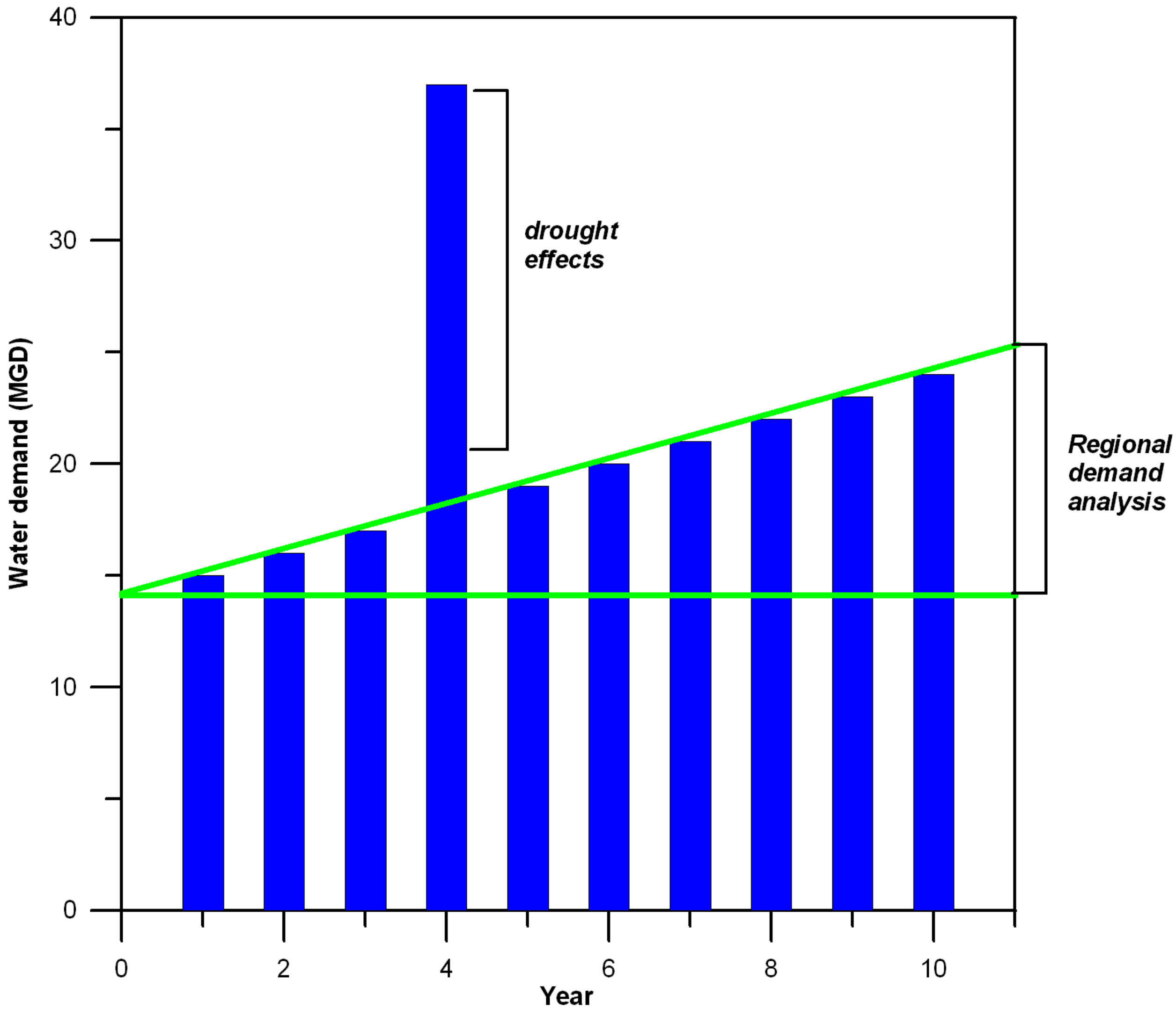

Figure 1.6: Example of potential drought effects.

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.

1.10.3 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).

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.

1.11 Organization of this report

The report is organized into an executive summary and seven chapters. The executive summary combines the results for all sectors and briefly discusses some of the implications of this study for the further analysis of water withdrawals in East-Central Illinois. Chapter 1 introduces the data and analytical models for estimating future water demands. The four major water use sectors are described in the four subsequent chapters (Chapters 2, 3, 4, and 5). Each of these chapters begins with a brief review of the definition of the water demand sector, a summary of the historical data, and the procedure for deriving water-demand relationships for the sector. This is followed by a description of the assumptions used to develop water-demand scenarios for the sector and a summary of the scenario results. An appendix is included for each chapter to provide additional historical data, model explanations, and results for each sector. Chapter 6 describes the sensitivity analysis, which shows the impacts on water withdrawals under five climate change scenarios and drought. This is followed by Chapter 7, which provides a summary of the regional information and recommendations for future water demand studies. References for all the chapters appear at the end of the report.

The final task of this project included an allocation of future withdrawals within each geographical area to the existing withdrawal points, groundwater wells and surface water intakes. The results of this work are not included in this report. Instead, the electronic tables of withdrawals allocated to individual points of water withdrawal were provided directly to the Illinois State Water Survey for their use as inputs into hydrologic groundwater (and surface water) models.

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