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Water Supply Planning:
Middle Illinois Progress Report

**Walt Kelly, Daniel Abrams, Vern Knapp, Scott Meyer,
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February 2016

Illinois State Water Survey
Prairie Research Institute
University of Illinois at Urbana-Champaign

Champaign, Illinois

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Contents

List of Figures

List of Tables

1 Introduction

This report presents a summary of 1) the technical information assembled to describe existing water availability and sources of supply within the 7-county (LaSalle, Livingston, Marshall, Peoria, Putnam, Stark, and Woodford Counties) Middle Illinois River Region in central Illinois (Figures 1 and 2) and 2) the development of preliminary computer models that will be used in future studies to estimate impacts to water availability resulting from future water development in the region. Through funding by the Illinois Department of Natural Resources (IDNR), the Illinois State Water Survey (ISWS) and Illinois State Geological Survey (ISGS) prepared this document for the Middle Illinois Regional Water Supply Planning Committee (MIRWSPC) to aid in the development of a plan for meeting the future growth of water supply demands within the basin to the year 2060. It contains background information to provide an overview of management criteria and an understanding of the constraints and policies used in conducting analyses and making decisions concerning water usage. Models will be applied to a broad range of conditions, including a set of selected future water use scenarios to more fully characterize water availability within the Middle Illinois River Region to the year 2060. In addition, as the MIRWSPC deliberates and prepares its water supply planning document, the information presented in this report will be reviewed and, in some cases, additional analysis may be performed and results revised. A more complete reporting of the model development, the results of the scenario simulations, and subsequent work concerning water availability will be published at the end of that forthcoming study.

The existing technical information compiled as the first task of this study includes a review of previous analyses and publications dealing with the Middle Illinois River Region’s water resources; collection of hydrogeological and hydrologic data, primarily as needed for modeling; and, in certain cases, additional analyses of that data, such as data mining of well records and yield analyses of surface water supply sources. This compiled information focuses on the three primary sources of water supply within the Middle Illinois River watershed: 1) direct withdrawals from the Illinois River; 2) public supply systems using the Vermilion River and off-channel reservoirs at Pontiac and Streator; and 3) groundwater from within the Middle Illinois River basin.

A companion report has been published (Meyer et al., In preparation) evaluating water demand scenarios out to 2060 for the Middle Illinois River, Northwest Illinois, and Kankakee River Regions.

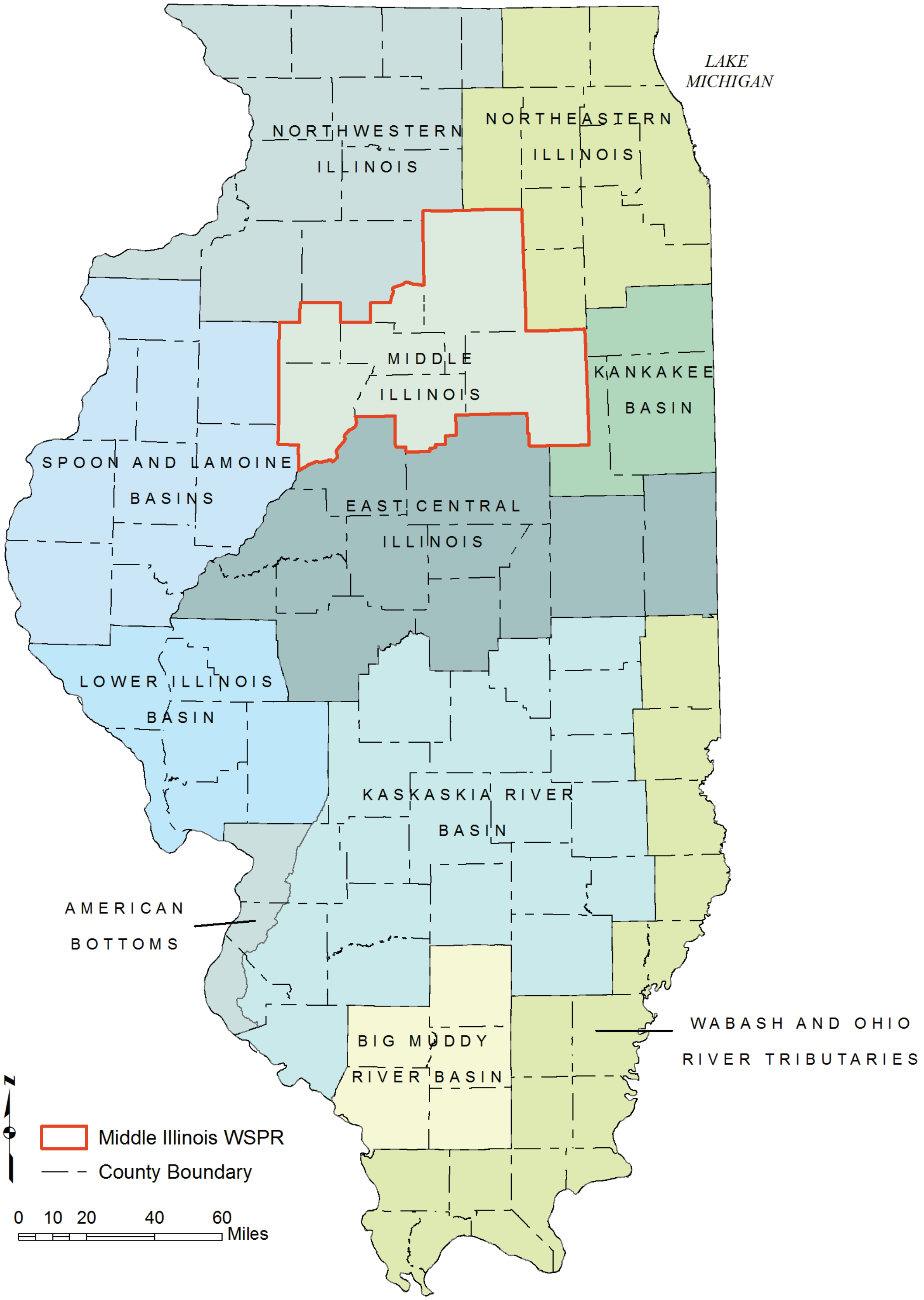

Figure 1. Water supply planning regions (WSPRs) in Illinois

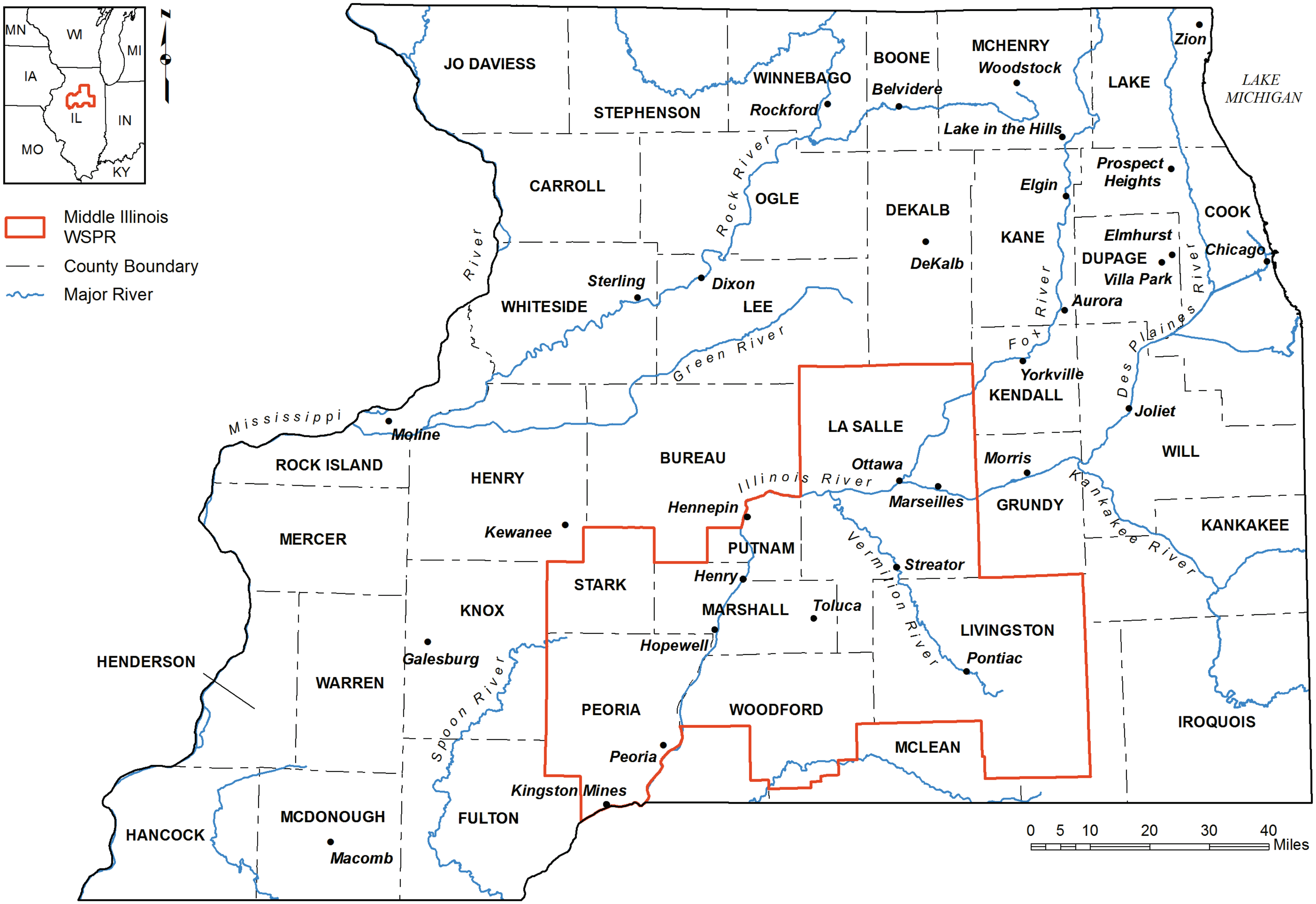

Figure 2. Location map

2 Demand Projections for the Middle Illinois WSPR

We have developed estimates of water demand in the Middle Illinois WSPR from 2015 to 2060. The estimates are developed separately for five major water-demand sectors: (1) public supply; (2) self-supplied domestic; (3) self-supplied thermoelectric power generation; (4) self-supplied industrial and commercial; and (5) self-supplied irrigation, livestock, and environmental. Estimates are developed for all sectors on a county level; estimates of demand for public supply are also developed at a facility level for 24 dominant public systems, including the largest two systems in each county.

2.1 Methodology

The techniques we used to develop estimates differ by sector and include unit-demand methods and multiple regressions. They provide estimates of future demand as a function of demand drivers and, for many sectors and subsectors, explanatory variables. Explanatory variables are variables influencing unit rates of water demand, such as summer-season temperature and precipitation, median household income, marginal price of water, employment-to-population ratio, labor productivity, and precipitation deficit during the irrigation season. For most sectors and subsectors, we estimated total demand by multiplying unit rates of water demand by demand drivers. Demand drivers included such measures as population served by public systems, population served by domestic wells, number of employees, gross thermoelectric power generation, irrigated cropland acreage, irrigated golf course acreage, and head counts of various livestock types.

We employed available data and analysis to estimate plausible future values of demand drivers, explanatory variables, and unit rates of water demand. For each sector, we developed three scenarios of future water demand that reflect three different sets of plausible socioeconomic and weather conditions. These include a less resource intensive (LRI) scenario, a current trends (CT) (or baseline) scenario, and a more resource intensive (MRI) scenario. To estimate water demand under each scenario, we used differing sets of justifiable assumptions regarding future values of explanatory variables, unit rates of water demand, and/or demand drivers. A "normal" climate, based on 1981-2010 climate "normals," was assumed in all scenarios. Although our estimates suggested a plausible range of future demand, they do not represent forecasts or predictions, and they do not indicate upper and lower bounds of future water demand. Different assumptions or different future conditions could result in predicted or actual water demand that is outside of this range.

2.1.1 Data Sources

We employed data from a diversity of sources to estimate future values of demand drivers, explanatory variables, unit rates of water demand, and—ultimately—total water demand. Facility-level historical water withdrawal data were obtained from the ISWS Illinois Water Inventory Program (IWIP) database. We also used county-level demand data developed by the United States Geological Survey (USGS), which in turn bases its estimates for many sectors on IWIP data. Counts of domestic wells were obtained from a database maintained by the ISWS. We obtained data on historical and future values of demand drivers and explanatory variables from state and federal agencies, including the Illinois Commerce Commission; Illinois Department of Employment Security; Illinois Department of Public Health; Illinois

Environmental Protection Agency; Midwestern Regional Climate Center, Center for Atmospheric Science, ISWS; United States Census Bureau; United States Department of Agriculture; United States Department of Labor Bureau of Labor Statistics; and the United States Energy Information Administration.

2.2 Draft Report

Our demand estimates will be provided and discussed in a draft report that was completed in December 2015. We have produced this report in anticipation of a local water-supply planning committee providing review and local knowledge to improve and make the estimates more relevant. In fact, for the self-supplied thermoelectric power generation and the self-supplied industrial and commercial sectors, we provide for the addition or retirement of new power plants and industrial/commercial establishments into our scenarios based on local knowledge provided by committee members. With the water supply planning committee for the Middle Illinois WSPR currently disbanded, however, we may need to make such assumptions without the guidance of local authorities.

2.3 Results

2.3.1 Demand for Self-Supplied Water for Thermoelectric Power Generation

Demand for self-supplied water for thermoelectric power generation—i.e., for power plants fueled by nuclear fission or fossil fuels—dominates water demand in the region (Figure 3). We discuss this sector in greater detail than other sectors, partly because of its dominance of regional water demand, but also because the fate of the water used in thermoelectric power generation is critically important in understanding its impacts, and because future demand for self-supplied water for thermoelectric power generation is particularly challenging to quantify.

Water for thermoelectric power generation is used almost entirely for cooling, and, because the demand for cooling water at power plants is great, most plants are sited adjacent to rivers or large surface water bodies. Cooling system design, as well as gross generation capacity, strongly influence water demand. Demand by plants using *once-through* cooling is typically greater per unit of generated electricity than by plants using *closed-loop* cooling, in which the cooling water is recirculated through heat exchangers, cooling lakes, or cooling towers at the plant. The proportion of the withdrawn water lost to evaporation or consumed is greater from plants using closed-loop systems, however. Less than 3 percent of the withdrawn water at plants using once-through cooling is typically consumed, mainly through evaporation (Solley et al., 1998). In plants using cooling towers in a closed-loop system, however, losses range from 30 percent in nuclear facilities to 70 percent in plants using fossil fuels (Dziegielewski and Bik, 2006). In both once-through and closed-loop cooling, cooling water is typically discharged to its source a short distance downstream of its point of withdrawal.

In the Middle Illinois WSPR, demand for self-supplied water for thermoelectric power plants totaled 655 Mgd in 2010, or 76 percent of total regional water demand of 866 Mgd (Figure 3). The United States Energy Information Administration reports that gross electricity generation at the responsible power plants totaled 26,922,862 megawatt-hours (MWh) in 2010. Assuming 1.05 gallons of evaporation per kilowatt-hour (KWh) of generated energy (Torcellini et al., 2003), the consumptive loss from the 866-Mgd demand is calculated to be about 77 Mgd in 2010, or about 12 percent of the total.

Future demand for self-supplied water for thermoelectric power generation in the Middle Illinois WSPR depends heavily on the gross generating capacity and the cooling system design of active power plants in the region. Estimation of this demand cannot be based on local demand for electricity, because electricity that is generated in the region may be sold outside the region. In fact, assuming an Illinois Commerce Commission estimate of per-capita electricity demand of 10.14 MWh/capita-year, we estimate that regional electricity demand in 2010 was only about 15 percent of gross generation in the Middle Illinois WSPR. The CT and MRI scenarios therefore assume, preliminarily, that regional gross thermoelectric power generation remains constant from 2010 to 2060, and that water demand continues at the 2010 level of 655 Mgd. The LRI scenario assumes that a single 136-megawatt (MW) generator at the E.D. Edwards power plant is retired effective 2015, reducing regional water demand to 588 Mgd.

As mentioned previously, our scenario definitions are flexible, and we seek review and guidance from local authorities regarding them. Specifically, we ask for local knowledge of the county location, gross generation capacity, likely operation start date, and cooling system design of proposed thermoelectric power generation facilities. We also seek information on plans to retire power plants or individual generators at plants as we have already assumed for the Edwards plant under the LRI scenario.

2.3.2 Other Water-Demand Sectors

This section discusses demand in the other four water-demand sectors considered in our analysis. These include public supply; self-supplied domestic; self-supplied industrial and commercial (IC); and self-supplied irrigation, livestock, and environmental (ILE). The environmental subsector included within the ILE sector includes water used to support environmental amenities such as wetlands, forest and prairie preserves, park districts, and game farms.

Figure 3 shows reported demand in 2010 based on published USGS estimates (United States Geological Survey, 2014) and withdrawal data reported to IWIP. Demand by self-supplied IC establishments in the Middle Illinois WSPR totaled 150 Mgd, or 17 percent of the total demand of 866 Mgd, with Peoria County accounting for about 85 percent of this demand. Demand by public water systems in 2010 totaled 46 Mgd, or 5 percent of total demand, with Peoria County accounting for 52 percent of the demand. Self-supplied ILE demand totaled 10 Mgd in 2010, or 1 percent of regional demand, and self-supplied domestic demand totaled 4 Mgd, less than 1 percent of regional demand. Regional water demand in 2010, not including the self-supplied demand for thermoelectric power generation, totaled 210 Mgd.

Figure 4 shows aggregate projected demand in the Middle Illinois WSPR to 2060 for all sectors except self-supplied thermoelectric power generation. From 2010 to 2060, total demand in the region increases to 241 Mgd under the LRI scenario, 320 Mgd under the CT scenario, and 425 Mgd under the MRI scenario. Use of a climate-normalized estimate of 2010 demand—one in which we used the methods of this study to estimate public supply and ILE demand under 1981-2010 normal climate—permits meaningful comparison of estimates of future demand with present demand as represented by 2010 socioeconomic conditions. We estimated 2010 climate-normalized demand at 213 Mgd, slightly higher than the reported total of 210 Mgd. Our 2060 LRI, CT, and MRI totals are, respectively, 13 percent, 50 percent, and 99 percent greater than the 2010 climate-normalized total. Figures 5, 6, and 7 show climate-normalized demand for each sector (omitting thermoelectric power generation) under each scenario. The figures show that most of the increase in total demand under all scenarios, but in particular the CT and MRI scenarios, is accounted for by increases in self-supplied IC demand.

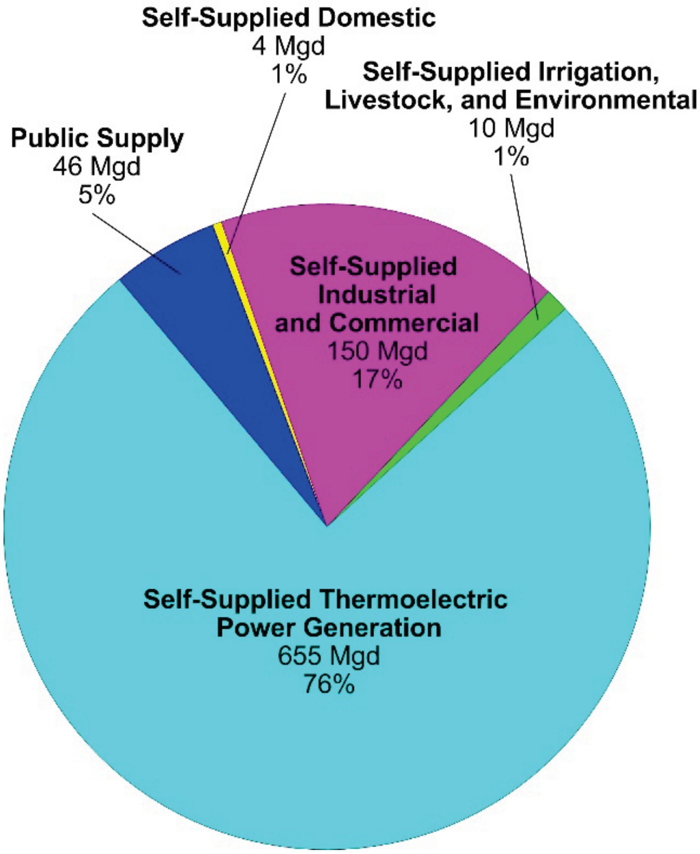

Figure 3. Estimated historical water demand in the Middle Illinois WSPR in 2010

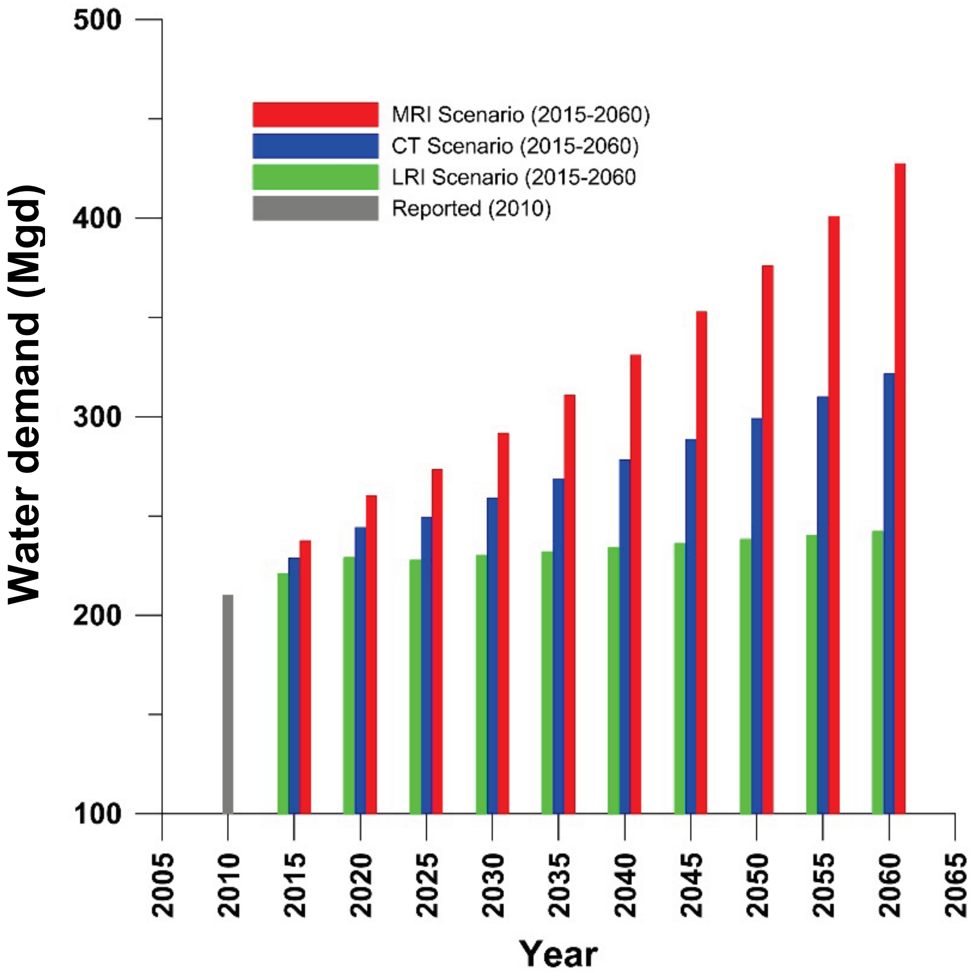

Figure 4. Total reported (2010) and projected (2015-2060) water demand in the Middle Illinois WSPR for all demand sectors except self-supplied thermoelectric power generation

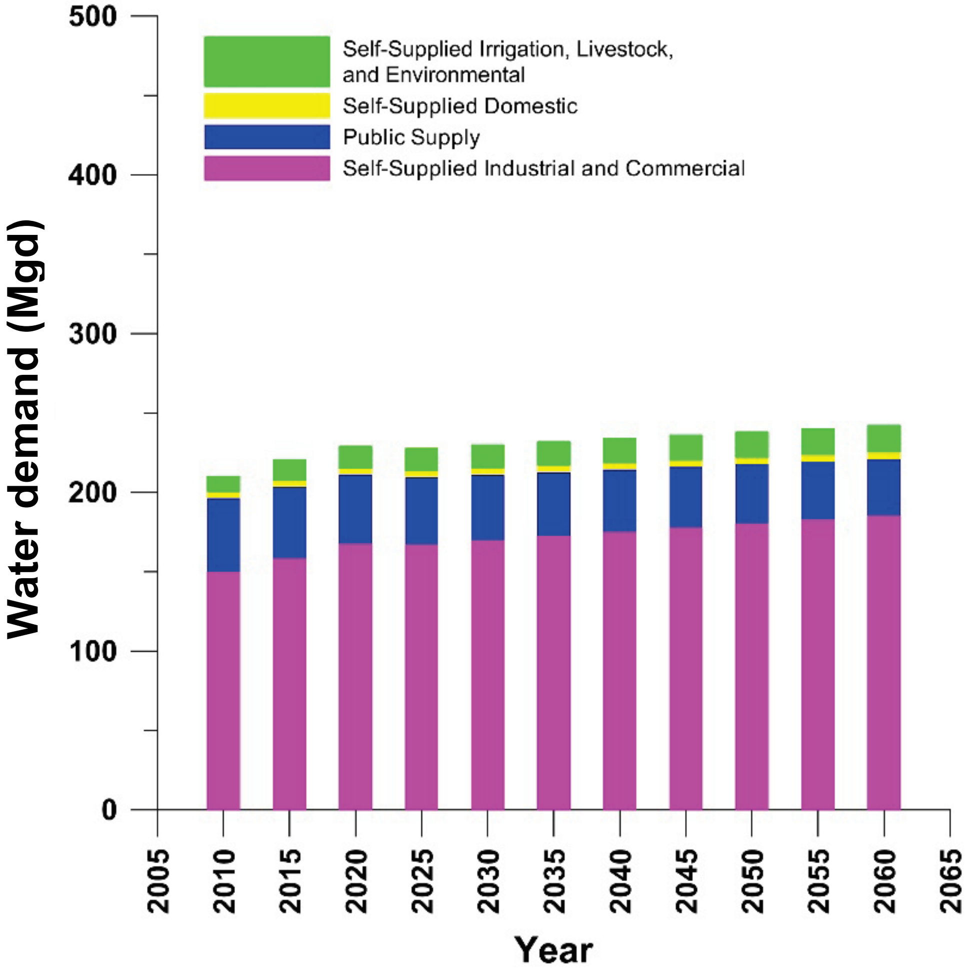

Figure 5. Climate-normalized historical (2010) and projected (2015-2060) water demand in the Middle Illinois WSPR for all demand sectors except self-supplied thermoelectric power generation, LRI scenario

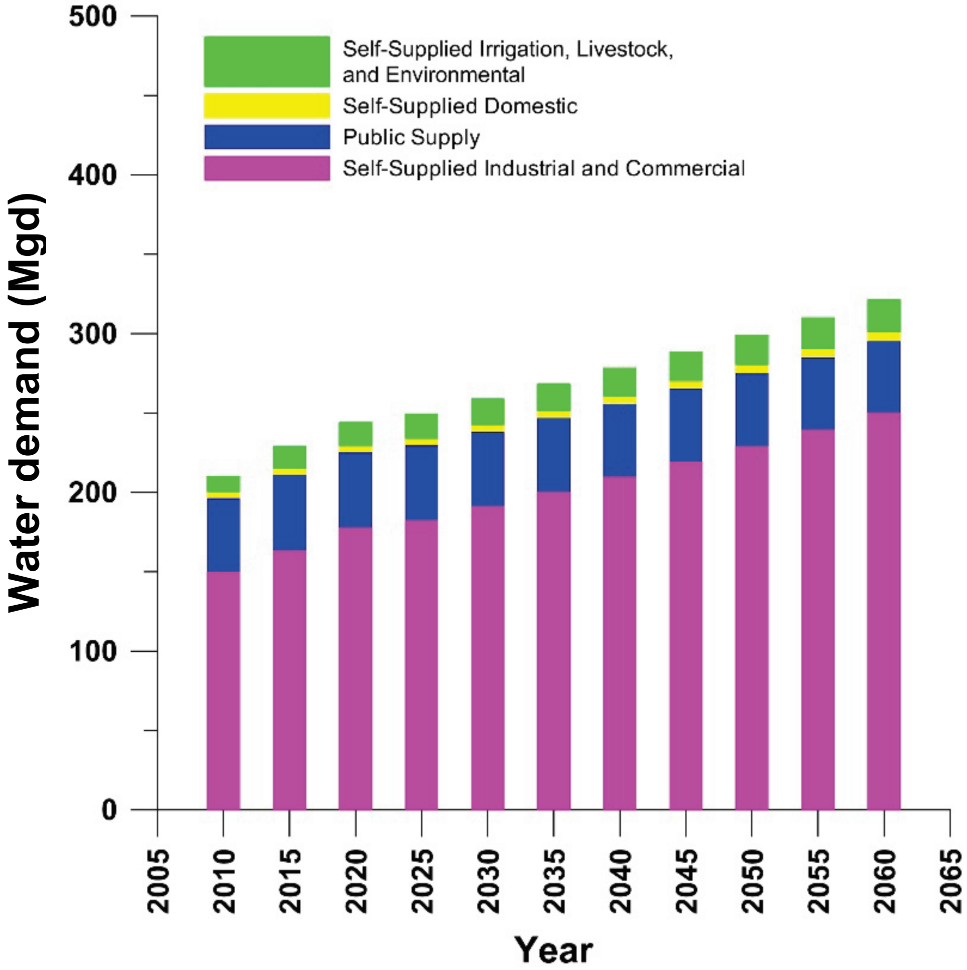

Figure 6. Climate-normalized historical (2010) and projected (2015-2060) water demand in the Middle Illinois WSPR for all demand sectors except self-supplied thermoelectric power generation, CT scenario

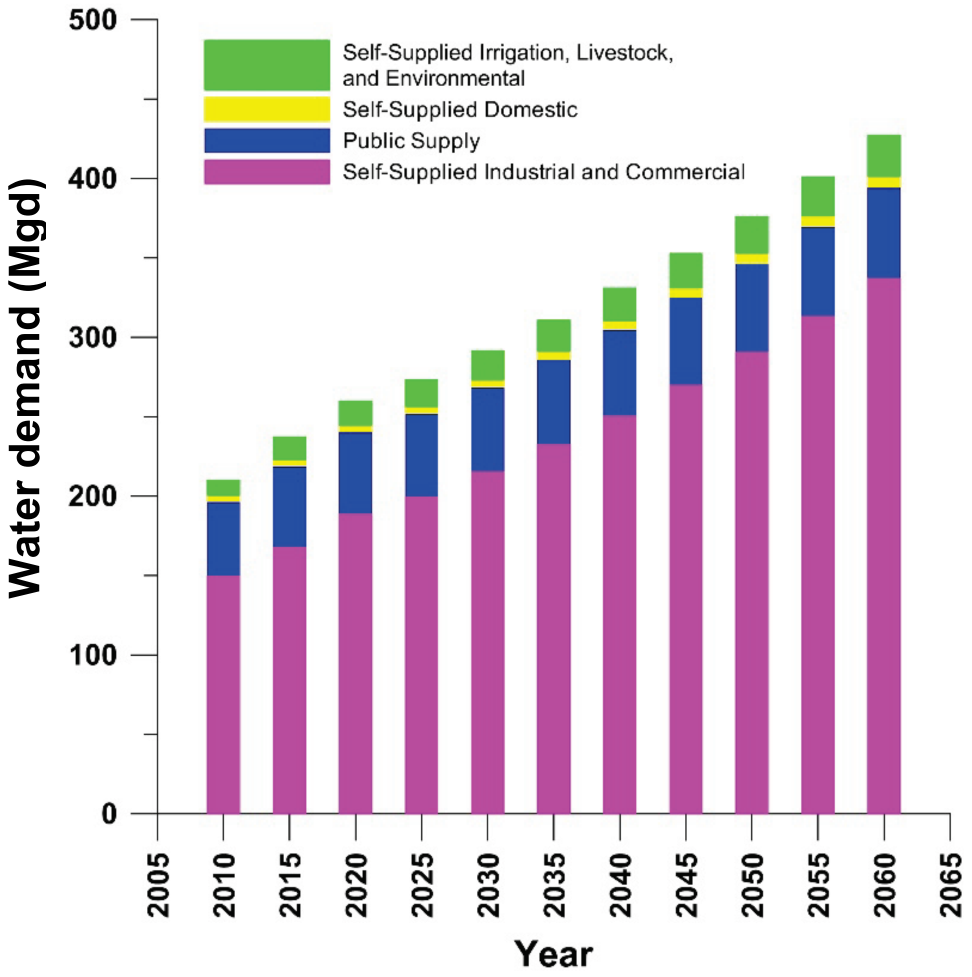

Figure 7. Climate-normalized historical (2010) and projected (2015-2060) water demand in the Middle Illinois WSPR for all demand sectors except self-supplied thermoelectric power generation, MRI scenario

3 Groundwater Studies in Middle Illinois

3.1 Aquifers of Illinois

Three classes of productive aquifers are generally present in Illinois: 1) sandstone, 2) weathered carbonate, and 3) coarse-grained unconsolidated (sand and gravel) aquifers.

1. Sandstone is a sedimentary rock with comparatively large pore spaces between grains, at least in Illinois. Furthermore, the pore spaces are generally interconnected, resulting in high permeability. Permeability is a measure of the ease with which water can move through a material. Sandstones in the Middle Illinois WSPR are mostly Cambrian or Ordovician in age, collectively referred to as the ***Cambrian-Ordovician sandstone aquifer***.

2. Carbonate rocks (limestone and dolomite) can also be aquifers in Illinois, in particular where they are within 125 feet of the bedrock surface. In Illinois, carbonates are more susceptible to weathering than other rock types (e.g., sandstone and shale). This weathering results in the development of secondary porosity in the form of solution-enlarged fractures, cracks, and crevices. As a result, highly productive weathered aquifers in Illinois are generally referred to as ***shallow carbonate bedrock aquifers***.

3. Bedrock in the Middle Illinois WSPR is covered with unconsolidated glacial deposits. ***Coarse-grained unconsolidated aquifers*** form where these deposits are generally composed of sand and gravel, common along rivers or in bedrock valleys. Sand and gravel aquifers generally have higher permeability and shallower water levels than most bedrock aquifers, which make them more economical to develop. However, shallow aquifers are often more susceptible to contamination, in particular if the sand and gravel is at or near land surface.

Many major aquifers in Illinois are contained within sequences of high- and low-permeability layers. These low-permeable layers are known as aquitards. In the presence of aquitards, the exchange of groundwater between aquifers is minimal. In Illinois, bedrock layers not composed of sandstone or weathered carbonates serve as aquitards. Fine-grained clays and silts within unconsolidated glacial material also act as aquitards and drastically limit recharge.

When aquifers that are overlain by aquitards are completely saturated, they are referred to as *confined*. Groundwater within confined aquifers is under pressure. Water in a well open to the confined aquifer rises to a level that represents this pressure; this water level is referred to as the *head*. In a confined aquifer, the head is by definition above the top of the aquifer. Eventually, if withdrawals from a confined aquifer are great enough, the head may fall below the top of the aquifer, causing the aquifer to become *unconfined*. An unconfined aquifer has an upper boundary that is defined by the head in the aquifer and not an aquitard (Freeze and Cherry, 1979). Unconfined aquifers can also occur naturally where overlying aquitards are not present, such as the outwash aquifers along major river corridors. In an unconfined aquifer, additional groundwater withdrawals beyond ambient groundwater flow are satisfied by drainage of water from the pore spaces in the aquifer.

3.2 Hydrostratigraphic Units

For purposes of groundwater investigations, the ISWS combines adjacent geologic strata with similar hydrologic characteristics into individual hydrostratigraphic units. Thirteen bedrock hydrostratigraphic units are present in the Middle Illinois WSPR (Table 1, Figure 8). Each unit is assigned a generalized geologic material (sand and gravel, silt and clay, carbonate, sandstone, shale, or crystalline) based on available geologic information and insight from calibrated groundwater flow models (Meyer et al., 2012; Meyer et al., 2013; Roadcap et al., 2013; Abrams et al., 2015). The generalized geologic material of each hydrostratigraphic unit reflects its regional effect on groundwater flow. However, other geologic materials are frequently present and may affect groundwater flow on a local scale.

The unconsolidated glacial material can be subdivided into two basic hydrostratigraphic units, fine- and coarse-grained Quaternary (Table 1); however, these units often occur in a complicated sequence of layers as a result of multiple glacial advances. In areas along the Illinois River where detailed mapping of Quaternary deposits have occurred, these hydrostratigraphic units are subdivided into named Quaternary layers (see McKay et al. (2010) and related ISGS geologic maps). Such detailed mapping has not been conducted in large areas of the Middle Illinois WSPR away from the Illinois River where thick sand and gravel deposits are uncommon. Therefore, stack maps developed by the ISGS will be utilized to subdivide fine- and coarse-grained materials of the Quaternary system, albeit in a crude manner. Areas which require more detailed geologic mapping will be identified as a part of this study.

The remaining 11 hydrostratigraphic units represent bedrock material. Maps depicting the top elevation of each bedrock hydrostratigraphic unit have been completed for the Middle Illinois WSPR. Due to a lack of data, these maps are more approximate than those completed for previous water supply planning regions (in particular Northeastern Illinois).

Several bedrock hydrostratigraphic units are at the bedrock surface in Illinois (Figure 9); these units are often weathered and can serve as productive aquifers. However, most of the Middle Illinois WSPR has the Pennsylvanian-Mississippian Unit at the bedrock surface. While this unit can contain thin layers of limestone and sandstone, it is predominantly shale, which typically has low permeability and hence does not generally form an aquifer. Only in northern LaSalle County are predominantly non-shale materials located at or near the bedrock surface.

Table 1. Geologic Composition of the Hydrostratigraphic Units Present in the Study Area

<table>
<tr><th>AGE (SYSTEM OR SERIES)</th><th colspan="2">STRATIGRAPHY</th><th>HYDROSTRATIGRAPHIC UNIT</th><th>GENERALIZED GEOLOGIC MATERIAL</th></tr>
<tr><td rowspan="2">QUATERNARY</td><td colspan="2" rowspan="2">Unconsolidated</td><td>Coarse-Grained Quaternary</td><td>Sand and gravel</td></tr>
<tr><td>Fine-grained Quaternary</td><td>Silt and clay</td></tr>
<tr><td>CRETACEOUS</td><td colspan="2" rowspan="4"><i>Lithostratigraphic units not detailed</i></td><td rowspan="4">Pennsylvanian-Mississippian</td><td rowspan="4">Shale</td></tr>
<tr><td>PENNSYLVANIAN</td></tr>
<tr><td>MISSISSIPPIAN</td></tr>
<tr><td>UPPER DEVONIAN</td></tr>
<tr><td>MIDDLE DEVONIAN</td><td colspan="2" rowspan="3"><i>Lithostratigraphic units not detailed</i></td><td rowspan="3">Silurian-Devonian</td><td rowspan="3">Carbonate</td></tr>
<tr><td>LOWER DEVONIAN</td></tr>
<tr><td>SILURIAN</td></tr>
<tr><td rowspan="6">ORDOVICIAN</td><td colspan="2">Maquoketa Group</td><td>Maquoketa</td><td>Shale</td></tr>
<tr><td colspan="2">Galena Group</td><td rowspan="2">Galena-Platteville</td><td rowspan="2">Carbonate</td></tr>
<tr><td colspan="2">Platteville Group</td></tr>
<tr><td rowspan="2">Ancell Group</td><td>Glenwood Formation</td><td rowspan="2">St. Peter</td><td rowspan="2">Sandstone</td></tr>
<tr><td>St. Peter Sandstone</td></tr>
<tr><td colspan="2">Prairie du Chien Group</td><td rowspan="2">Prairie du Chien-Eminence</td><td rowspan="2">Carbonate</td></tr>
<tr><td rowspan="9">CAMBRIAN</td><td colspan="2">Jordan Formation (only northwestern Illinois), Eminence Formation</td></tr>
<tr><td colspan="2">Potosi Dolomite</td><td rowspan="2">Potosi-Franconia</td><td rowspan="2">Carbonate</td></tr>
<tr><td colspan="2">Franconia Formation</td></tr>
<tr><td colspan="2">Ironton Formation</td><td rowspan="2">Ironton-Galesville</td><td rowspan="2">Sandstone</td></tr>
<tr><td colspan="2">Galesville Formation</td></tr>
<tr><td rowspan="3">Eau Claire Formation</td><td>Proviso Member</td><td rowspan="2">Eau Claire</td><td rowspan="2">Shale and Carbonate</td></tr>
<tr><td>Lombard Member</td></tr>
<tr><td>Elmhurst Member</td><td rowspan="2">Mt. Simon</td><td rowspan="2">Sandstone</td></tr>
<tr><td colspan="2">Mt. Simon Formation</td></tr>
<tr><td>PRECAMBRIAN</td><td colspan="2"><i>Lithostratigraphic units not detailed</i></td><td>Precambrian</td><td>Crystalline</td></tr>
</table>

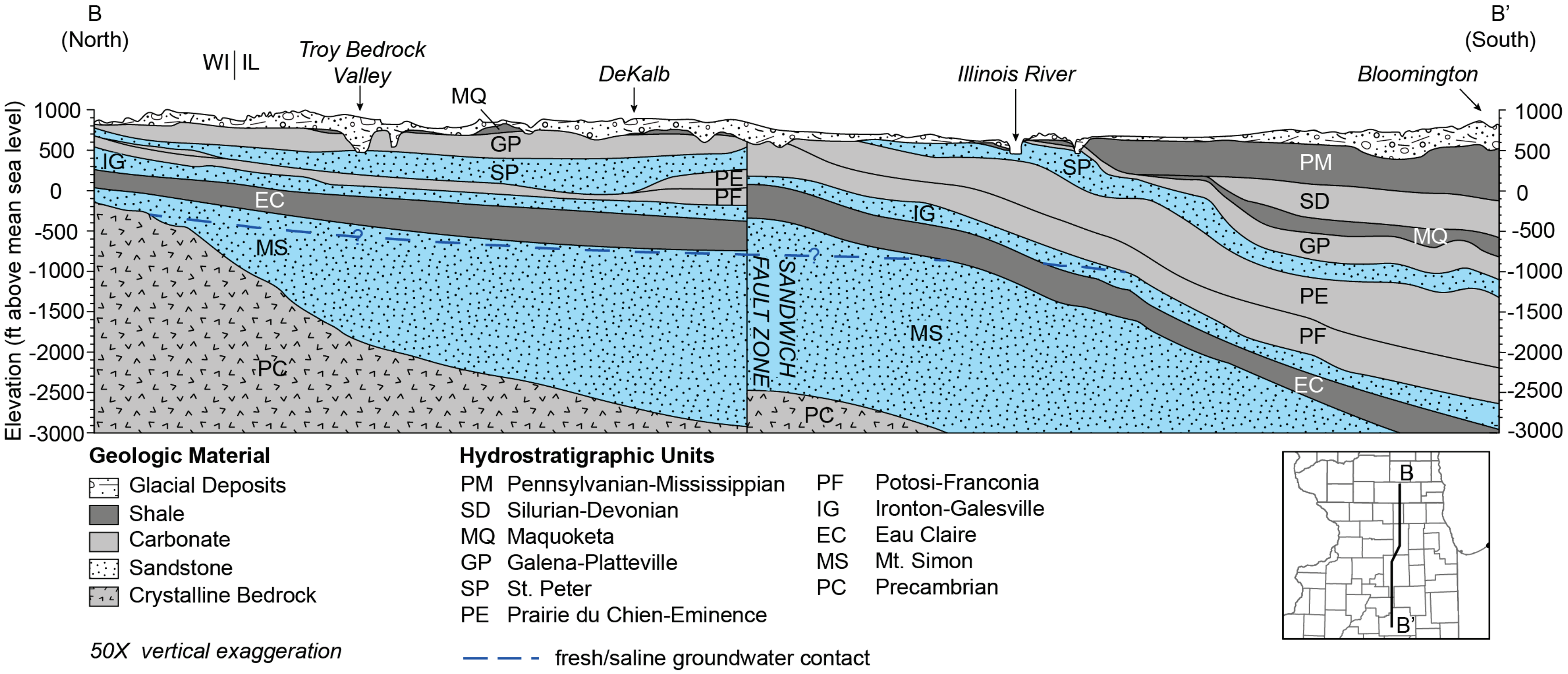

Figure 8. North-to-south cross section from southern Wisconsin to central Illinois showing the hydrostratigraphic units of the study area. Note the presence of the Sandwich Fault Zone, which offsets the hydrostratigraphic units.

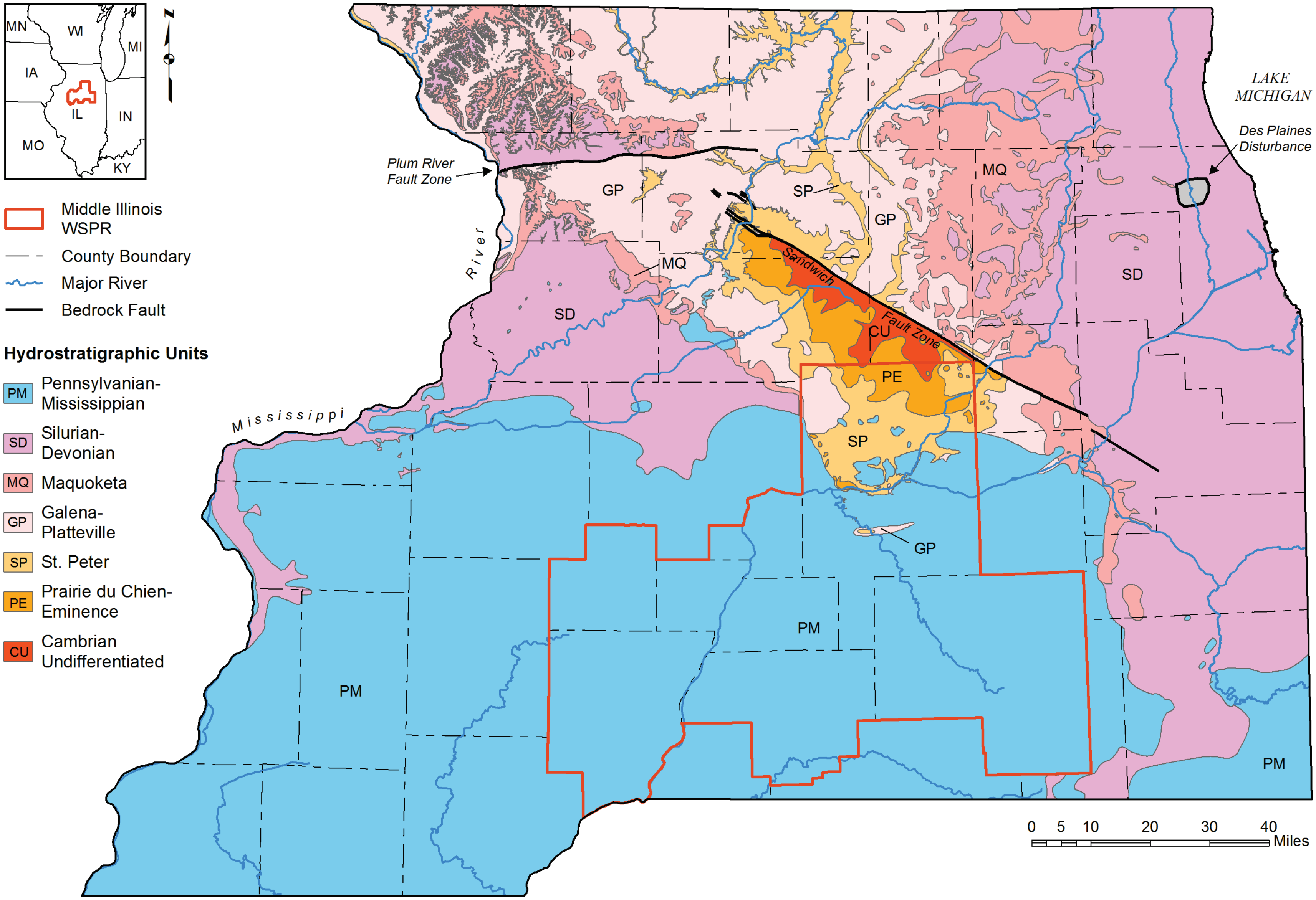

Figure 9. Hydrostratigraphic units present at the bedrock surface (Mudrey et al., 1982; Kolata et al., 2005). Note that all units below the Prairie du Chien-Eminence Unit are grouped into a Cambrian Undifferentiated category.

3.3 Sand and Gravel Aquifers in the Middle Illinois WSPR

The thick sand and gravels along the Illinois River from Hennepin to Peoria form what has been commonly referred to as the Sankoty Aquifer. Recent work by the ISGS (McKay et al., 2010), however, shows that much of the sand is actually from later glacial advances than the older glacial advance to which the Sankoty sands were previously attributed. The Sankoty sand and gravels are hydrologically connected to the Illinois River and are a productive aquifer in the Middle Illinois WSPR, as indicated by Figure 10, which consists of data collected from public supply, self-supplied commercial and industrial, and some irrigation wells by IWIP.

The Sankoty Aquifer in the Peoria area was studied by Marino and Schicht (1969) and Burch and Kelly (1993) to help assess the impacts of heavy pumpage on water levels. Because the gradient of the Illinois River is so flat, groundwater flow generally follows a perpendicular flow path from the valley walls to the river. However, local cones of depression have developed around the larger pumping centers in Peoria. In an effort to mitigate the drawdown and provide cooler water, the ISWS constructed and monitored artificial groundwater recharge pits next to the river (Suter and Harmeson, 1960). Studies at Henry in Marshall County by Ray et al. (1998) also show groundwater flow being perpendicular to the river. In addition, these studies indicate that flooding along the river can also impact the groundwater flow system as well as groundwater quality.

3.3.1 Water Quality

The two most important contaminants in shallow sand and gravel aquifers in the Middle Illinois WSPR are arsenic and nitrate. Arsenic concentrations greater than the drinking water standard (10 micrograms per liter (μg/L)) are common in the region, especially in Woodford County (Figure 11). Arsenic is a naturally occurring contaminant, being present in the sediments that make up the aquifer, and it is dissolved into the groundwater when geochemical conditions are suitable. There is widespread geographic variability in arsenic concentrations, which has also been observed in other parts of the state (Kelly et al., 2005) (Kelly and Holm, 2011).

Nitrate-nitrogen (NO_3-N), on the other hand, is an anthropogenic contaminant, with various sources including agricultural activities (synthetic fertilizer, livestock manure, soil disruption) and human waste (sewage and septic systems). The drinking water standard for NO_3-N is 10 milligrams per liter (mg/L), and concentrations greater than 2 to 3 mg/L generally indicate contamination from human sources. Elevated concentrations of NO_3-N were found in a number of wells located along the Illinois River, while concentrations were much lower in wells away from the river (Figure 12). Elevated NO_3-N is indicative of the shallow, unconfined alluvial aquifer in the Illinois River valley. Aquifers like these are vulnerable to surface activities, including runoff from cropped fields and septic discharge.

Chloride (Cl^-) is a common contaminant that generally indicates human activities, although there are natural sources as well. Where there are no significant natural sources, concentrations greater than 15 mg/L generally indicate human contamination. In the Middle Illinois Region, Cl^- concentrations were elevated in certain areas (Figure 13). In the area near

Starved Rock, this is likely due to an upwelling of brines from deeper bedrock formations. For example, an old Salt Well on Starved Rock property that was used for salt making by early settlers has very high Cl^- concentrations. Elevated levels in other parts of the region are probably the result of agricultural runoff, septic/sewage, and/or road salt runoff. Road salt runoff may be the reason for the relatively elevated levels in the Peoria area.

Well depth is an important variable for NO_3-N and Cl^-, but not for arsenic (Figure 14). Nitrate-N and Cl^- concentrations were not well correlated, indicating different sources for these two contaminants.

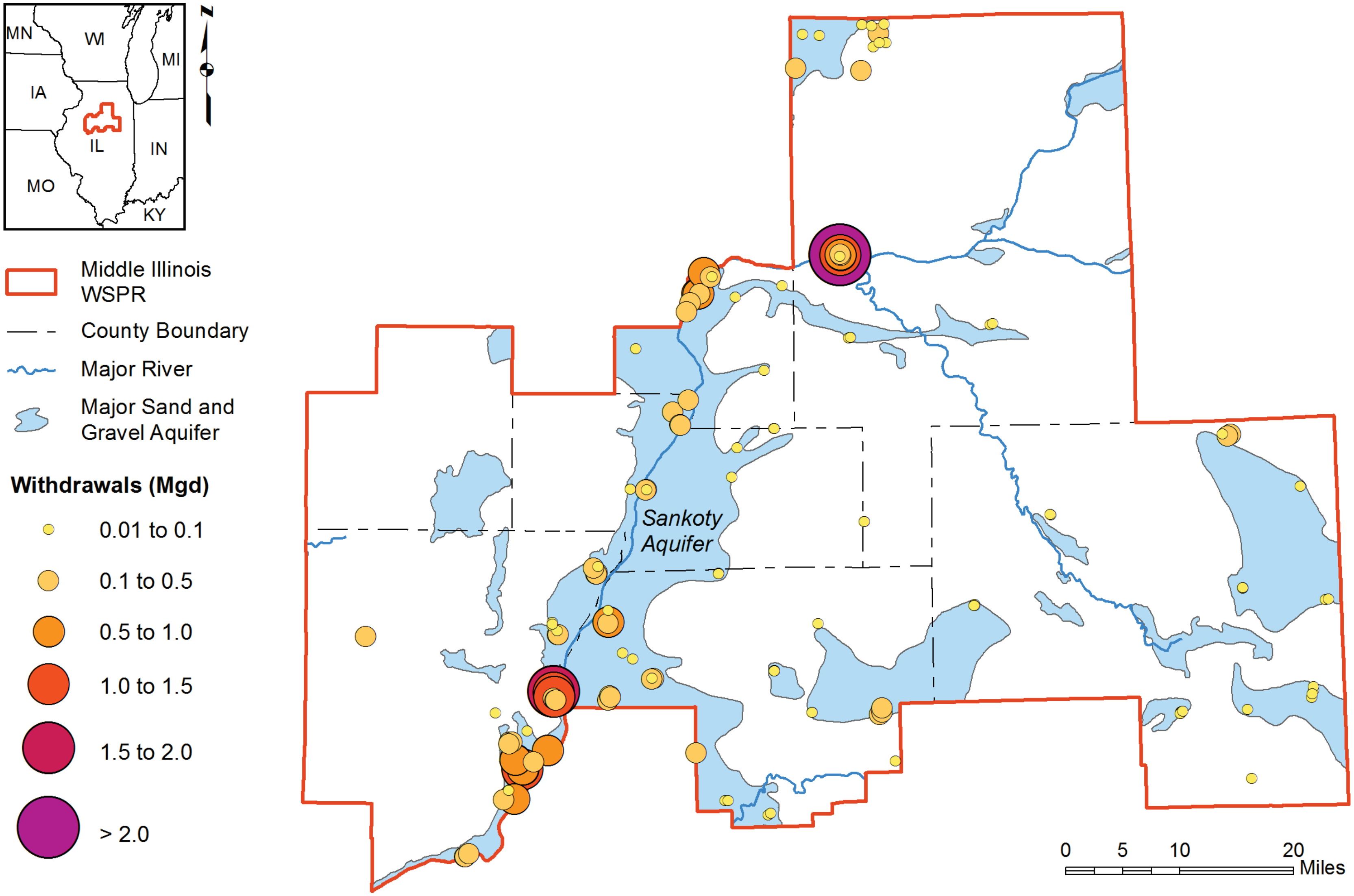

Figure 10. Withdrawals of water in millions of gallons per day (Mgd) from sand and gravel wells reporting to IWIP

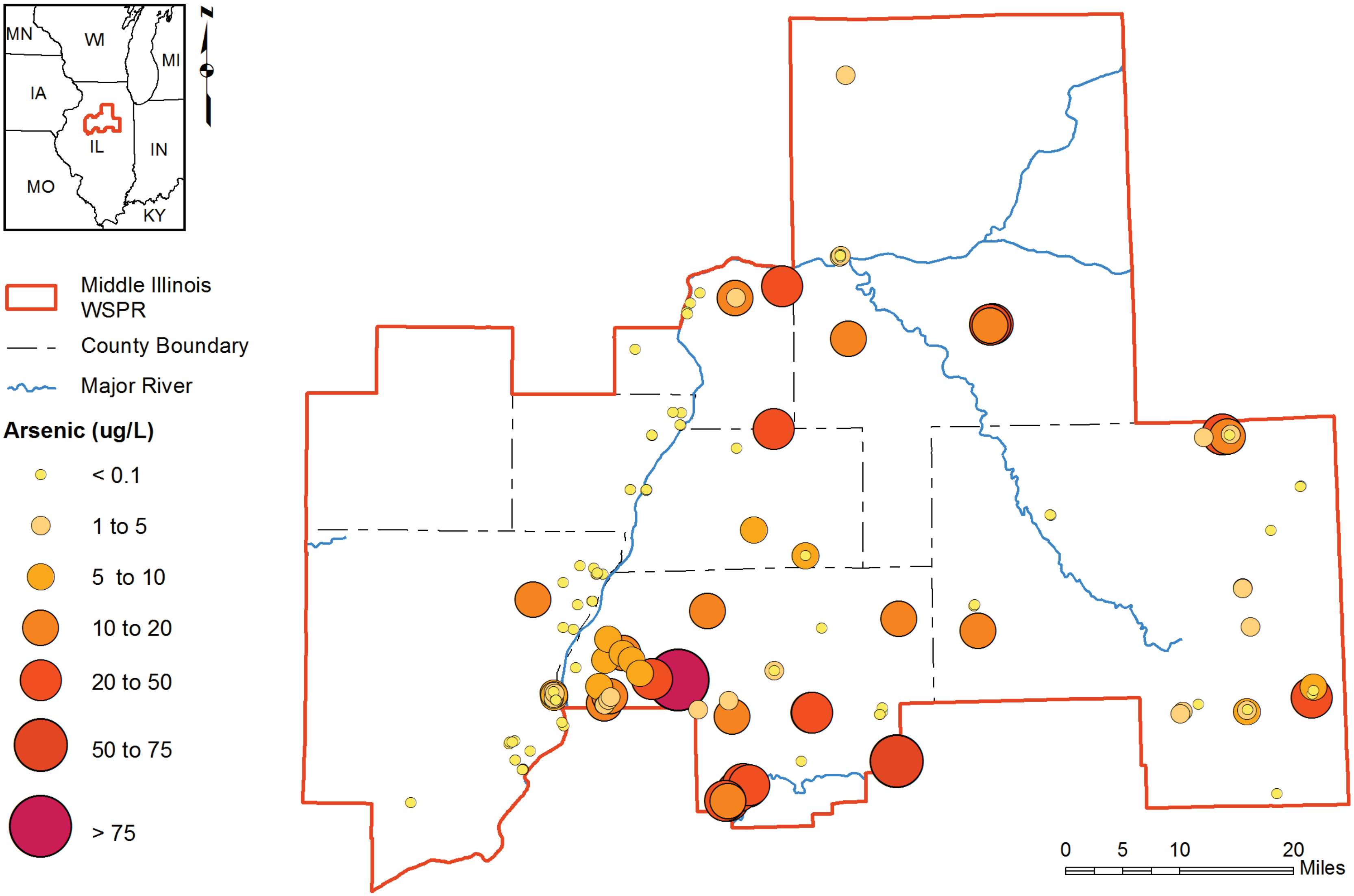

Figure 11. Arsenic concentrations in sand and gravel aquifers in the Middle Illinois Region. The drinking water standard is 10 µg/L.

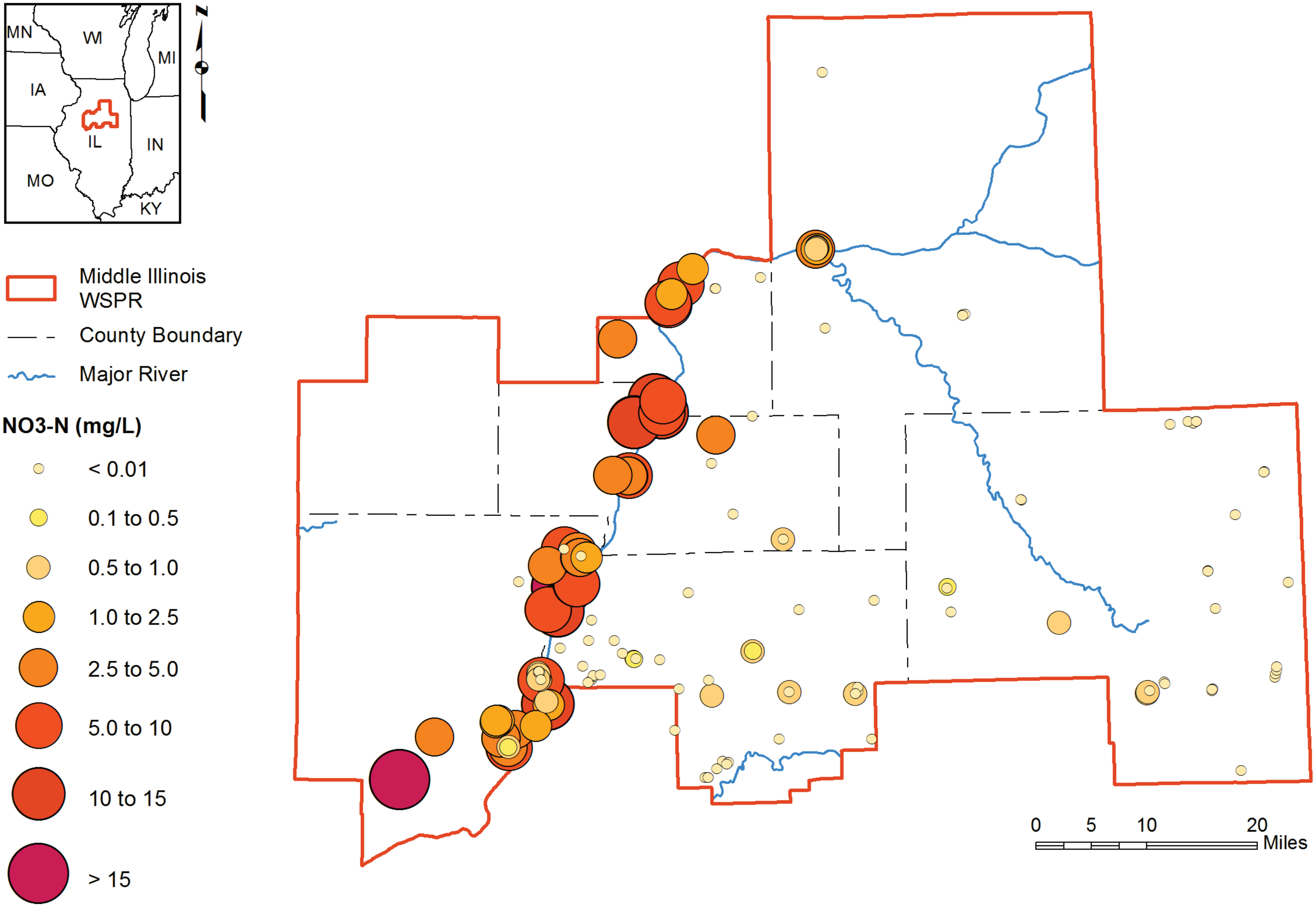

Figure 12. Nitrate-N concentrations in sand and gravel aquifers in the Middle Illinois Region. The drinking water standard is 10 mg/L.

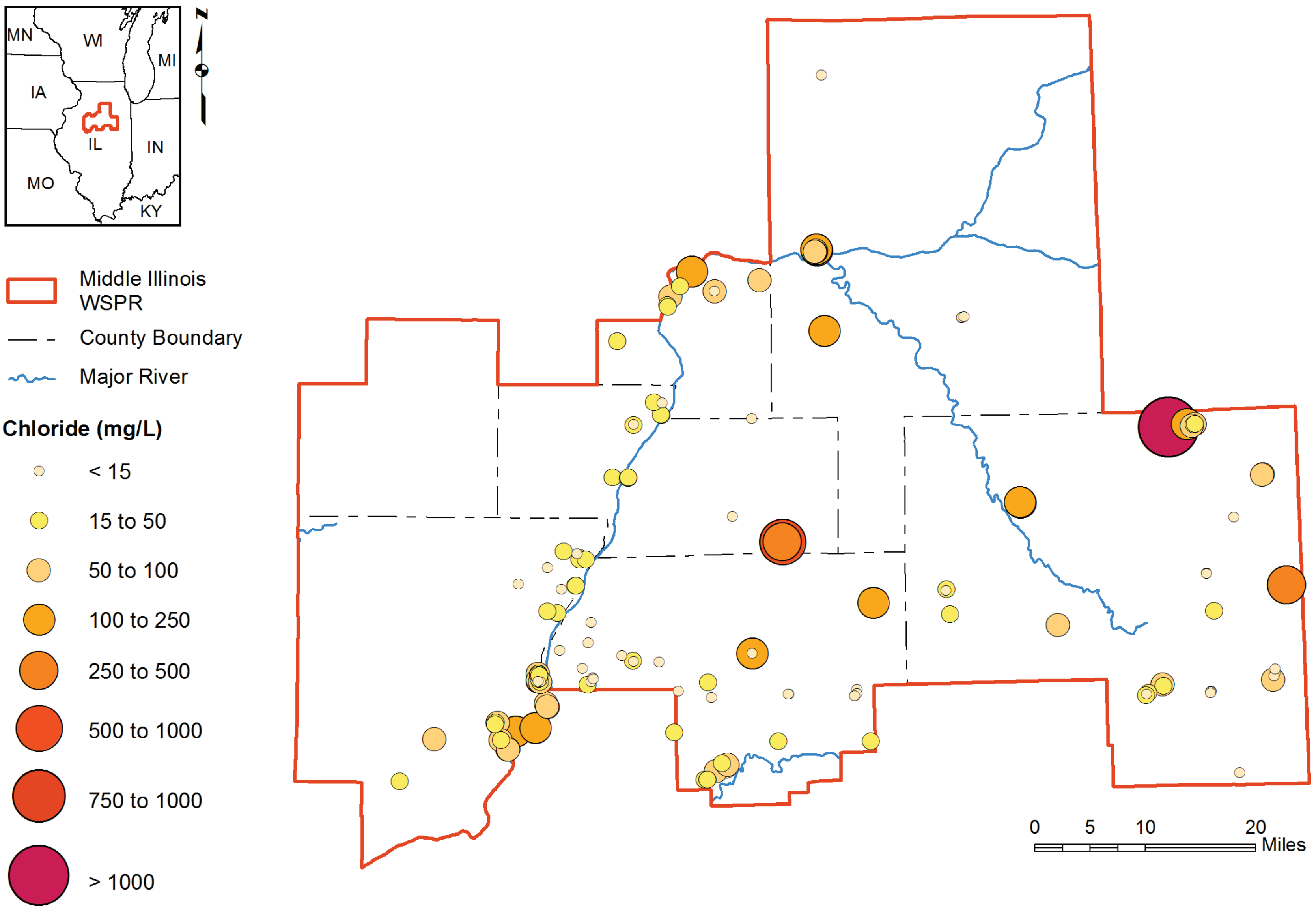

Figure 13. Chloride concentrations in sand and gravel aquifers in the Middle Illinois Region. The secondary drinking water standard is 250 mg/L.

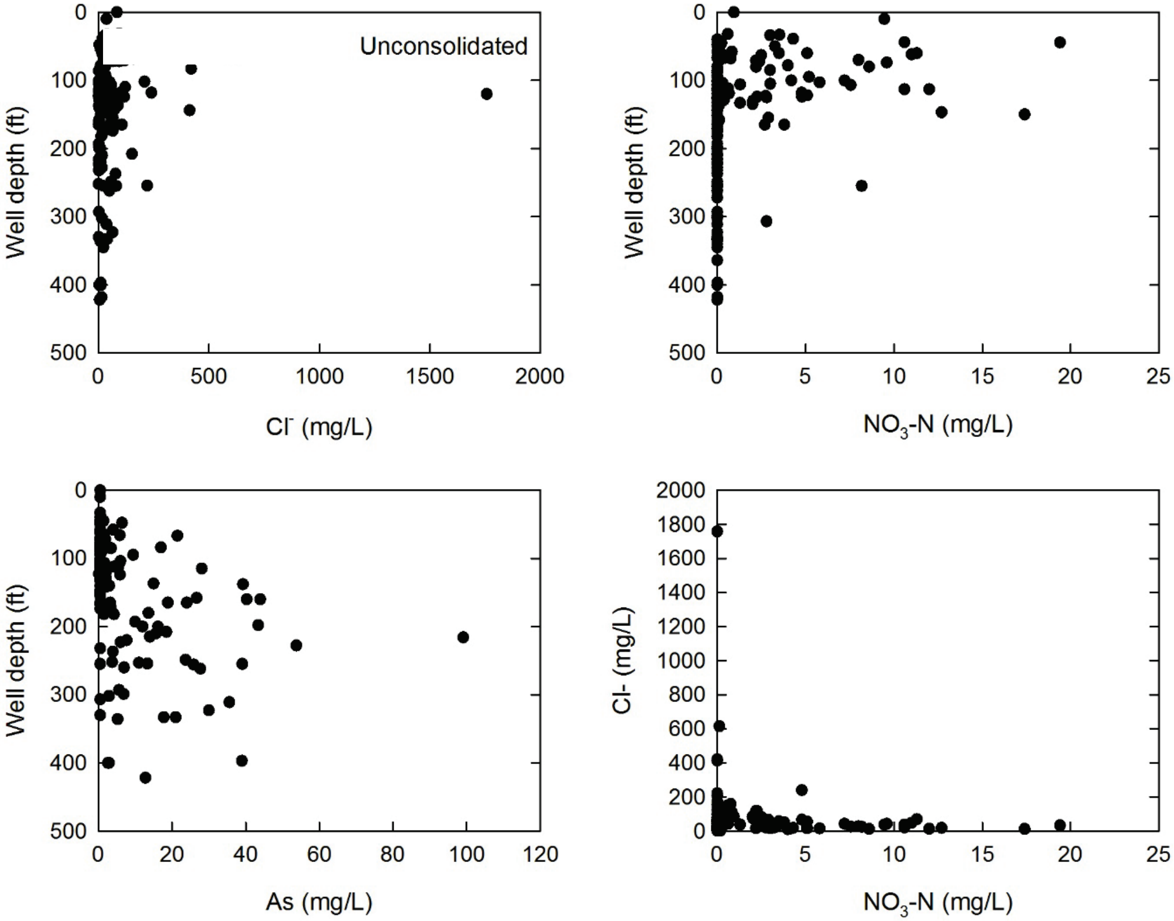

Figure 14. Chloride, nitrate-N, and arsenic concentrations as a function of depth (ft) in sand and gravel aquifers in the Middle Illinois Region. Nitrate-N vs. chloride concentrations (lower right).

3.4 Shallow Bedrock Aquifers in the Middle Illinois WSPR

Weathered bedrock aquifers are not heavily utilized in the Middle Illinois WSPR, primarily due to the lack of carbonate units at the bedrock surface within the region (Figure 9). Thin lenses or layers of sandstones and carbonates within the Pennsylvanian-Mississippian Unit support small withdrawals in local areas, particularly Stark County.

3.5 Sandstone Aquifers in the Middle Illinois WSPR

Three sandstone aquifers are used in the Middle Illinois region. From shallowest to deepest, these are the St. Peter, New Richmond, and Ironton-Galesville Sandstones (Figure 8). In the Middle Illinois WSPR, the St. Peter Sandstone comprises almost all of the St. Peter Unit (Willman et al., 1975). The St. Peter Sandstone is at the bedrock surface in most of the northern half of LaSalle County, although it is eroded away at the northern border of the county. In deeply incised bedrock valleys, the St. Peter Sandstone often underlies coarse-grained glacial aquifers. It is hydrologically connected to the Illinois River in LaSalle County.

The New Richmond Sandstone, which is contained within the Prairie du Chien-Eminence Unit (Figure 8), is also near the bedrock surface in LaSalle County. Here, it often serves as an aquifer, although wells open to the New Richmond are also commonly open to the overlying St. Peter or underlying Ironton-Galesville Sandstones. The New Richmond Sandstone is not readily used in the rest of the state.

The Ironton-Galesville sandstone comprises the entirety of the Ironton-Galesville Unit (Figure 8) and consists of well-rounded quartz sand grains similar to the St. Peter Sandstone. In the Middle Illinois WSPR, the Ironton-Galesville Sandstone is overlain and separated from the St. Peter Sandstone by two predominantly (unweathered) carbonate hydrostratigraphic units, the Prairie du Chien-Eminence and the Potosi-Franconia, which together function as an aquitard.

Except in LaSalle County, most bedrock wells in the region are high-capacity municipal or industrial wells. This is mainly because the bedrock aquifers are at a significant depth (in some cases greater than 2,000 feet). These bedrock wells are drilled where there are no shallower sand and gravel aquifers or they are insufficient to provide the necessary volumes of water. In contrast, in LaSalle County, especially north of the Illinois River, there are many bedrock wells but they are much shallower than in the rest of the region (Figures 8 and 15). This is because of geologic structures that have brought the St. Peter and New Richmond Sandstones up to much shallower depths.

In 2014, the ISWS conducted its largest study of Cambrian-Ordovician sandstone aquifer heads in Illinois since 1980. This study included the entirety of the Middle Illinois WSPR. The 2014 potentiometric surface of the Cambrian-Ordovician sandstone aquifers is shown in Figure 16. The highest heads were located in north-central Illinois. Heads that exceeded 600 feet above mean sea level (AMSL) in Illinois are generally located in the area where leakage to sandstone is relatively high due to the absence of shale. The exception to this is in LaSalle County, where even though shale is absent, heads fell below 600 ft. This is largely because the sandstone in LaSalle County is close to the surface, so heads are controlled by elevations in the Illinois River, which range from 450 to 540 feet AMSL.

The majority of the sandstone in the Middle Illinois WSPR is covered by shale that limits the replenishment of groundwater removed from the sandstone aquifers. Consequently, small head changes (25-50 feet) have been observed since 1980 for most of the region. The largest head change in the Middle Illinois WSPR between 1980 and 2014 occurred in Marshall County. This observation was made at wells in Toluca and Hopewell, although pumping from these facilities does not seemingly explain such a large change. It is possible that all three measurements were in error or that pumping from the sandstone has occurred that is not currently reported to IWIP. These measurements will be repeated in 2016.

The highest demands from the sandstone aquifers occur in the northern portion of LaSalle County. However, sandstone aquifers used in this area (St. Peter and New Richmond) are near the bedrock surface and receive relatively high rates of leakage to replenish any water withdrawn; hence heads have changed very little in this region from 1980 to 2014 (Figure 17). Relatively stable heads are also observed for two Ottawa wells (Figure 18). In contrast, heads at a nearby industrial facility well where shale overlies sandstone have decreased by nearly 100 feet since data records began in the mid-1960s (Figure 18).

It appears that the large sand mining operations in the Ottawa area are not having a regional impact on heads in the Cambrian-Ordovician sandstone aquifers, although the local and seasonal impacts were not assessed during the course of this study.

3.5.1 Water Quality

Most of the bedrock wells have relatively high total dissolved solids (TDS) concentrations, greater than the secondary drinking water limit of 500 mg/L (secondary standards are not enforced but are for aesthetic purposes; water with TDS > 500 mg/L begins to taste salty). Water in the bedrock aquifers is old, having migrated through the subsurface for thousands of years. The longer water is in contact with rocks and sediments, the higher the TDS levels tend to be. LaSalle County is the exception, having much lower TDS values than the rest of the region due to the shallower nature of the aquifers there and thus much younger water.

Because of the high TDS levels, many elements and aqueous species have elevated concentrations. As the TDS levels increase, Cl^- and sodium become the dominant ions in the water; this is a natural phenomenon which is also true of seawater and brines. Chloride has a secondary drinking water standard of 250 mg/L, which is exceeded in some of the bedrock wells in the region (Figure 19). There are several other elements with concentrations approaching or exceeding drinking water standards, including fluoride and radium (Figures 20 and 21). These contaminants are all produced naturally within the aquifers. Fluoride has both a primary (enforceable) standard (4 mg/L) and secondary standard (2 mg/L). The primary standard for total radium is 5 picoCuries/L (pCi/L). The use of these bedrock aquifers as drinking water sources requires treatment in order to meet the drinking water quality regulations.

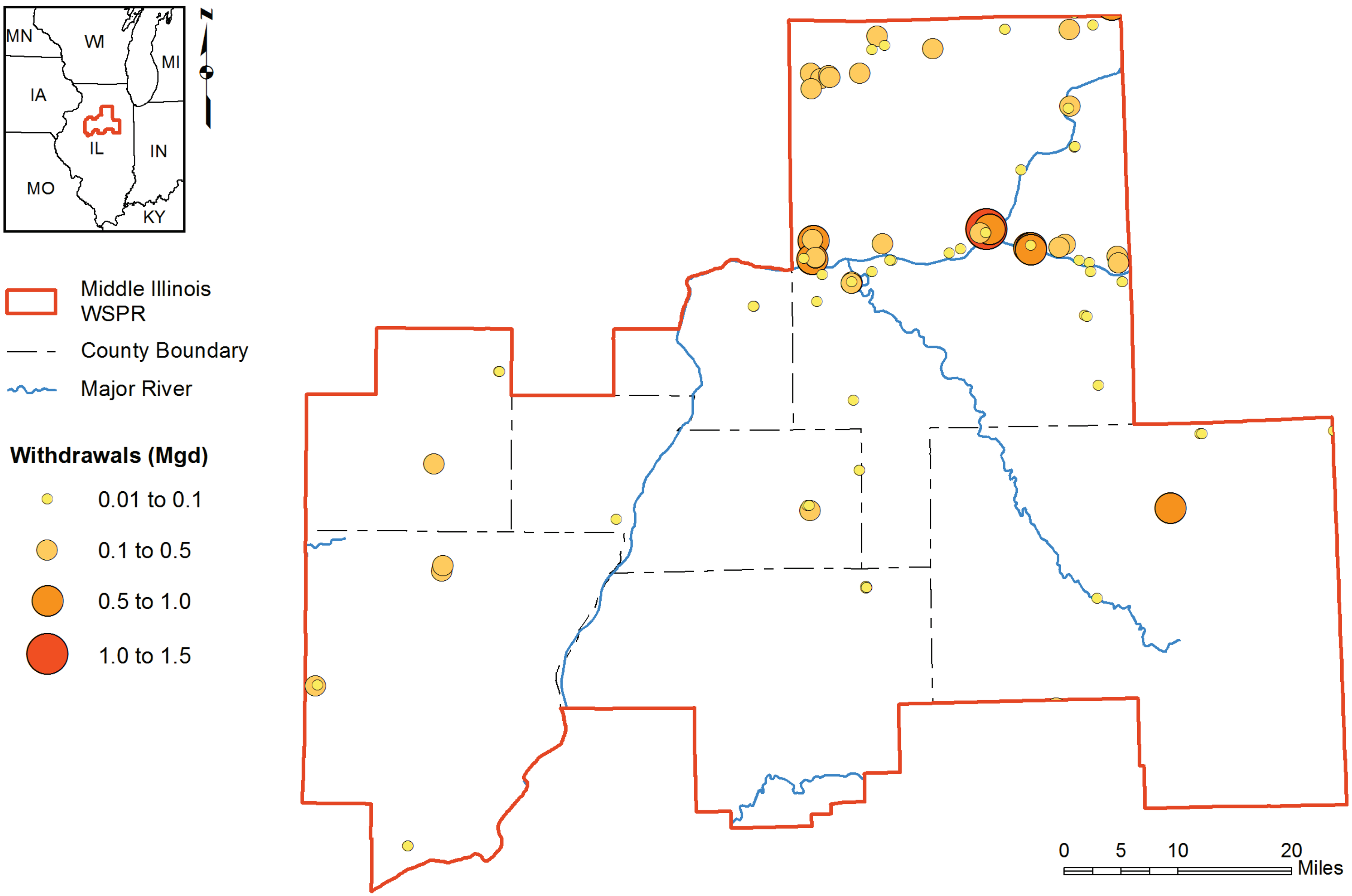

Figure 15. Withdrawals of water in millions of gallons per day (Mgd) from wells with a primary source of water from sandstone

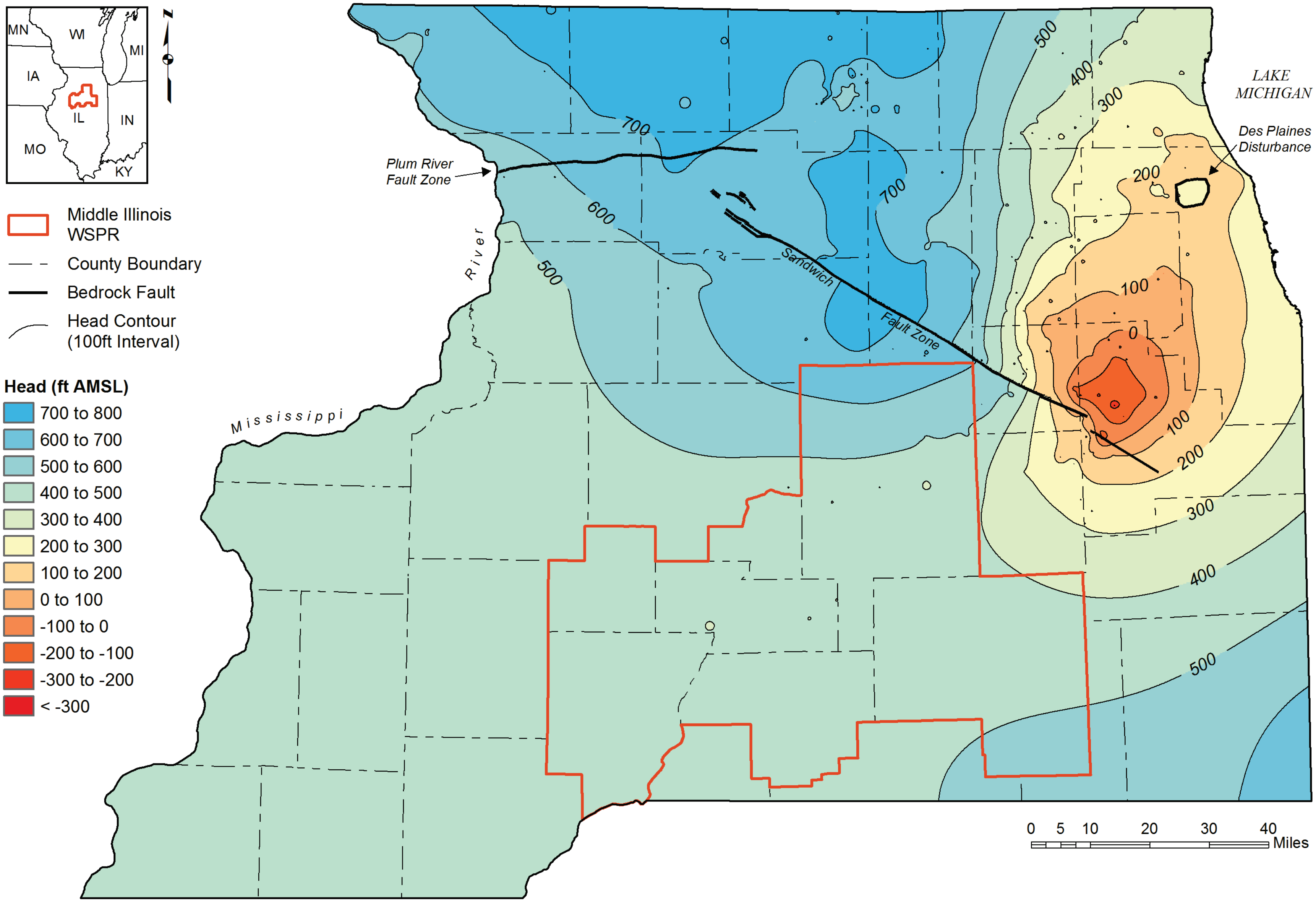

Figure 16. Potentiometric surface of the Cambrian-Ordovician sandstone aquifers in 2014

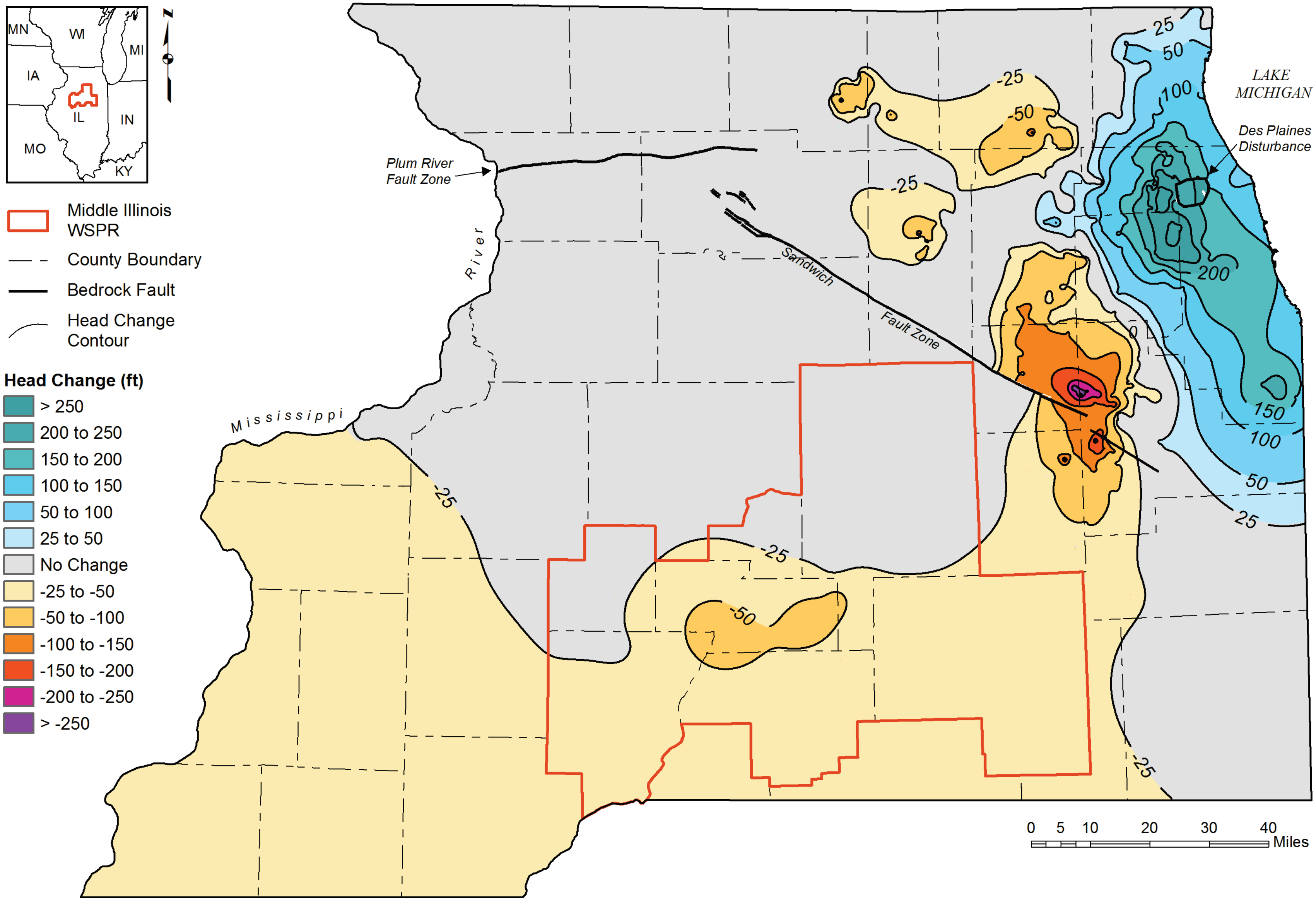

Figure 17. Change in heads from the Cambrian-Ordovician sandstone aquifers between 1980 and 2014

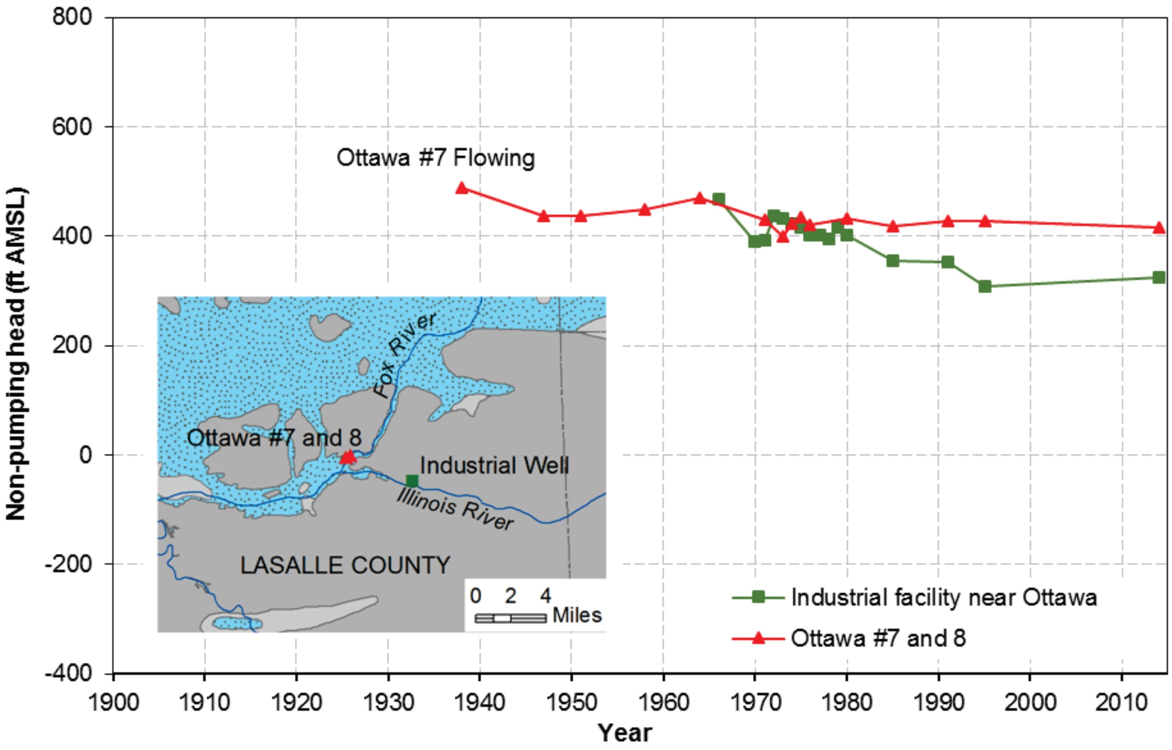

Figure 18. Observed heads at Ottawa #7 (1938-1951) and #8 (1958-2014) and an industrial facility near Ottawa, IL. The blue area in the inset image depicts where the St. Peter Sandstone is at the bedrock surface, while the dark gray area depicts where the sandstone is overlain by shale.

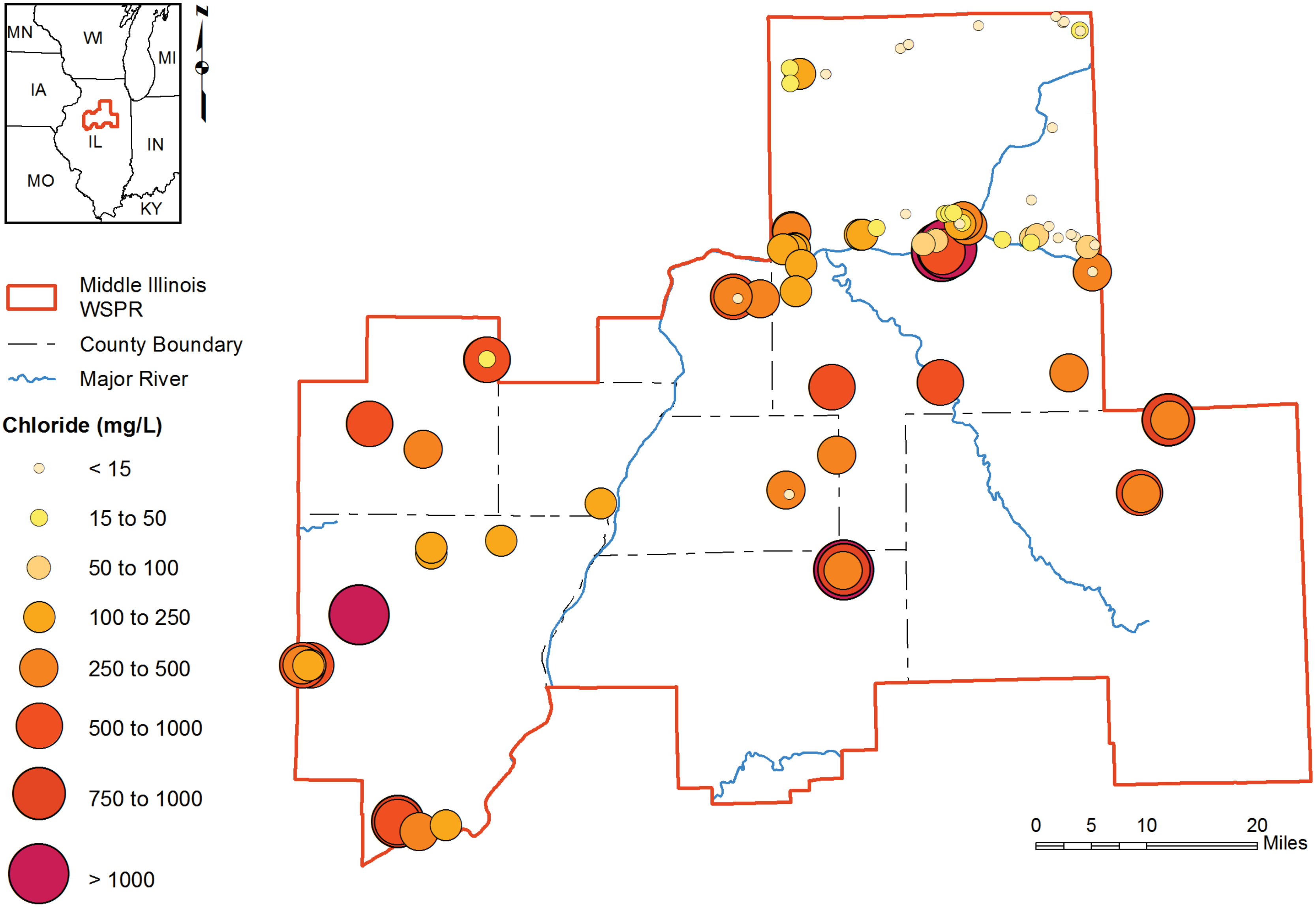

Figure 19. Chloride concentrations in in Cambrian-Ordovician sandstone aquifers in the Middle Illinois Region. The secondary drinking water standard is 250 mg/L.

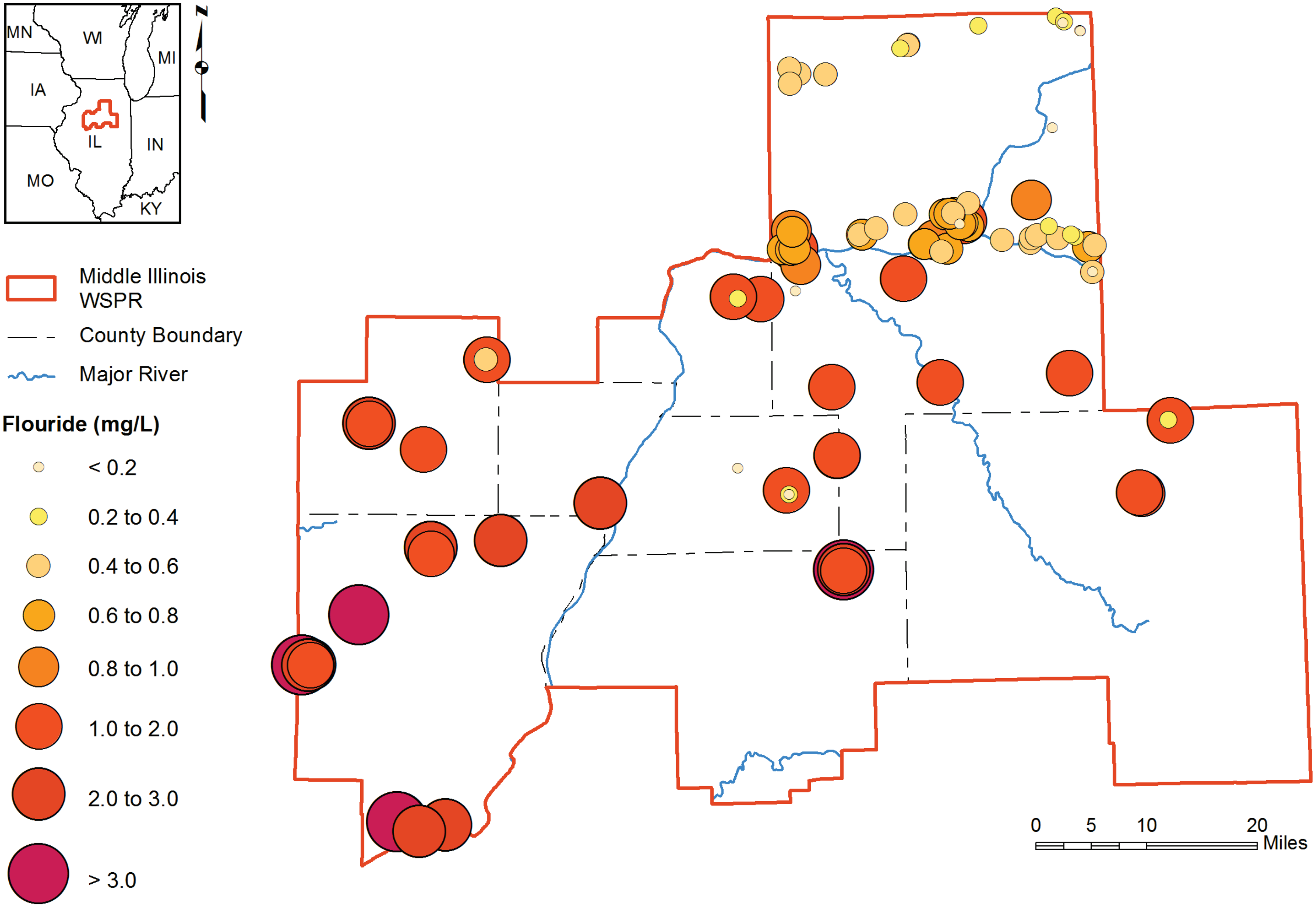

Figure 20. Fluoride concentrations in Cambrian-Ordovician sandstone aquifers in the Middle Illinois Region. The primary drinking water standard is 4 mg/L.

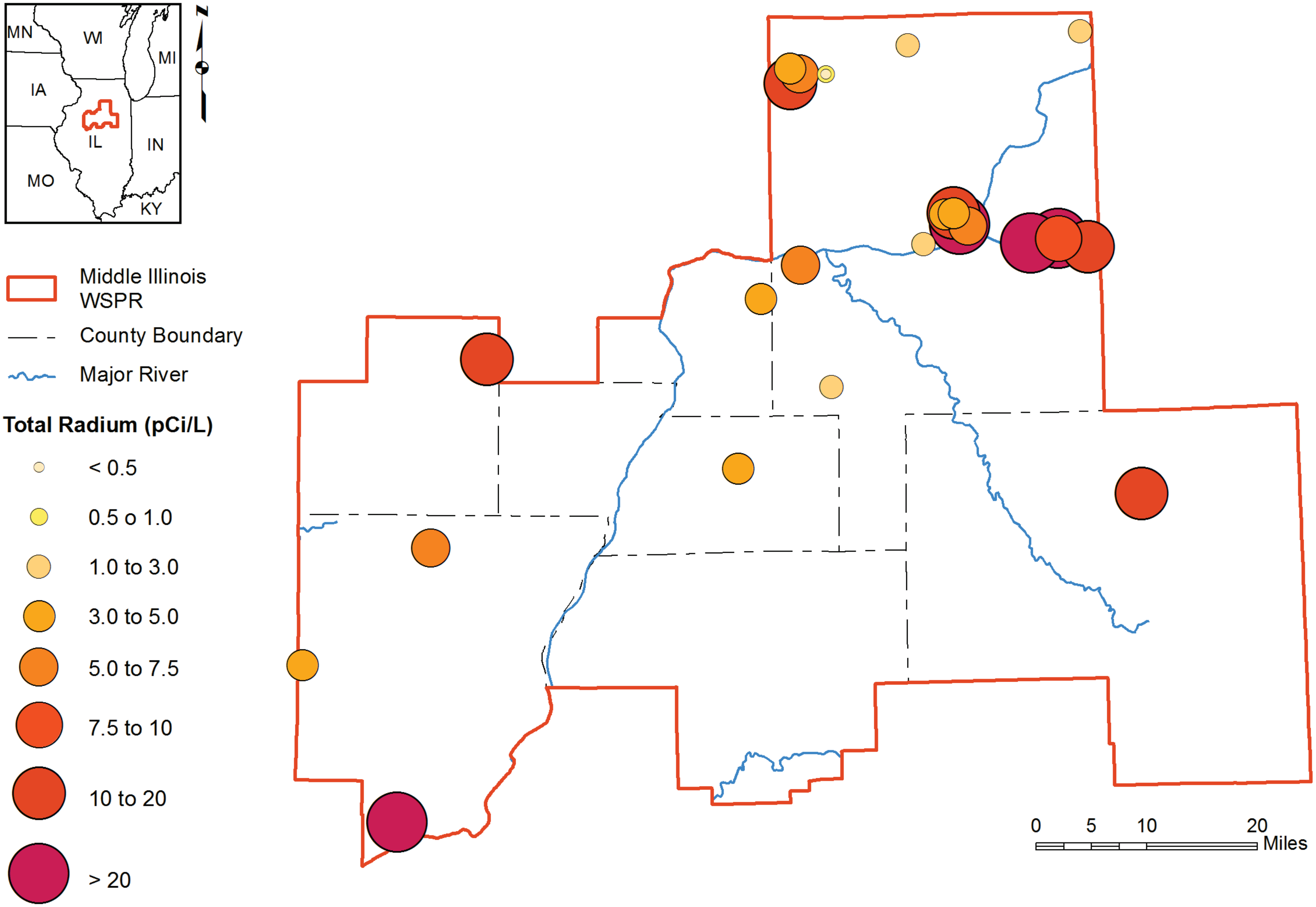

Figure 21. Total radium concentrations in Cambrian-Ordovician sandstone aquifers in the Middle Illinois Region. The drinking water standard is 5 pCi/L.

3.6 Statewide Groundwater Flow Model

Withdrawals from an aquifer may have far-reaching impacts. For example, the steady decrease in heads in the Middle Illinois WSPR from 1980 to 2014 (Figure 17) may largely be an influence of groundwater withdrawals from either northeastern Illinois (Abrams et al. 2015) or Iowa (Gannon et al., 2009). To better address these far-reaching issues, the ISWS has started to develop a groundwater flow model that extends over the northern half of Illinois. The following section provides a model development update.

The surface water network for the groundwater flow model has been developed by identifying low elevations along a digital elevation map and using those to delineate the surface water network. Further refinement of the stream network will occur by assigning reach specific properties to each stream to better simulate the exchange between groundwater and surface water, which will differ depending on stream order, soil properties, and land use type (i.e. urban vs agricultural).

Detailed mapping of the Quaternary system is not currently available for the Middle Illinois WSPR. Instead, as a first order approximation, the ISWS has utilized the major sand and gravel aquifer map shown in Figure 10 to classify the entire thickness of Quaternary materials. Before completion of the Middle Illinois study, the ISWS will also incorporate the more detailed Quaternary geologic mapping into the groundwater flow model for northeastern Illinois and the Mahomet aquifer system. For the rest of the state, stack maps, which depict the geologic composition of the first 15 meters of the subsurface, will be used to add more detail to the shallow groundwater system. An outcome of water supply planning for Middle Illinois will be to identify areas where more detailed geologic mapping is necessary.

During water supply planning for northeastern Illinois, the top elevation of all bedrock hydrostratigraphic units listed in Table 1 were mapped for all of the model domain, including Indiana and Wisconsin. For more details, see Meyer et al. (2009). These elevations have been incorporated into the groundwater flow model for the state, as shown for the bedrock surface elevation in Figure 22. The lowest bedrock elevations represent bedrock valleys that are important areas for sand and gravel deposits (compare the blue areas in Figure 22 with the major sand and gravel aquifers in Figure 10). Figure 8 shows the elevations in cross-sectional view that were used to develop the groundwater flow model. This image depicts the Illinois River bedrock valley incising into the St. Peter Sandstone, which is an important hydrologic control on heads in the area.

While the model is still under development at the time of this publication, it has been used to generate preliminary groundwater-level contours for predevelopment times (i.e., before 1863) of the northern portion of the state for the sandstone system (Figure 23). These contours agree reasonably well with those developed in previous ISWS and U.S. Geological Survey reports (Weidman and Schultz, 1915; Anderson, 1919; Young and Siegel, 1992; Burch, 2002; Abrams et al., 2015). Note that there are more detailed contours in LaSalle County along the Illinois River, where the sandstone is near land surface and the river has a strong hydrologic connection with it.

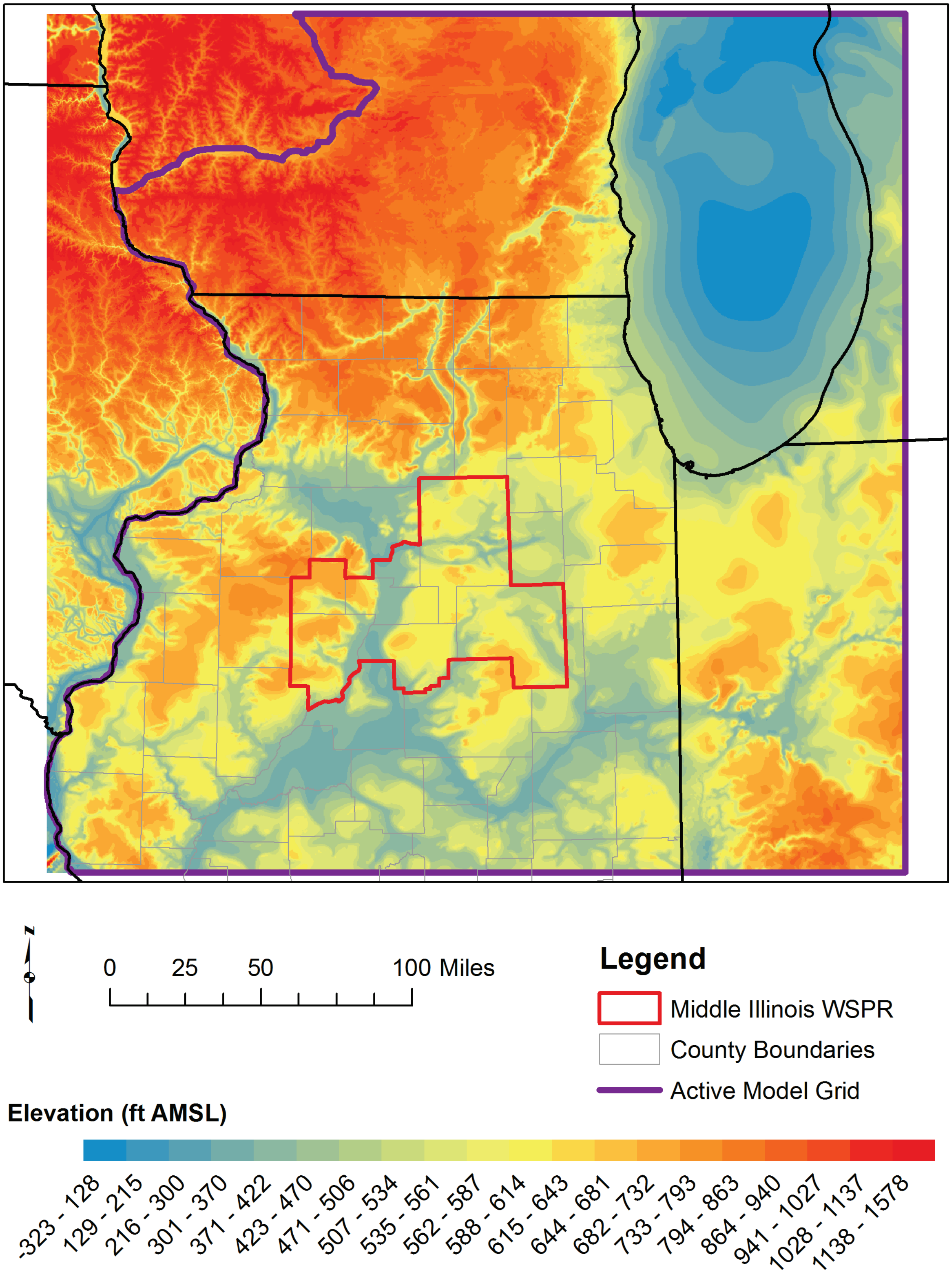

Figure 22. Bedrock surface elevation in the model area

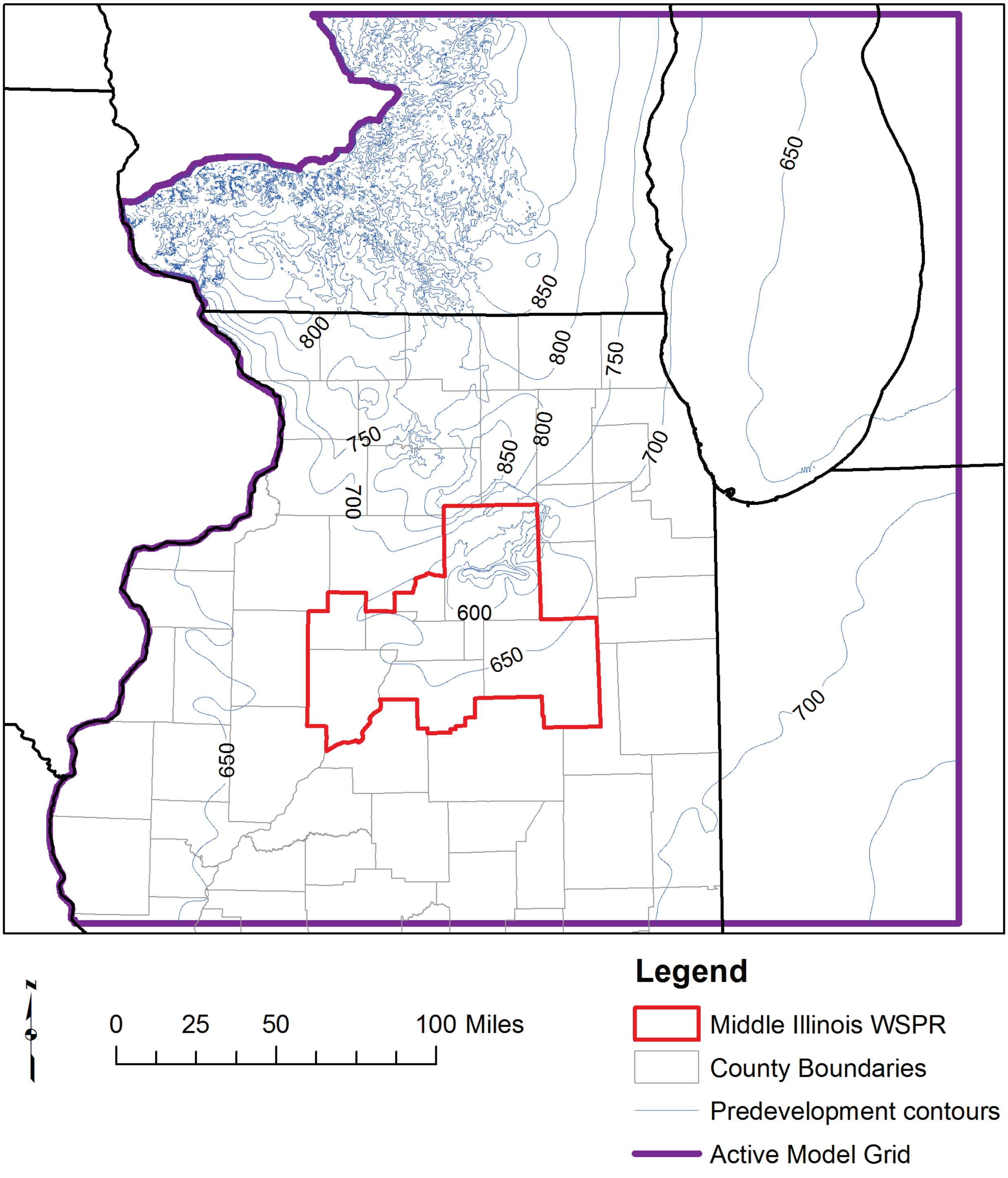

Figure 23. Predevelopment contours for the Cambrian-Ordovician sandstone aquifer system from the groundwater flow model

4 Surface Water Studies in Middle Illinois

Surface water in the Middle Illinois WSPR is a significant source for public supplies and for industrial, navigation, and recreation purposes. Streamflow in most rivers and streams in the Middle Illinois WSPR reach a very low level during drought conditions, and many streams could dry up completely, though they may carry abundant streamflow during normal or wet conditions. Table 2 shows the observed minimum daily flows at selected USGS streamflow gages; many have observed flows of 0 cfs. The primary surface water sources in the region include the Illinois and Vermilion Rivers (Figure 24). Big Bureau Creek is also expected to contain noticeable low flow during drought periods, with some flow appearing to reach the river by way of the Hennepin Canal. In the absence of pertinent low flow measurements and uncertainty regarding the connection with the canal, it is not considered a potential water supply source.

It should be noted that part of the Fox River watershed lies in LaSalle County but is not included in the surface water assessment in the Middle Illinois WSPR as it has been extensively investigated during the water supply planning study for the Northeastern Illinois WSPR. Climate variability and change, among other factors such as water use, effluent discharges, and watershed management practices, can have direct impacts on surface water availability. In addition, the Lake Michigan diversion has substantive impacts on the availability of water in the Illinois River, especially during low flow periods. Another important factor influencing water availability during drought conditions is the operation of locks and dams on the Illinois Waterway. For the Vermilion River, the only two surface water users are the Pontiac and Streator public water systems.

Table 2. The Observed Minimum Daily Flows at the Selected USGS Gages

Site No	Site Name	Observed minimum daily flow (cfs)
05542000	Mazon River near Coal City, IL	0
05543500	Illinois river at Marseilles, IL	461
05554000	North Fork Vermilion River near Charlotte, IL	0
05554500	Vermilion River at Pontiac, IL	0
05555300	Vermilion River near Leonore, IL	2.6
05556500	Big Bureau Creek at Princeton, IL	0
05557000	West Bureau Creek at Wyanet, IL	0
05558500	Crow Creek (West) near Henry, IL	0
05559000	Gimlet Creek at Sparland, IL	0
05559500	Crow Creek near Washburn, IL	0
05559700	Senachwine Creek at Chillicothe, IL	0
05561000	Ackerman Creek at Farmdale, IL	0
05568500	Illinois River at Kingston Mines, IL	600

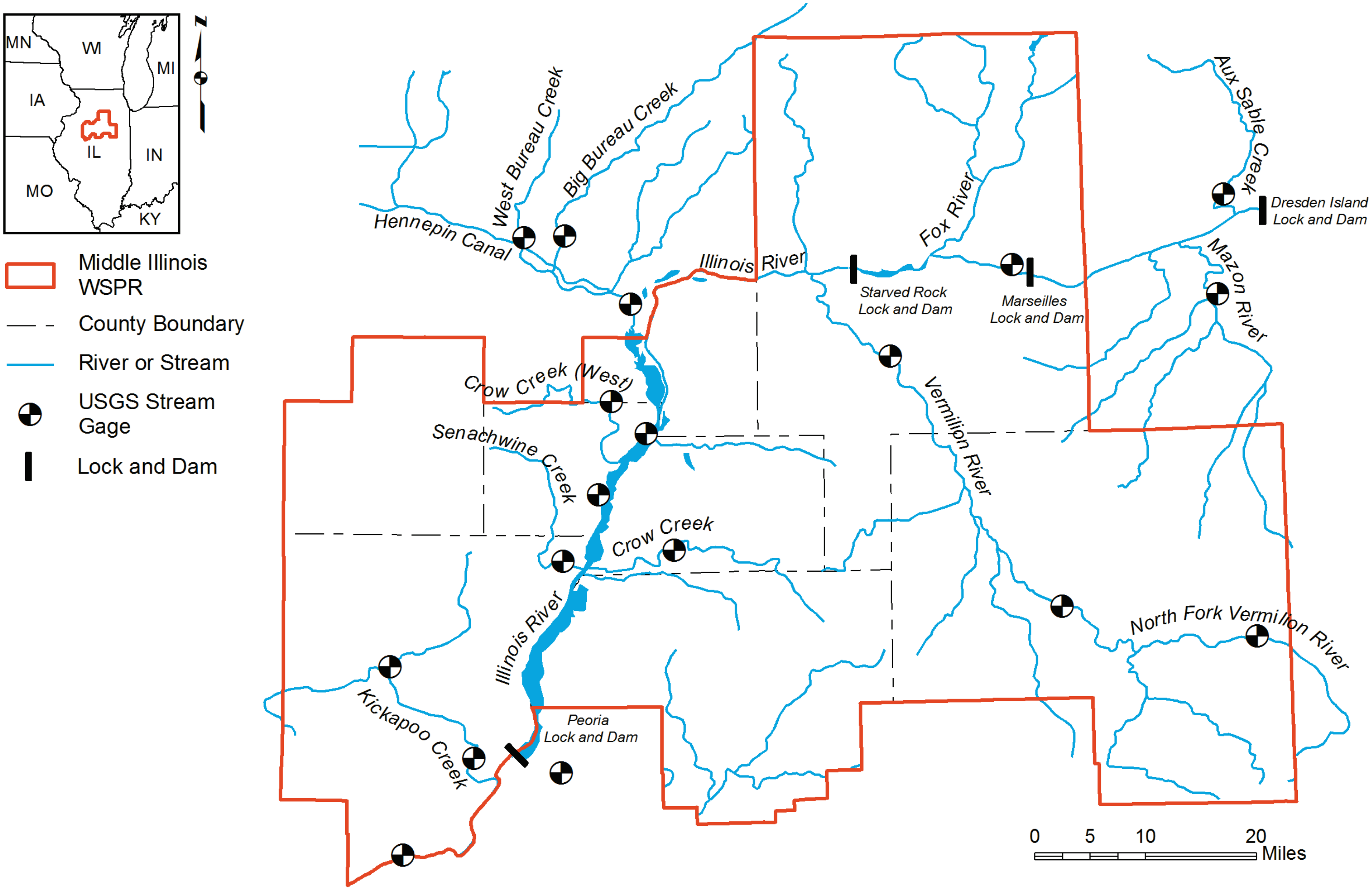

Figure 24. Surface water network in the Middle Illinois WSPR, with associated USGS gaging stations

4.1 Sources of Withdrawals (2012)

The primary sectors that use surface water in the region include power generation, industry, and public supply systems. Figure 25 shows the surface water withdrawals in the Middle Illinois WSPR. Surface water is heavily utilized along the Illinois River by industries, with most of the largest withdrawals (> 10 MGD) for non-consumptive use by power plants. Public supplies, such as Peoria, utilize the Illinois River for consumptive uses as well, although their usage is much less than by industry. The public water systems in Pontiac and Streator withdraw water from the Vermilion River.

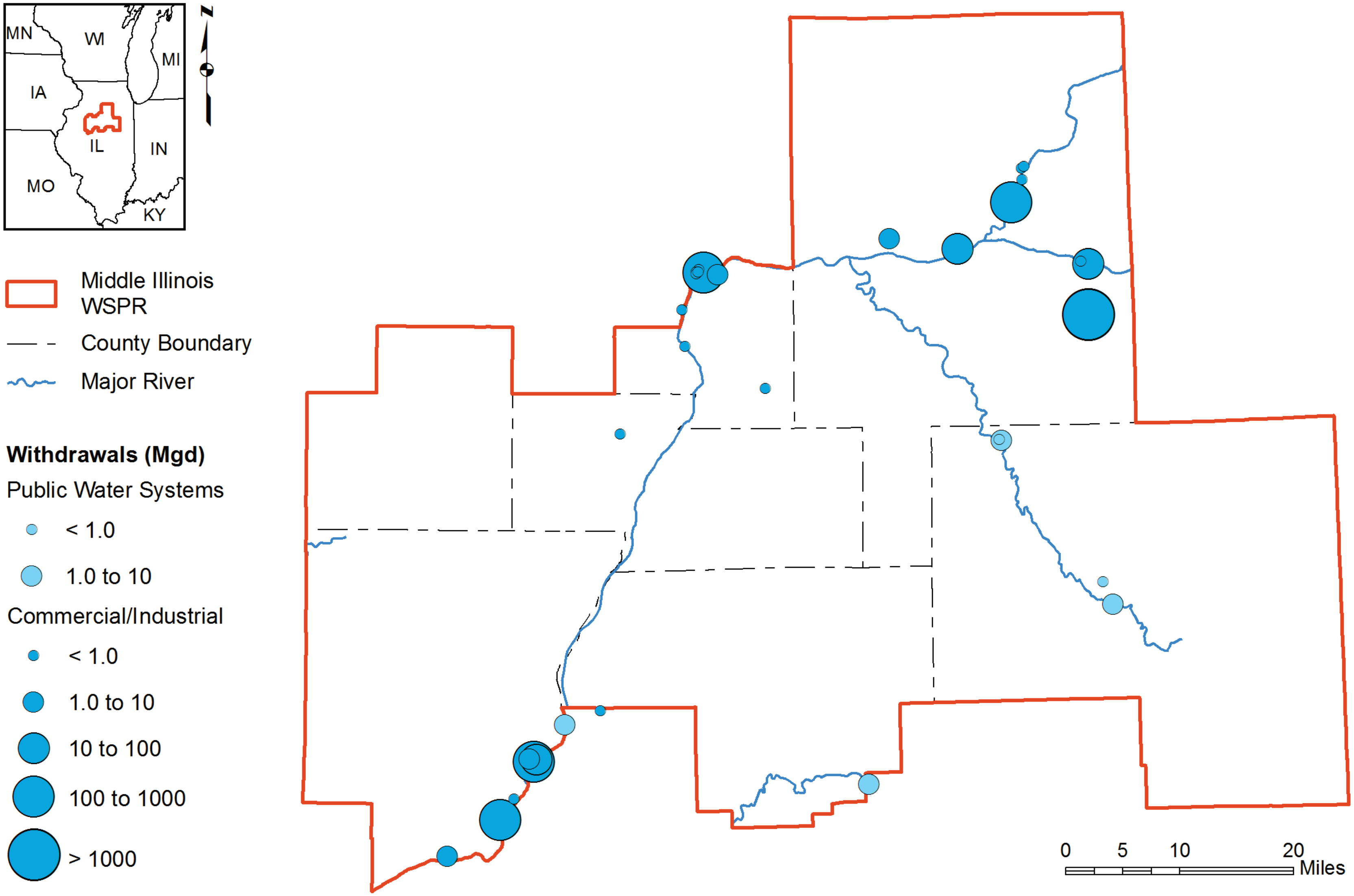

Figure 25. Surface water intakes and magnitude of withdrawals in million gallons per day (Mgd) for public supply, industrial, and commercial irrigation water usages

4.2 Climate Variability and Streamflows

The driving forces for streamflow are the magnitude, intensity, and timing of precipitation. Long-term climatic and hydrologic records in the Middle Illinois show considerable climate variability and resulting hydrology variability. Figure 26 shows the annual average precipitation and streamflow and corresponding 10-year-moving-averages for the Illinois River. The precipitation records are for the central Illinois climate division which covers most counties of the study area. The hydrology records are for the USGS gage at the Illinois River at Kingston Mines, IL. The annual streamflow is expressed as the depth of water spread uniformly over the entire watershed in inches, such that a direct comparison with precipitation for the concurrent period could be performed. Figure 26 shows that both precipitation and streamflow have increased since the period of 1965 to 1970 and the precipitation and streamflow since 1970 are consistently high. The wet period after 1970 is part of multi-decadal climatic and hydrologic variability (Knapp, 2005). Precipitation and streamflow are closely related; the correlation between annual precipitation and streamflow is 0.77 and the correlation between the 10-year moving average precipitation and streamflow is 0.86.

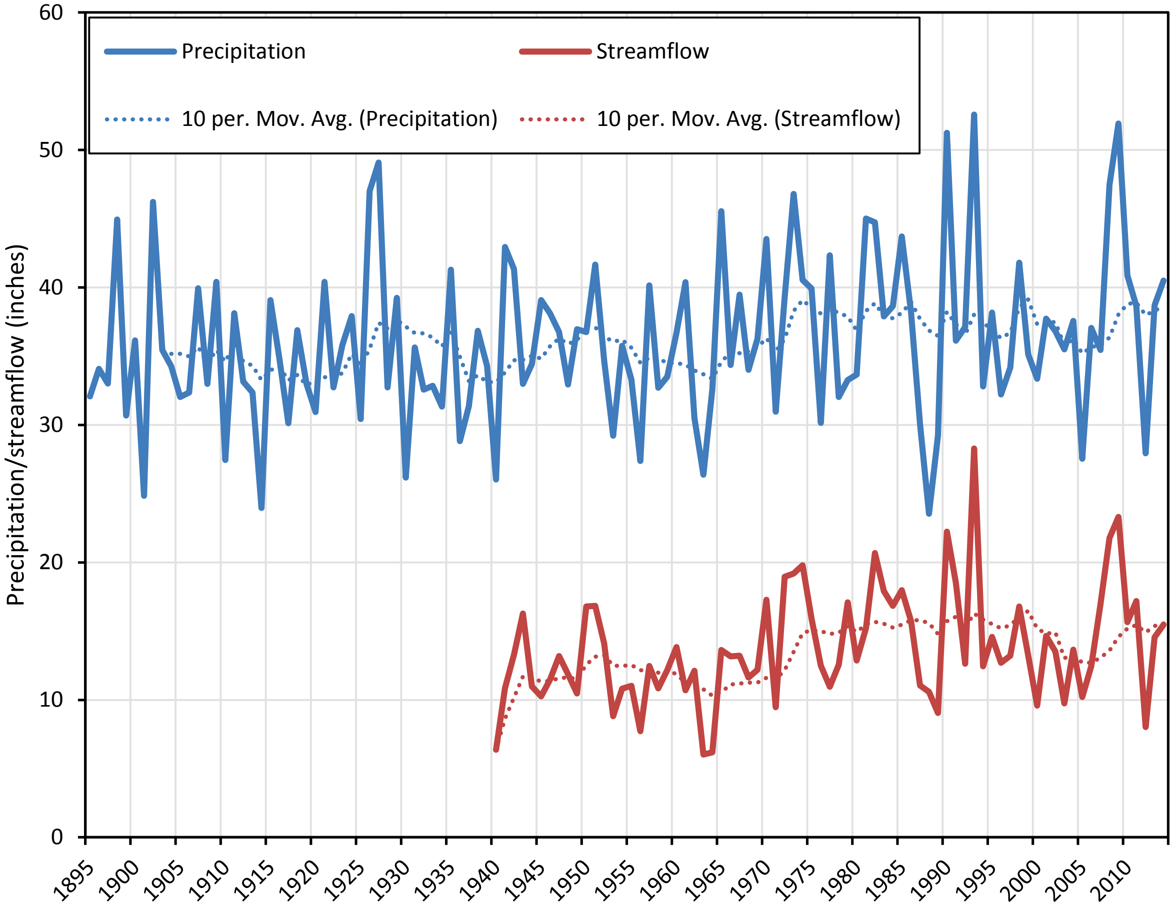

Figure 26. Annual precipitation and streamflow for the Illinois River at Kingston Mines, IL

Three periods of records were examined to analyze the differences between wet and dry periods (Table 3): the period of record for the Leonore gage, 1932 to 2014; a period of extended low precipitation and streamflow, 1932 to 1964; and a period of a prolonged high precipitation and streamflow, 1970 to 2014. For all periods, the difference between the average precipitation and streamflow is defined as the estimated annual evapotranspiration, the amount of water returned to the atmosphere through evaporation and plant transpiration. The evapotranspiration is similar for the three periods, approximately 27 inches. Given the error of estimation, it is reasonable to conclude that evapotranspiration has essentially been constant over the entire period. While the average precipitation in the wet period is only 9 percent more than that of the dry period, the average streamflow in the wet period is 48 percent greater than that of the dry period. This demonstrates that hydrologic variability is greater than climatic variability for the period of record, which makes water supply planning for drought conditions challenging.

Table 3. Comparison of Annual Average Precipitation, Streamflow, and Evapotranspiration for Three Selected Periods of Record for the Vermilion River Watershed (inches/year)

Periods	Precipitation	Streamflow	Estimated Evapotranspiration
1932-2014	36.9	9.8	27.2
1932-1964	35.0	7.7	27.3
1970-2014	38.2	11.4	26.8

4.3 Lake Michigan Diversion

While the Middle Illinois WSPR does not directly use water diverted from Lake Michigan, the Lake Michigan diversion does supply a significant component of streamflow in the Illinois River, especially for low flow periods or during extreme drought conditions. In 1930, the U.S Supreme Court ordered Illinois to reduce its diversion to 1,500 cubic feet per second (cfs), exclusive of Chicago's growing public water supply. The operational change of the Lake Michigan diversion is so remarkable that the hydrologic regime in the Illinois River before 1939 is not representative of that after 1939. In 1967, the U.S. Supreme Court set a new limit for the diversion at 3,200 cfs, inclusive of public water supply from Lake Michigan. The amount of water diverted from Lake Michigan has been reduced substantively since 1994 due to many factors such as reduced leakage, less discretionary diversion, and improved water use efficiency (Meyer et al., 2012). Increased water costs also likely have played a role.

4.4 Changes in Illinois River Low Flows

For nearly 60 years, from the late-1930s to the mid-1990s, low flows on the Illinois River remained relatively unchanged. During this period, the annual 7-day low flow at the Marseilles USGS gage averaged roughly 4,000 cfs, and the 10-year low flow for these years was estimated to be around 3,200 cfs. The lowest observed flow conditions during this period occurred in two drought years, 1940 and 1963, which had respective 7-day low flows of 2,570 and 2,694 cfs. Although the Kankakee River normally provides the largest source of flow in the upper portion of the Illinois River, during the lowest flow conditions the Chicago Sanitary and Ship Canal (CSSC) is the dominant source of water.

In the 1990s, two changes occurred that have since caused significant reductions in low flows from the CSSC. The first change was a reduction in Chicago's water usage, which has since greatly reduced effluent discharges to the CSSC. Effluent discharges to the CSSC during the lowest flow periods are now about 40 percent less than they were roughly 20 years ago. The second change was the elimination of discretionary diversions from Lake Michigan during the cool season (October through March). The primary purpose for these discretionary flows was to maintain water quality standards in the CSSC; however, ongoing improvements to wastewater treatment made these flows unnecessary at lower water temperatures. Communication with IDNR indicates that discretionary water quality diversions during the warm season will also be lessened or discontinued in the near future; and, although this has yet to occur, such a change could additionally impact low flows in the CSSC.

In the 17 years since 1998, the average annual low flow in the Illinois River at Marseilles has been reduced to 3,000 cfs. The 7-day low flow in eight of those years have been below 2,400 cfs, i.e., lower than in any previous year from 1900 to 1998. The two lowest 7-day flows observed at Marseilles occurred during the droughts of 2005 (1,670 cfs) and 2012 (1,680 cfs). With the ongoing reductions in Chicago's water use and effluent discharges, the ISWS estimates that the 2005 drought conditions would today result in a low flow of about 1,570 cfs. If discretionary diversions are to be eliminated entirely (i.e., also during the warm season) the ISWS estimates that the lowest flows in the Illinois Waterway will be reduced by an additional 100 cfs if not more.

ISWS Estimates of the 7-day, 10-year low flow ($Q_{7,10}$) at Marseilles (cfs)

Note: * designates recent unpublished estimates

Year	Flow
1970	3,240
1980	3,200
1990	3,185
2001	1,990
2015*	1,670
Near future*	1,570

Observed 7-day Low Flows at Marseilles in Recent Years (cfs)

Year	Flow
1998	1,990
1999	1,990
2002	2,320
2003	2,370
2005	1,670
2010	2,179
2012	1,680
2013	2,154

4.5 Low Flow Fluctuations in the Upper Illinois Waterway

Recent reductions in low flow quantity have exposed another aspect of low flow characteristics in the Illinois Waterway, that being high-frequency flow fluctuations associated with gate operations of the waterway's locks and dams. These fluctuations were especially notable during the 2012 drought as they pertained to IDNR's management of water withdrawal permits and protected flow limits on the upper Illinois River. Flows in the upper Illinois River can rapidly rise and fall in response to gate operations. The ISWS conducted two aspects of analysis to better characterize and understand these flow fluctuations: 1) a hydrologic analysis of available flow and stage records (from the USGS and USACE) in the portion of the waterway from the Starved Rock Lock and Dam upstream to the Lockport powerhouse; and 2) a hydraulic modeling analysis of the gate operations and low flows in the same reach of the waterway. The hydraulic modeling effort was eventually reduced to the specific reach between the Starved Rock and Dresden Island Locks and Dams to avoid the effects associated with inconsistencies in the hydrologic inputs to the model.

The hydrologic analysis of gage records identified a number of inconsistencies between the available calculated flow amounts. These inconsistencies are a result of normal variability (error) in flow records of all natural streams, and are typically associated with the frequency of measurement and the shifting of the stage-discharge relationship that occur between measurements. Low flow observations for the Illinois River at Marseilles, for example, can be influenced by pool fluctuations that are controlled by the operation of the Starved Rock dam located 16 miles downstream. Analyses of such factors help identify which gage(s) and flow records may be the most consistent for making near real-time decisions concerning permitted water withdrawals.

UNET is a one-dimension unsteady flow model that simulates flow in a complex network of open channels. The UNET unsteady flow routing model was used to simulate flow and stage conditions in the upper Illinois River, with particular focus on the Marseilles pool during the low flow conditions that existed in September and October of 2012. The model was used not only to replicate the effects of the observed gate operations and flows from the dams on the river, but also to investigate alternative operation schemes. Operation of the powerhouse and dam at Lockport (by MWRD) often creates alternating periods of high discharge (when the turbines are producing power) and low discharge (when water is being retained for the next wave of power production). At each successive downstream dam, the USACE considers the operation changes being made at the dam located immediately upstream and anticipates the associated rise and fall of flow amounts. The UNET simulations indicate that the USACE is effectively able to pass these flow fluctuations farther downstream and still maintain the operational levels of pools behind each lock and dam. However, with these operations there is relatively little attenuation of the flow fluctuations downstream.

Although the detailed analysis is not included in this report, the operation alternatives simulated in this study suggest that modifications can be made in the pool management at each dam to incrementally lessen the amount of flow fluctuation downstream and thereby increase the short-term minimum flow levels. Simulated flow releases associated with selected operation scenarios are shown in Figures 27 and 28 for the Dresden Island and Marseilles dams, respectively. The scenarios generally involve reducing the range in the operational pool level at each dam during low flow conditions.

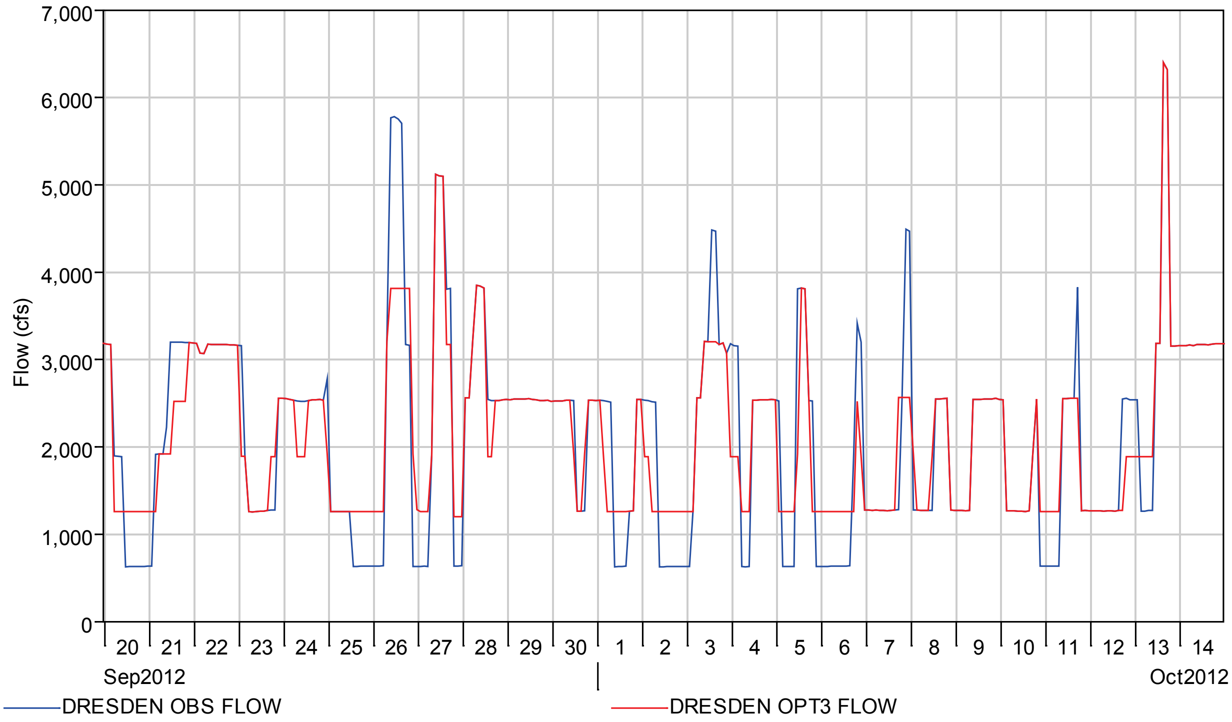

Figure 27. Comparison of observed Dresden Island dam outflow (blue) in September-October 2012 to a simulated operation alternative (red), showing an associated increase in the minimum release

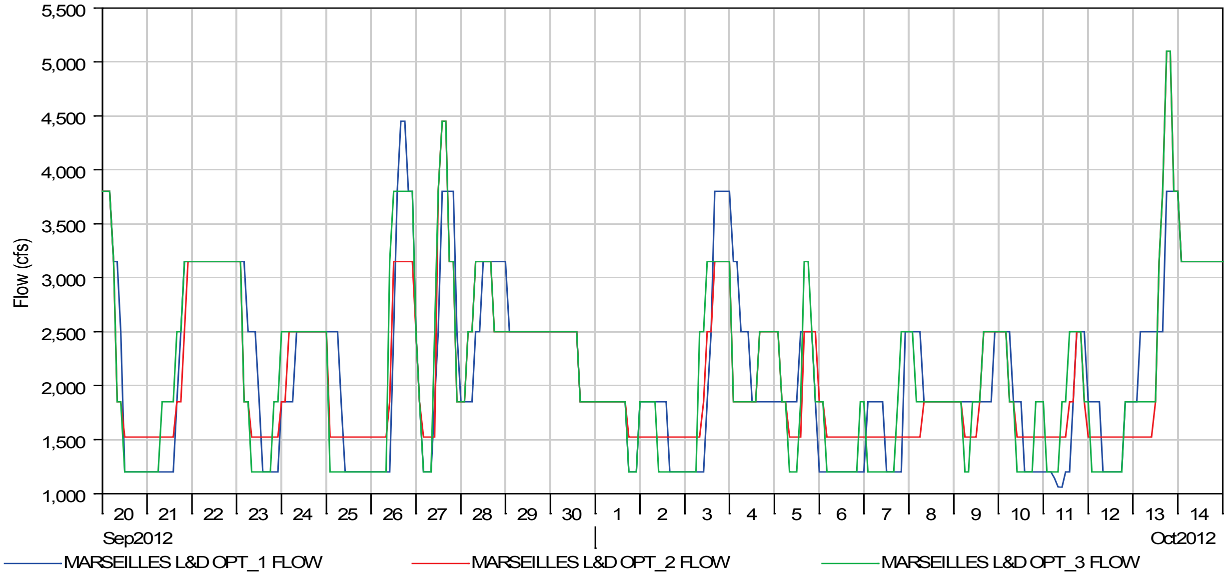

Figure 28. Comparison of Marseilles dam outflow for selected operation alternatives (September-October 2012)

4.6 Pontiac and Streator Public Water Systems

Pontiac and Streator use low-head impoundments in the Vermilion River and off-stream reservoirs to provide their public water supply. Both systems pump as much river water as possible into the off-stream reservoir and into the water treatment plants if river quality is acceptable and the water level in the river is above the intake. When water quality in the river is not preferable or the water level in the river is too low, the off-stream reservoir is used to provide water to the water treatment plants. The yield of the Pontiac public water system has been estimated to be 3.5 Mgd, which is above the projected water demand of 1.4 to 2.0 Mgd. The calculated $Q_{7,10}$ at the USGS gage at the Vermilion River at Leonore, IL is 4.6 Mgd, which is greater than the projected Streator demand of 1.5 to 1.7 Mgd. USGS low flow measurements on the Vermilion River at Streator taken during the drought of 2012 indicate that the Streator system can use nearly all of the available low flow in the river at that location. Thus, much of the low flow measured downstream at Leonore appears to accumulate in the river downstream of Streator. Both Pontiac and Streator have ion exchange systems to remove nitrate if needed.

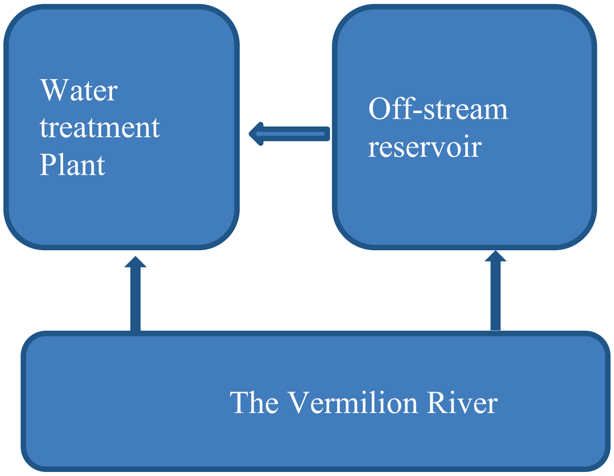

Figure 29. General operation rules of Pontiac and Streator public water system

4.7 Illinois River Model

The Illinois Streamflow Accounting Model (ILSAM) is a watershed management information tool designed to provide resource managers and planners with information on streamflow frequencies along major streams within a watershed of interest. ILSAM is applicable for major streams that have upstream contributing drainage areas of at least 10 square miles (Table 4).

In ILSAM, the streamflow can be separated into two components: 1) unaltered flow conditions as influenced primarily by the climate, topography, hydrogeology, and prevailing land-use conditions in the watershed, and 2) modifications to flow conditions by human activities that produce a quantifiable change in the temporal response of flow from the watershed. In Illinois, the quantifiable flow modifiers primarily include withdrawals, effluent discharges, and reservoirs. The ISWS developed a suite of approaches to characterize the flow modifiers and develop unaltered flow in Illinois. Complete descriptions of the methods used in ILSAM were presented in several earlier reports (Knapp, 1985; Knapp et al., 1985; Knapp, 1988; 1992; Knapp and Russell, 2004; Knapp, 2012). ILSAM produces estimates of flow statistics for 154 different streamflow parameters for any selected stream location. These streamflow statistics fall into four categories: mean flow, flow duration frequency, low flow, and drought flow.

For gages that do not have a complete record for the base period of record, the streamflow parameters are adjusted using record-extension techniques. The flow modifiers, including withdrawals and effluent in the Middle Illinois, are analyzed with the IWIP database and the NPDES effluent discharge database of the IEPA to characterize the flow modifiers for each gage. Then streamflow parameters under unaltered conditions are computed by excluding the flow modifiers. For details of the these steps, readers are referred to various ISWS reports (Knapp et al., 1985; Knapp and Russell, 2004). The ISWS is incorporating the newly updated hydrologic analysis results for the Middle Illinois WSPR into ILSAM.

Table 4. USGS Streamflow Gages in Middle Illinois Used in the Study and Pertinent Information

Site No	Site Name	Drainage area (sq mi)	Record length (years)	Record start	Record end
05541710	Aux Sable Creek Near Morris, Il	172	7	2007/03/16	present
05542000	Mazon River Near Coal City, Il	455	73	1939/10/01	present
05543500	Illinois River At Marseilles, Il	8259	94	1919/10/01	present
05554000	North Fork Vermilion River Near Charlotte, Il	186	19	1942/10/01	1962/09/30
05554500	Vermilion River At Pontiac, Il	579	71	1942/10/01	present
05555300	Vermilion River Near Leonore, Il	1251	83	1931/05/08	present
05556500	Big Bureau Creek At Princeton, Il	196	78	1936/03/01	present
05557000	West Bureau Creek At Wyanet, Il	86.7	30	1936/03/01	1966/09/30
05558000	Big Bureau Creek At Bureau, Il	485	10	1940/10/01	1951/09/30
05558300	Illinois River At Henry, Il	13544	32	1981/10/01	present
05558500	Crow Creek (West) Near Henry, Il	115	22	1949/05/13	1971/10/01
05559000	Gimlet Creek At Sparland, Il	5.66	25	1945/10/01	1971/09/30
05559500	Crow Creek Near Washburn, Il	115	26	1944/10/01	1971/10/01
05559700	Senachwine Creek At Chillicothe, Il	84.5	5	2007/12/02	present
05561000	Ackerman Creek At Farmdale, Il	11.2	26	1953/12/01	1980/09/30
05563000	Kickapoo Creek Near Kickapoo, Il	119	17	1944/10/01	1962/09/30
05563500	Kickapoo Creek At Peoria, Il	297	29	1942/03/24	1971/09/30
05568500	Illinois River At Kingston Mines, Il	15818	74	1939/10/01	present

5 Summary

1. There are significant and productive sand and gravel aquifers in the region, primarily in the Illinois River valley, but also in western Woodford County, eastern and western Livingston County, and northwestern LaSalle County. Sand and gravel aquifers in the Illinois River valley are connected to the river, and groundwater levels fluctuate in response to river stage. These aquifers are vulnerable to surface contamination, especially NO_3-N. Arsenic, which is a naturally occurring contaminant, can also be elevated in these aquifers.
2. The St. Peter Sandstone is a productive aquifer throughout the region, although its usefulness decreases further south due to increasing depth and salinity. Pumping over the past 35 years has resulted in a head decrease of 25 to 50 feet in the sandstone aquifer in most of the region. This decrease is probably not of immediate concern for water supply, but water levels should be monitored regularly.
3. The main water quality concern in the sandstone aquifer, other than salinity, is radium, which is above the drinking water standard in most of the wells. Fluoride levels are also naturally elevated in many wells, often greater than the secondary drinking water standard (2 mg/L), but lower than the primary standard (4 mg/L).
4. The northern half of LaSalle County is distinctly different from the rest of the region with respect to the sandstone aquifer. Geologic structures have thrust the sandstone up north of the Illinois River, and the character of the sandstone aquifer, with respect to both hydrogeology and water quality, is different from the rest of the region.
5. The primary surface water sources in the Middle Illinois WSPR include the Illinois River and Vermilion Rivers. The Illinois River provides sufficient and reliable water supply for public water supply and industry. The Vermilion River provides water supply to meet Pontiac and Streator public water systems. The water supply in Pontiac and Streator has to be enhanced by off-stream reservoirs and ion exchange systems for both water quantity and quality purposes.
6. Changes in the Lake Michigan diversion have made a marked impact on low flow in the Illinois River. With the decreasing diversion from Lake Michigan, the lowest flow amount along the Illinois River could be expected to decrease again in the near future. Although these changes are not limiting with regard to the availability of flow for most water supply needs, they can pose challenges for low flow and protected flow management of the river.
7. Operation of the powerhouse at Lockport during low flow conditions can create sizeable fluctuations in the amount of water released downstream. At each successive downstream lock and dam on the Des Plaines and Upper Illinois Rivers, operations by the USACE appear to effectively pass these fluctuations downstream while attempting to maintain the target pool level behind each dam. An existing unsteady flow routing model (UNET) for the Illinois River was used to replicate these operating conditions with a specific focus on the Marseilles dam and pool. This model was also used to investigate the impacts related to selected alternative operation scenarios. These scenarios suggest that there is the potential to incrementally attenuate the low flow fluctuation at each successive downstream dam through modest changes in pool level management. This study did not attempt to evaluate the

possibility that modifications could also be made at Lockport to reduce the amplitude of the flow fluctuations.

8. Water demand for thermoelectric power generation dominates present and future demand in the region. Present (2010) water demand for thermoelectric power generation totals 655 Mgd, which is 76 percent of the total reported demand of 866 Mgd. This water, which is surface water used for cooling, is largely returned to its source after use. We estimated that roughly 77 Mgd, or 12 percent, of the total demand 2010 demand of 655 Mgd was evaporated. Future demand for thermoelectric power generation will depend strongly on cooling system design and gross generation capacity of operating power plants in the region. Our scenarios of maximum demand assume that no new power plants will be built, and that present power plants will continue to operate at 2010 levels until 2060, with water demand remaining at 655 Mgd.
9. We estimated demand for public supply, self-supplied domestic demand, self-supplied industrial and commercial (IC) demand, and self-supplied irrigation, livestock, and environmental (ILE) demand to 2060. We estimated these demands under three plausible scenarios of socioeconomic, weather conditions, a less resource-intensive (LRI) scenario, a moderate current-trends (CT) scenario, and a more resource-intensive (MRI) scenario. Total reported demand for these four water-demand sectors totaled 210 Mgd in 2010, with self-supplied IC demand accounting for 150 Mgd of this total. From 2010 to 2060, total demand for these four sectors increases to 242 Mgd under the LRI scenario, 322 Mgd under the CT scenario, and 428 Mgd under the MRI scenario. Most of the increase in total demand under all scenarios, but in particular the CT and MRI scenarios, is accounted for by increases in self-supplied IC demand.

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