Appendix G. Estimation of Future Pumping

Two forecasts of estimated future pumping from individual wells have been developed for this project and are used in analyzing the impacts of projected pumping discussed in Section 3.3. One of the forecasts assumes that modest improvements in water conservation are made in the Public Supply and Self-Supplied Commercial and Industrial water-use sectors in Illinois and, from the standpoint of preserving water availability, might be considered an optimistic forecast. These pumping conditions are referred to in this report as *low-pumping conditions*. An alternative forecast, one of *high-pumping conditions*, assumes that no such improvements in water conservation are made in the Public and Self-Supplied Commercial and Industrial sectors of Illinois. Both forecasts assume no improvements in water conservation in any water-use sectors except Public Supply and Self-Supplied Commercial and Industrial.

Both forecasts further assume existing 2000-2003 well locations and source intervals for the duration of the forecast (from 2005 through 2050). In essence, the forecasts assume that the existing 2000-2003 well network remains in service and satisfies all water demand through 2050. The authors acknowledge that maintenance of the 2000-2003 well network through 2050 and its use to satisfy all water demand through 2050 is unlikely. The modeled network is, however, representative of a probable, though conservative, future well network, wherein replacement wells are drilled in precisely the same locations and finished with precisely the same source intervals as predecessor wells taken out of service. We further acknowledge that it might be physically impossible for an existing well in the 2000-2003 network to supply the water that is forecasted to be withdrawn from it, particularly in rapidly developing counties with greatly increasing water demand. Any single forecasted well with an implausibly high forecasted withdrawal rate can, however, be considered as representing a well field, with all of the wells in the field being located in the same model cell and open to the same source interval. In the sense that well locations and source intervals do not change from those in 2002-2003, both forecasts might be considered "business-as-usual" scenarios wherein water-supply development questions are handled on a nearsighted basis, without communication or coordination among public water systems, self-supplied industries, irrigators, and other water users.

In addition to forecasted withdrawals from existing deep domestic wells, both scenarios include withdrawals from forecasted deep domestic wells that have not yet been drilled. Wells are forecasted in each cell of the regional model nearfield on the basis of 1974-2003 drilling rates of such wells as indicated by the ISWS Private Well Database, a database generally containing records of low-capacity wells supplying households and commercial facilities. The low-pumping and high-pumping estimates contain precisely the same forecasts of withdrawals from existing and projected deep domestic wells.

G.1 Forecasted Pumping from Public Wells, Self-Supplied Commercial and Industrial Wells, and Irrigation Wells

G.1.1. Illinois

G.1.1.1. Forecasted Well Locations and Source Intervals

The locations of forecasted wells in Illinois and their source intervals are based on withdrawals for the years 2000 through 2003 included in the withdrawal database compiled for this project. Most of these data were obtained from the ISWS PICS Database, an electronic database of withdrawal data compiled largely from owner-reported withdrawal measurements and estimates. These data are augmented with estimates for years of non-reporting to the ISWS by facility owners. The sources, processing, and uncertainty of these withdrawal data are discussed in detail in Appendix B). A withdrawal forecast for 2005 to 2050 was developed for wells in the withdrawal database that showed any withdrawal during the years 2000, 2001, 2002, or 2003. A total of 2007 Illinois wells satisfied this requirement.

Thus, locations and source intervals of forecasted withdrawals are identical to those of real wells used during 2000-2003, as discussed in the introduction to this appendix. Withdrawals were forecasted for wells if observed withdrawals during any one of the years 2000-2003 were nonzero to provide for the possibility that a recently used well (e.g., a well pumped during 2001, but not 2002 and 2003) would be brought back into service.

G.1.1.2. Forecasted Pumping Rates

Forecasted pumping rates are based on the water-use sector and county location of each well, on the latest pumping rate recorded in the project withdrawal database for the years 2000 through 2003, and on county-level estimates of water demand in Illinois counties developed by statistical modeling by Dziegielewski et al. (2005). The last pumping rate recorded in the withdrawal database compiled for this project for the years 2000, 2001, 2002, or 2003 was increased in proportion to the change in county-level demand for the county location of the well and the well's water-use sector. The year of the recorded withdrawal rate that was employed to develop the projected future withdrawal rate in 2005-2050 is referred to in this report as the *basis year* for the forecasted rate. Wells were assigned to one of three water-use sectors—Public Supply, Self-Supplied Commercial and Industrial, and Irrigation—based on codes already present in the ISWS PICS Database that distinguish among these water uses.

Map depictions of basis year withdrawals and projected 2025 and 2050 withdrawals from Public, Self-Supplied Commercial and Industrial, and Irrigation wells in the regional model nearfield are shown in Figure G-1 (basis year), Figure G-2 and Figure G-3 (low-pumping conditions), and Figure G-4 and Figure G-5 (high-pumping conditions).

Dziegielewski et al. (2005) used multiple regression to model Public Supply water use in 2000, 2005, 2010, 2015, 2020, and 2025 and Self-Supplied Commercial and Industrial water use in 2005, 2010, 2015, 2020, and 2025. Dziegielewski et al. (2005) recognized modest effects of water conservation as a variable explaining water use in these sectors between 1985 and 2000. They developed two separate sets of water-use estimates in the sectors for the years 2005-2025, one using a multiple-regression model

that assumes continued improvements in water conservation, and the second using a multiple-regression model that assumes improvements do not continue beyond 2000. These estimates correspond to this study's estimates of low- and high-pumping conditions described previously (page G-1). For all Illinois counties, both sets of estimates of water demand in the Public Supply and Self-Supplied Commercial and Industrial sectors were entered into a database to facilitate later data processing. In addition, estimates of observed 2000 water use in these sectors, reported by the U.S. Geological Survey (USGS) and appearing in the report by Dziegielewski et al. (2005), were entered into the database.

Water use in the Irrigation sector was estimated by Dziegielewski et al. (2005) for 2005, 2010, 2015, 2020, and 2025 using a "rainfall deficit" method. Only a single set of estimates of future irrigation water use was developed by Dziegielewski et al. (2005), and these estimates were entered into the database mentioned in the previous paragraph.

The present study employs ratios of the county-level estimates of sector water use by Dziegielewski et al. (2005) to estimate 2005-2050 water use on a well-by-well basis. These estimates are calculated from the last nonzero value of water use at the well during the basis year—2000, 2001, 2002, or 2003—as recorded in the database of groundwater withdrawals assembled for this project. This approach required that additional, provisional estimates and projections of county-level water use, by sector, be developed from the data appearing in Dziegielewski et al. (2005). Estimates were calculated for the years 2001-2003 and—on a five-year basis—projections were developed for 2030-2050. County-level water use estimates for 2001-2003 were calculated somewhat differently for the Public Supply, Self-Supplied Commercial and Industrial, and Irrigation sectors owing principally to the differing availability of estimates and data in Dziegielewski et al. (2005) for these sectors.

Figure G-6 illustrates the projection procedure for Public Supply water use in Kane County as an example of the procedure followed independently for all Illinois counties included in the project. With the exception of two counties, DuPage and Knox, estimates of 2001-2003 Public Supply water use are based on linear interpolation between the USGS reported 2000 water use and the modeled Public Supply 2005 water use. USGS reported estimates of 2000 Public Supply water use in DuPage and Knox Counties appear to be unrealistically low, probably because both of these counties import a significant proportion of water for public supply from outside the county, and these imports are not accounted for in the value reported by the USGS. Thus, projections of 2001-2003 Public Supply water use in DuPage and Knox Counties are based on linear interpolation between the modeled estimates of 2000 and 2005 Public Supply water use in those counties developed by Dziegielewski et al. (2005). Projections of 2030-2050 Public Supply water use were developed on a five-year basis by extrapolating the change in modeled water use rates between 2020 and 2025 from Dziegielewski et al. (2005) and are highly conjectural. As illustrated in Figure G-6, projections of 2001-2003 and 2030-2050 Public Supply water use were estimated for conditions of low pumping and high pumping using modeled water use estimates corresponding to these scenarios provided by Dziegielewski et al. (2005).

The projection procedure for county-level Self-Supplied Commercial and Industrial water use, shown for Kane County in Figure G-7, is similar to that used to project Public Supply water use. Self-Supplied Commercial and Industrial water use was

estimated for the years 2001-2003 by linear interpolation between the USGS reported water use in 2000 and the modeled 2005 water use in that sector developed by Dziegielewski et al. (2005). Highly speculative projections of 2030-2050 Self-Supplied Commercial and Industrial water use were developed using the change in modeled water use rates between 2020 and 2025 from Dziegielewski et al. (2005). Separate estimates of water use under low- and high-pumping conditions were developed using modeled water use estimates provided by Dziegielewski et al.(2005). In the case of Kane County, continued improvements in water conservation in the Self-Supplied Commercial and Industrial sector make the difference between increasing and decreasing water use (Figure G-7).

A similar projection procedure was employed to estimate county-level water use in the Irrigation sector in 2001-2003 and 2030-2050. Since Dziegielewski et al. (2005) did not develop separate estimates of future Irrigation water use based on whether conservation improvements continue in that sector, only a single set of projected values was generated. The projection procedure is illustrated graphically for Kane County in Figure G-8. As for the Public Supply and Self-Supplied Commercial and Industrial Irrigation water use sectors, Irrigation water use was estimated for the years 2001-2003 by linear interpolation between the USGS reported water use in 2000 and the modeled 2005 water use in that sector developed by Dziegielewski et al. (2005). Projections of 2030-2050 Irrigation water use assume the change in modeled water use rates between 2020 and 2025 from Dziegielewski et al. (2005) and are speculative.

No further efforts to generate county-level estimates of 2000-2003 sector water use were made than those based on the data provided by Dziegielewski et al. (2005), for example, consultation of either the withdrawal database developed for this project (see Appendix B) or the ISWS PICS Database (a database of water withdrawals in Illinois). The withdrawal database developed for this project is not complete enough to allow development of 2000-2003 water-use estimates, since it includes only groundwater withdrawals, not surface-water withdrawals or imports from outside a county. Moreover, the database does not even cover all groundwater withdrawals in most Illinois counties of the regional model domain. All groundwater withdrawals are included only in an accounting area covering northeastern Illinois. Estimates of sector water use could have been developed from the ISWS PICS Database, but such estimates would have required significant effort to develop and would have contributed negligibly, if at all, to the accuracy of the well-by-well projections of 2005-2050 withdrawals, which would be rough approximations of future pumping in either case. It is also noteworthy that both the USGS and Dziegielewski et al. (2005) used the ISWS PICS Database to develop their observation-based and model-based county-level estimates of sector water use.

Ratios of modeled and projected county-level sector water use in 2005-2050 to estimated county-level sector water use in 2000-2003 were calculated. These ratios were employed to project well-by-well withdrawals for all wells used in any year during 2000-2003 by multiplying the ratio by the withdrawal during the latest year of use of the well during the basis year. For example, to calculate the projected withdrawal in 2010 with improvements in conservation (low pumping conditions) for a public sector well in Kane County, which was pumped at 800 cubic feet per day (ft^3/d) in 2003, the 2003 pumping rate was multiplied by the ratio of estimates of 2010 to 2003 county-level water use for the Public Supply sector in Kane County under a “conservation scenario” based in the

statistical modeling of Dziegielewski et al. (2005). Since this ratio is about 1.122, the projected 2010 withdrawal from the well in 2010 is calculated as 1.122 × 800, or about 896 ft^3/d. If the well was pumped at a rate of 800 ft^3/d in 2001, but not in 2002 or 2003, the projected withdrawal from the well under low-pumping conditions was calculated using the ratio of estimates of 2010 to 2001 Kane County water use for the Public Supply sector in Kane County under low-pumping conditions: 1.216. Thus 2010 withdrawals are calculated as 1.216 × 800, or about 973 ft^3/d. If the well was used in 2000, but not in 2001-2003, projected withdrawals for the years 2005-2050 were—with the exception of two counties—calculated using the ratio of modeled (2005-2025) or projected (2030-2050) county-level sector water use to USGS-reported sector water use in 2000. In the case of Public Supply sector wells in DuPage and Knox Counties, projected withdrawals in 2005-2050 were calculated using the ratio of modeled/projected county-level sector water use in 2005-2050 to modeled Public Supply water use in 2000, as discussed on page G-3.

G.1.2. Indiana and Wisconsin

G.1.2.1. Forecasted Well Locations and Source Intervals

As described for Illinois, the locations and source intervals of forecasted wells in Indiana and Wisconsin correspond to those wells that were active during one or more years of the period 2000-2002 as indicated by the withdrawal database developed for this project (2003 is omitted because withdrawal data for 2003 were unavailable during database development). These data were obtained from the Wisconsin Geological and Natural History Survey (personal communication, 2002) and the Indiana Department of Natural Resources (personal communication, 2003). See Appendix B for details of the sources, processing, and uncertainty of these withdrawal data. If the database shows that any quantity of water was withdrawn from one of these wells in any of the years 2000, 2001, or 2002, withdrawal estimates for 2005-2050 were developed for that well based on the last year of nonzero withdrawals. A total of 771 Indiana wells and 385 Wisconsin wells satisfied this requirement.

G.1.2.2. Forecasted Pumping Rates

In a procedure closely similar to that used for Illinois withdrawal forecasting, pumping rates for Indiana and Wisconsin are forecasted on the basis of the water-use sector and county location of each well, on the latest pumping rate recorded in the project withdrawal database for the years 2000 through 2002 (the *basis year* for the projection), and on county-level estimates of water use in Indiana and Wisconsin counties developed by statistical modeling, in this case by Dziegielewski et al. (2004). The last pumping rate recorded in the project withdrawal database for the years 2000, 2001, or 2002 was increased in proportion to the change in county-level demand for the county location of the well.

Dziegielewski et al. (2004) estimated county-level water use for the Public Supply sector, and no other water use sector. For purposes of developing groundwater withdrawal forecasts for this project, the authors therefore assumed that withdrawals from all Indiana and Wisconsin wells change in proportion to county-level Public Supply water use. This assumption no doubt introduces error to the forecasted withdrawals since all of these wells do not serve the Public Supply sector. Of the 2056 Illinois wells for which

withdrawal forecasts have been developed, only 1196 (58 percent) are used for Public Supply, whereas 551 and 309 fall within the Self-Supplied Commercial and Industrial sector and Irrigation sector, respectively. Dziegielewski et al. (2004) did not develop separate county-level water use forecasts for scenarios of continuation, versus discontinuation, of improvements in water conservation, as was done for Illinois counties by Dziegielewski et al. (2005). Thus, only a single forecast of groundwater withdrawals for Indiana and Wisconsin wells was made for the present study, and this forecast was assumed to represent low- and high-pumping conditions (see p. G-1).

For all Indiana and Wisconsin counties having groundwater withdrawals represented in the project withdrawal database, county-level estimates of water use in the Public Supply sector were entered into a database to facilitate data processing. In addition, values of observed 2000 water use in the Public Supply sectors, reported by the USGS and appearing in the report by Dziegielewski et al. (2004), were entered into the database. As described previously for the Public Supply sector of Illinois (page G-3 and Figure G-6), estimates of Public Supply water use in the Indiana and Wisconsin counties were calculated for the years 2001 and 2002 and, on a five-year basis, projections were developed for the years 2030-2050. Estimates of 2001 and 2002 water use are based on linear interpolation between the USGS reported 2000 water use and the modeled Public Supply 2005 water use. Highly speculative projections of 2030-2050 Public Supply water use were developed on a five-year basis by extrapolating the change in modeled water use rates between 2020 and 2025 from Dziegielewski et al. (2004).

Ratios of modeled and projected county-level sector water use in 2005-2050 to estimated county-level sector water use in 2000-2002 were calculated. These ratios were employed to project well-by-well withdrawals for Indiana and Wisconsin wells used in any year during the period 2000-2002 by multiplying the ratio by the withdrawal during the latest year of well use in 2000-2002. An example of this calculation is described on page G-3.

G.2 Forecasted Pumping from Self-Supplied Deep Domestic Wells in Northeastern Illinois

Deep domestic wells are included in the pumping forecasts, but the wells are assumed to pump at identical rates under both low- and high-pumping conditions.

G.2.1. Forecasted Well Locations and Source Intervals

Forecasted deep domestic wells fall into two groups: (1) wells already in existence in 2003 (Figure G-9), and (2) wells that will be drilled and placed into service in 2005-2050 (Figure G-10 and Figure G-11).

Wells falling into the first group were identified to develop the database of groundwater withdrawals using the procedure discussed in Section B.2.1.4. Unless a well in this group was identified as having been sealed, the well was forecasted as being in service for the entire period 2005-2050. The specific source intervals of these wells within the deep units during 2005-2050 are unchanged from those that were characterized for the period ending in 2003 using the procedure discussed in Section B.2.1.4. Withdrawal forecasts were developed for a total of 3060 domestic wells in existence in 2003.

Wells falling into the second group, those forecasted to be drilled and placed in service during the period 2005-2050, were identified by assuming a linear growth rate of the deep domestic well population, based on 1974-2003 drilling rates, per grid cell of the regional model nearfield. Forecasted wells are located at the center of each grid cell. The open intervals of the forecasted wells are based on the subcrop belt of the well's location and on the statistical analysis of open intervals presented in Section B.2.1.4. Assumed open intervals are summarized in Table B-7. For example, predicted deep domestic wells located in the Silurian-Devonian Carbonate Unit subcrop of the Quaternary Unit are forecasted to be open to the Galena-Platteville Unit and the Ancell Unit (regional model layers 10-12). A total of 68 domestic wells were added to the withdrawal forecast for 2005, and this total rises to 2844 wells in the 2050 forecast (Figure G-12).

G.2.2. Forecasted Pumping Rates

Pumping rates for the period 2005-2050 are based on linear interpolation of estimates of per-capita self-supplied domestic water use developed at five-year increments for the period 1960-2000 by the USGS and reported by Dziegielewski et al. (2005) (Figure B-12), together with the assumption that each well supplies 3.4 people (Illinois Department of Energy and Natural Resources, 1998). Figure G-13 shows assumed pumping rates per well based on these assumptions for 2005-2050.

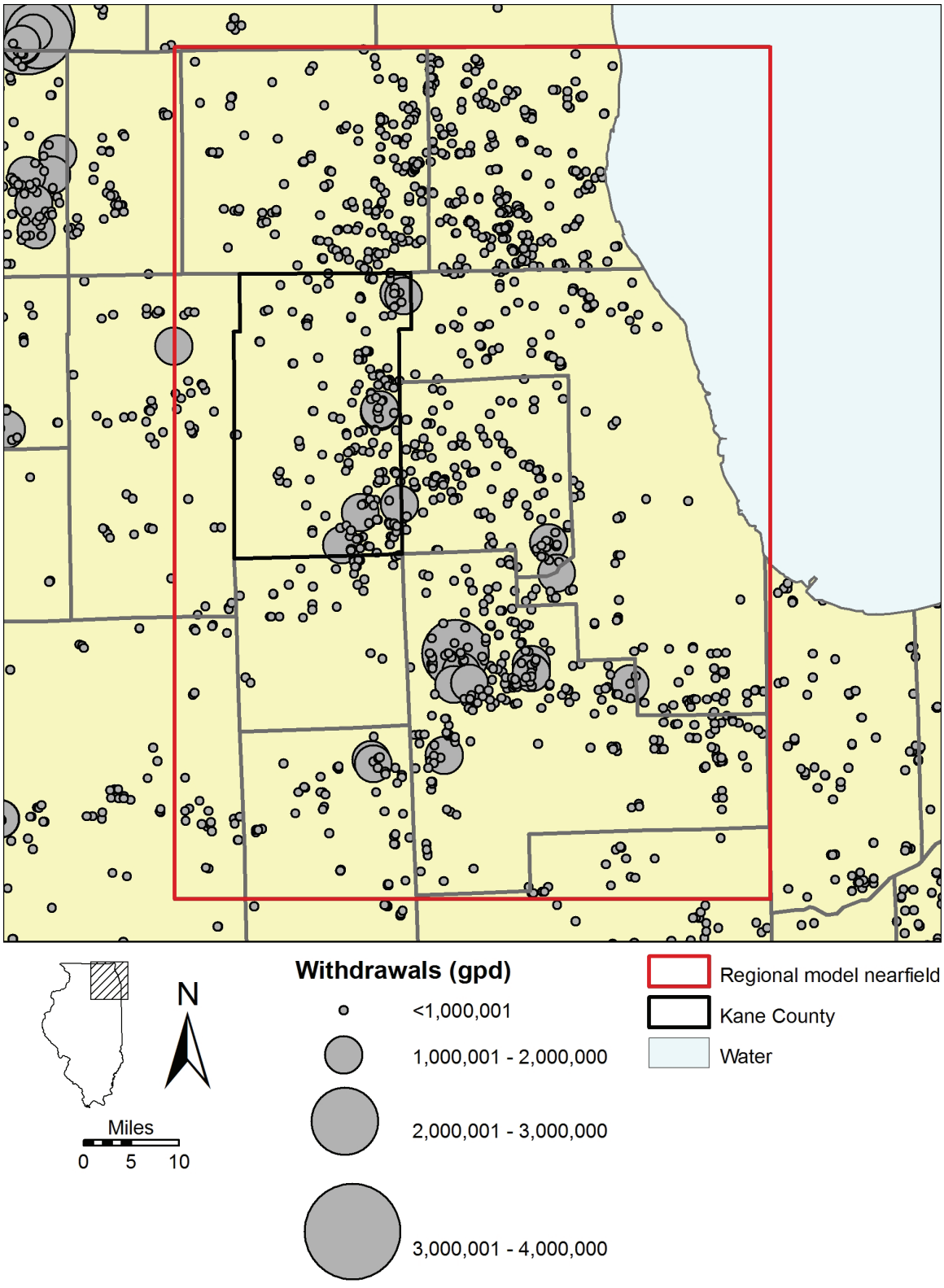

Figure G-1. Withdrawals in gallons per day (gpd) from Public Supply, Self-Supplied Commercial and Industrial, and Irrigation wells in northeastern Illinois during the basis year for projections.

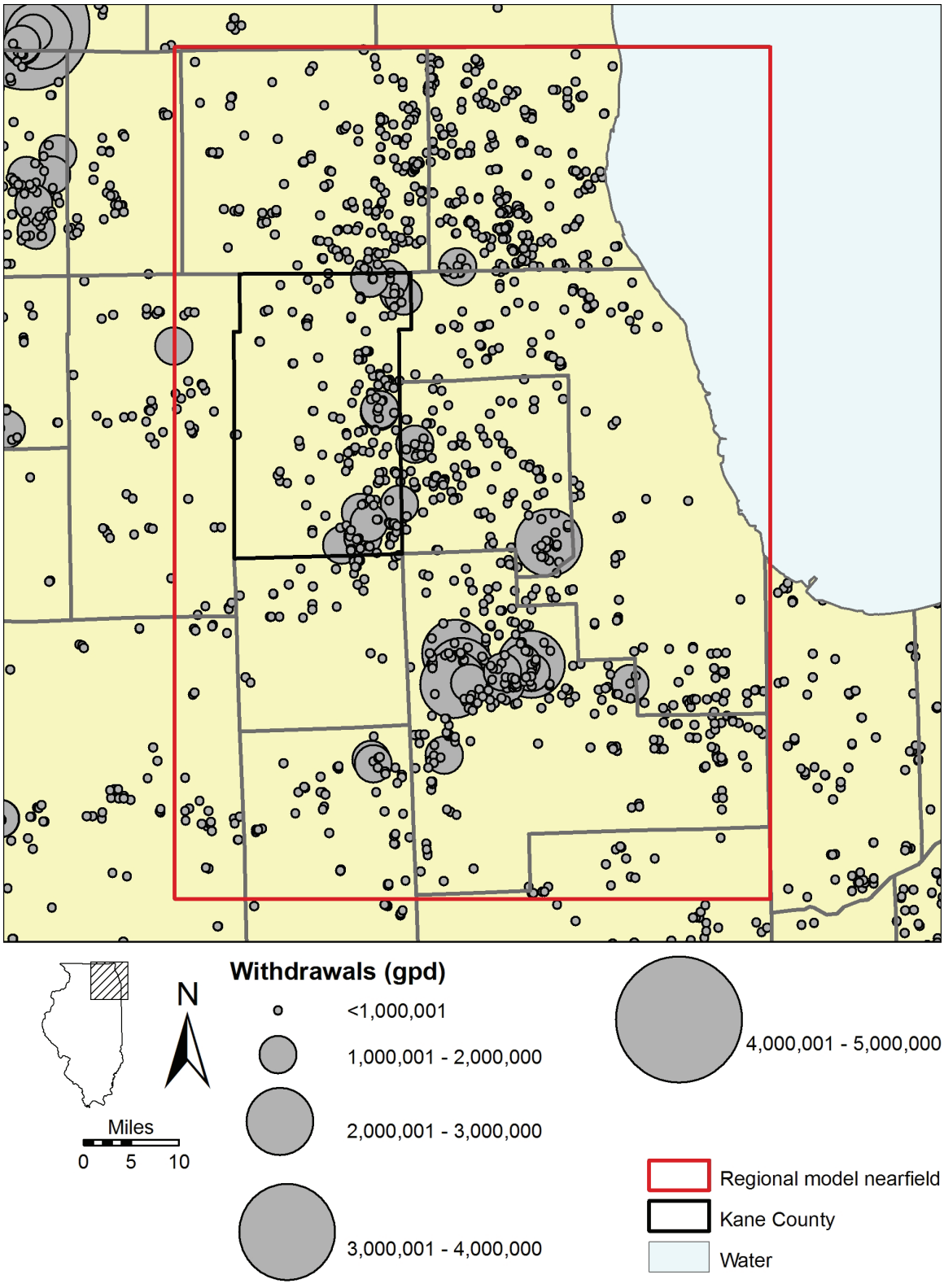

Figure G-2. Projected 2025 withdrawals from Public Supply, Self-Supplied Commercial and Industrial, and Irrigation wells in northeastern Illinois, low-pumping conditions.

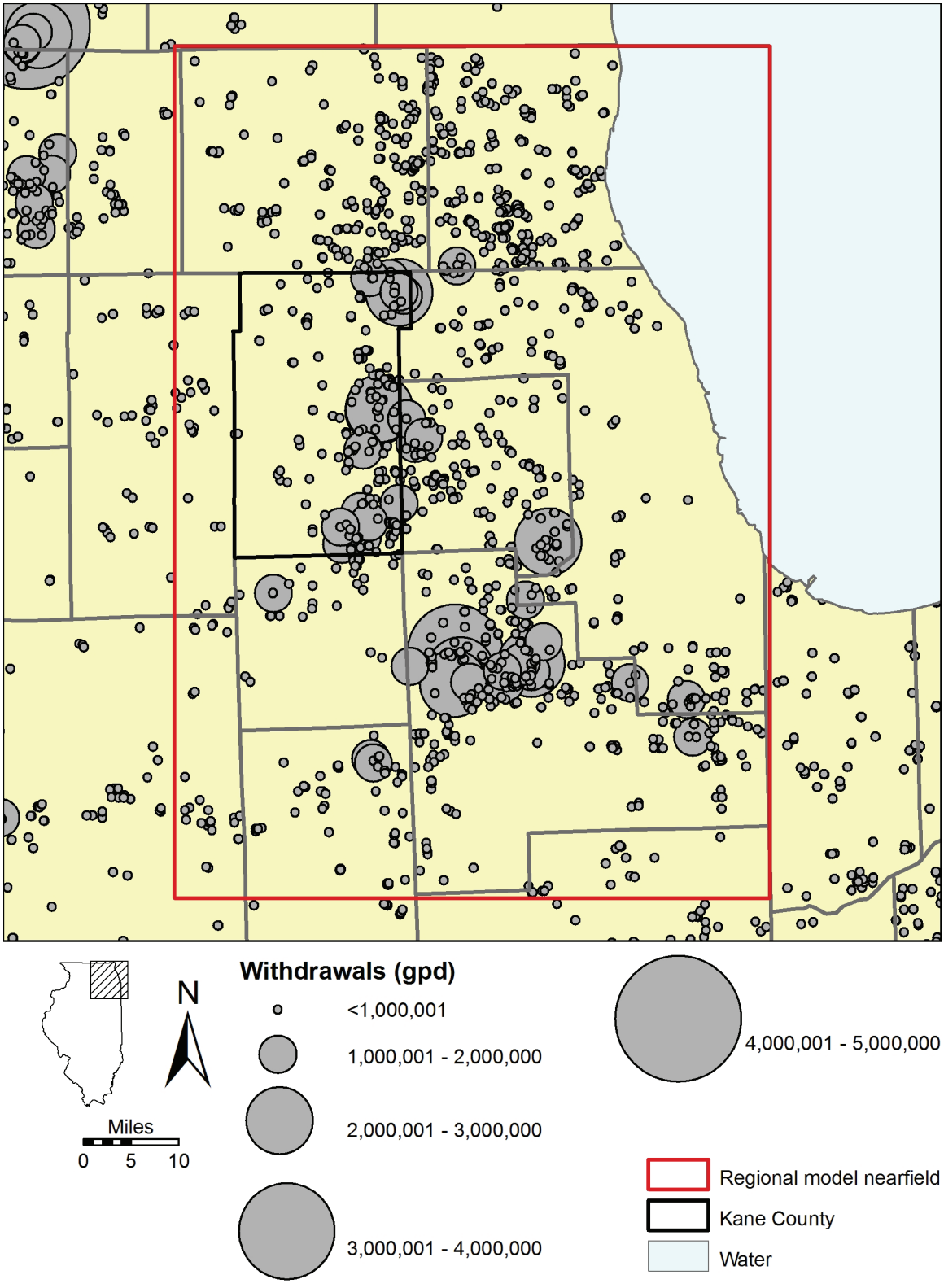

Figure G-3. Projected 2050 withdrawals from Public Supply, Self-Supplied Commercial and Industrial, and Irrigation wells in northeastern Illinois, low-pumping conditions.

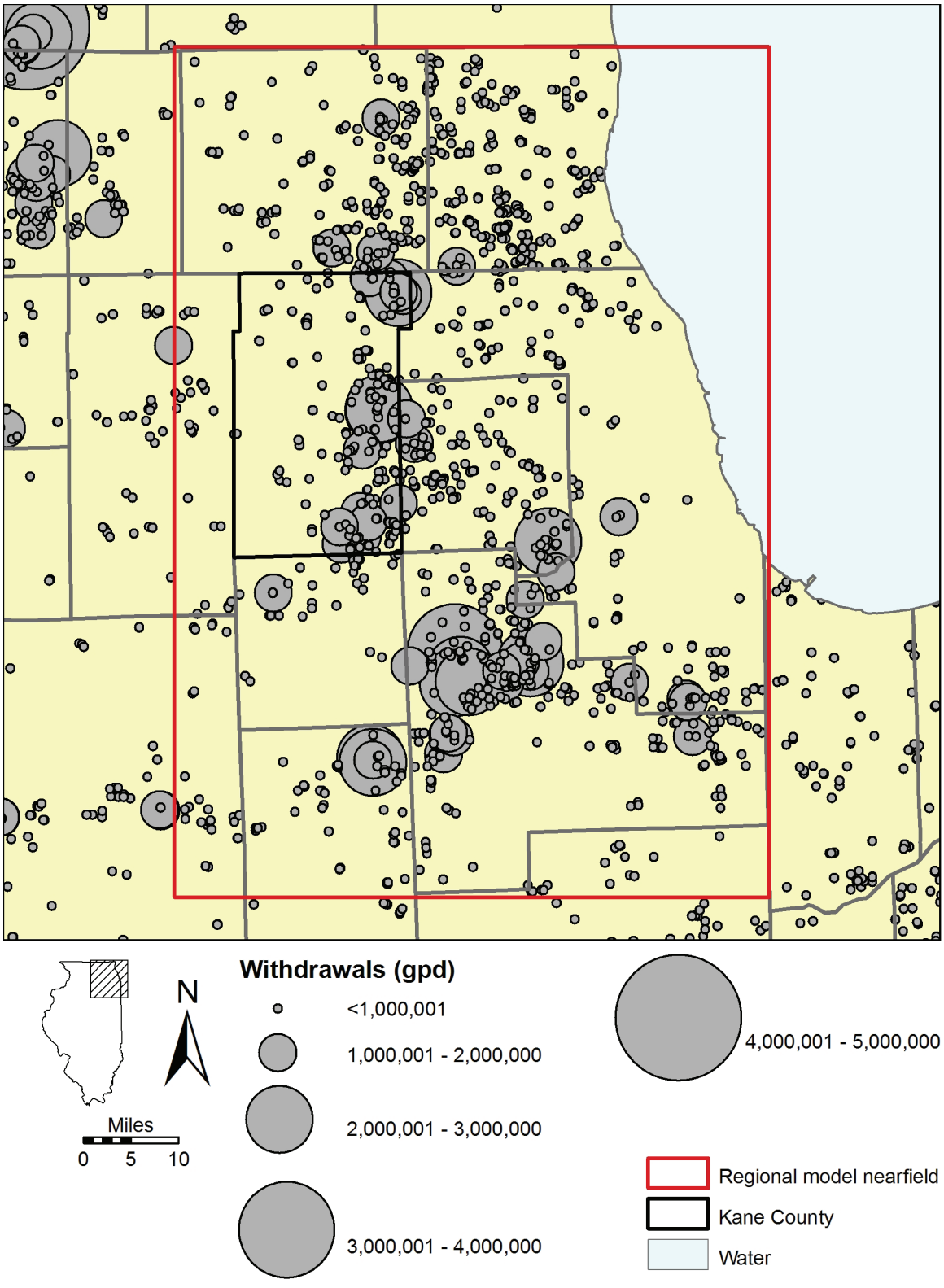

Figure G-4. Projected 2025 withdrawals from Public Supply, Self-Supplied Commercial and Industrial, and Irrigation wells in northeastern Illinois, high-pumping conditions.

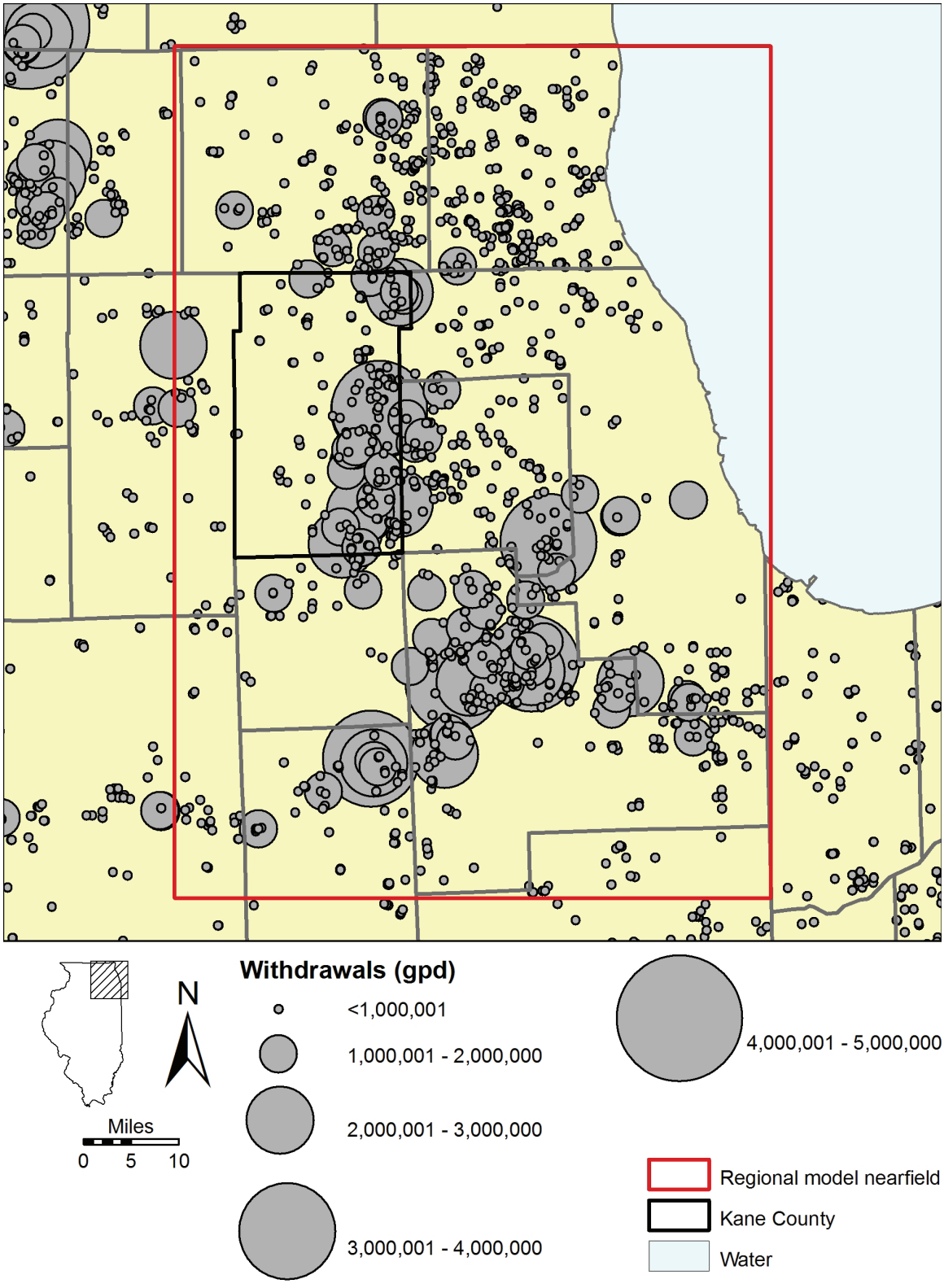

Figure G-5. Projected 2050 withdrawals from Public Supply, Self-Supplied Commercial and Industrial, and Irrigation wells in northeastern Illinois, high-pumping conditions.

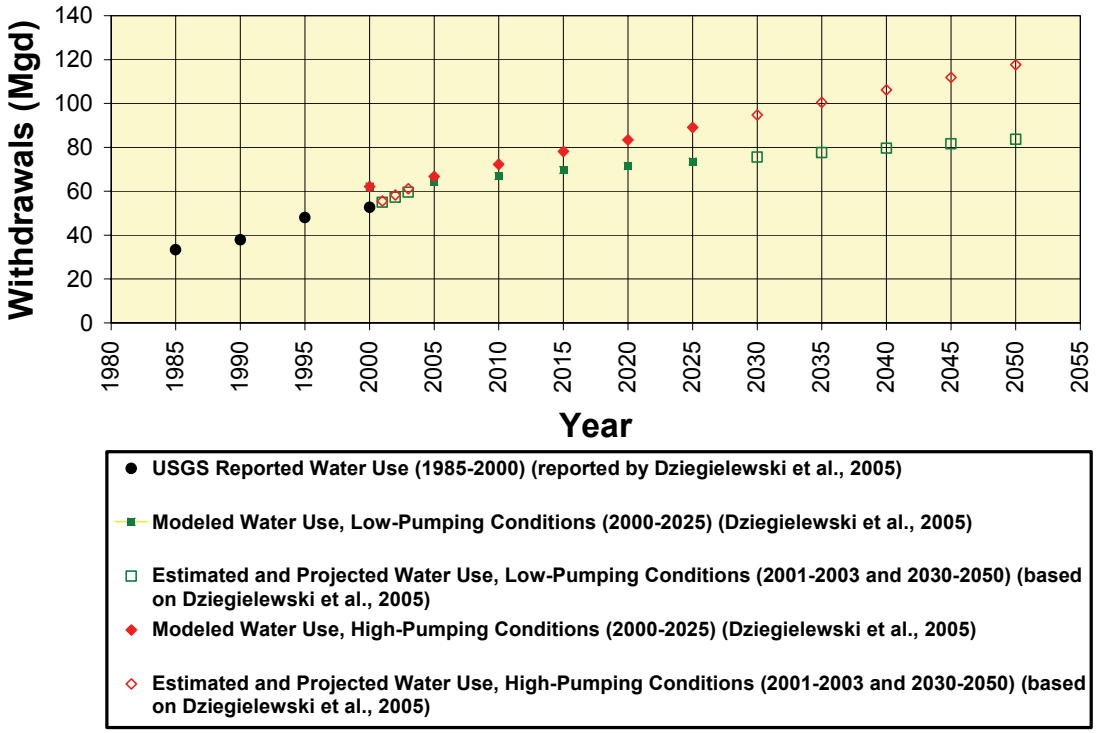

Figure G-6. Projection of Kane County water use in the Public Supply sector for the years 2001-2003 and 2030-2050 from data and estimates published by Dziegielewski et al. (2005).

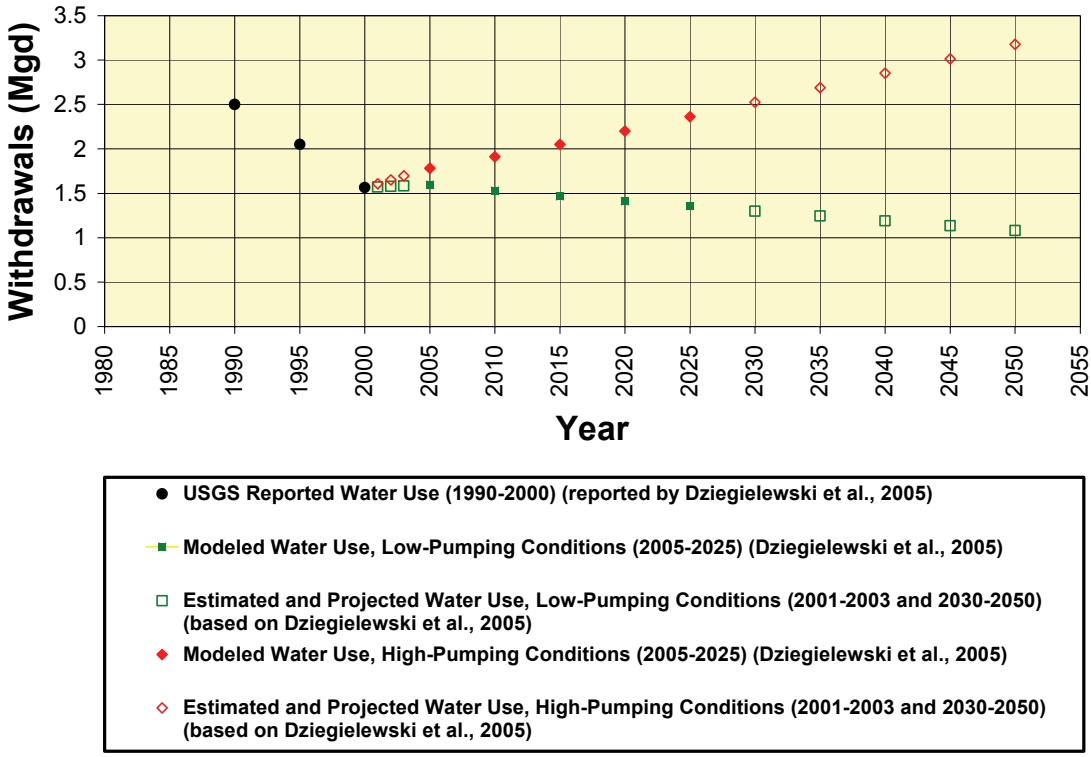

Figure G-7. Projection of Kane County water use in the Self-Supplied Commercial and Industrial sector for the years 2001-2003 and 2030-2050 from data and estimates published by Dziegielewski et al. (2005).

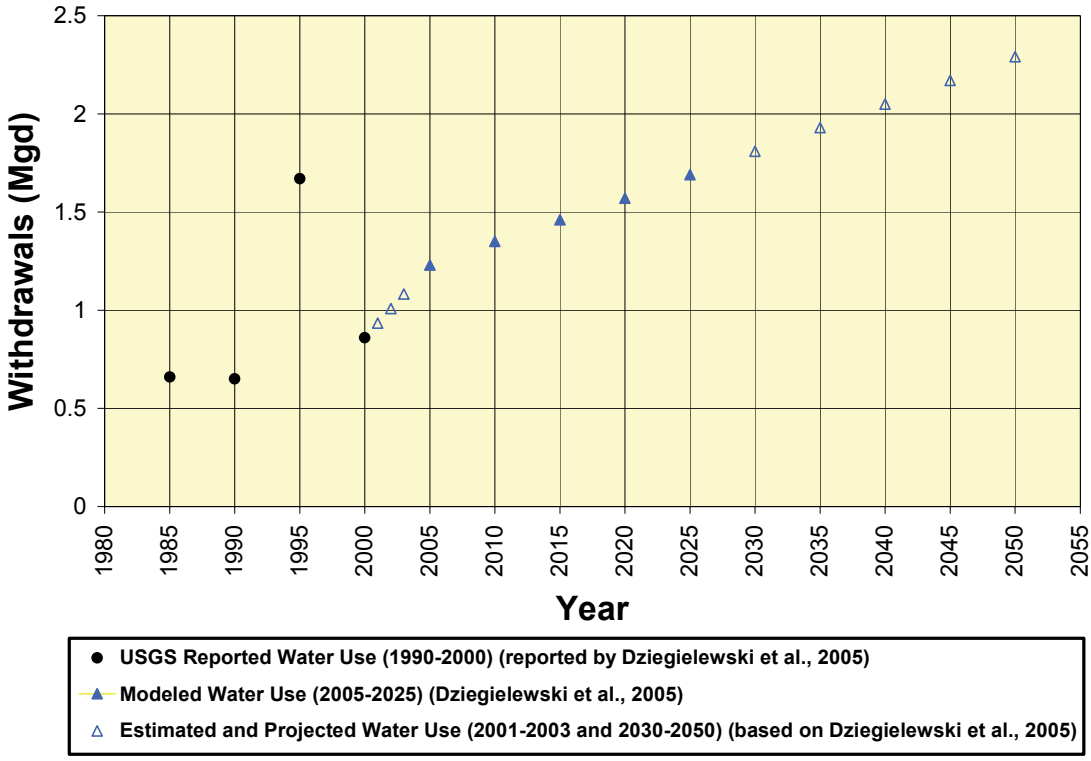

Figure G-8. Projection of Kane County water use in the Irrigation sector for the years 2001-2003 and 2030-2050 from data and estimates published by Dziegielewski et al. (2005).

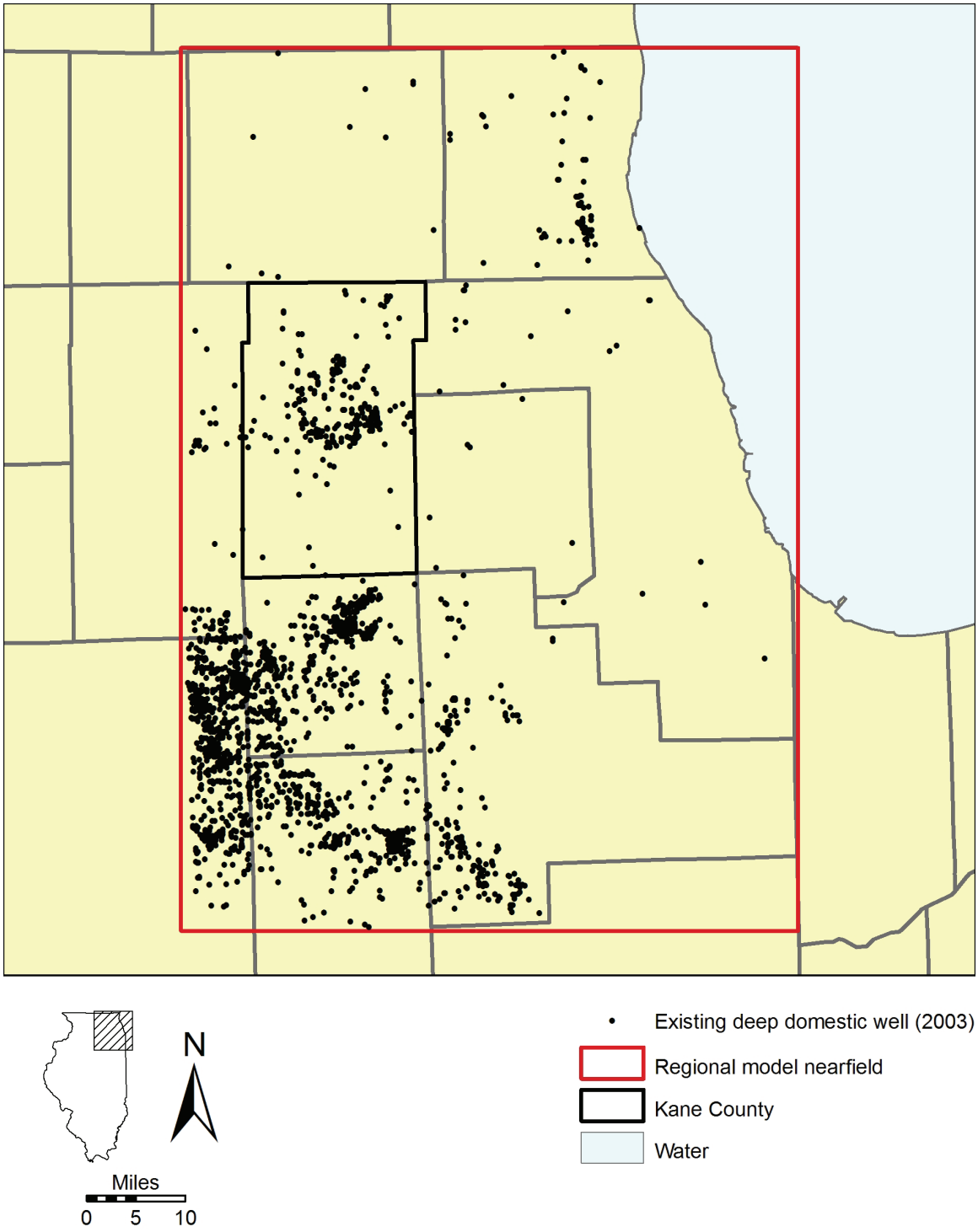

Figure G-9. Existing domestic wells open to the interval underlying the Galena-Platteville Unit for which withdrawals were projected for the period 2005-2050. See Figure G-13 for assumed withdrawal rates from these wells.

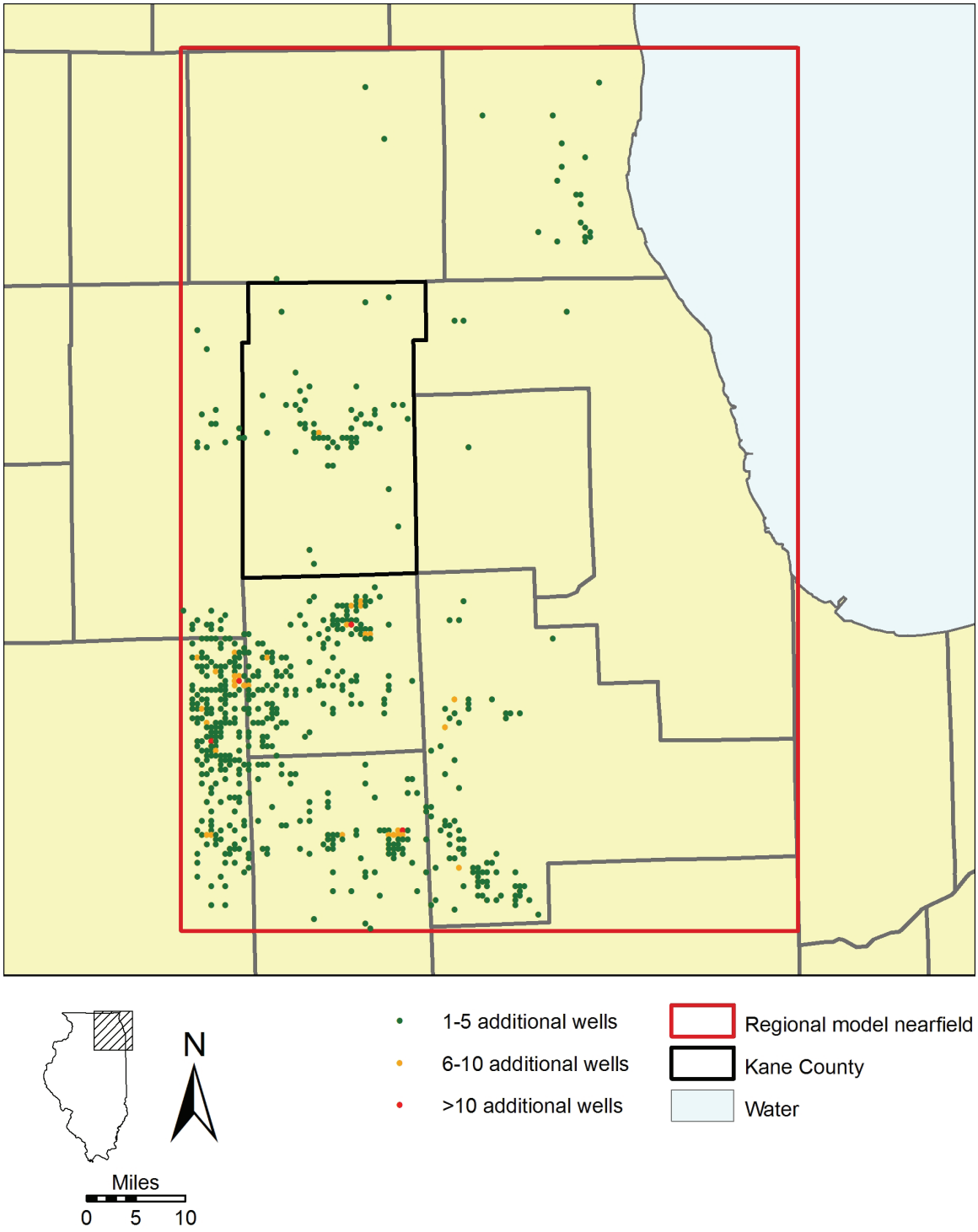

Figure G-10. Projected deep domestic wells, not existing in 2003, to be drilled and in service by 2025 and for which withdrawals were projected. See Figure G-13 for assumed withdrawal rates from these wells.

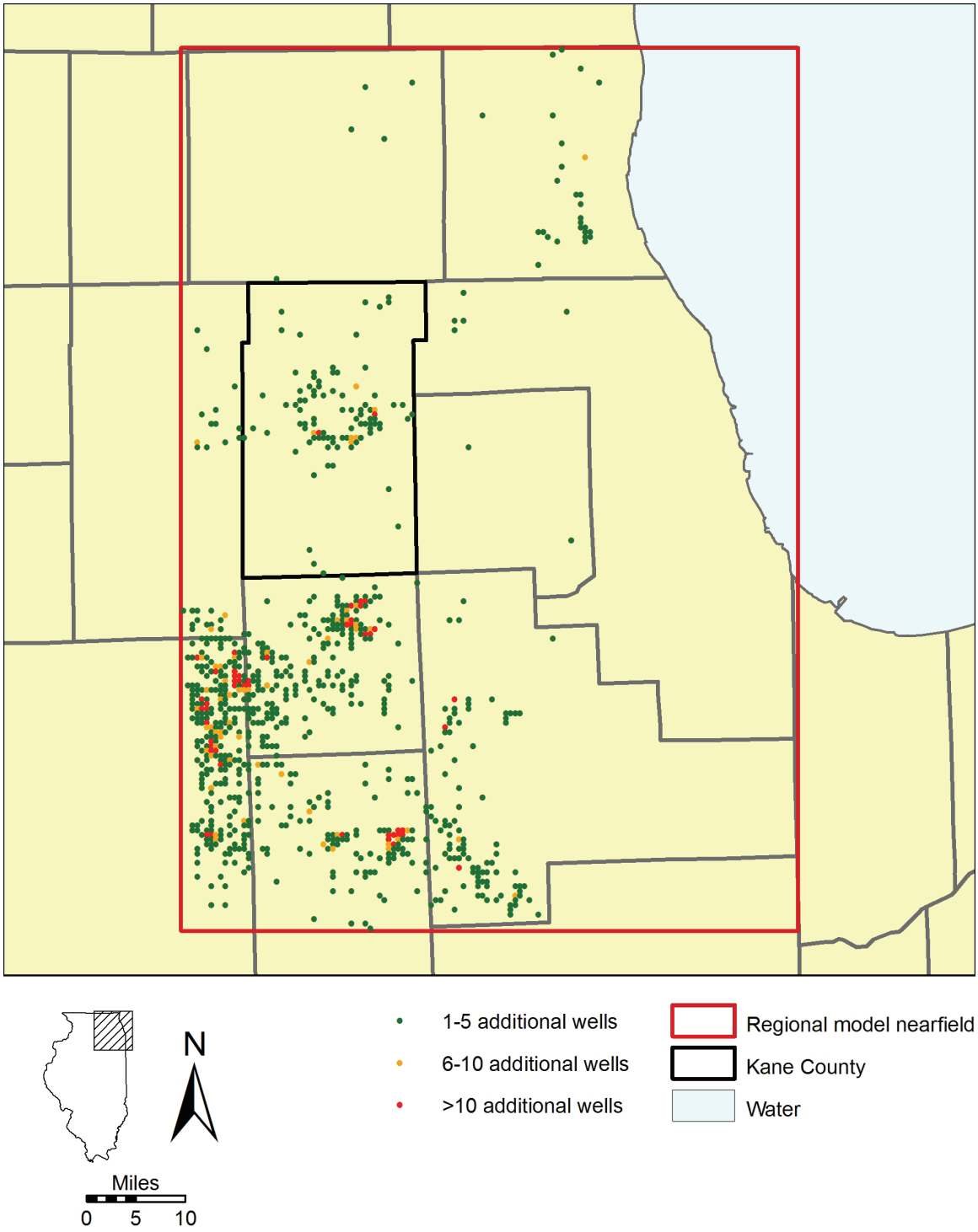

Figure G-11. Projected deep domestic wells, not existing in 2003, to be drilled and in service by 2050 and for which withdrawals were projected. See Figure G-13 for assumed withdrawal rates from these wells.

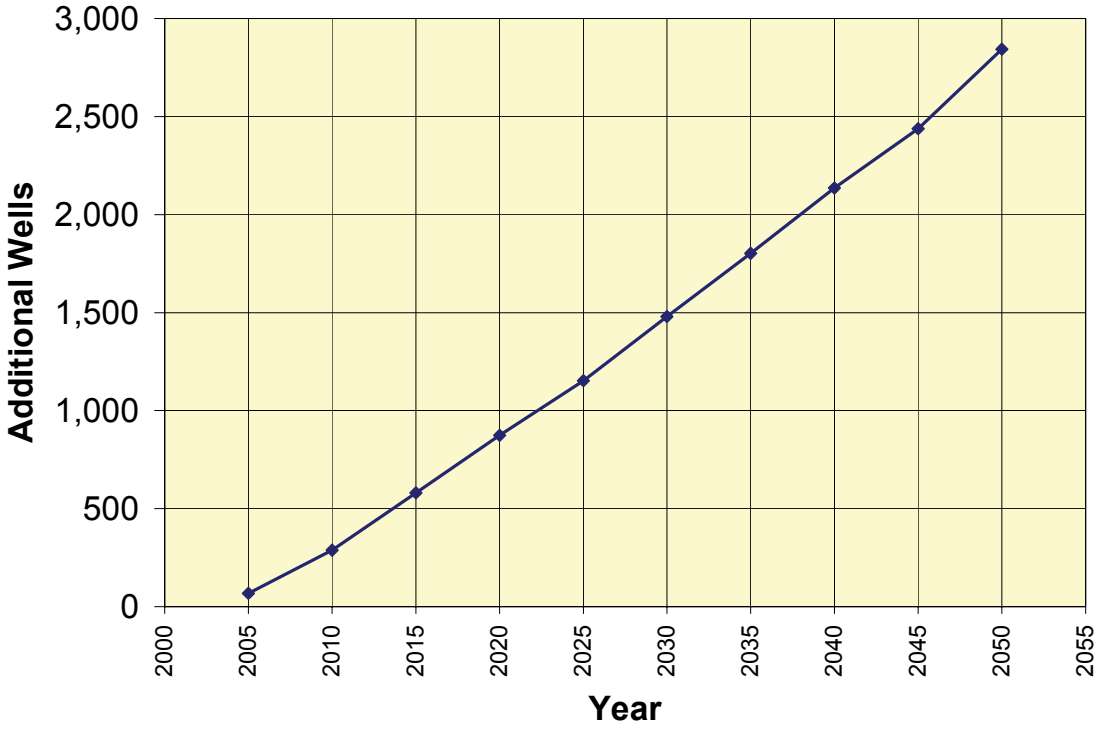

Figure G-12. Added deep domestic wells.

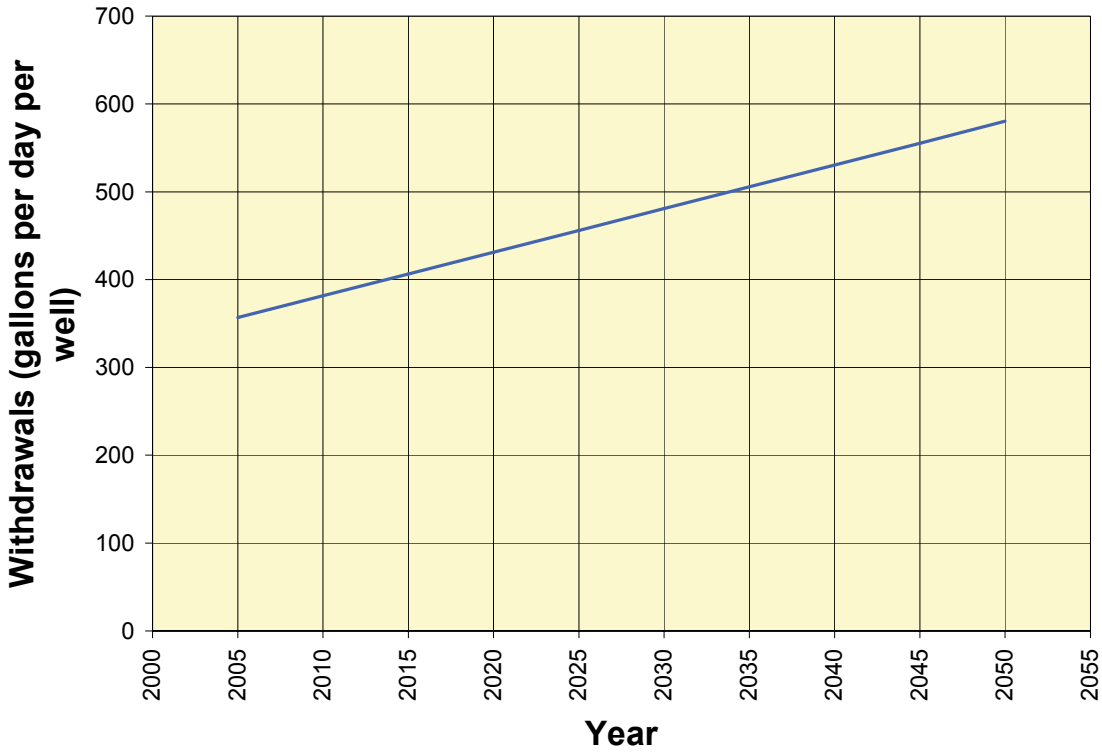

Figure G-13. Assumed withdrawal rate per well for domestic wells, 2005-2050.

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