Kane County Water Resources Investigations:

Simulation of Groundwater Flow in Kane County and Northeastern Illinois

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Executive Summary

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1. Introduction

This report discusses an assessment of groundwater resources supplying water to Kane County, Illinois, a rapidly growing county on the west side of the greater Chicago metropolitan area. This study assimilates the available data into a set of computer models of groundwater flow in regional and local aquifers, quantifying the components of the hydrologic cycle and assessing the impact of historical and projected pumping. The modeling study is part of a comprehensive project assessing surface water, geology, and groundwater in Kane County.

The water resources assessment project was motivated by a combination of factors and trends. The population of Kane County is projected to increase more than 70 percent from the 2000 population to over 718,000 by 2030. Although this population increase likely will be accompanied by greatly increased water demand, Lake Michigan, the source of water upon which the northeastern Illinois region has historically relied, may not be available due to legal constraints and the significant expense of conveying water from the lake to Kane County. These limitations have prompted planners and decision-makers to look to water resources within Kane County to meet projected demands. Studies conducted prior to the initiation of the present investigation in 2002 offered only a regional, qualitative understanding of the geology and hydrology, scattered sets of sporadic observations, and isolated studies of local issues. Although these legacy studies are inadequate for fostering detailed water-resources planning, they suggested the possibility of water shortages in Kane County by 2025 (Northeastern Illinois Planning Commission, 2002).

In response to these factors, the Kane County Development Department commissioned the Illinois State Water Survey and Illinois State Geological Survey to assess groundwater and surface water resources to support county water-supply planning efforts. This assessment includes the present study, whose goal is to ascertain the current and future status of groundwater resources in Kane County, Illinois. To achieve this goal, this study develops and applies computer models of groundwater flow to clarify the relationships between aquifers and streams and to quantify the effects of current and future groundwater usage. The study assembles the data collected in the field, retrieved from archives and synthesized during 2002 to 2006, and assimilates them into computer models that simulate groundwater flow.

This executive summary briefly describes the development, application, and results of computer modeling conducted for the study. The more extensive main report discusses the hydrologic characteristics of geological materials in the Kane County area and documents the data review and inference of parameters, the development and calibration of the groundwater models, and their detailed results. Readers should consult the main report for these details, as well as an overview of hydrogeologic concepts, the regional setting, and model development. Readers interested in basic concepts of hydrology may find the introduction by Alley et al. (1999) to be useful. Anderson and Woessner (2002) provide extensive guidance on the practice of developing groundwater flow models.

2. Sources of Water to Kane County

Significant local sources of water to Kane County include the Fox River—already utilized by the Cities of Elgin and Aurora—and groundwater. Total water withdrawals by public water systems, irrigators, and self-supplied commercial and industrial facilities in the county have increased from about 25 to 61 million gallons per day (Mgd) from 1964 to 2003 (Figure 1). Kane County has always relied entirely on its locally available water sources and has never received water from Lake Michigan.

Since the late 1980s, surface water used in the county has been obtained almost entirely from the Fox River by the Elgin and Aurora public water systems. Elgin began withdrawing water from the Fox River in 1983, and Aurora began in 1992. Prior to 1979, surface withdrawal data in the county are not available, but withdrawals were probably near zero during this time period. Questions pertaining to the availability of water from the Fox River in Kane County are beyond the scope of the present report, but the topic is discussed in a related report on the surface waters of Kane County by Knapp et al. (2007).

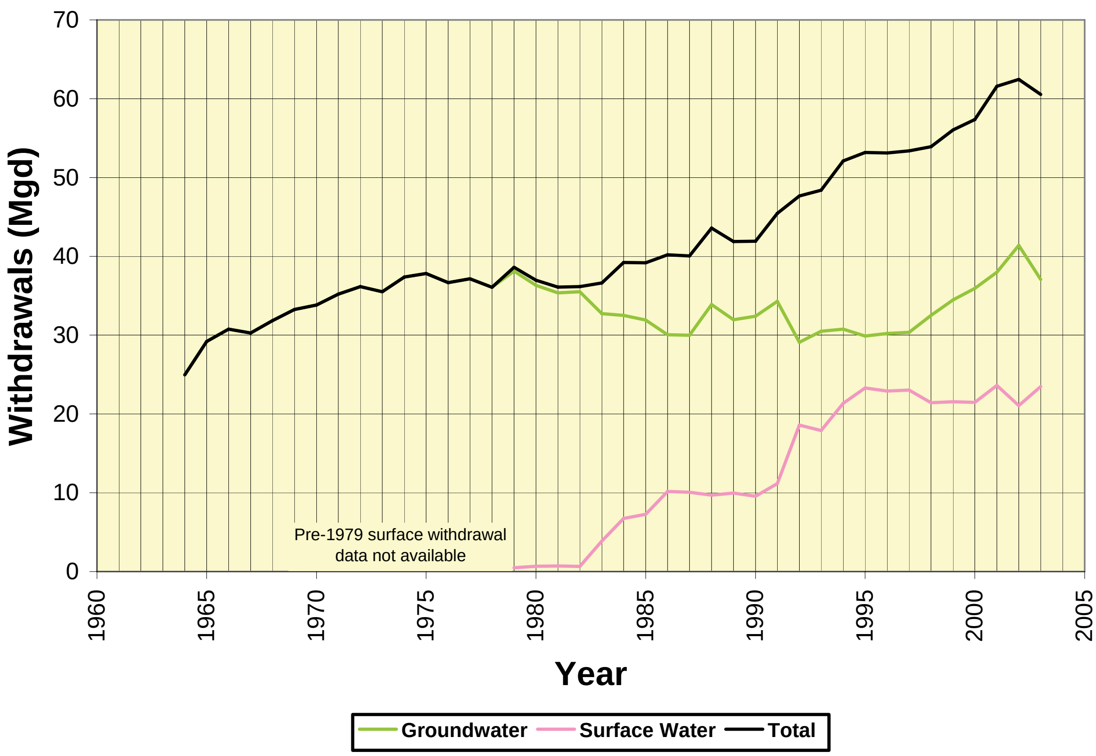

Figure 1. Water withdrawals by public water systems, irrigators, and self-supplied commercial and industrial facilities in Kane County from 1964 to 2003.

Groundwater sources available to Kane County include deep and shallow aquifers (Figure 2). The deep aquifers are layers consisting principally of sandstone, and for purposes of this study are referred to as the Ancell Unit, Ironton-Galesville Unit, and Mt. Simon Unit. In Kane County and the rest of northeastern Illinois, the Ancell Unit consists predominantly of the well-known St. Peter Sandstone, a productive aquifer that is a common target of deep wells in the region. The Mt. Simon Unit is used far less than the Ancell and Ironton-Galesville Units because of the expense of drilling to it and because its lower portions contain water that is too salty for most uses. In other parts of the regional model domain, the rocks included in the Ancell, Ironton-Galesville, and Mt. Simon Units are not aquifers, so the generic term *Unit* is employed to refer to these materials.

Shallow aquifers include the Shallow Bedrock Aquifer (a layer of weathered rocks encompassing the uppermost 50 to 100 feet of bedrock) and several discontinuous layers of unconsolidated sand and gravel contained in the glacial drift overlying the aquifer. In Kane County, the Shallow Bedrock Aquifer consists principally of dolomite and shale of Silurian and Ordovician age. Although the Shallow Bedrock Aquifer is defined by the porosity associated with weathering at the bedrock surface and is therefore present throughout Kane County, it is most productive in the eastern part of the county, where the uppermost bedrock consists of the dolomite of Silurian age. The comparatively pure, thinly bedded Silurian dolomite facilitates weathering and consequent development of porosity and permeability. These factors increase aquifer productivity.

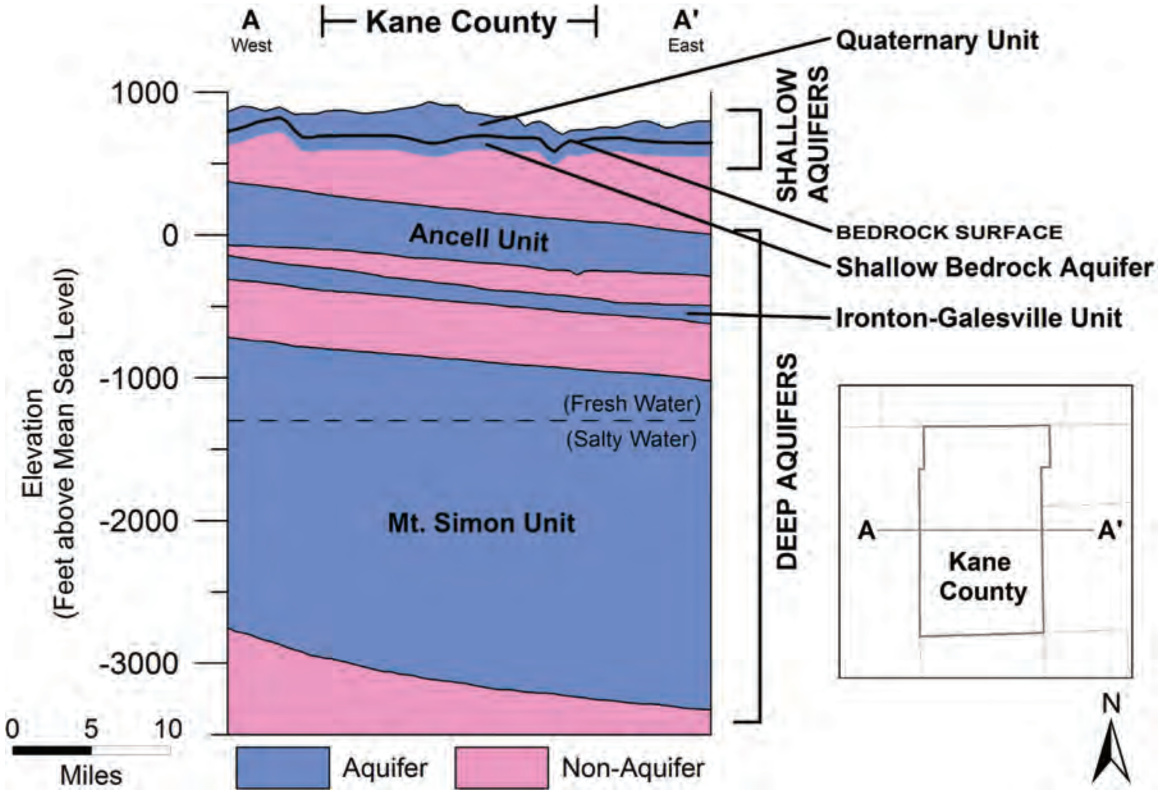

Figure 2. Major aquifers of the Kane County area.

Groundwater withdrawals generally have increased from about 25 Mgd in 1964 to 40 Mgd in 2003 (Figure 3). The exception to this increasing trend was the late 1970s through the early 1990s, when withdrawals declined as the large Elgin and Aurora public water systems shifted from the deep aquifers to the Fox River. Since the early 1990s, groundwater withdrawals have increased significantly, from about 30 to 40 Mgd, to accommodate water demand increases associated with population growth. Since the late 1990s, Kane County groundwater withdrawals have been divided about equally between the deep and shallow aquifers.

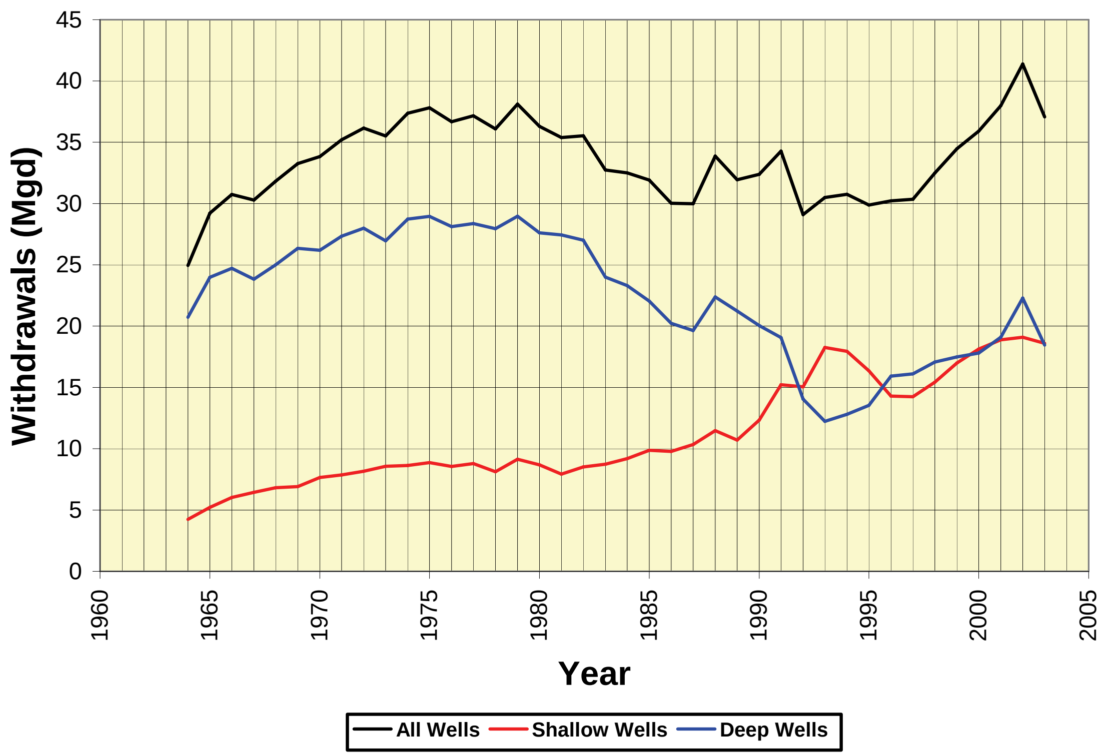

Figure 3. Groundwater withdrawals by public water systems, irrigators, and self-supplied commercial and industrial facilities in Kane County from 1964 through 2003.

3. Groundwater Flow Models

Understanding the relationships between these water resources and their response to withdrawals requires a quantitative approach that assimilates the available observations and knowledge, computes flow rates and water levels, and projects these into the future for alternative water-use scenarios. For the present study, these requirements are met using a computer groundwater flow model, which is a set of interrelated mathematical equations that represent water flow in aquifers and streams, solved using a computer program. Computer modeling of groundwater flow involves reviewing available data and information, developing a conceptual model of the aquifers and the stresses on them, choosing a computer program that solves mathematical equations describing flow, inferring input parameters for the computer program, calibrating and verifying the model against flow and water level observations to ensure realism and accuracy, and simulating various combinations of stresses of interest (Anderson and Woessner, 2002). Models developed for this study use the computer program MODFLOW (Harbaugh et al., 2000; McDonald and Harbaugh, 1988) to simulate groundwater flow processes of the conceptual model. MODFLOW is a thoroughly documented and widely used program developed by the United States Geological Society (USGS) that uses the finite-difference method, a mathematical technique which divides the aquifer into a grid of blocks to solve equations representing groundwater flow through porous media.

Two groundwater models have been developed for this study (Figure 4), the first of which is a *regional-scale model* that provides an analysis of the deep aquifers and the overall groundwater flow patterns. The regional model consists of 20 layers that simulate groundwater flow in all geological materials from the land surface down to the deep underground crystalline rocks that are effectively impervious (Figure 5). It includes both the shallow and deep aquifers in a large portion of Illinois, Indiana, Michigan, Wisconsin, and Lake Michigan. The regional model employs a variable resolution, with its highest resolution in a rectangular *nearfield* area covering all of northeastern Illinois, where cells have horizontal dimensions of 2,500 feet (ft) (Figure 6). The regional-scale model quantifies groundwater flow in the deep aquifers of the model nearfield area and evaluates regional flow patterns in shallow aquifers. Nested inside the regional-scale model is a second, local-scale model of much greater detail that quantifies groundwater flow within the shallow aquifers of Kane County and surrounding townships. The effects of regional-scale groundwater flow are transferred to the local model by assigning flow rates simulated by the regional model to the boundaries of the local model. Because the flow across the local boundaries changes little with time, this process of nesting the models, or Telescopic Mesh Refinement, need only be done once for the local-scale model.

Figure 4. Areal extent of groundwater flow models.

HYDROSTRATIGRAPHIC UNIT	MODEL LAYER
Quaternary Unit (QT)	1
	2
	3
Upper Bedrock Unit (UB)	4
Silurian-Devonian Carbonate Unit (SD)	5
	6
	7
Maquoketa Unit (MQ)	8
	9
Galena-Platteville Unit (GP)	10
	11
Ancell Unit (AN)	12
Prairie du Chien-Eminence Unit (PE)	13
Potosi-Franconia Unit (PF)	14
Ironton-Galesville Unit (IG)	15
Eau Claire Unit (EC)	16
Mt Simon Unit (MS)	17
	18
	19
	20

Figure 5. Layer scheme of regional-scale model.

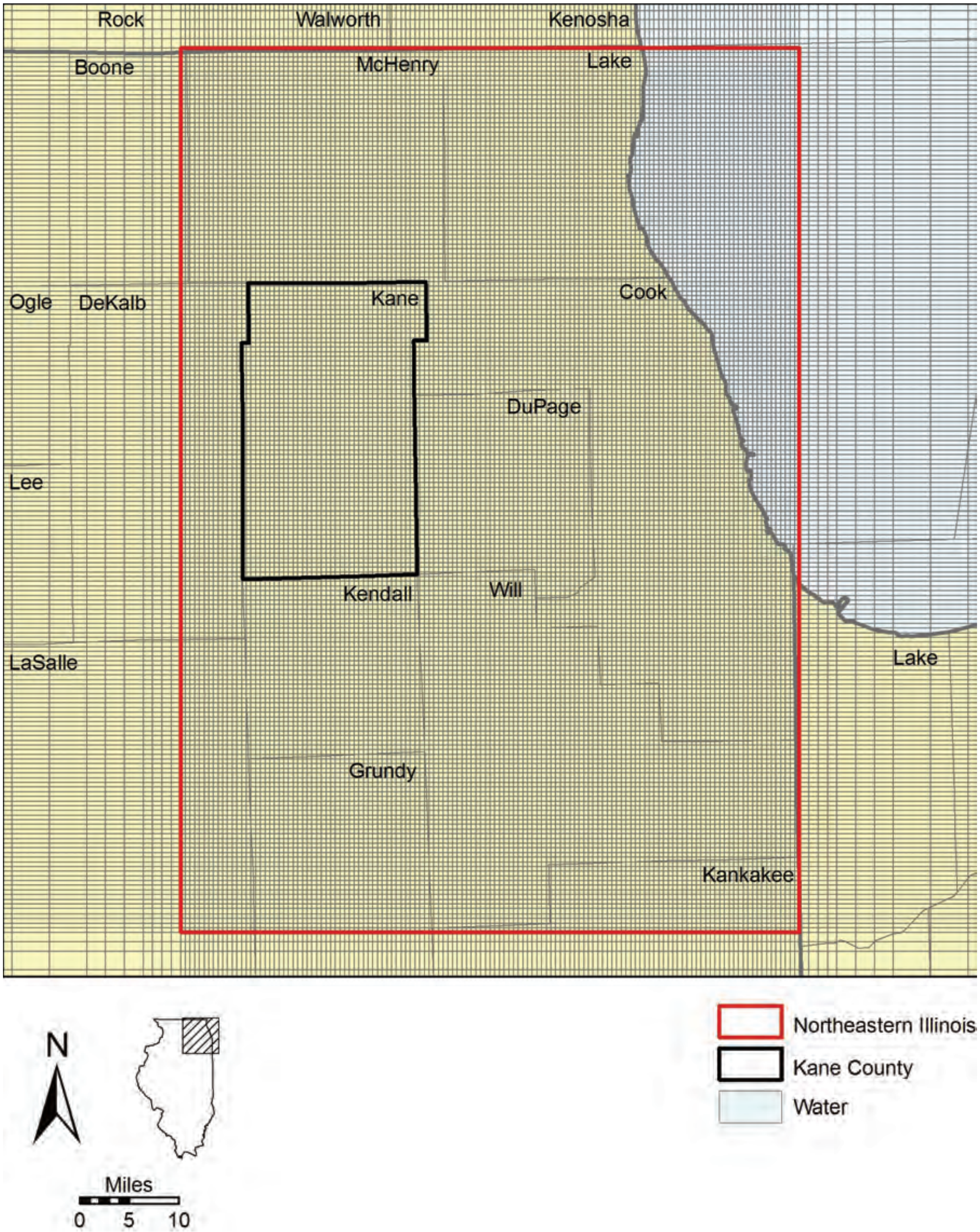

Figure 6. Detail of northeastern Illinois showing regional model grid and regional model nearfield.

The local-scale model is more highly resolved, using 15 layers and a horizontal grid spacing of 660 ft to simulate flow in a domain including only the shallow units in Kane County and the surrounding areas out to a distance of about 6 miles from the county boundaries (Figure 7, Figure 8). The local model provides detailed analysis of groundwater flow in Kane County shallow aquifers and interactions between groundwater and surface water. The purposes of the local model are to quantify groundwater flow, estimate wellfield capture zones, and evaluate groundwater-surface water interaction in the shallow aquifers of Kane County and the immediately adjacent areas. The lowermost interval represented in the local-scale model is the Shallow Bedrock Aquifer (local-scale model layer 15). In terms of the hydrostratigraphic units represented in the regional-scale model (Figure 5), the Shallow Bedrock Aquifer of the local-scale model is equivalent to portions of the Silurian-Devonian Carbonate Unit, Maquoketa Unit, and Galena-Platteville Unit within 50 to 100 ft of the bedrock surface. The Upper Bedrock Unit of the regional-scale model is not present in the Kane County area and is not represented in the local-scale model. The 14 layers of the local-scale model overlying the Shallow Bedrock Aquifer represent the same materials represented in the regional-scale model as the Quaternary Unit; in the regional-scale model, the Quaternary Unit is represented with three model layers.

To ensure that the models accurately represent hydrogeological conditions within their domains, data employed for characterization of layer elevations, parameters, and boundary conditions in both are based to the extent possible on a wide range of published and unpublished observations. Parameters such as hydraulic conductivity and recharge rates are specified on a zoned basis. The models have been calibrated so that they reproduce observed estimates of head and base flow within the uncertainty of these observations. The models facilitate analysis of predevelopment conditions and the impacts of historical and future scenarios of groundwater development, and they readily permit insight into cause-and-effect relationships pertaining to groundwater flow.

Groundwater flow models developed for this project are available to the public to simulate groundwater flow in Kane County and northeastern Illinois and to provide a framework for more detailed, site-specific studies. The models represent a synthesis of data and information available to the authors during the period from 2002 to 2008, and they were developed using procedures and computer software widely accepted during that time. Model users should understand that the models, and the analyses based on them, are works in progress reflecting currently available technologies, modeling approaches, and data. Both models and analyses should be updated periodically to reflect newly available data, information, and analysis, as well as new approaches to data synthesis and analysis, modeling techniques, and computer software.

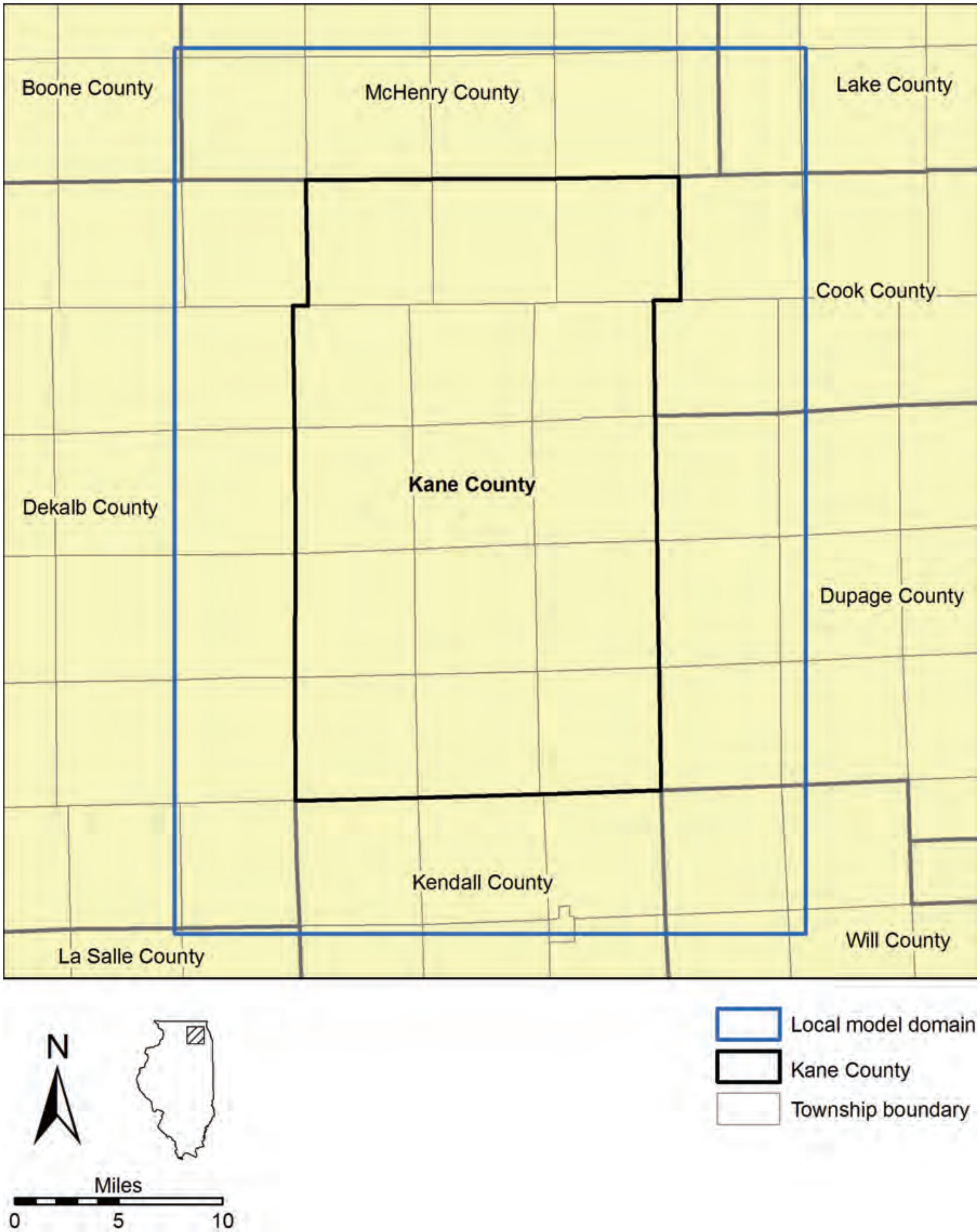

Figure 7. Local-scale model domain.

HYDROSTRATIGRAPHIC UNIT		MODEL LAYER
Equality Unit		1*
Surficial Henry Unit		
Wadsworth Diamicton Unit		2
Wadsworth Sand Unit		
Haeger Diamicton Unit		
Beverly Unit		3
Yorkville Diamicton Unit		4
Yorkville Sand Unit		5
Batestown Diamicton Unit		6
Batestown Sand Unit		7
Tiskilwa Unit		8
Ashmore Unit		9
Glasford Unit	Upper Glasford Diamicton Unit	10
	Upper Glasford Sand Unit	11
	Middle Glasford Diamicton Unit	12
	Lower Glasford Sand Unit	13
	Lower Glasford Diamicton Unit	14
Shallow Bedrock Aquifer		15

*Layer 1 includes the uppermost 10 ft of material. Where the aggregate thickness of the Equality Unit and Surficial Henry Unit is less than 10 ft, layer 1 includes enough of the underlying unit so that total thickness is 10 ft.

Figure 8. Layer scheme of local-scale model.

4. How Much Groundwater is Available in Kane County?

This question cannot be answered without making so many qualifying assumptions that the answer is unusable as a management guideline. Collective withdrawals from a network of wells, such as those in Kane County, cause the water elevation in wells (*head*) that are open to the source aquifers to decline. These head declines (*drawdowns*) can lead to increased pumping expenses and decreased well yields; decreased groundwater discharge to streams, causing reduced streamflow; reduced water levels in lakes and wetlands; and changes in the vegetation. In some settings, reduced heads also can result in decreased groundwater quality, requiring expensive treatment. Therefore, the question of how much water can be pumped from wells sustainably depends on how wells affect the environment and what the public considers to be acceptable environmental impacts (Alley et al., 1999; Bredehoeft, 2002; Bredehoeft et al., 1982; Devlin and Sophocleus, 2005). Moreover, the impacts of groundwater withdrawals constantly change as recharge rates adjust to climate change, new wells are drilled, old wells are abandoned, and pumping rates at individual wells rise and fall both inside and outside of Kane County. Lastly, the availability of groundwater is very much related to the price the public is willing to pay for groundwater treatment. For example, if the public is willing to pay for desalination of deep groundwater or if technological advances decrease the cost of desalination, then more groundwater will be available.

In this study, then, instead of generating single-value estimates of groundwater availability, plausible future pumping and recharge scenarios were simulated using groundwater flow models that quantify the impacts of these scenarios. If these impacts are considered by local water managers to be unacceptable, they may choose to adapt policy and target monitoring and water-management efforts to track and mitigate impacts countywide or in affected areas. Groundwater flow models developed for this project also may be used for future analysis of other scenarios to test effects of alternative management strategies.

For this project, both historic pumping and estimates of future pumping are simulated. Two future *pumping conditions*, which are refered to as low-pumping conditions and high-pumping conditions, are simulated (Figure 9), through the end of 2049. These pumping conditions are simulated for “normal” (i.e., historic) recharge rates and for reduced and elevated recharge rates to demonstrate possible effects of climate change. Historic pumping rates simulated on the models cover the period 1864 through 2003, and are based on databases maintained by university and state authorities in Illinois and Indiana and on data compiled for previous groundwater flow modeling projected in Illinois and Wisconsin. Post-2003 pumping data were not available when the groundwater flow models for this project were developed. Estimates of future pumping through 2050 were developed from forecasts assembled by Dziegielewski et al. (2004, 2005). Under low-pumping conditions, withdrawals in Kane County are assumed to increase from about 37 to 52 Mgd from 2003 to 2050; under high-pumping conditions, Kane County withdrawals are assumed to increase from 37 to 71 Mgd from 2003 to 2050. The project timeline required the authors to estimate pumping rates for both low- and high-pumping conditions in 2005, yet at the time of printing, the 2005 pumping rates are historic fact. Actual pumping in Kane County in 2005 (44 Mgd) exceeded estimated 2005 pumping under both low- and high-pumping conditions (40 Mgd in both cases). Assumed reduced and elevated recharge rates differ from place to place in the model domains, but in Kane County they are specified at about 12 percent lower and higher than the “normal” historic rate.

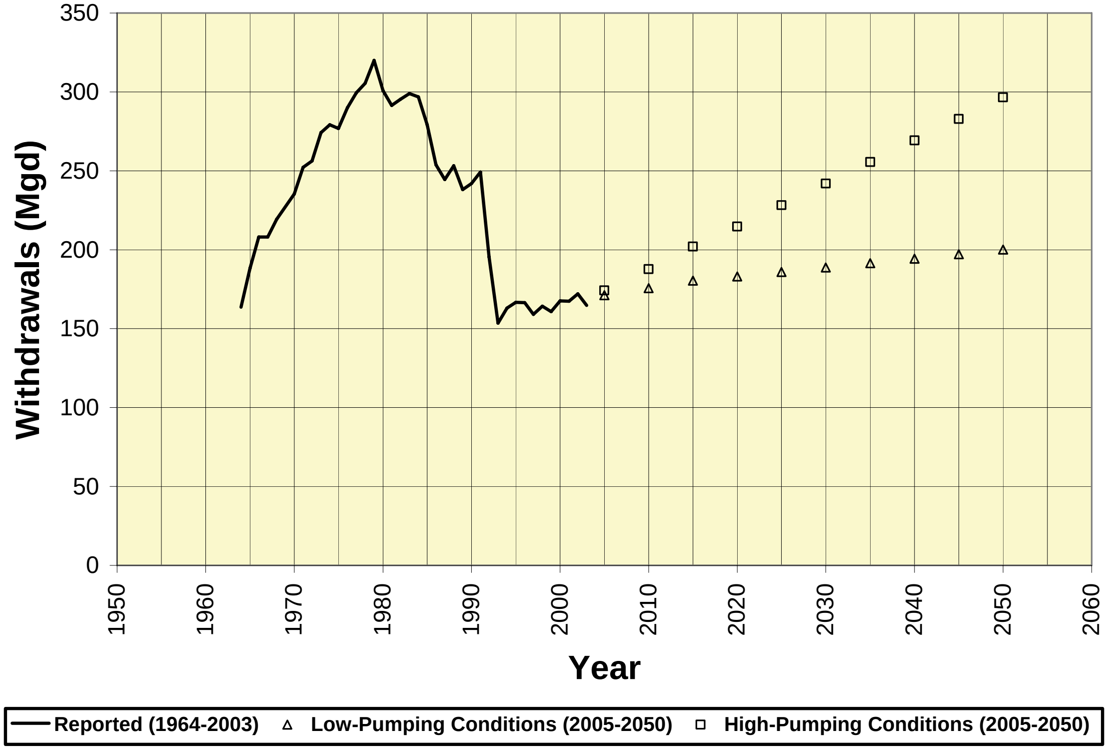

Figure 9. Historic and projected groundwater withdrawals in the regional model nearfield of northeastern Illinois (Figure 6).

5. Model Analysis

5.1. General Flow Patterns

To understand the consequences of present-day withdrawals and to evaluate projected pumping scenarios, this study first assesses *predevelopment conditions* with the models. Predevelopment conditions (i.e., in the late 1800s, prior to the growth in groundwater pumping) are inferred from sparse historical data and modern streamflow statistics. This assumed predevelopment state is a typical assumption of hydrolgeologic studies in the Midwest and is justified by the small trend in baseflow reported by Meyer (2005) for urbanization. However, predevelopment conditions are poorly known and remain a research topic that lies outside the scope of the present study. The initial analysis includes model calibration, where input parameters are adjusted within their plausible ranges until model simulations of heads and flows are similar to the observed heads and flows. In general, the regional model is most accurate within the Ancell aquifer of northeastern Illinois, and the local model is most accurate within Kane County. The simulated heads and flows are within the error of the available observations, and the degree of accuracy is similar to comparable models of Midwestern hydrogeology.

Model analysis shows that groundwater in shallow aquifers of Kane County flows from upland recharge areas and discharges to nearby wells or surface waters. Under predevelopment conditions, shallow groundwater discharged exclusively to surface waters and wetlands, but under present-day conditions, a proportion of discharge occurs through wells. This change has the effect of reducing groundwater discharge to wetlands and surface water, although a portion of the withdrawals will ultimately be returned to surface waters as effluent from wastewater treatment plants and runoff. In most of northeastern Illinois, including all but the southwesternmost corner of Kane County, relatively impermeable rocks overlie the deep aquifers, greatly reducing exchange of water between the shallow and deep aquifers. Groundwater flow within the deep aquifers occurs on a regional scale, with most recharge into the aquifers occurring in north-central Illinois, west of Kane County, where the impermeable rocks overlying the deep aquifers are absent. Under predevelopment conditions, groundwater in the deep aquifers underlying northeastern Illinois slowly discharged upward into the shallow units, and ultimately to surface waters—primarily the upper Illinois River and lower Fox River—with limited diffuse upward leakage to Lake Michigan. Presently, the deep groundwater flow is dominated by discharge to wells in Cook, DuPage, Kane, and Will Counties in Illinois and to wells in Milwaukee and Waukesha County, Wisconsin. The greatest drawdowns in the Chicago area correspond to areas of greatest historical pumping, and include Joliet, Aurora, and an area corresponding to the Cook-DuPage county line. Model results indicate that locations and magnitudes of drawdown and streamflow reduction are caused by pumping from both deep and shallow aquifers.

Simulated heads in shallow aquifers mimic surface topography, with a pattern of high heads in northwestern Kane County that decline toward the south and east to lows along the Fox River. This pattern becomes more muted with depth, so small topographic features reflected in the hydraulic heads of the shallowest aquifers are less apparent in the heads of the more deeply-buried aquifers. Drawdown is limited by capture of streamflow, so the impact of wells is not as widespread as in the deep aquifers. Model simulations suggest that the capture of streamflow by shallow wells can significantly reduce natural groundwater discharge to streams in some areas.

5.2. Modeling of Historical Conditions

Simulations of historical withdrawals (from 1864 to 2002 with the regional-scale model and from 1964 to 2003 with the local-scale model) verified that simulated heads and flows accurately represent observed heads and flows. Regional model simulations were conducted to characterize drawdown in the principal deep aquifers of northeastern Illinois—the Ancell and Ironton-Galesville Units. Simulations with the local-scale model were employed mainly to characterize drawdown in the shallow aquifers in the Kane County area and to quantify reductions in streamflow in Kane County streams.

In general, model simulations show that drawdown in the deep aquifers is much greater than in the shallow aquifers, this difference reflecting the availability of *replacement water* to the aquifers (i.e., water entering the aquifers to replace groundwater withdrawn through wells). In northeastern Illinois, impermeable confining units greatly limit leakage into the deep aquifers from above, so replacement water for these aquifers is derived principally by slow, lateral movement from north-central Illinois where impermeable cover is absent. In contrast, impermeable materials are discontinuous in the Quaternary materials and therefore do not greatly limit entry of replacement water into the shallow aquifers. Thus, drawdown in these aquifers is offset by comparatively high rates of leakage into the aquifers. Some of this replacement water originates as captured streamflow, which is a consequence of (1) diversion of recharge into shallow wells that would otherwise discharge to a stream and (2) leakage of water from stream channels in response to pumping. Although streamflow capture tends to reduce drawdown in shallow aquifers, this can result in reduced groundwater discharge to streams. Pumping from the deep aquifers in southeastern Wisconsin contributes to drawdown in northeastern Illinois, but pumping in northwestern Indiana, which is almost entirely limited to the shallow aquifers, has little effect on heads in northeastern Illinois.

5.2.1. Head Change in Deep Aquifers

Simulation with the regional model for 2002 suggests that drawdown since the start of pumping in the Aurora area—the location of greatest drawdown in Kane County—exceeded 500 ft in the Ancell Unit (Figure 10) and 1100 ft in the Ironton-Galesville Unit, the most important deep aquifers in the region. A steep west-to-east gradient has become established in both aquifers across Kane County, a result of the county’s location between the heavily pumped Chicago area to the east and the recharge area to the west. This places the county between the large drawdowns of the Chicago cone of depression and small drawdowns where the impermeable cover is absent and leakage from shallow aquifers is greater (Figure 11). Thus, simulated drawdown in eastern Kane County (e.g., St. Charles, as shown in Figure 12 and Figure 13) is greater than to the west (see Maple Park in Figure 12 and Figure 13) because the eastern area is more affected by heavy pumping and is less affected by leakage from shallow aquifers to the west. This pattern causes water levels in deep wells to decline, requiring increasingly greater expense to lift groundwater from deep wells. In addition, head declines in these units in the Chicago area have the potential to induce migration of salty water from deeper units and from areas south of the metropolitan area, reducing water quality.

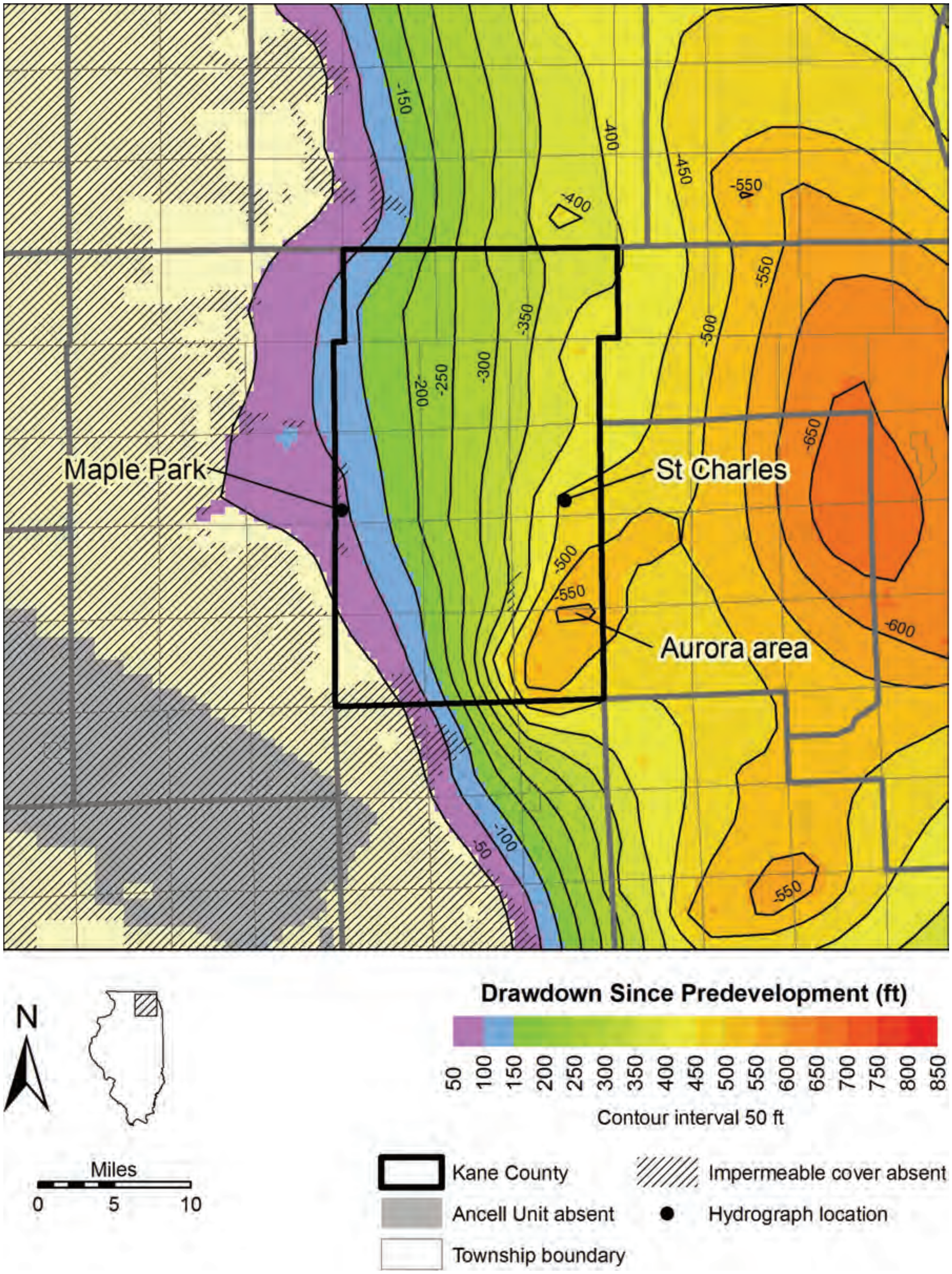

Figure 10. Simulated drawdown due to pumping in the Ancell Unit in the Kane County area in 2002.

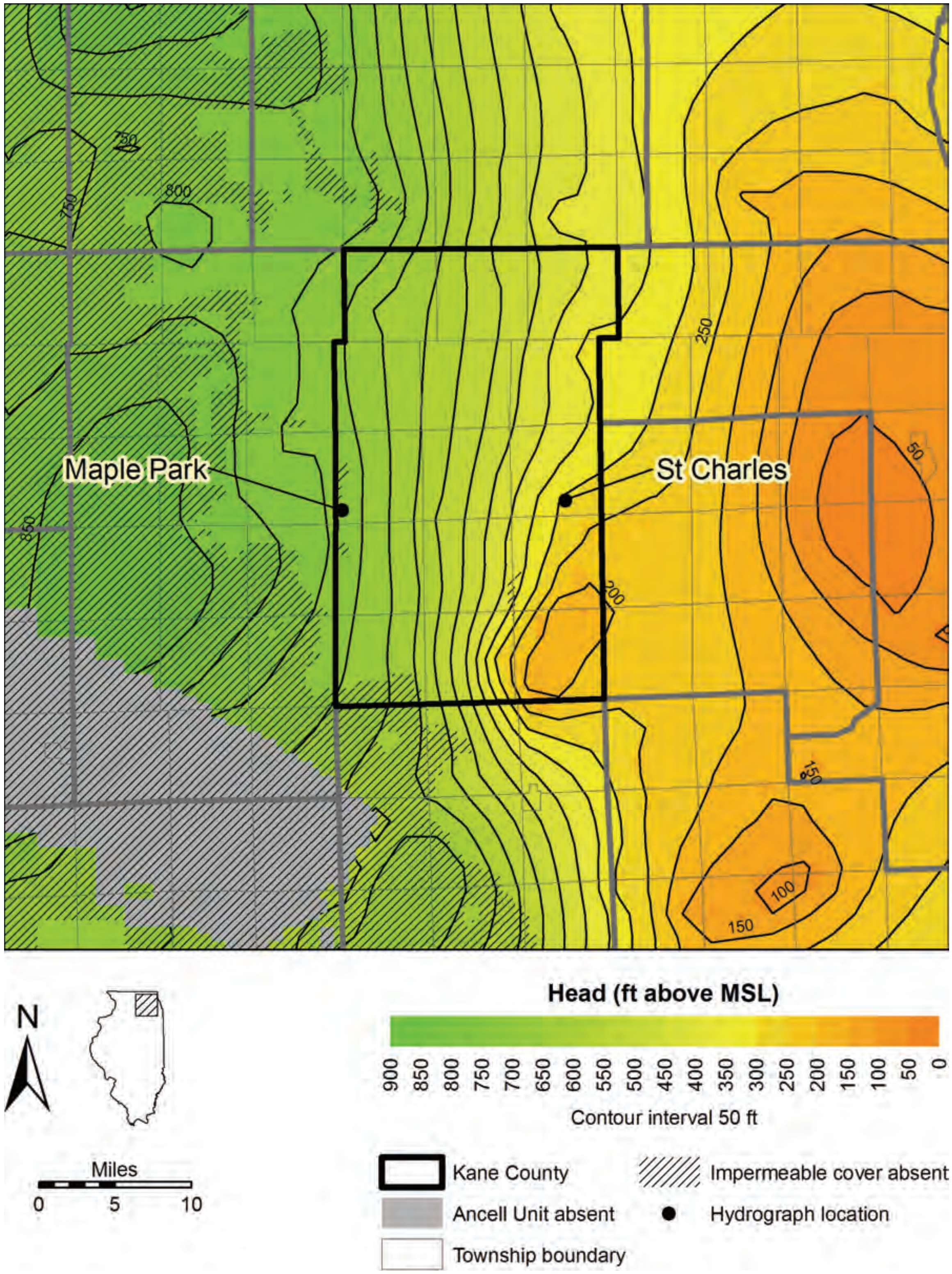

Figure 11. Simulated head in feet above mean sea level (ft above MSL) in the Ancell Unit in the Kane County area in 2002.

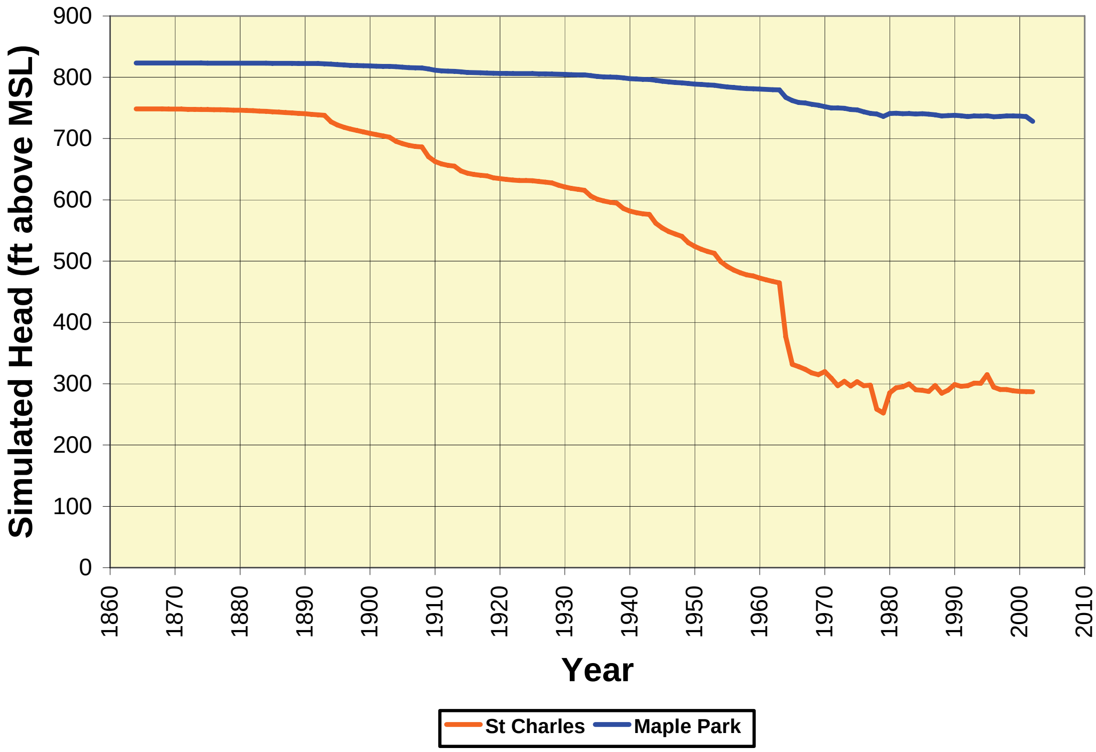

Figure 12. Simulated head from 1864 to 2002 in the Ancell Unit at St. Charles and Maple Park.

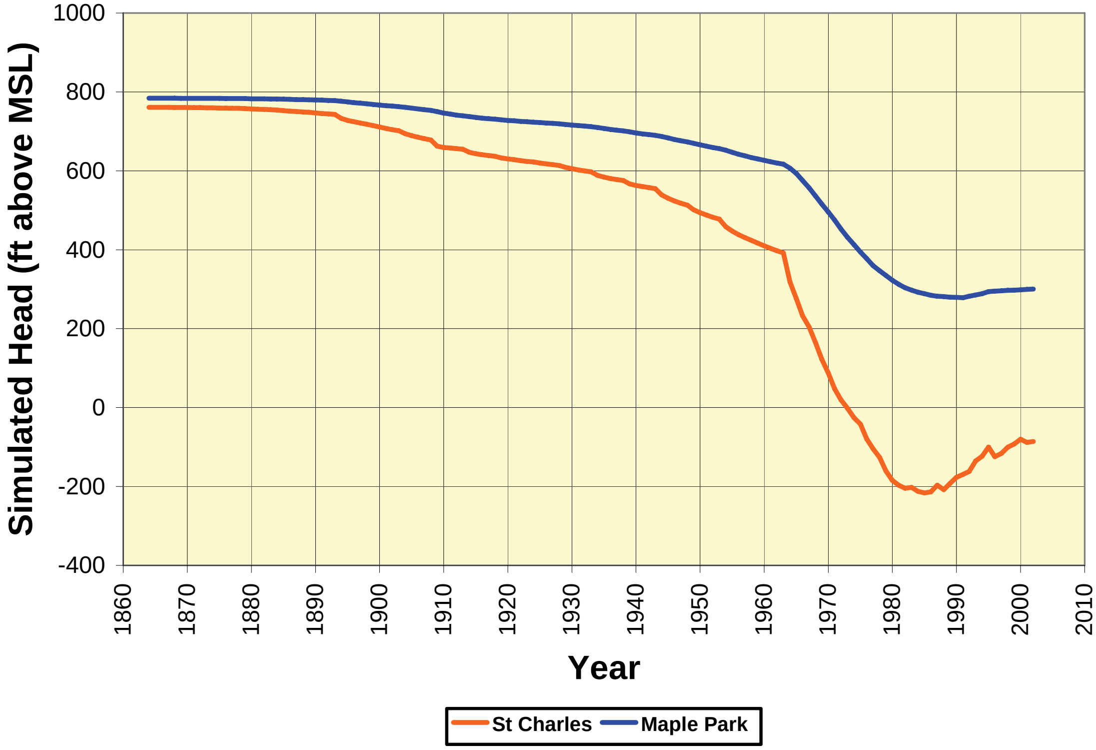

Figure 13. Simulated head from 1864 to 2002 in the Ironton-Galesville Unit at St. Charles and Maple Park.

In parts of northeastern Illinois east of Kane County, simulated heads in the deep aquifers recover after 1979, when numerous deep wells in those areas began to be abandoned as water suppliers converted to a Lake Michigan source (note the overall decline in withdrawals from 1979 to 1993 in Figure 9) (Figure 14). During the same period, public water systems at Elgin (1983) and Aurora (1992) began withdrawing water from the Fox River, greatly reducing their withdrawals from the deep aquifers. Model simulation suggests that the latter conversion, together with communities further east converting to water supplied from Lake Michigan, caused some recovery of heads in Kane County. In Figure 14, this recovery is evident in the Elgin area of northeastern Kane County, where the figure shows an increase in head (recovery) of over 50 ft since 1979. Recovery is not evident in the Aurora area in Figure 14 because the conversion to Fox River water began there in 1992, and heads in 2002 at Aurora were still well below those in 1979. With the exception of Elgin and Aurora, the effect of the water-source conversions on simulated Ancell heads in Kane County has been more to slow the decline in heads than to cause actual recovery.

There are potential problems associated with the decline of Ancell Unit heads near and below the top of the Ancell Unit:

- Studies of the Ancell in the Green Bay area of Wisconsin (Schreiber et al., 2000) suggest that exposure to oxygen of a thin interval at the top of the Ancell Unit containing sulfide minerals including small amounts of arsenic—as could happen where Ancell heads decline to within 100 ft of the top of the unit—could cause an increase in arsenic concentrations in groundwater withdrawn from deep wells to levels exceeding the United States Environmental Protection Agency (USEPA) drinking water standard of 10 micrograms per liter. Studies by the Illinois State Geological Survey suggest that sulfide minerals are present at the top of the Ancell Unit in northeastern Illinois, but it is not understood whether these minerals contain the arsenic that is present in Wisconsin.
- Since many deep wells in northeastern Illinois are open to both the Ancell Unit and the Ironton-Galesville Unit, desaturation of the Ancell Unit could increase the proportion of Ironton-Galesville groundwater withdrawn from these wells. This increased proportion of Ironton-Galesville groundwater may reduce water quality, because the Ironton-Galesville groundwater is believed to be poorer in quality than the Ancell Unit groundwater, containing, most notably, high concentrations of dissolved radium and barium (Gilkeson et al., 1983). Concentrations of barium and radium in the Ironton-Galesville often exceed the USEPA drinking water standards of 1 milligram per liter and 5 picocuries per liter, respectively.
- Since drawdown in the deep aquifers causes water levels in the wells to decline, it can cause deep well productivity to decline and pumping expenses to increase. These problems are exacerbated with desaturation of the Ancell Unit.

Because of these potential difficulties, maps have been developed for this study showing the *available head* above the top of the Ancell. Available head is the difference between Ancell Unit head and the top of the Ancell. These maps do not show areas where available head remains above 100 ft, but areas with less than 100 ft of available head might be considered for monitoring or as priorities for planning. Simulated Ancell Unit head remains above the top of the Ancell Unit in 2002, but pumping from deep wells has caused Ancell head to decline to within 100 ft of the top of the unit in the Aurora area (Figure 15). Model simulations suggest that the areas of low available head southwest of Kane County, adjacent to the area where the Ancell is absent, existed during predevelopment. Maps of future simulated available head are included in Section 5.3.2.

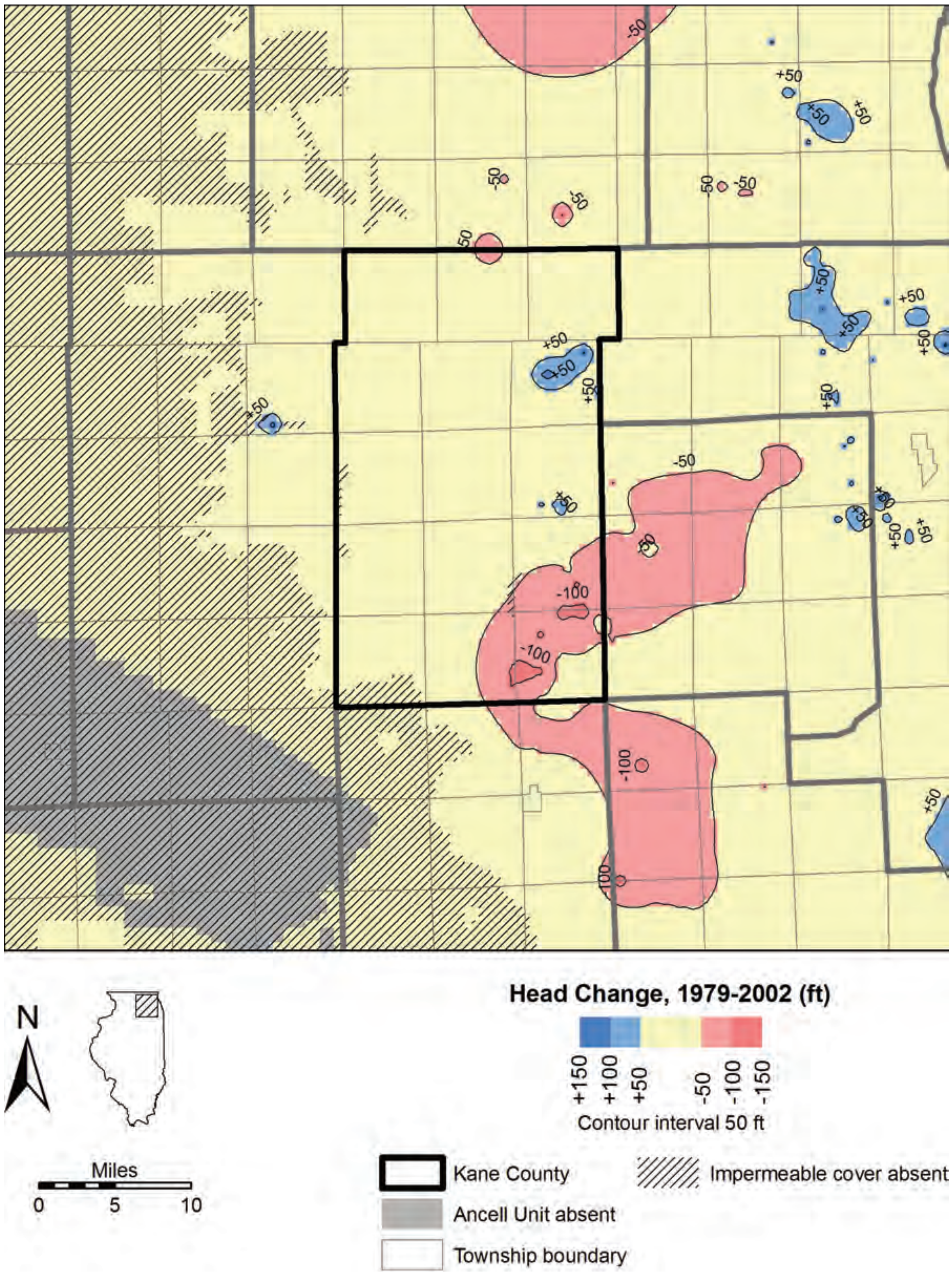

Figure 14. Change in simulated head in the Ancell Unit in the Kane County area, 1979-2002.

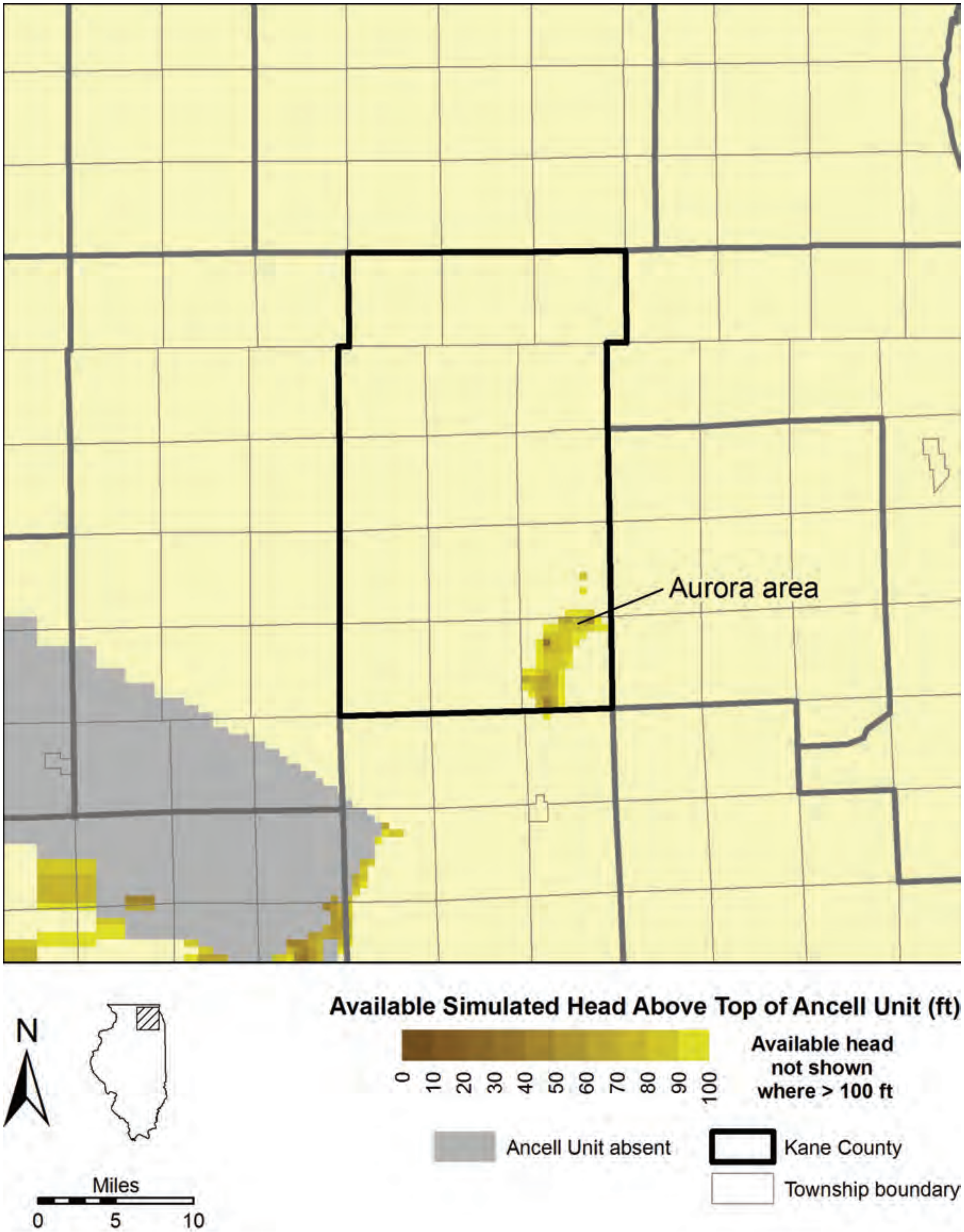

Figure 15. Available simulated head above the top of the Ancell Unit in 2002.

5.2.2. Head Change in Shallow Aquifers

Drawdown in the shallow aquifers is much less than in the deep aquifers because withdrawn groundwater is replaced at much higher rates. Two large areas of significant shallow aquifer drawdown (here defined as drawdown greater than or equal to 20 ft) affected the Kane County area in 2003, both crossing the borders of Kane County. A map of simulated drawdown in the Shallow Bedrock Aquifer, the deepest of the shallow aquifers, is representative of drawdown in all overlying aquifers (Figure 16). Drawdown in these areas is partially attributable to pumping outside of the county and is compounded by large withdrawals, low hydraulic conductivities, and hydrogeological settings that reduce streamflow capture. The significant drawdowns observed in northeastern Kane and southeastern McHenry Counties are the consequence of wells operated by the Villages of Algonquin, Carpentersville, East Dundee, Lake in the Hills, and the City of Crystal Lake (Figure 17). The drawdown in this area exceeds 60 ft in Kane County near the McHenry County border, in the area of Algonquin wells 7, 8, 9, and 11. Pumping by the City of West Chicago and Village of Warrenville in DuPage County causes a second area of significant drawdown that crosses into Kane County and impacts the Cities of Batavia and Geneva (Figure 18).

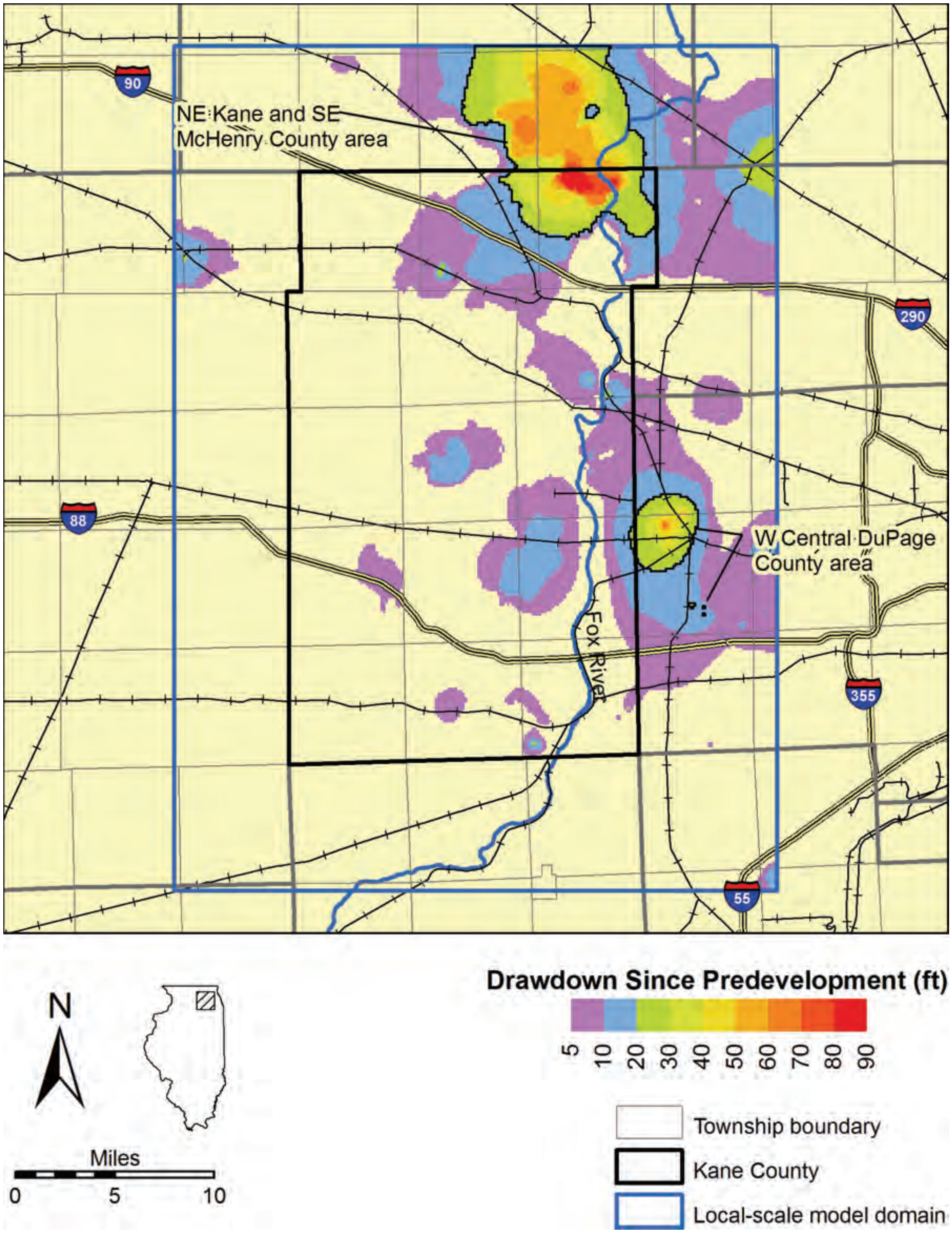

Figure 16. Simulated 2003 drawdown in the Shallow Bedrock Aquifer in the Kane County vicinity, with areas of significant drawdown mentioned in the text identified.

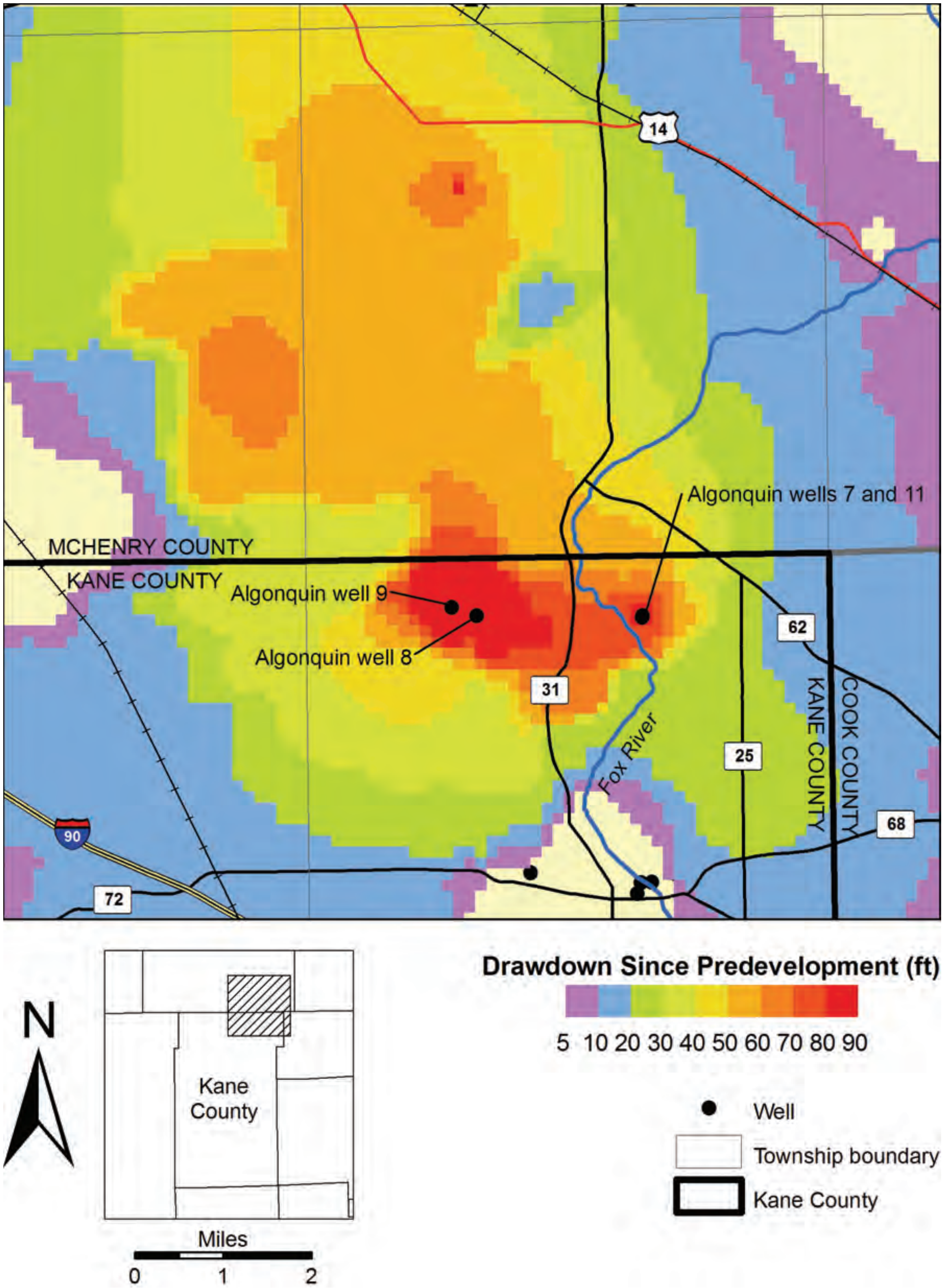

Figure 17. Simulated 2003 drawdown in the Shallow Bedrock Aquifer in northeastern Kane County and southeastern McHenry County.

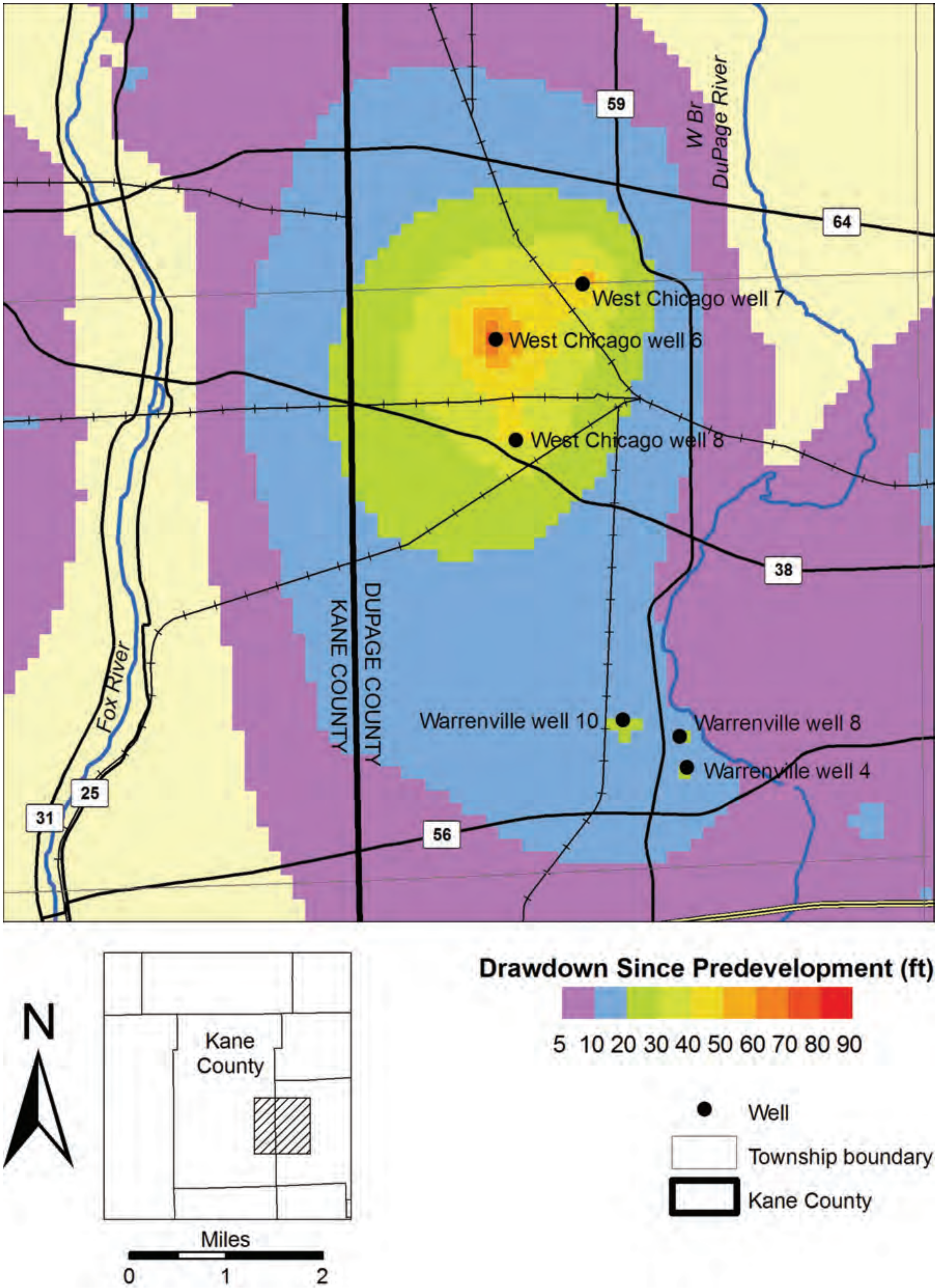

Figure 18. Simulated 2003 drawdown in the Shallow Bedrock Aquifer in east-central Kane County and west-central DuPage County.

5.2.3. Changes in Streamflow

As discussed in Section 5.1, a proportion of the water withdrawn from shallow wells originated as captured streamflow, meaning that the pumped water is either groundwater diverted to wells that otherwise would discharge to streams or that it is water induced to leak from stream channels by pumping wells. The local-scale model suggests that, as of 2003, streamflow capture by groundwater pumping had reduced natural groundwater discharge to streams in and near Kane County by about 17 percent (Figure 19). This capture of streamflow by wells would be observable as a reduction in base flow in streams (that part of streamflow originating as groundwater discharge), although it is likely that discharge of effluent compensates for the base flow reduction in some stream reaches downstream of wastewater treatment plant outfalls (Knapp et al., 2007). This reduction of natural groundwater discharge is irregularly distributed and is greatest in streams in the eastern part of the county where shallow pumping is greatest (Figure 20, Table 1). Model simulations suggest that the greatest reduction in natural groundwater discharge by 2003 occurred in Mill Creek upstream of Batavia (reach 512 in Figure 20). In this area, public supply wells operated by the Cities of Batavia and Geneva have reduced groundwater discharge by 68 percent relative to nonpumping conditions (Figure 21).

Other stream reaches receiving substantially less natural groundwater discharge in 2003 as a consequence of pumping include the West Branch of the DuPage River upstream of Warrenville (reach 520 in Figure 20, 52 percent reduction) and the Fox River upstream of Algonquin (reach 503 in Figure 20, 46 percent reduction). Both of these streams lie largely outside Kane County, however, and therefore outside the area of greatest model accuracy.

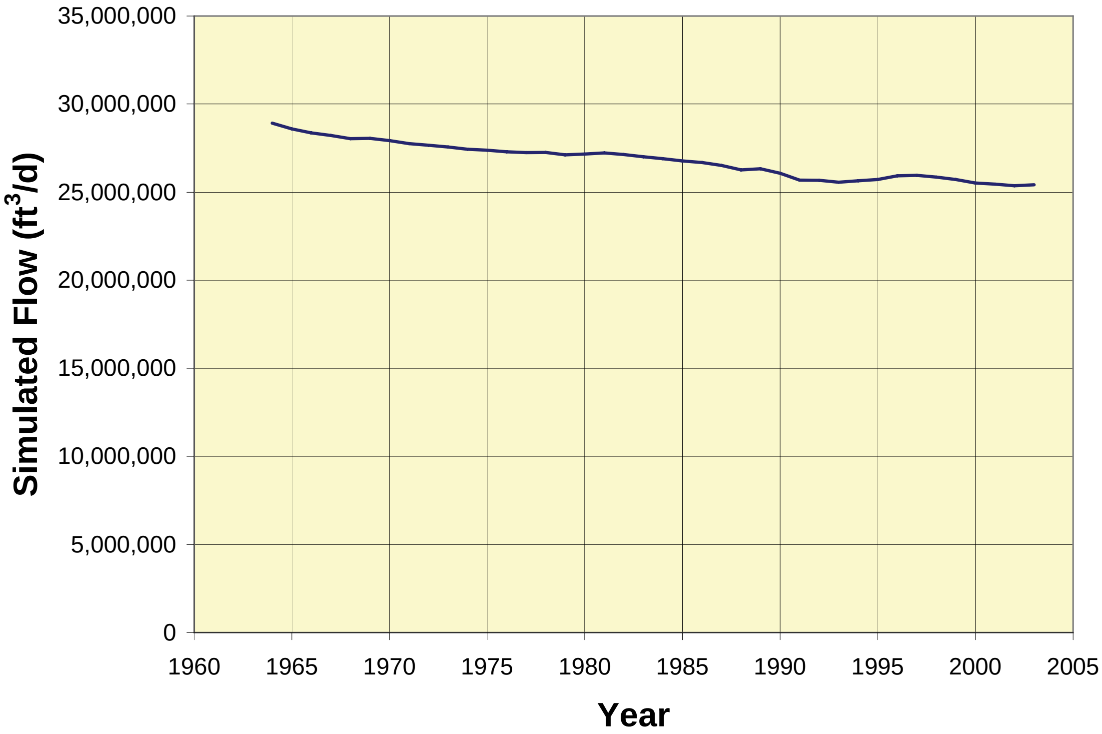

Figure 19. Total simulated natural groundwater discharge in local model domain.

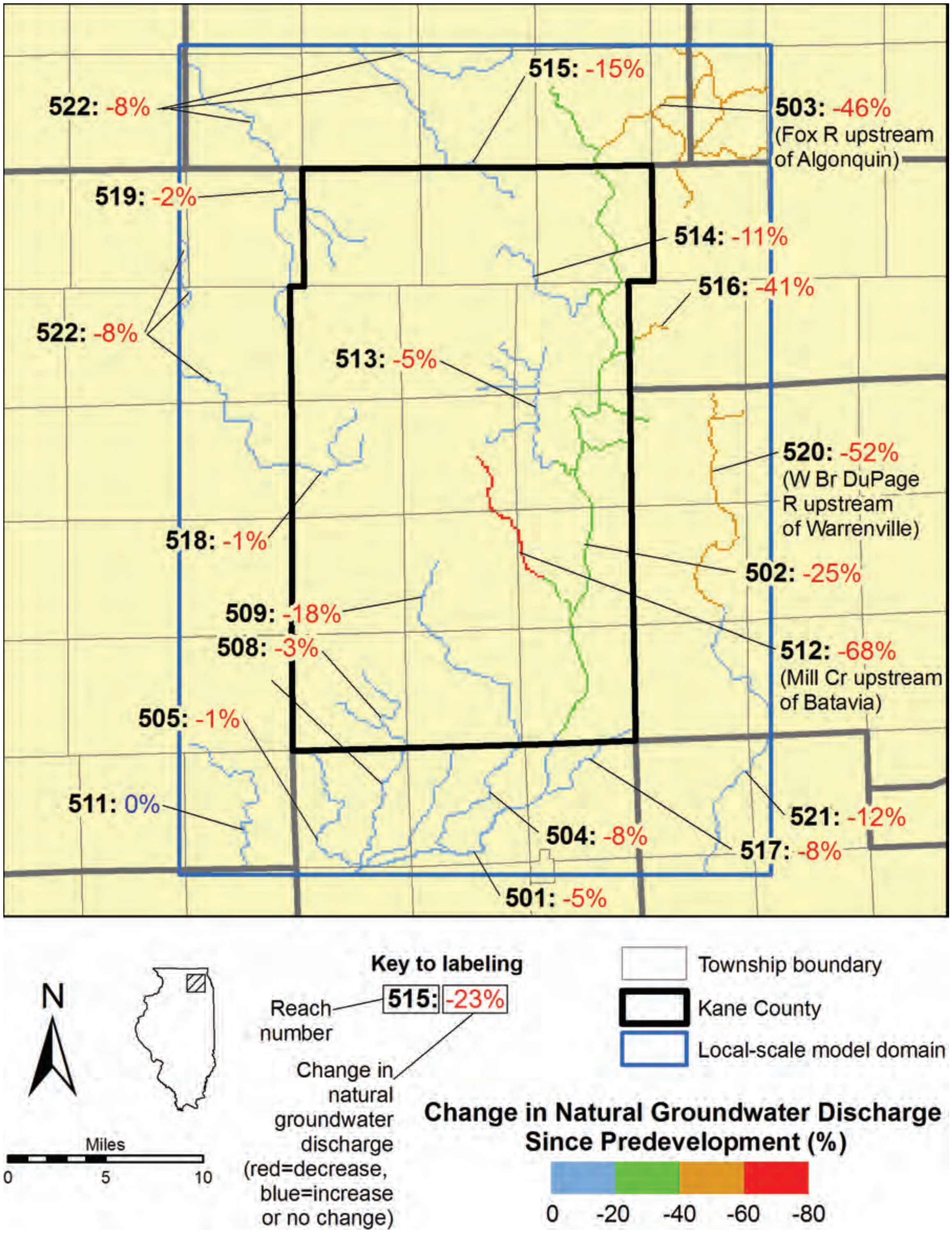

Figure 20. Change in natural groundwater discharge caused by pumping by stream reach in the Kane County area in 2003, with reaches discussed in text identified (see Table 1 for identification of all reaches).

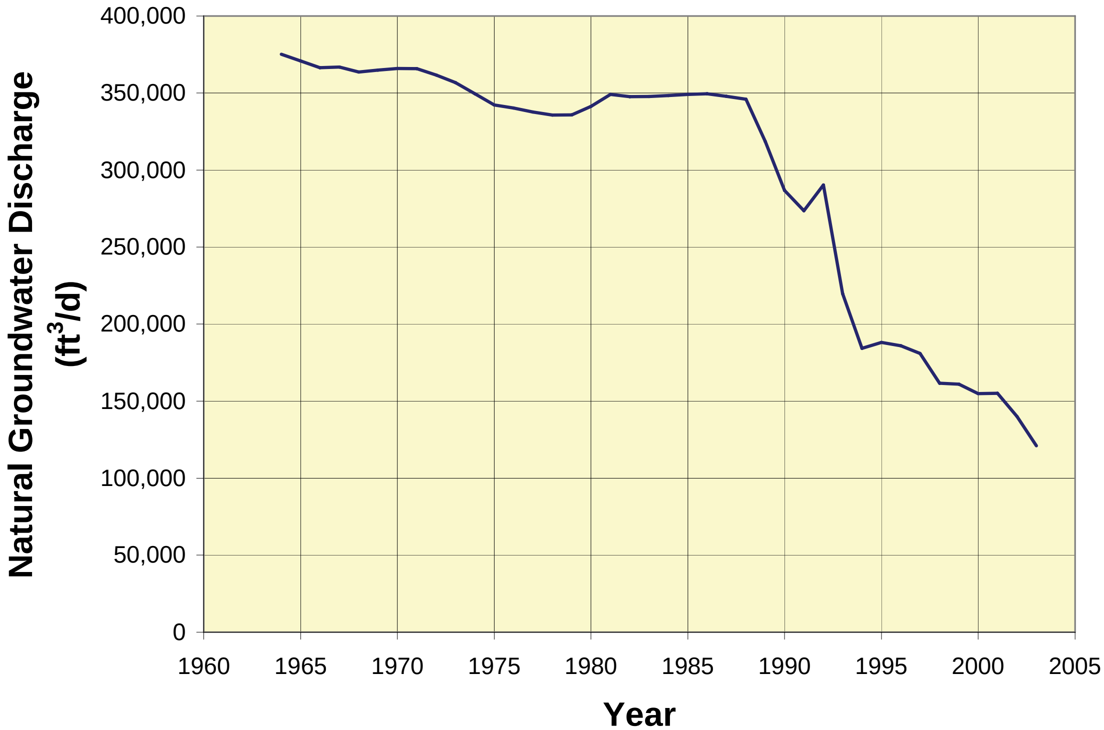

Figure 21. Simulated natural groundwater discharge to Mill Creek upstream of Batavia (reach 512).

Table 1. Principal Streams Included in Reaches Shown in Figure 20 and Change in Natural Groundwater Discharge Due to Pumping in 2003 (%)

Reach Number	*Principal Streams*	*Change in Natural Groundwater Discharge Due to Pumping (%)*
501	Fox River downstream of Montgomery; Big Rock Cr downstream of Kane County boundary	-5
502	Fox River from Algonquin to Montgomery; Norton Cr; Brewster Cr; Crystal Cr; lower portions of Mill Cr, Ferson Cr, Poplar Cr, and Tyler Cr	-25
503	Fox River upstream of Algonquin; Spring Cr; Flint Cr	-46
504	Blackberry Cr from Montgomery to Yorkville	-8
505	Little Rock Cr downstream of Kane County boundary	-1
507	Big Rock Cr downstream of Kane County boundary	-11
508	Big Rock Cr upstream of Kane County boundary; Welch Cr	-3
509	Blackberry Cr from Elburn to Montgomery	-18
511	Somonauk Cr	0
512	Mill Cr upstream of Batavia	-68
513	Ferson Cr upstream of St Charles; Otter Cr; Stony Cr; Fitchie Cr	-5
514	Tyler Cr	-11
515	S Br Kishwaukee River upstream of Huntley	-15
516	Poplar Cr	-41
517	Waubonsie Cr	-8
518	Union Ditch No 3; Virgil Ditch No 3; Union-Virgil Ditch No 2	-1
519	Upper Coon Cr	-2
520	W Br DuPage River upstream of Warrenville	-52
521	DuPage River; W Br DuPage River downstream of Warrenville	-12
522	Aggregated tributaries of S Br Kishwaukee River outside Kane County	-8

5.3. Modeling of Future Conditions

5.3.1. Scenarios

After calibration, the models were used to simulate possible future scenarios of groundwater pumping and changes in recharge rates that might result from climate variability. A total of four scenarios were simulated for the period 2005 to 2050 (Table 2), including two scenarios that assume no change in recharge (i.e., no impact of climate variability) for two different trends in the growth of groundwater pumping (previously discussed as *low*- and *high-pumping conditions* in Section 4). A third scenario, the most resource-intensive of the four, assumes the high-pumping trend and reduced recharge rates. The last scenario, the least resource-intensive, assumes the low-pumping trend and elevated recharge rates. Although this study examines only these four scenarios, the model and its supporting databases have been structured to permit a knowledgeable user to simulate a wide range of future scenarios.

The four scenarios simulated for the investigation were chosen to represent plausible well configurations and pumping rates in addition to a plausible range of recharge rates. Pumping rates are based on county-level forecasts of water withdrawals reported by Dziegielewski et al. (2004, 2005). Low-pumping conditions were characterized based on estimates of Dziegielewski et al. (2005) that assume continued improvements in water conservation by public water systems and self-supplied commercial and industrial facilities. High-pumping conditions are based on estimates of Dziegielewski et al. (2005) that assume improvements in water conservation by such water systems made before 2001 do not continue. Well locations and source aquifers are assumed to be the same as those for wells in operation during the period 2000-2003. The range of recharge rates is intended to simulate the effect that climate variability might have on groundwater recharge in the Kane County area. The simulated range of recharge rates is based on reported plausible ranges of recharge rates in the region for the historic period (Arnold et al., 2000; Bloyd, 1974; Cherkauer, 2001; Holtschlag, 1997). For brevity, the four modeled scenarios are referred to as *HL* (high pumping, low recharge), *HC* (high pumping, calibrated recharge), *LC* (low pumping, calibrated recharge), and *LH* (low pumping, high recharge).

For each scenario, we report change in head in significant aquifers and change in natural groundwater discharge, because these two effects, if large enough, might be considered unacceptable to residents of Kane County. For example, drawdown (reduction in head), affects water levels in wells, and therefore may cause reduced yields and increased pumping expenses. Reduction in natural groundwater discharge reduces stream base flow and consequently may affect the availability of streamflow for water supply, maintenance of riparian habitats, and recreation.

Table 2. Transient Simulations to 2050

<table>
<tr><th>Abbreviation</th><th>Pumping Conditions</th><th>Recharge Conditions</th><th>Intensity of Resource Use</th><th>Figures Showing Results</th></tr>
<tr><td>HL</td><td>High</td><td>Low</td><td>Most</td><td>Figure 31, Figure 35, Figure 36</td></tr>
<tr><td>HC</td><td>High</td><td rowspan="2">Calibrated</td><td rowspan="2">Intermediate</td><td>Figure 22, Figure 25, Figure 27, Figure 28,
Figure 29, Figure 32, Figure 35, Figure 37</td></tr>
<tr><td>LC</td><td>Low</td><td>Figure 23, Figure 26, Figure 27, Figure 28, Figure 30, Figure 33, Figure 35, Figure 38</td></tr>
<tr><td>LH</td><td>Low</td><td>High</td><td>Least</td><td>Figure 34, Figure 35, Figure 39</td></tr>
</table>

5.3.2. Head Change in Deep Aquifers

Simulations of these future scenarios using the regional-scale model suggest that recharge variations due to climate variability will have a negligible effect on heads in the deep aquifers of the region before 2050. That is, model simulations of the HL and HC scenarios are nearly identical, as are simulations of the LC and LH scenarios. The results are so similar that this discussion is restricted to the results of regional modeling the HC and LC scenarios.

Model simulations suggest that head in the Ancell Unit will continue to decline through 2049 in all of Kane County, and declines after 2002 will exceed 50 ft in much of the county given both high- and low-pumping conditions. The greatest declines in Ancell Unit head in northeastern Illinois are projected to occur in the vicinity of Joliet and Aurora. In limited parts of these areas, simulated heads decline more than 150 ft between 2002 and 2050 under both high- and low-pumping conditions (Figure 22, Figure 23). The simulations suggest heads will continue to recover to a limited degree in eastern parts of northeastern Illinois, where many water systems abandoned deep wells in the 1980s and 1990s. The combination of continued head declines in the Joliet-Aurora area and continued head recovery in Cook and DuPage Counties shifts the deepest parts of the Chicago area cone of depression west-southwest to the Joliet-Aurora area (compare Figure 24 with Figure 25 and Figure 26). In most of Kane County, model simulations suggest that the recovery of Ironton-Galesville heads, which began in the 1980s, will continue at decreasing rates, followed by a renewed decline (Figure 27, Figure 28).

The modeling suggests that the Ancell Unit may become partially desaturated (i.e., the pore spaces may drain) by 2049 (Figure 29, Figure 30). These areas are surrounded by regions where available Ancell Unit simulated head is less than 100 ft. As discussed in Section 5.2.1, deep wells in the areas where Ancell Unit is near to the top of the Ancell, and where the Ancell Unit is partially desaturated, may be vulnerable to increases in arsenic, barium, and radium concentrations that, left untreated, may be harmful to human health. Partial desaturation of the Ancell Unit could also lead to declines in well yield and increased pumping expenses.

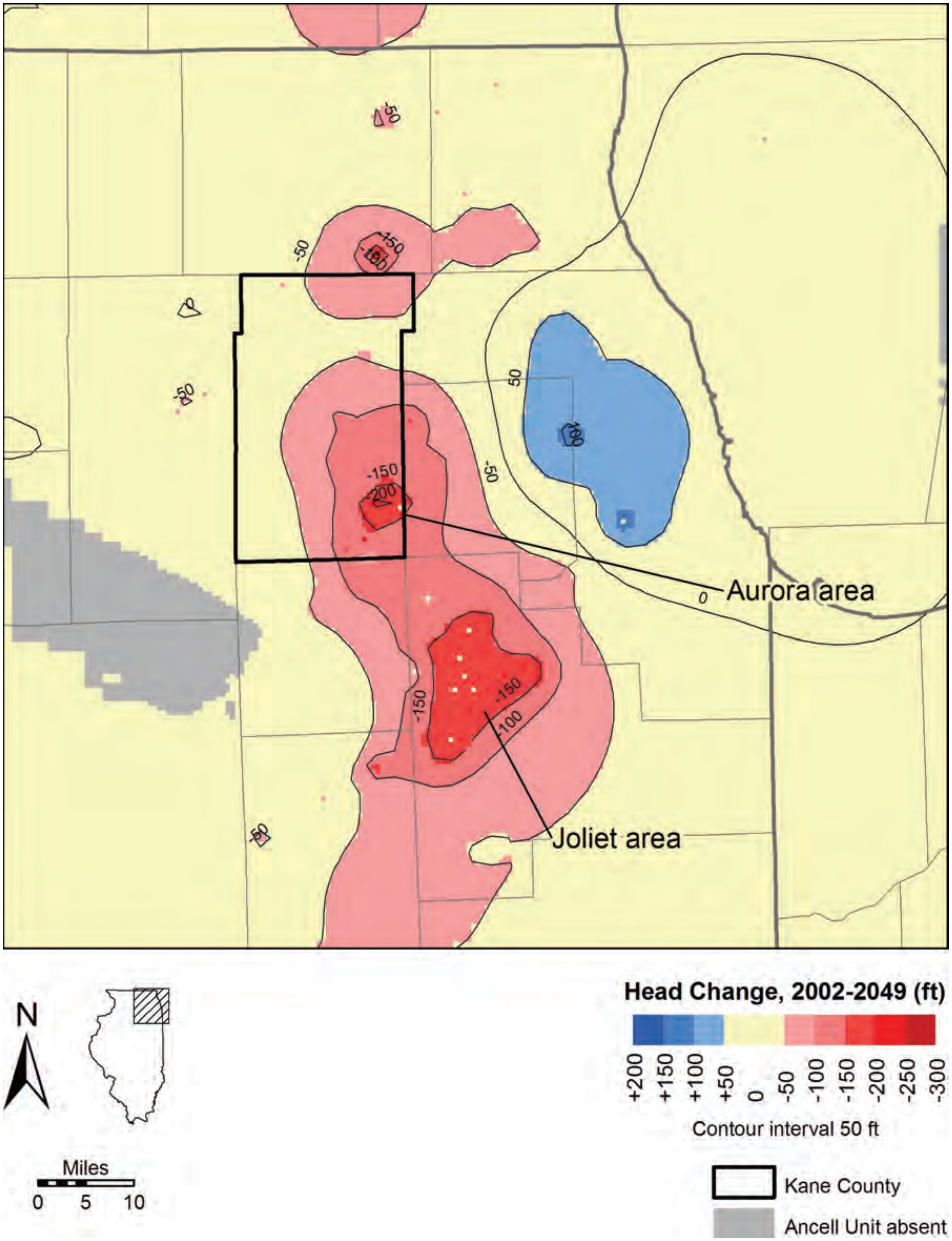

Figure 22. Change in simulated head between the end of 2002 and end of 2049 in Ancell Unit, scenario HC.

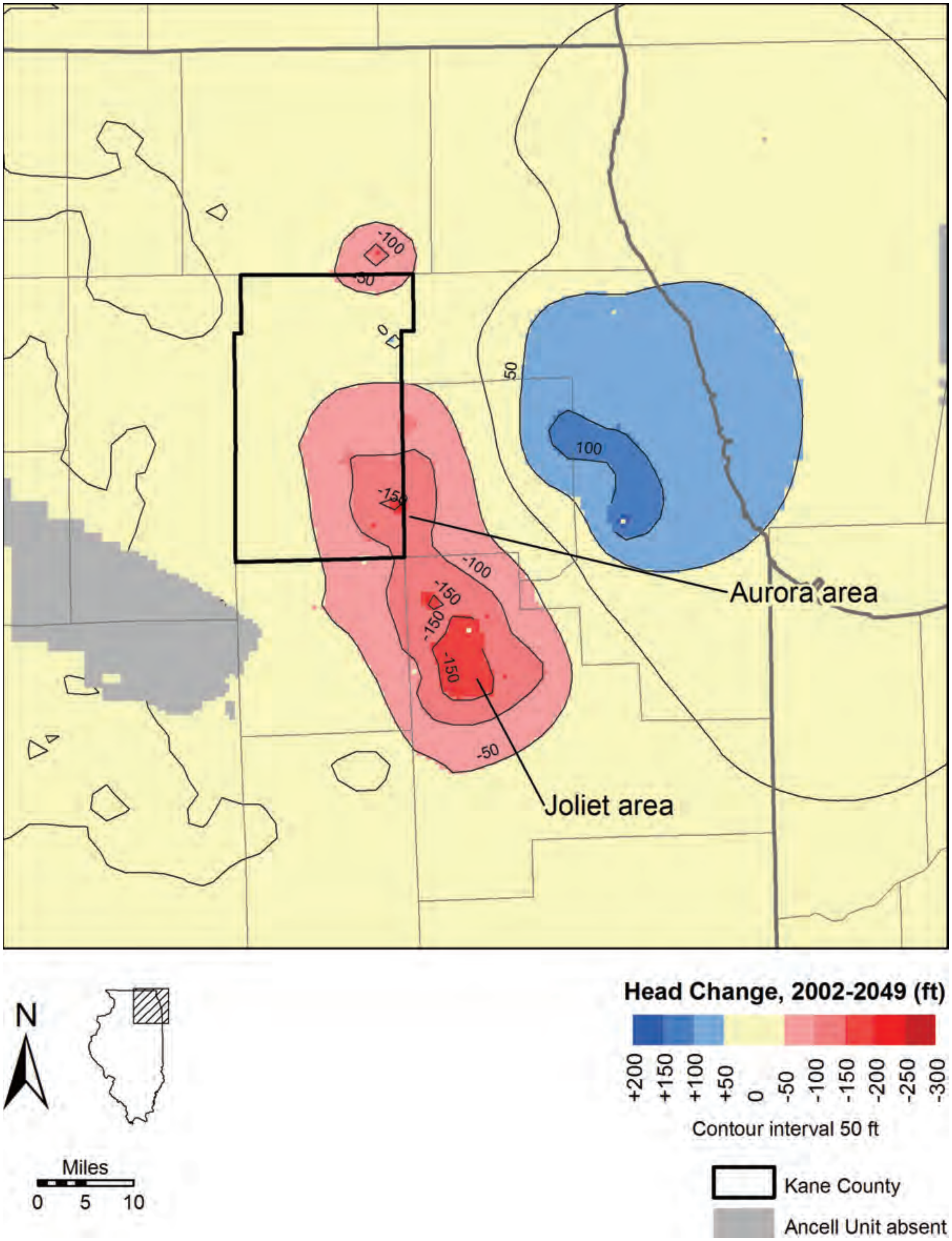

Figure 23. Change in simulated head between the end of 2002 and end of 2049 in Ancell Unit, scenario LC.

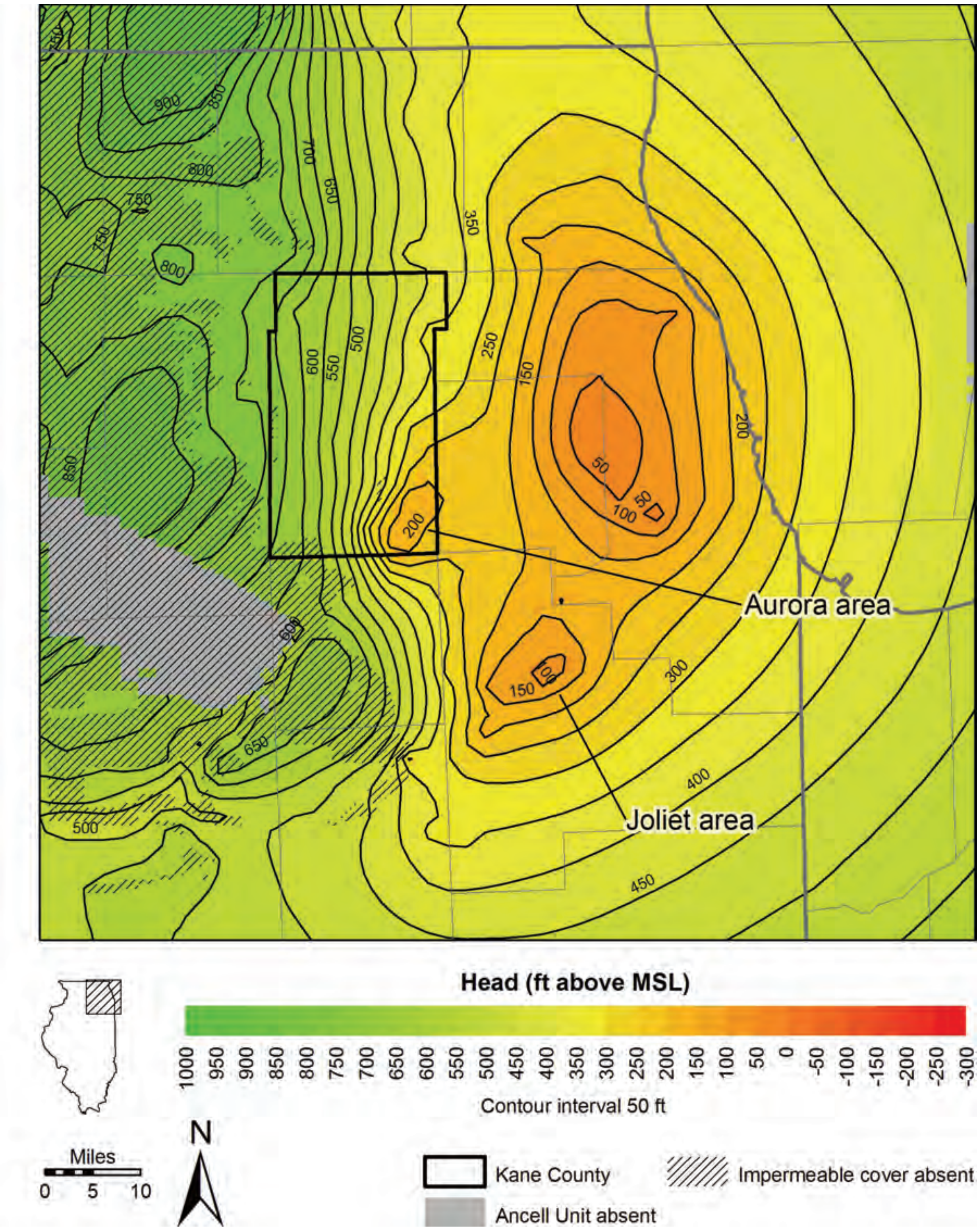

Figure 24. Simulated head in Ancell Unit at the end of 2002.

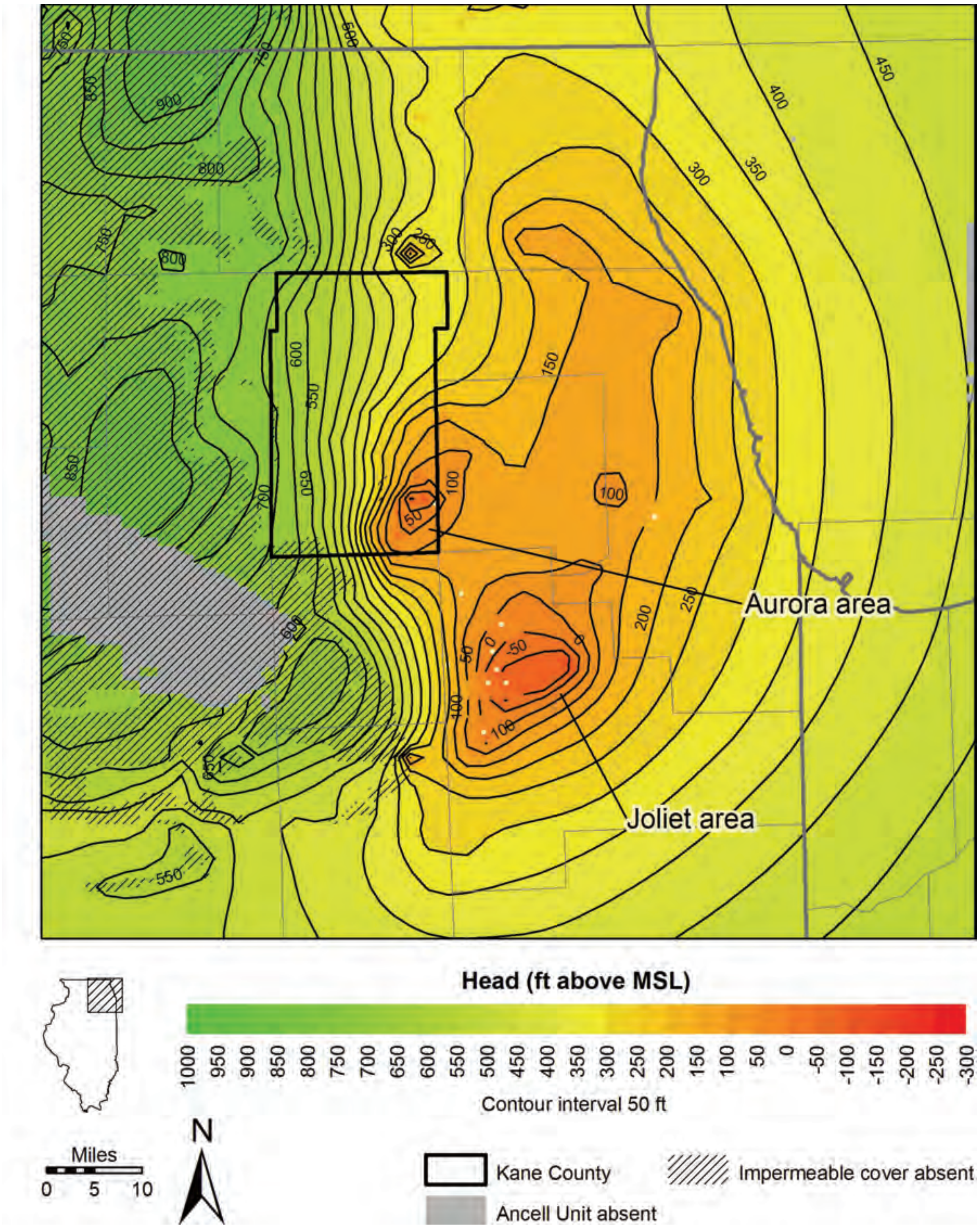

Figure 25. Simulated head in Ancell Unit at the end of 2049, scenario HC.

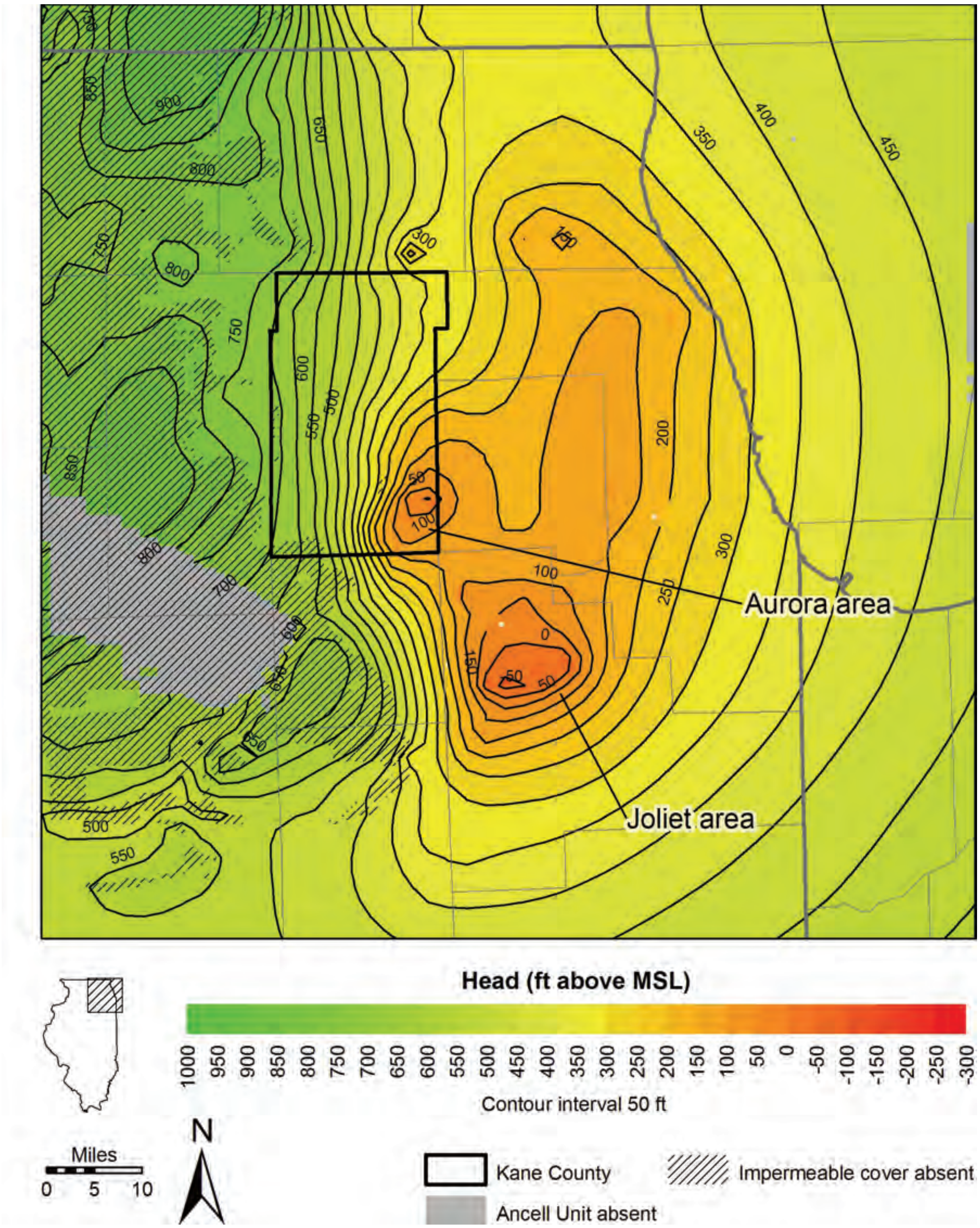

Figure 26. Simulated head in Ancell Unit at the end of 2049, scenario LC.

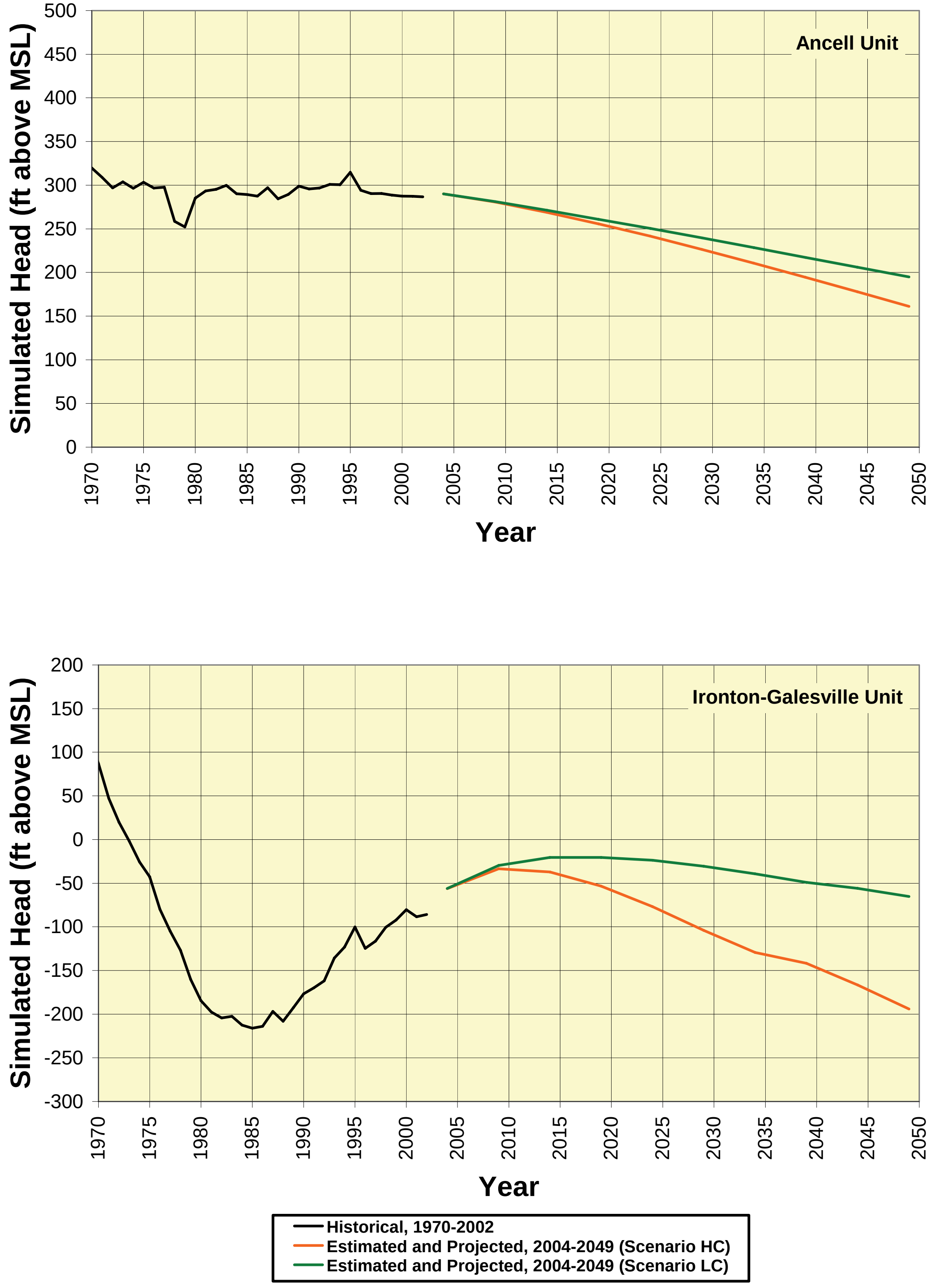

Figure 27. Simulated head from end of 1970 to end of 2049 in Ancell (top) and Ironton-Galesville Units (bottom) at St. Charles. See Figure 10 and Figure 11 for location.

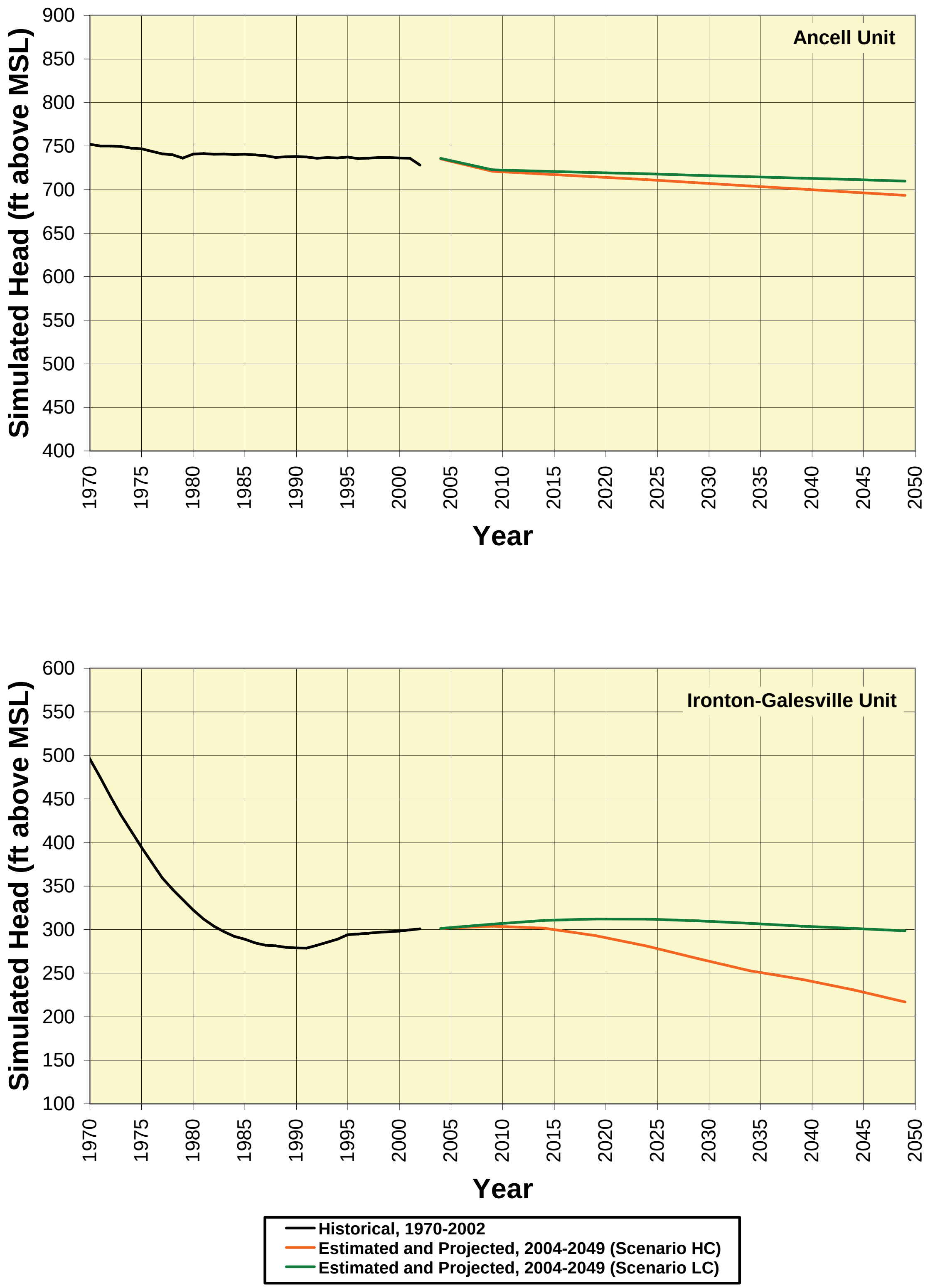

Figure 28. Simulated head from end of 1970 to end of 2049 in Ancell (top) and Ironton-Galesville Units (bottom) at Maple Park. See Figure 10 and Figure 11 for location.

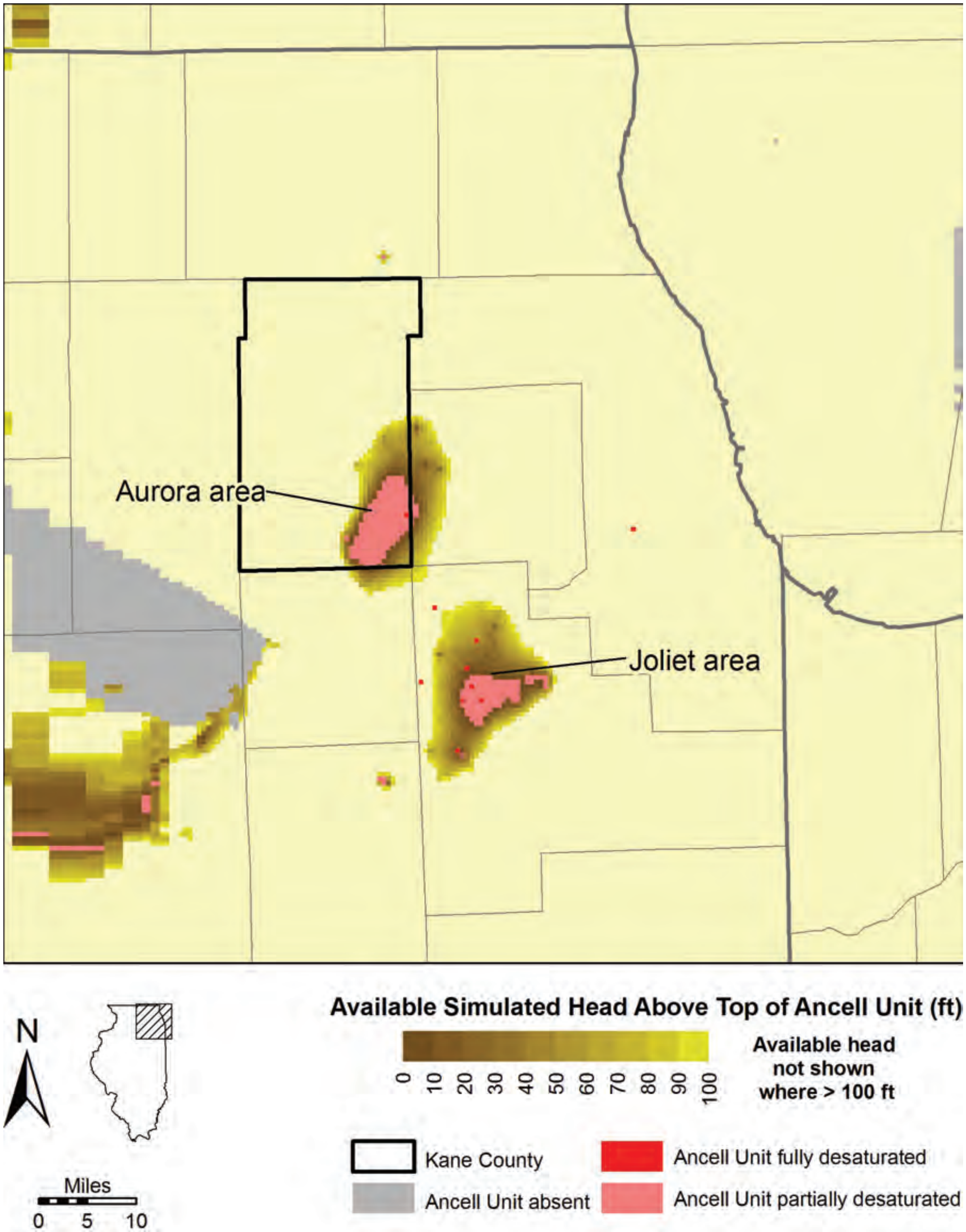

Figure 29. Available simulated head above the top of the Ancell Unit at the end of 2049, scenario HC.

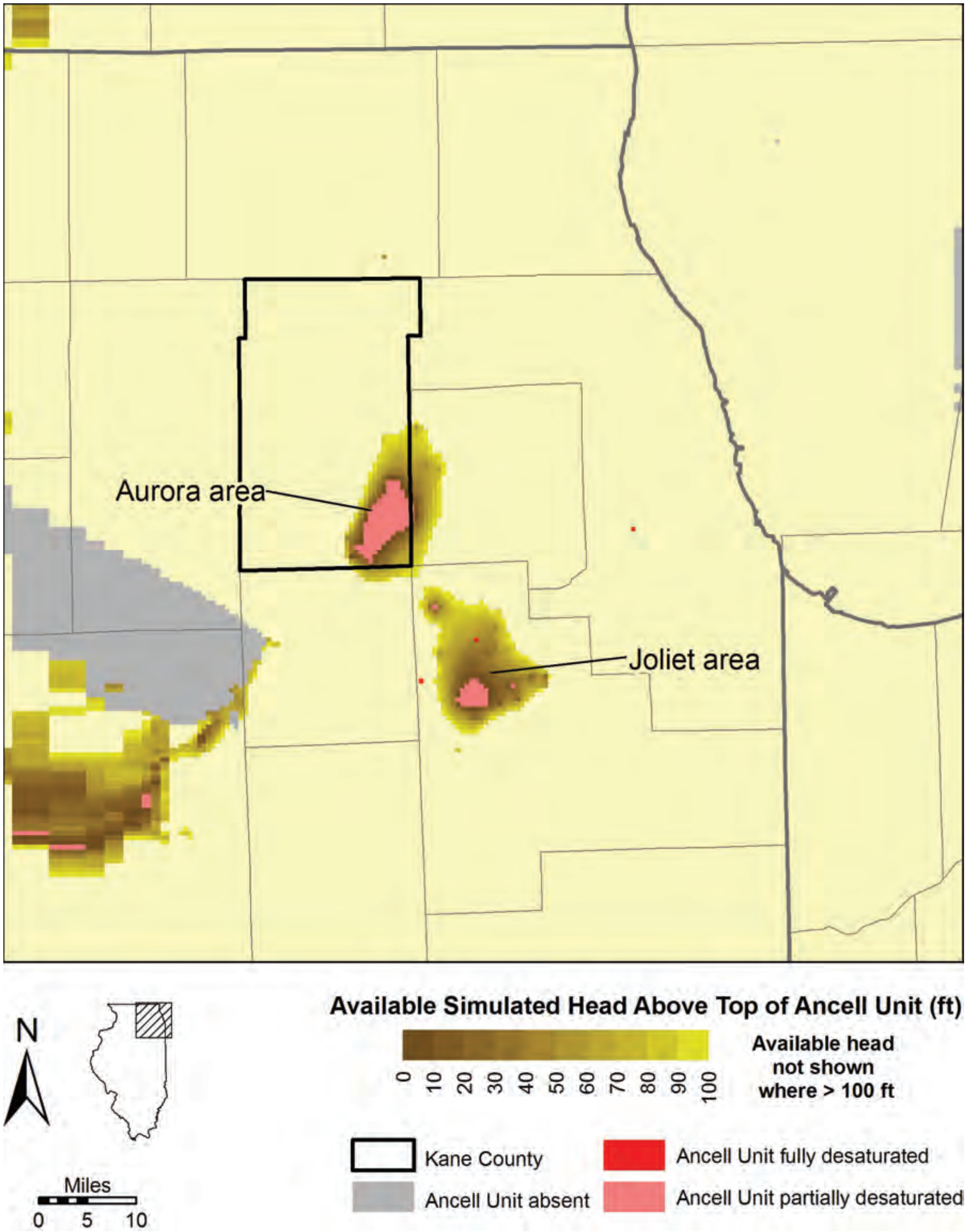

Figure 30. Available simulated head above the top of the Ancell Unit at the end of 2049, scenario LC.

5.3.3. Head Change in Shallow Aquifers

Simulations of future scenarios of pumping and recharge using the local-scale model suggest that areas of significant drawdown present in 2003 will expand by 2050 (compare Figure 16 with Figure 31, Figure 32, Figure 33, and Figure 34). These areas include the southeastern McHenry-northeastern Kane County region and the area surrounding West Chicago and Warrenville public-supply wells in west-central DuPage County. The simulations suggest a greater degree of expansion under high-pumping and low-recharge conditions. In contrast to the deep aquifers, recharge rates have an appreciable effect on the simulated heads of the shallow aquifers. Simulated post-2003 drawdown is as high as 40 to 50 ft in 2050 in the area surrounding Algonquin wells 7 and 11. The simulations suggest that a third area of significant drawdown may develop around public-supply wells operated by Batavia and Geneva. This decline is in the area west of Batavia and Geneva discussed previously as a location of significant decline in natural groundwater discharge to Mill Creek in 2003.

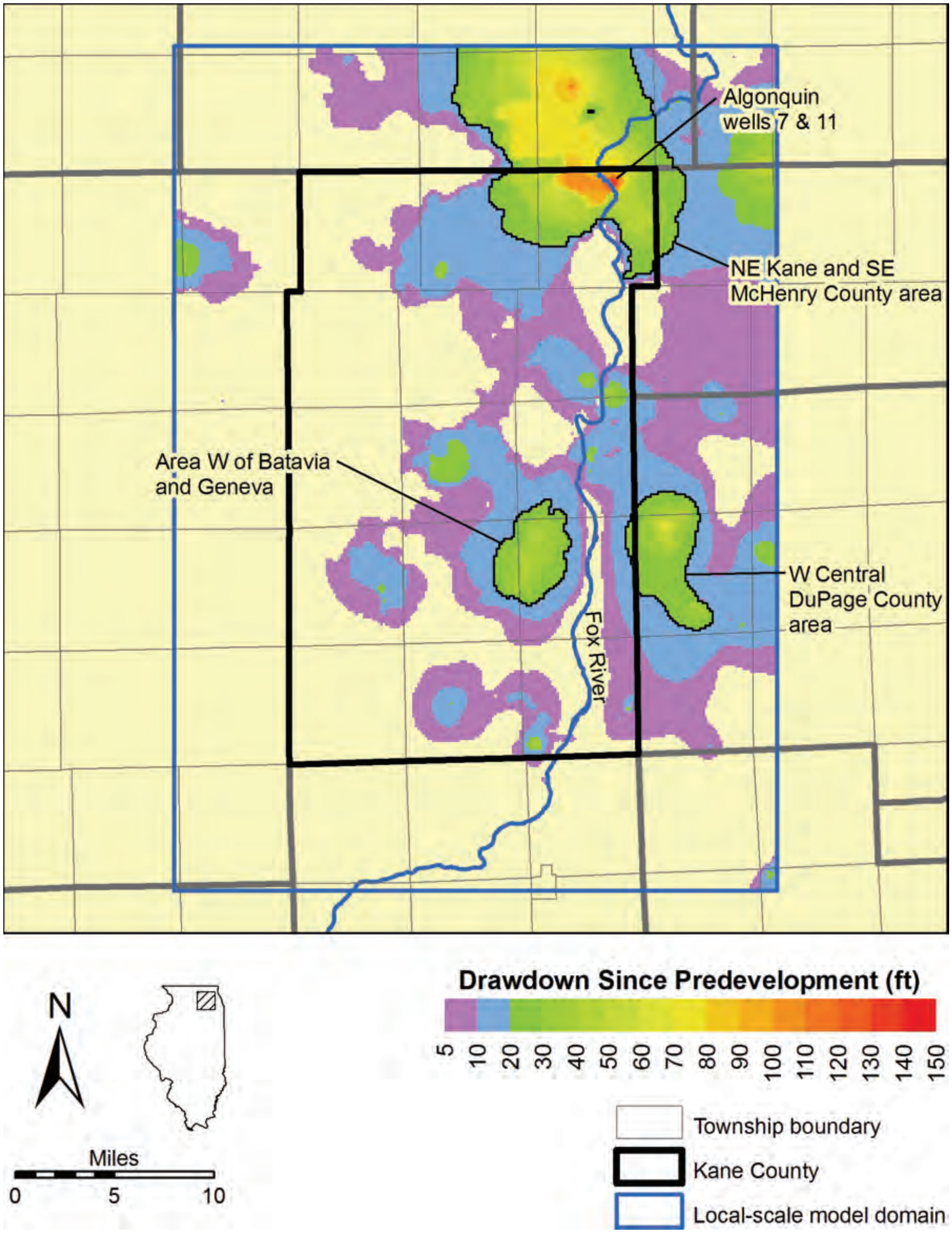

Figure 31. Simulated drawdown in the Shallow Bedrock Aquifer at the end of 2049, scenario HL, with areas of significant drawdown mentioned in the text identified.

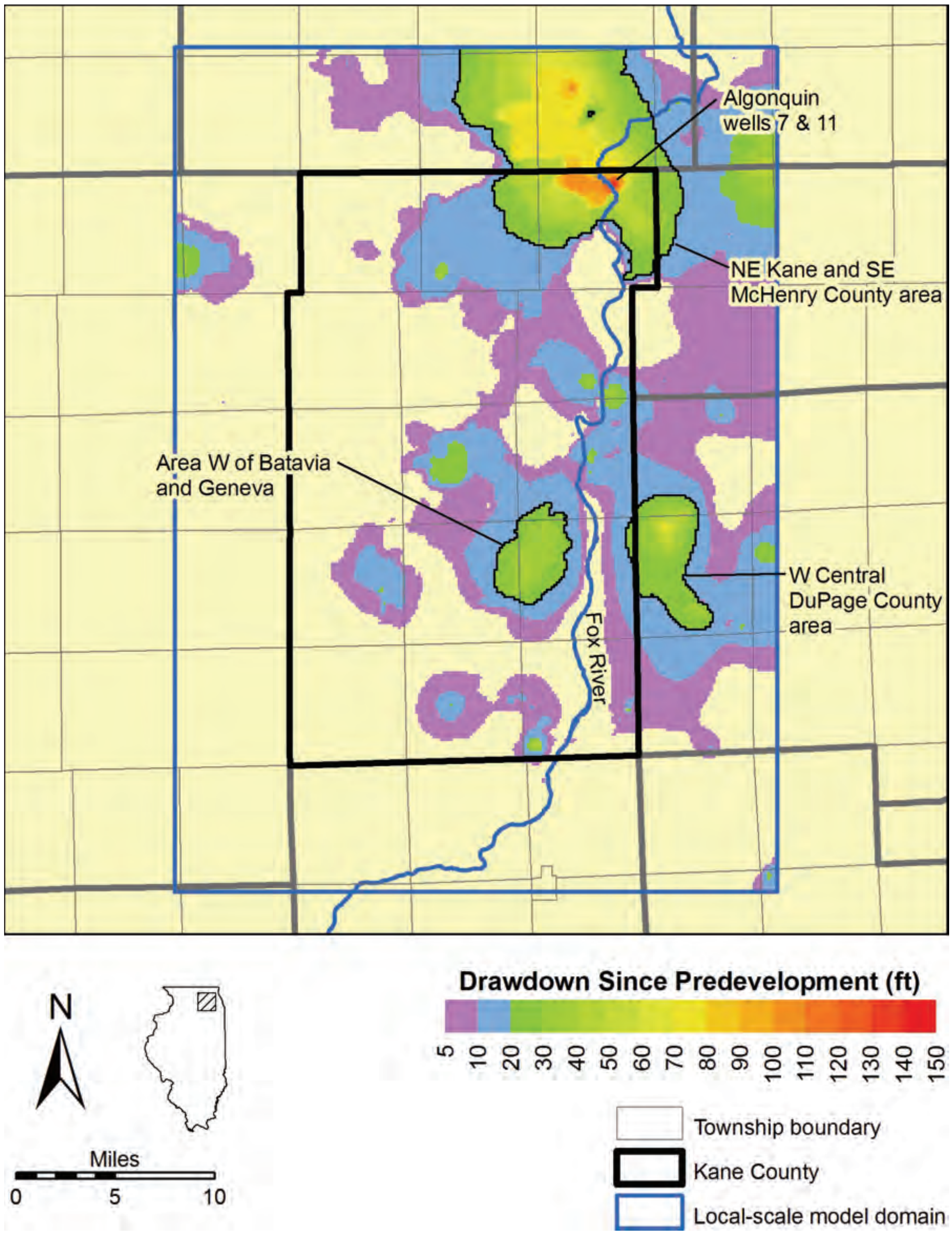

Figure 32. Simulated drawdown in the Shallow Bedrock Aquifer at the end of 2049, scenario HC, with areas of significant drawdown mentioned in the text identified.

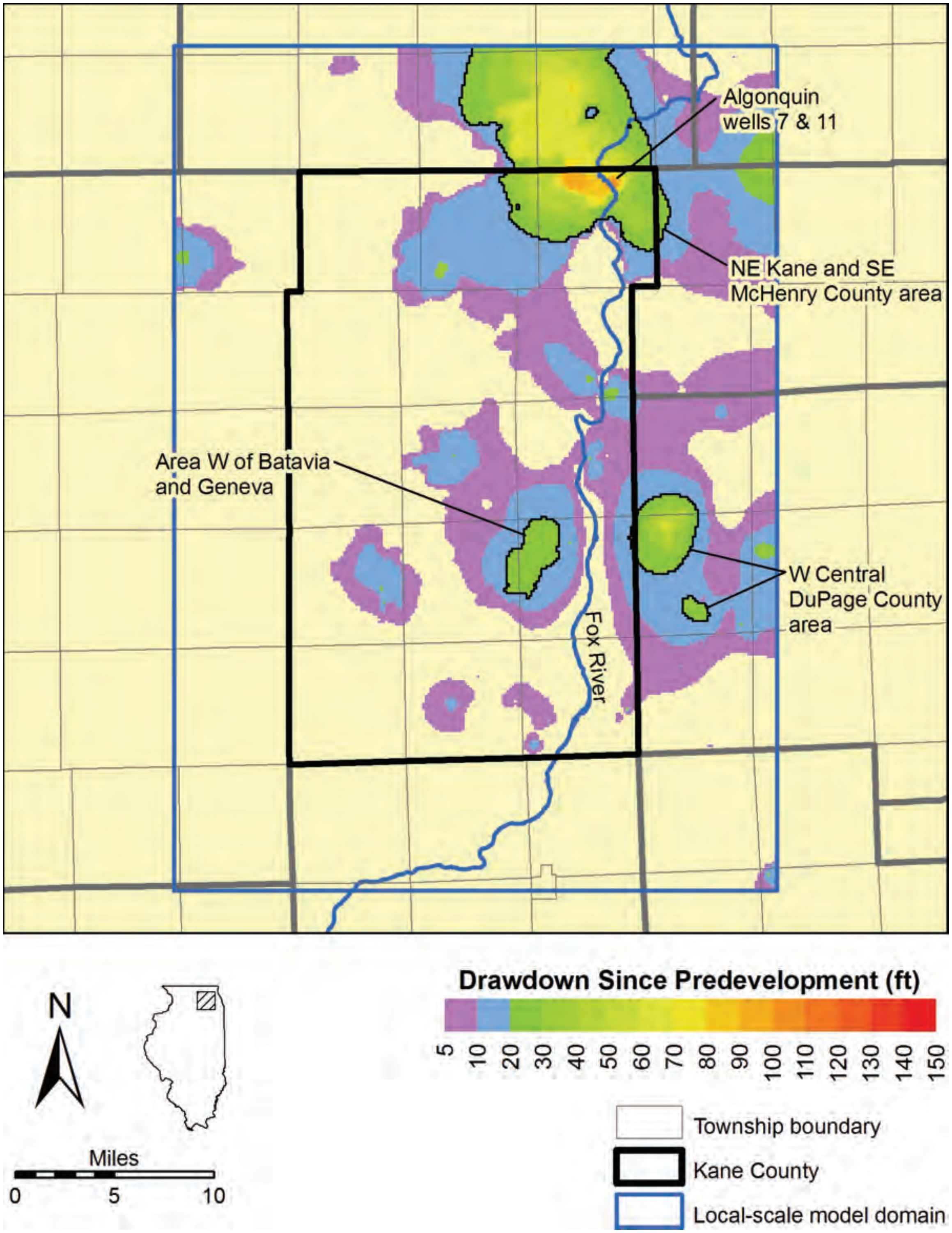

Figure 33. Simulated drawdown in the Shallow Bedrock Aquifer at the end of 2049, scenario LC, with areas of significant drawdown mentioned in the text identified.

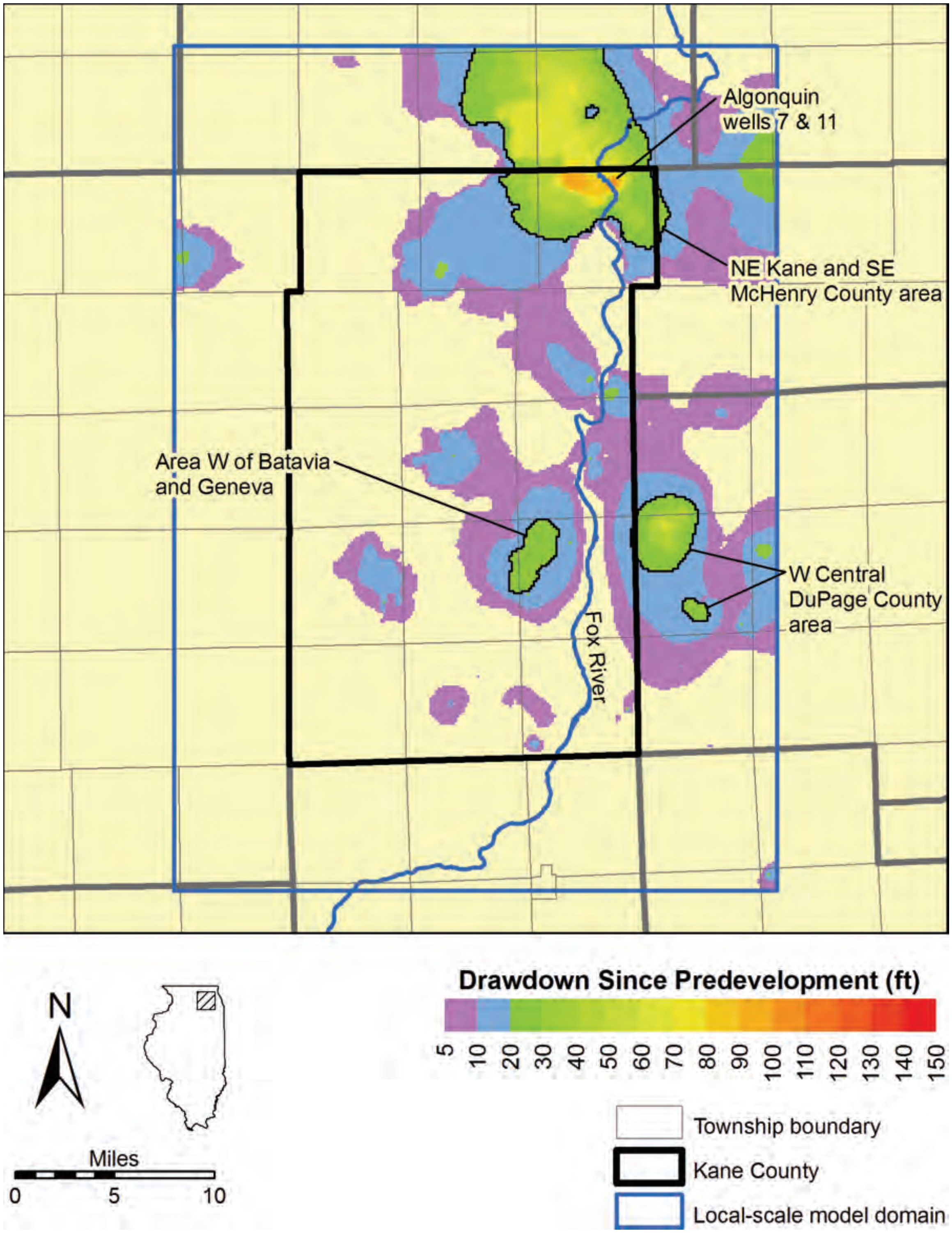

Figure 34. Simulated drawdown in the Shallow Bedrock Aquifer at the end of 2049, scenario LH, with areas of significant drawdown mentioned in the text identified.

5.3.4. Changes in Streamflow

Simulations using the local-scale model suggest that changes in recharge rates would impact base flow to streams in the Kane County area to a greater degree than the shallow or deep heads (Figure 35). In all four scenarios, total simulated natural groundwater discharge to streams in the Kane County area is less in 2025 and 2050 than under predevelopment conditions. The simulations suggest that if recharge rates do not change from historical rates, natural groundwater discharge in the Kane County area in 2050 will occur at rates that are 20 to 26 percent lower than estimated predevelopment rates (scenarios LC and HC, respectively). If recharge rates decline to plausibly low rates and pumping is higher (scenario HL), the model suggests that natural groundwater discharge in 2050 in the Kane County area will occur at a rate that is 38 percent lower than estimated predevelopment rates. If recharge rates increase to plausibly high rates and pumping is less (scenario LH), 2050 discharge will be only 8 percent less than estimated predevelopment rates. Discharge of effluent could compensate for future reductions in natural groundwater discharge, but only in areas downstream of wastewater treatment plant outfalls.

Simulated changes in natural groundwater discharge affect streams in the region irregularly, however (Figure 36, Figure 37, Figure 38, Figure 39, and Table 3). Streams experiencing the greatest reduction in groundwater discharge are located in areas of high pumping from the shallow aquifers and where pumped aquifers are hydraulically connected to the streams. Simulations of high-pumping conditions (scenarios HL and HC) show that natural groundwater discharge to Mill Creek could cease entirely upstream of Batavia. This cessation is simulated to occur between 2015 and 2020 under scenario HL, and in 2050 under scenario HC. High-pumping simulations (scenarios HL and HC) suggest that other large reductions in natural groundwater discharge are predicted for the Fox River upstream of Algonquin and the West Branch of the DuPage River upstream of Warrenville. Both areas lie largely outside of Kane County, however, and therefore outside the area of greatest model accuracy. Nevertheless, the fact that the model simulations suggest significant declines in natural groundwater discharge in these areas cannot be dismissed, and additional investigations are warranted.

Simulation of scenario LH suggests that under high-recharge conditions with less pumping, natural groundwater discharge to some streams could increase above predevelopment rates, although the total rate in the Kane County area is less than that of predevelopment.

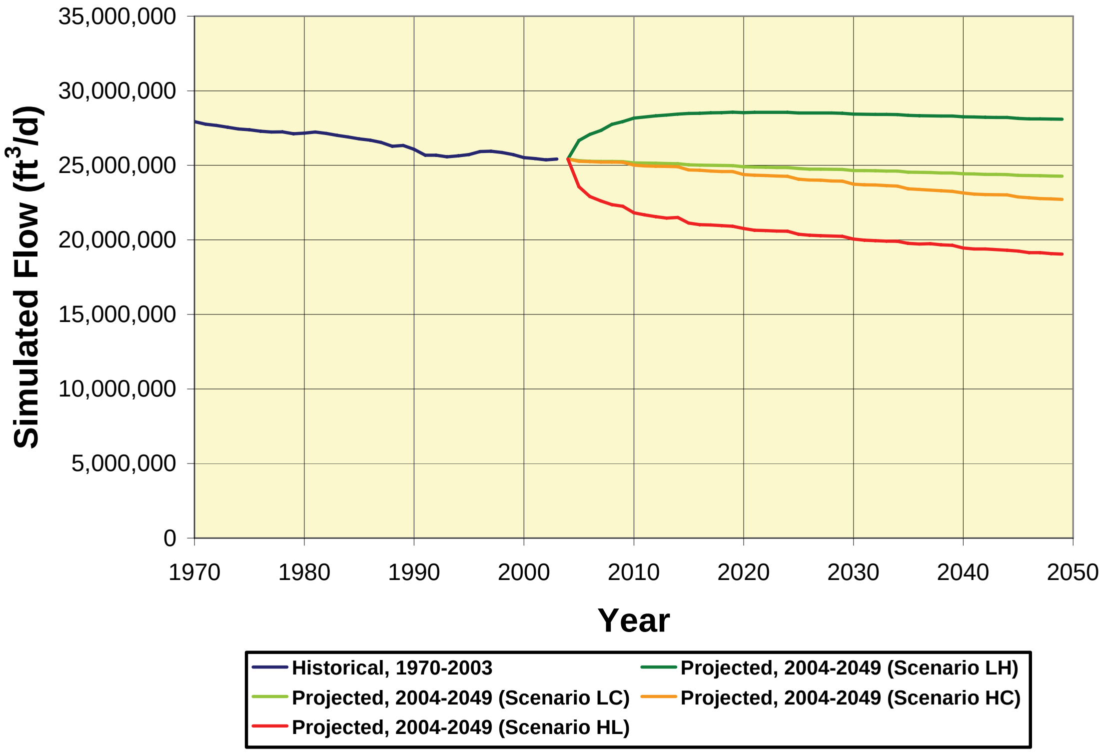

Figure 35. Total natural groundwater discharge to streams in the local-scale model domain.

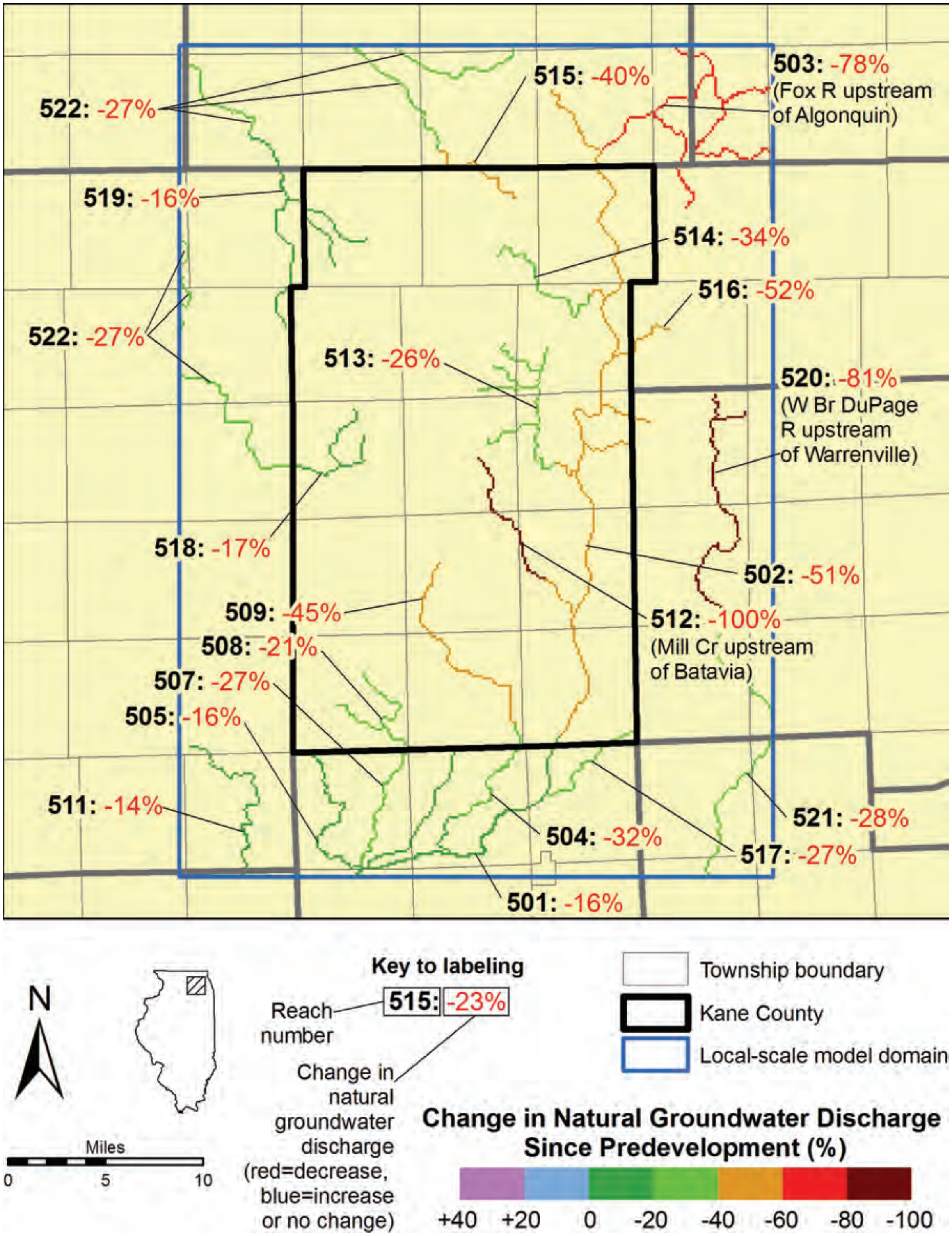

Figure 36. Change in simulated natural groundwater discharge since predevelopment by stream reach in the Kane County area at the end of 2049, scenario HL, with reaches discussed in text identified (see Table 1 for identification of all reaches).

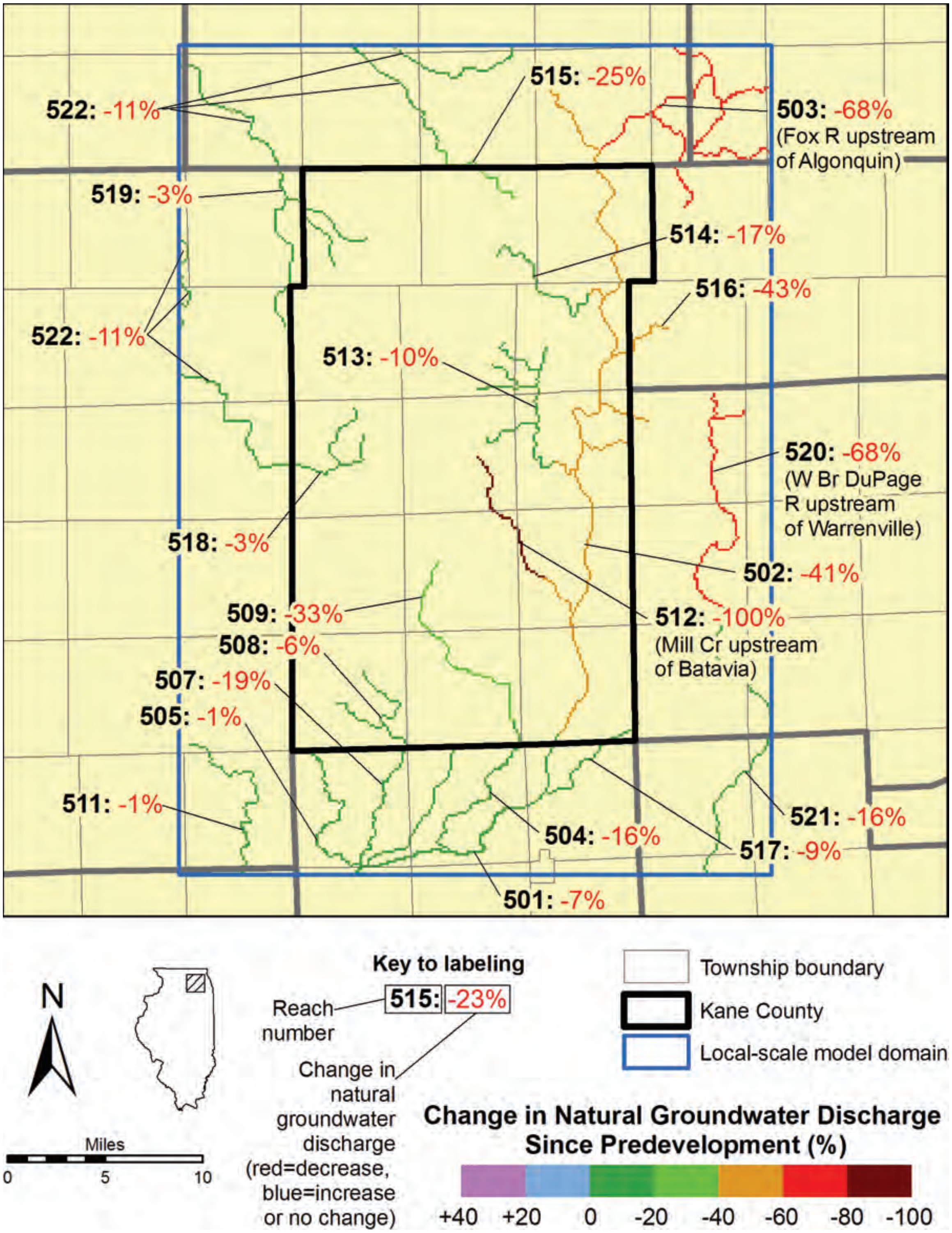

Figure 37. Change in simulated natural groundwater discharge since predevelopment by stream reach in the Kane County area at the end of 2049, scenario HC, with reaches discussed in text identified (see Table 1 for identification of all reaches).

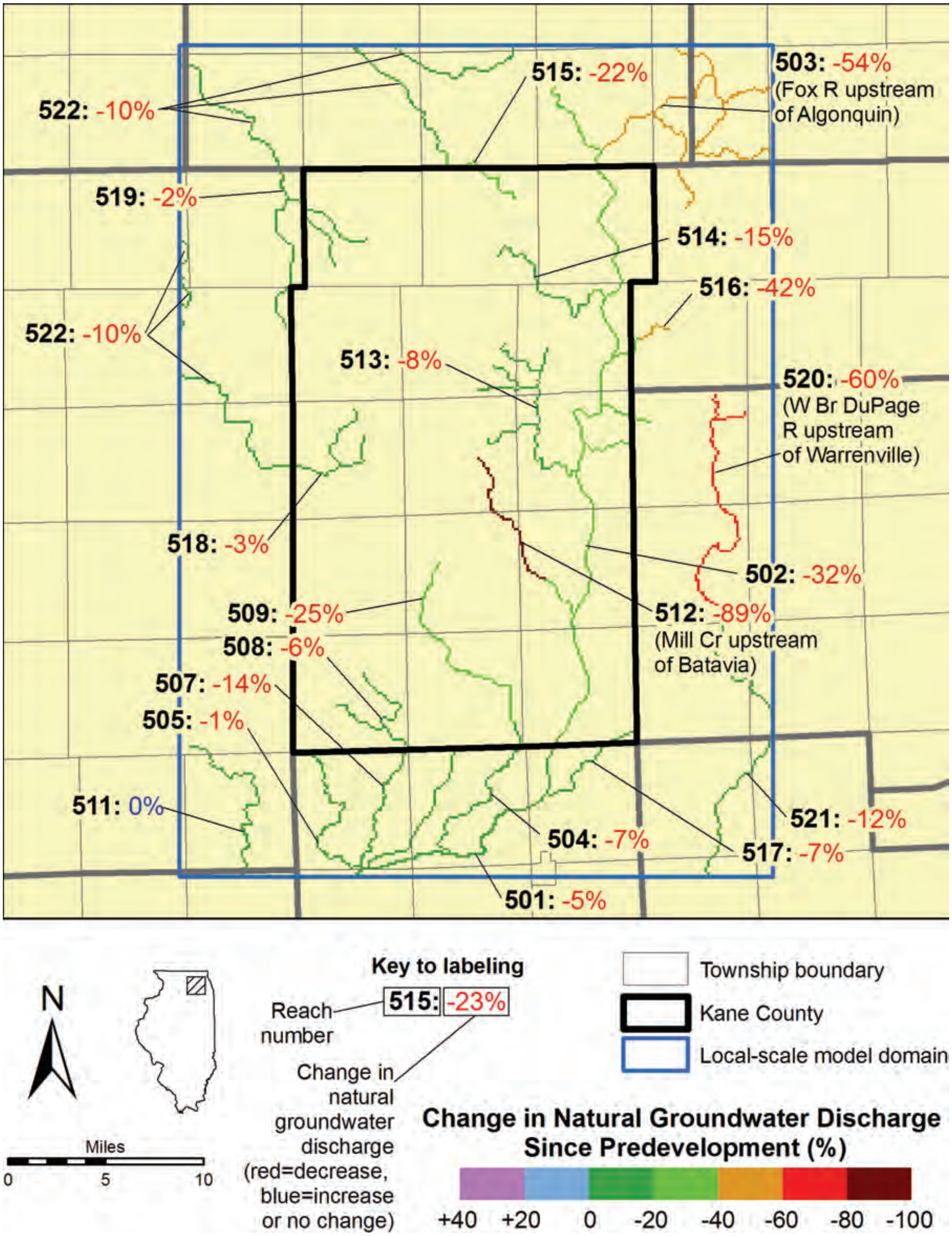

Figure 38. Change in simulated natural groundwater discharge since predevelopment by stream reach in the Kane County area at the end of 2049, scenario LC, with reaches discussed in text identified (see Table 1 for identification of all reaches).

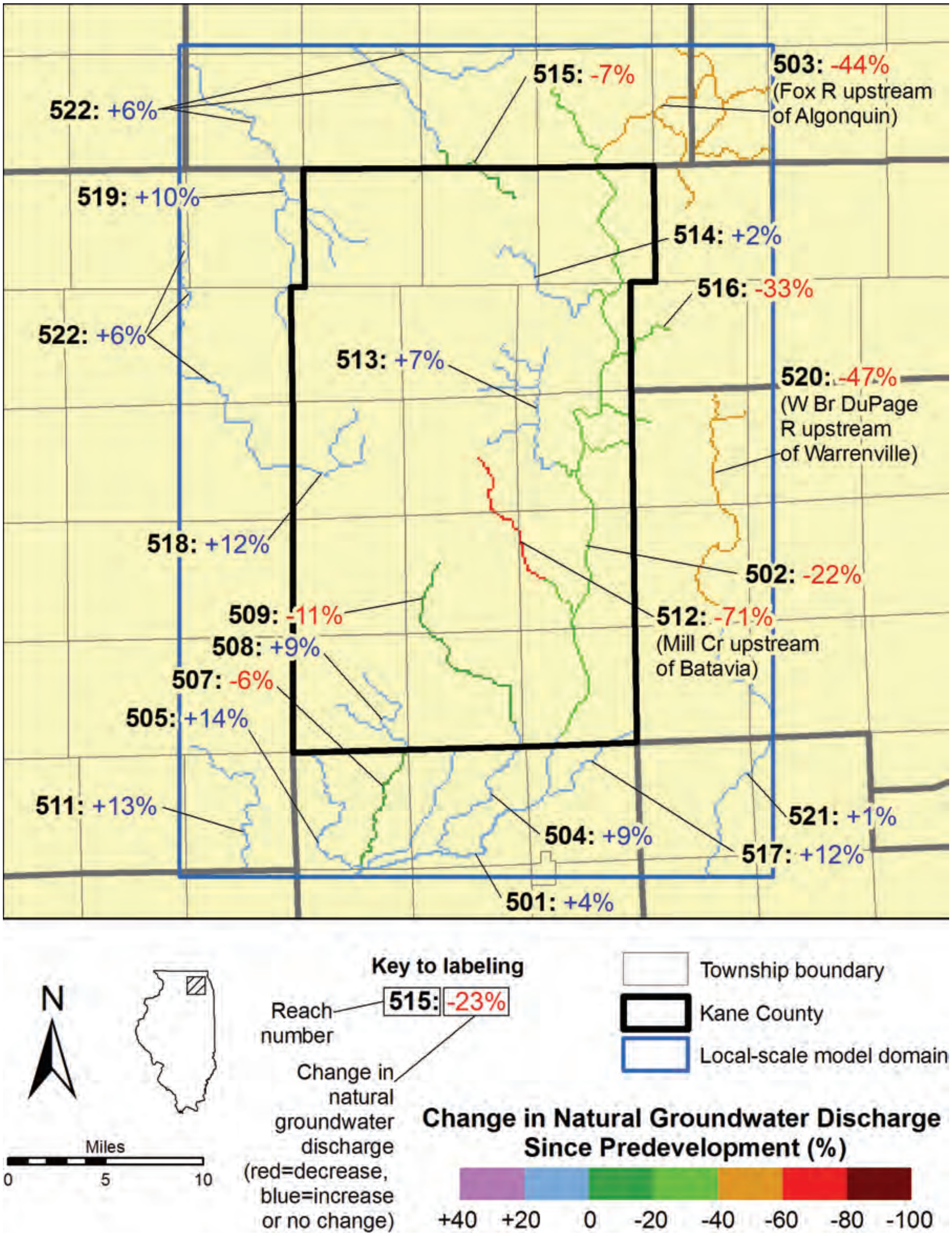

Figure 39. Change in simulated natural groundwater discharge since predevelopment by stream reach in the Kane County area at the end of 2049, scenario LH, with reaches discussed in text identified (see Table 1 for identification of all reaches).

Table 3. Estimated Total Change in Natural Groundwater Discharge at end of 2024 and 2049, by Stream Reach

Reach Number	***Principal Streams***	***Change in Natural Groundwater Discharge Due to Pumping***							
		2024				***2049***			
		HL*	***HC***	***LC***	***LH***	***HL***	***HC***	***LC***	***LH***
501	Fox River downstream of Montgomery; Big Rock Cr downstream of Kane County boundary	-15%	-6%	-5%	+4%	-16%	-7%	-5%	+4%
502	Fox River from Algonquin to Montgomery; Norton Cr; Brewster Cr; Crystal Cr; lower portions of Mill Cr, Ferson Cr, Poplar Cr, and Tyler Cr	-42%	-32%	-29%	-19%	-51%	-41%	-32%	-22%
503	Fox River upstream of Algonquin; Spring Cr; Flint Cr	-65%	-55%	-50%	-40%	-78%	-68%	-54%	-44%
504	Blackberry Cr from Montgomery to Yorkville	-27%	-11%	-8%	+8%	-32%	-16%	-7%	+9%
505	Little Rock Cr downstream of Kane County boundary	-16%	-1%	-1%	+14%	-16%	-1%	-1%	+14%
507	Big Rock Cr downstream of Kane County boundary	-22%	-14%	-12%	-4%	-27%	-19%	-14%	-6%
508	Big Rock Cr upstream of Kane County boundary; Welch Cr	-19%	-4%	-4%	+10%	-21%	-6%	-6%	+9%
509	Blackberry Cr from Elburn to Montgomery	-37%	-24%	-21%	-8%	-45%	-33%	-25%	-11%
511	Somonauk Cr	-13%	-1%	0%	+12%	-14%	-1%	0%	+13%
512	Mill Cr upstream of Batavia	-100%	-87%	-82%	-64%	-100%	-100%	-89%	-71%
513	Ferson Cr upstream of St Charles; Otter Cr; Stony Cr; Fitchie Cr	-23%	-8%	-7%	+8%	-26%	-10%	-8%	+7%
514	Tyler Cr	-29%	-14%	-14%	+2%	-34%	-17%	-15%	+2%
515	S Br Kishwaukee River upstream of Huntley	-34%	-20%	-19%	-5%	-40%	-25%	-22%	-7%
516	Poplar Cr	-50%	-41%	-41%	-33%	-52%	-43%	-42%	-33%
517	Waubonsie Cr	-25%	-7%	-7%	+11%	-27%	-9%	-7%	+12%
518	Union Ditch No 3; Virgil Ditch No 3; Union-Virgil Ditch No 2	-17%	-2%	-2%	+12%	-17%	-3%	-3%	+12%
519	Upper Coon Cr	-15%	-3%	-2%	+10%	-16%	-3%	-2%	+10%
520	W Br DuPage River upstream of Warrenville	-71%	-58%	-55%	-42%	-81%	-68%	-60%	-47%
521	DuPage River; W Br DuPage River downstream of Warrenville	-25%	-13%	-11%	+1%	-28%	-16%	-12%	+1%
522	Aggregated tributaries of S Br Kishwaukee River outside Kane County	-26%	-10%	-9%	+6%	-27%	-11%	-10%	+6%
	TOTAL	-33%	-21%	-19%	-6%	-38%	-26%	-20%	-8%

* Key to scenarios: HL=high pumping, low recharge; HC=high pumping, model-calibrated recharge; LC=low pumping, model-calibrated recharge; LH=low pumping, high recharge

6. Summary

Computer simulation of plausible scenarios of future pumping and recharge conditions suggests that significant additional drawdown, reduction in stream base flow, and changes in the quality of groundwater withdrawn from deep wells are all possible in parts of the Kane County area before 2050.

- Model simulations suggest that over 500 ft of drawdown and over 1100 ft of drawdown have occurred in the Ancell and Ironton-Galesville Units, respectively, in southeastern Kane County since pumping began in the nineteenth century. These units are the two principal deep aquifers in the region. Drawdown causes water levels in wells open to these aquifers to decline, increasing pumping expenses and, in extreme cases, causing water-supply interruptions that can be addressed only by replacing the wells or lowering the pumps. Drawdown could also lead to increases in salinity of deep well water. Slight increases in total dissolved solids have been recognized in time series of sample results collected at Aurora and Joliet, two locations of large withdrawals from the deep aquifers (Kelly and Meyer, 2005).
- Model simulations suggest that greater than 50 ft of additional drawdown in the deep aquifers will occur between 2002 and 2050 in much of Kane County under both low- and high-pumping conditions. Depending on specific operating rates, additional drawdowns in excess of 50 ft are possible immediately near pumping wells. Drawdown will be greatest in the Aurora area of southeastern Kane County. In addition to reducing well productivity, the additional drawdown may lead to increasing concentrations of radium, barium, arsenic, and salinity in water withdrawn from deep wells.
- Modeling shows that two large areas of significant drawdown (that is drawdown greater than or equal to 20 ft) affected the Kane County area in 2003. Both areas cross the borders of Kane County. One area covers parts of northeastern Kane County and southeastern McHenry County and is a collective response to pumping of wells operated by the Villages of Algonquin, Carpentersville, East Dundee, Lake in the Hills, and the City of Crystal Lake. The second large area of significant shallow aquifer drawdown is a response to pumping by the City of West Chicago and Village of Warrenville and barely crosses the Kane County border with DuPage County to include small parts of the Cities of Batavia and Geneva.
- Simulations of future scenarios of pumping and recharge suggest that areas of significant drawdown in the shallow aquifers present in 2003 will likely expand by 2050. The simulations suggest that a third area of significant shallow aquifer drawdown will likely develop around public-supply wells operated by Batavia and Geneva west of those cities.
- Model simulations suggest that, as of 2003, streamflow capture by pumping had reduced natural groundwater discharge to streams within the local model domain by about 17 percent. This streamflow capture would be observable as a reduction in base flow in streams (that part of streamflow originating as groundwater

discharge). Streamflow accounting models suggest that discharge of effluent may be compensating for the base flow reduction (Knapp et al., 2007).

- Model simulations suggest that the greatest reduction in natural groundwater discharge by 2003 occurred in Mill Creek upstream of Batavia, where simulated capture of streamflow by supply wells operated by the Cities of Batavia and Geneva has reduced groundwater discharge by 68 percent relative to nonpumping conditions.
- Model simulations suggest that, overall, if recharge rates do not change from historical rates, natural groundwater discharge in the Kane County area in 2050 will likely decline to rates that are 20 to 26 percent lower than estimated predevelopment rates.
- If recharge rates decline to plausibly low rates and pumping is high, model simulations suggest that natural groundwater discharge in the Kane County area in 2050 will likely decline by 38 percent from estimated predevelopment rates. If recharge rates increase to plausibly high rates and pumping is low, 2050 discharge may increase to a level that is about 8 percent less than the estimated predevelopment rate.
- Model simulations suggest that natural groundwater discharge to Mill Creek may cease entirely upstream of Batavia before 2050. The model suggests other large reductions in natural groundwater discharge to the Fox River upstream of Algonquin and the West Branch of the DuPage River upstream of Warrenville.

7. Future Work

7.1. Modeling Studies

The models developed for this project are designed for use in future water studies of Kane County and northeastern Illinois and will provide a rational basis for developing policy and management strategies pertaining to water-resources development in the county and region. Withdrawal rates, well locations, source intervals, and other factors may be modified to evaluate the impact of development strategies beyond the four scenarios discussed in this report. In addition, the models can be used to provide boundary fluxes for future high-resolution inset models developed to address a variety of local groundwater issues.

The models and databases developed for this study can be adapted for research on a variety of subjects bearing on water availability in the region. For example, the regional-scale model can be adapted to examine the impact of salty water on deep groundwater circulation in the Mt. Simon Unit and within the Ancell and Ironton-Galesville Units south of the Chicago area. Such an analysis would address the possibility of whether pumping could eventually induce salty water into deep wells in northeastern Illinois, reducing groundwater quality and limiting use of the deep groundwater.

Simulations with the local-scale model suggest that groundwater withdrawals have appreciably reduced natural groundwater discharge to many streams in the Kane County area. The extent to which these reductions are offset by discharges of effluent is not well understood, however, and an investigation of this topic could be a useful contribution to water-resources management in Kane County. Knapp et al. (2007) show that reduction in natural groundwater discharge to the Fox River may be more than offset by effluent, with low flows in the Fox River possibly higher now than under predevelopment conditions. The opposite could be true for many tributary streams, however. Groundwater that is withdrawn from the tributary watersheds, after distribution through public water systems and treatment as wastewater, is not typically discharged as effluent in the stream reaches affected by the withdrawals. It is instead discharged into another stream, commonly, the Fox River in Kane County.

7.2. Monitoring

Monitoring of aquifer heads should be considered in areas of significant simulated 2003 and future drawdown. At minimum, such monitoring would include installing observation wells open to principal aquifers in problem areas and quarterly measurement of water levels in these wells. Monitoring provides a relatively inexpensive mechanism for early identification of problematic downward water-level trends and establishes head data that are invaluable for future analysis. Streamflow monitoring of streams projected to incur significant simulated baseflow reduction, such as Mill Creek, is also recommended.

7.3. Database Expansion and Improvement

As syntheses of available data, all models can be improved with acquisition of new observations or through novel and alternative approaches to characterizing model input data. In general, the available database for model development suffers from imprecision, geological and geographical bias, sporadic and irregular data collection and compilation efforts, and poor documentation. These shortcomings reflect the fact that data collection, analysis, and mapping have largely been conducted for local studies over a long period of time, using a range of technologies and approaches, and for purposes other than groundwater flow modeling.

The experiences gained through this modeling study suggest that compilation of comprehensive, accurate withdrawal data is needed for database expansion and improvement. As a parameter to which shallow heads and streamflow are highly sensitive, accurate characterization of recharge and discharge is probably the second greatest data need, yet accurate measurement of recharge is problematic and a subject of active research (National Research Council, 2004). Other data that would increase the accuracy and usefulness of groundwater models of Kane County and northeastern Illinois include observations of hydraulic properties of all the modeled units, aquifers and aquitards alike, observations of base flow (natural groundwater discharge) to streams, and water levels in wells. Coordination with authorities in Indiana and Wisconsin in database expansion and improvement would improve the comprehensiveness and quality of the efforts.

Finally, there is a possibility that a thin layer containing arsenic-bearing minerals exists at the top of the Ancell Unit in northeastern Illinois, and pumping-induced reduction of heads in the Ancell could cause arsenic to be released to groundwater from this layer. Such a layer is known to be present in eastern Wisconsin (Schreiber et al., 2000), but there is a need for more comprehensive study to verify the presence of the arsenic-bearing layer in Illinois and confirm that arsenic can be liberated as a consequence of declining heads.

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