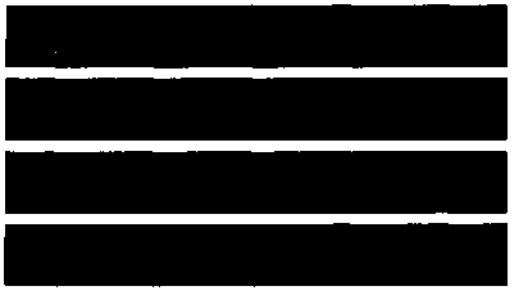
Research Report 119

The New Chicago Model: A Reassessment of the Impacts of Lake Michigan Allocations on the Cambrian-Ordovician Aquifer System in Northeastern Illinois

by
Stephen L. Burch



ILLINOIS STATE WATER SURVEY

DEPARTDY

The New Chicago Model: A Reassessment of the Impacts of Lake Michigan Allocations on the Cambrian-Ordovician Aquifer System in Northeastern Illinois

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ABSTRACT

This study reports the effects of substituting water from Lake Michigan for ground-water withdrawals in northeastern Illinois. It describes the use of a digital computer model to predict future ground-water levels based on anticipated pumping schedules. The model focuses primarily on the "Chicago region," which consists of Cook, DuPage, Kane, Kendall, Lake, McHenry, and a portion of Will and Grundy Counties.

The effort made during this project departed so far from the original Chicago model, that the code used in this report is referred to as the "New Chicago Model." The source code for the new model was translated from Fortran to QuickC, although most of the variable names used by Prickett and Lonnquist (1971) were preserved, particularly in calculations of head, storage, and recharge at each node. The new version was developed and tested in the era of the Intel 80286 processor, and several runs were made on the faster 80386-based machines.

Six geologic surfaces were used in the New Chicago Model to define the five-layer Cambrian-Ordovician aquifer system. Each layer varies in hydraulic conductivity and thickness, and therefore in its ability to transmit water. The transmissivities of each layer, when summed at each node, describe the aquifer system in greater detail than has been done previously. Distinctive stratigraphic controls exerted by the Prairie du Chien Group in Illinois and the Mt. Simon in Wisconsin have been included to help incorporate regional differences into the New Chicago Model.

The pumpage data set contains information on 1,150 individual wells. A distance-weighting program was developed to distribute a proportional amount of an individual well's historical pumpage to each of the surrounding four comers of the model grid. Demand forecasts were developed on the basis of trends at each facility utilizing the Cambrian-Ordovician aquifer. Future well locations were determined simply by averaging the Lambert coordinates for each well at each of the 289 Illinois facilities.

The model predicts that Chicago's regional pumping cone will first become shallower without becoming significantly smaller in areal extent. Ground-water levels will rise throughout much of northeastern Illinois between 1985 and 1990, particularly in Cook County, since it was the first to switch to Lake Michigan water. The model predicts that by 2010, water levels will rise in some places by 350 feet or more throughout DuPage and much of western Cook Counties, and by almost 650 feet around Elmhurst. Water levels will rise by 50 feet or more as far away as Belvidere, DeKalb, Morris, and Kankakee. The actions taken in Illinois will even cause water levels to rise in southeastern Wisconsin and northwestern Indiana.

1. INTRODUCTION

Schicht et al. (1976) estimated that the practical sustained yield of the deep ground-water system in northeastern Illinois was 65 million gallons per day (mgd). However, pumpage has exceeded this amount every year since 1959. The inevitable consequence is that critical water levels will be reached. When this occurs, well yields will decline significantly and water users will have to look elsewhere for supplies.

In 1966, the U.S. Supreme Court issued a decree concerning diversions of water from Lake Michigan. As a result of an amendment to that decree, the state of Illinois planners had to formally recognize the need to reduce pumpage from the Cambrian-Ordovician aquifer system (Fetter, 1981). Accordingly, the 81st General Assembly directed the Illinois Department of Transportation/Division of Water Resources (IDOT/DWR) to implement a long-term program for allocating Lake Michigan water. The program regulates the use of Lake Michigan water by Illinois and has funded impact studies of pumpage from the deep sandstone underlying northeastern Illinois.

This study is also a result of the allocation program and reports the effects of substituting Lake Michigan water for ground-water withdrawals. It describes the use of a digital computer model used to predict the effect of anticipated pumping schedules on ground-water levels. The model, originally developed by the Illinois State Water Survey (Prickett and Lonnquist, 1971), is a predictive or "deterministic" one. It solves equations numerically and is useful in describing certain cause-and-effect relationships. With its simplifying assumptions about ground-water flow equations, aquifer boundaries, and initial starting conditions, the model can be used to predict water levels. Conclusions about ground-water drawdowns or recoveries can be made by comparing the results of different simulations.

Visocky (1982) used the traditional Chicago model developed by Prickett and Lonnquist to predict the impact that Lake Michigan substitutions would have on ground-water levels in northeastern Illinois. But since the conclusion of that study, several changes have been made in the Lake Michigan allocation program. The original pumpage schedules used by Visocky are no longer in effect, and the model has become outdated because of improvements in computer technology. Therefore, revised simulations have become necessary and possible.

An enhanced version of the traditional Chicago model was developed for this project. The new model incorporates updated pumping schedules and other information refinements over earlier models. The study area, however, is the same as that of the traditional model: 148 miles wide and 148 miles long, spanning northeastern Illinois and southeastern Wisconsin. The model focuses primarily on the "Chicago region." As defined by Suter et al. (1959), the focus area consists of Cook, DuPage, Kane, Kendall, Lake, McHenry, and a portion of Will and Grundy Counties, all in northeastern Illinois. Figure 1 illustrates the overall study area and highlights the focus area.

Purpose and Scope

The objective of this report is to outline the goals that guided the redevelopment of the traditional model, to describe the methodology used to prepare pumpage and head data for

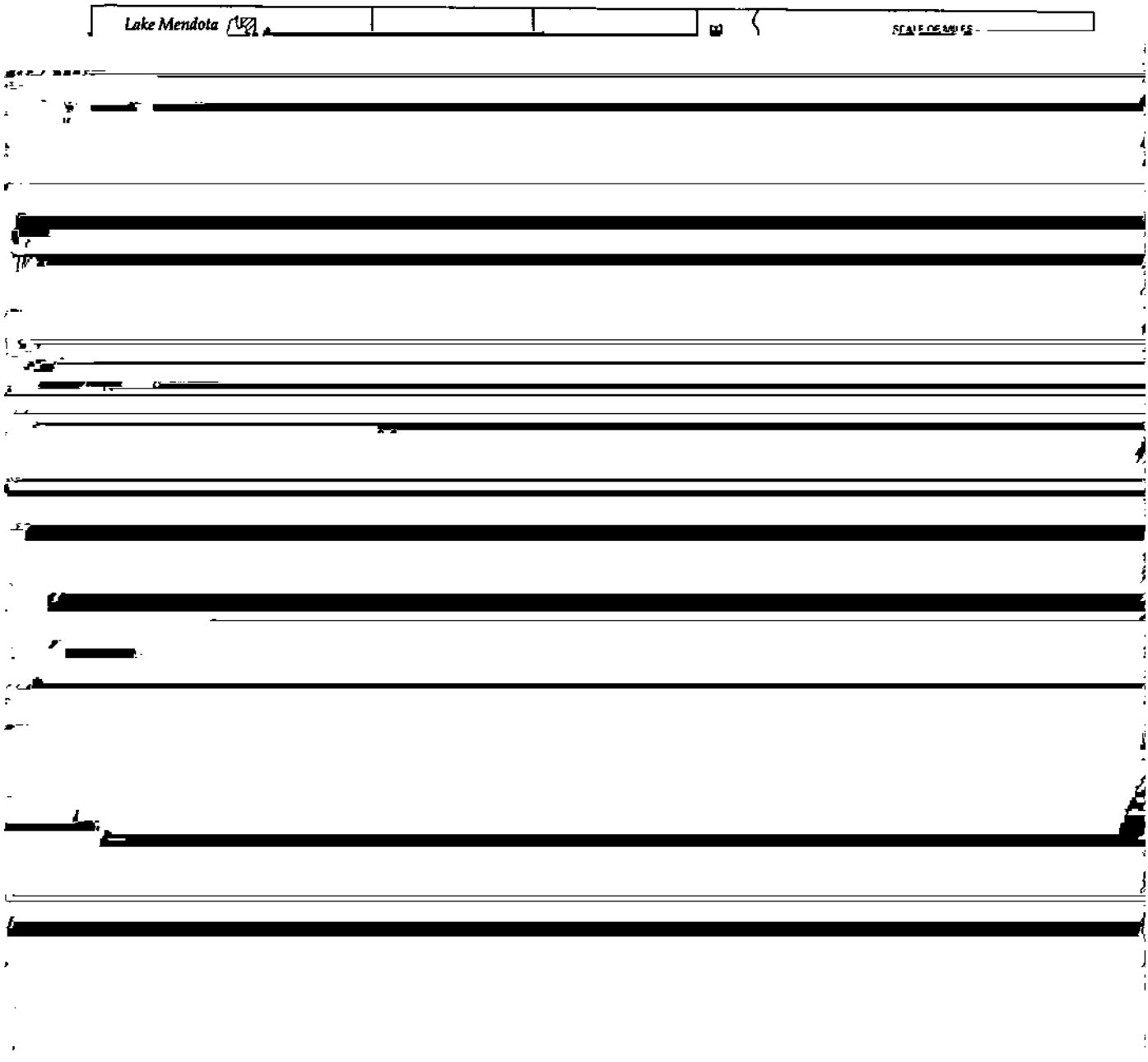


Figure 1. The study area

2. MODELING THE HYDROGEOLOGIC SYSTEM

The procedure for developing a deterministic (predictive) ground-water model is fourfold. The first step is to understand the physical behavior of the ground-water system and to form a conceptual model of how it works. The modeler must abstract the real system into an operational computer code that will preserve the essential elements of the hydrogeologic system.

Next the model user must assemble a large body of data, such as boundary definitions, water levels, and pumping patterns (Bachmatt et al., 1980). These data serve as a starting point for preliminary computer simulations.

The third step involves calibrating the model to ensure that it can reproduce a set of historical data with some acceptable degree of accuracy (Konikow, 1978). Calibration frequently involves adjustment of input parameters, particularly those that are poorly known. A quantitative evaluation of the response to an adjustment should be made to see whether the degree of changed response is directly proportional to the adjustment. Once the model has been calibrated to reproduce historical data effectively, the next step is to verify whether or not its accuracy and predictive capabilities are within acceptable limits. These tests should not be dependent on the calibration data.

Having been established as a reliable tool, the model is finally ready to make ground-water level predictions. Future scenarios can be developed for periods as long or short as the user cares to specify with situation data.

Hydrogeologic Setting

The ground-water resources of northeastern Illinois have been described in numerous reports of the Illinois State Water Survey and the Illinois State Geological Survey. The resources comprise four major aquifer systems, best described by the comprehensive, early work of Suter et al. (1959): the unconsolidated sand-and-gravel deposits of glacial age; 2) the shallow dolomite formations, mainly of Silurian age; 3) the Cambrian-Ordovician aquifer system, which provides the most ground water to the region; and 4) the often saline Mt. Simon aquifer of lower Cambrian age.

A stratigraphic column

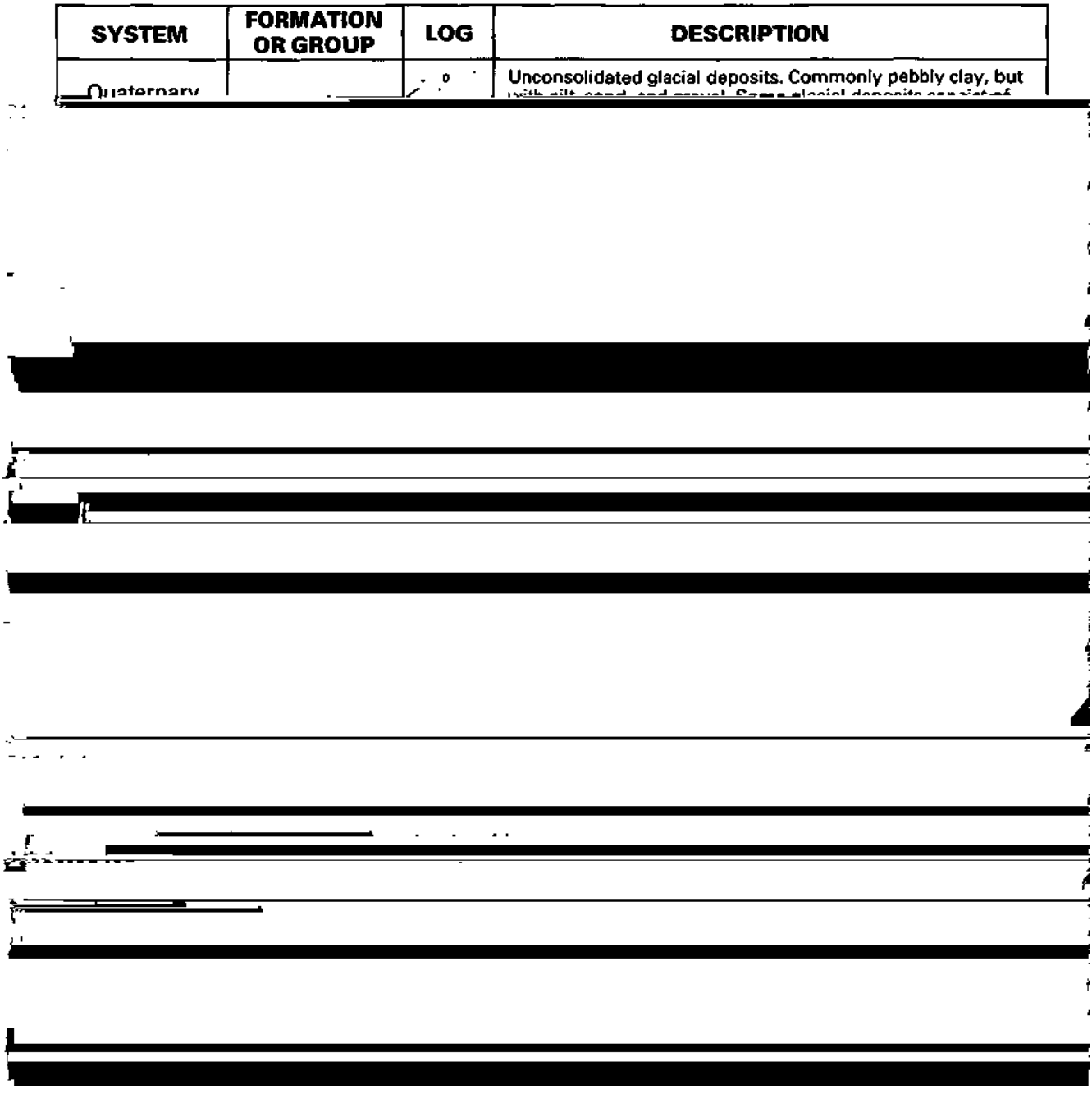


Figure 2. Stratigraphic column showing nomenclature and classification in the study area

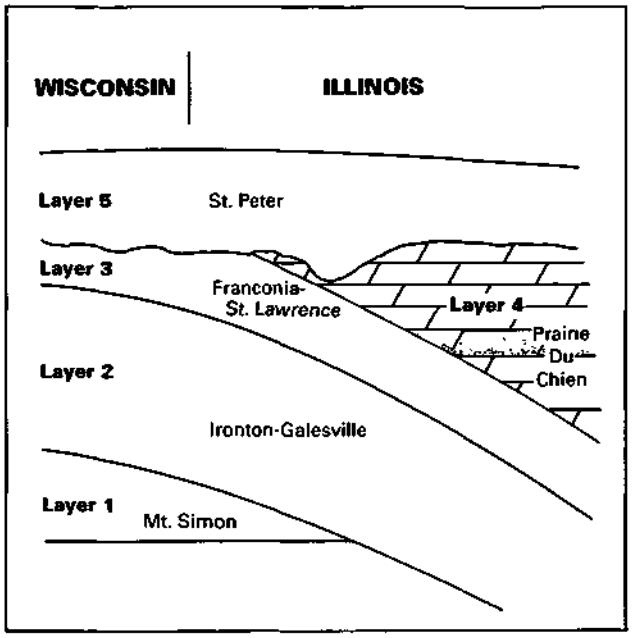


Figure 3. Stratigraphic relationships in the New Chicago Model

Above the Mt. Simon is the Ironton-Galesville Formation. This geologic unit is the principal water-yielding unit of the entire system, according to Suter et al. (1959). It has excellent hydraulic properties and is perhaps the most uniformly distributed of all the layers. It ranges in thickness from about 100 to 200 feet A hydraulic conductivity value of 100 gpd/sq ft was used successfully during calibration and subsequent model runs. Prickett and Lonnquist used a K-value of 48.57 gpd/sq ft in their model (1971, fig. 73). Young (1976) chose to agree with Prickett and Lonnquist, so the value used here is double the traditional value for the Ironton-Galesville.

The Franconia-SL Lawrence layer (as it is known in Wisconsin) constitutes the third layer of the model. In

In Wisconsin, values reported for artesian storage coefficients seem to confirm this observation. Foley et al. (1953) reported an average value of 0.00039 in the Milwaukee-Waukesha area. Young (1976) modeled the Chicago and Milwaukee region, and although he relied on Prickett and Lonnquist for many numbers, he reduced the artesian storage coefficient to 0.0004 in his model.

Consequently there is precedent for adjusting the artesian storage coefficient But the choice of values employed could either deepen or broaden a cone of depression. It follows then that the better the choice, the better the representation of the pumping surface. Freeze and Cherry (1979) point out, by way of illustration, that for a given transmissivity, a larger value of storage coefficient will result in a shallower and less extensive cone.

Water-Table Conditions. In Prickett and Lonnquist's traditional Chicago model, the water-table storage coefficient was defined at a constant 100 times the artesian value. The new code allows the user to define the value and employ it in the New Chicago Model when the water level at a grid node drops below the top of the St. Peter Sandstone. In practice, this condition occurs in three areas: in the dewatered area of Dupage County, Illinois, in the areas of high recharge, and where the St. Peter has become exposed along the Sandwich Fault

Goals of Model Redevelopment

The Forn00 Tc (d) Tj (,) Tj -01a93ag,

were identified and their pumping records compiled for use with the new model.

Since 1980 the Illinois State Water Survey has maintained computer records of ground-water pumpage. Prior to that time, however, only penciled notations on paper were kept for most communities, industries, and golf courses in northeastern Illinois. From time to time the Water Survey published summaries of these notes, which generally represented annual compilations for each county and usage type. These early records, which were diligently maintained between 1964 and 1980, were combined with the computer data to form the best available record of ground-water pumpage in northeastern Illinois.

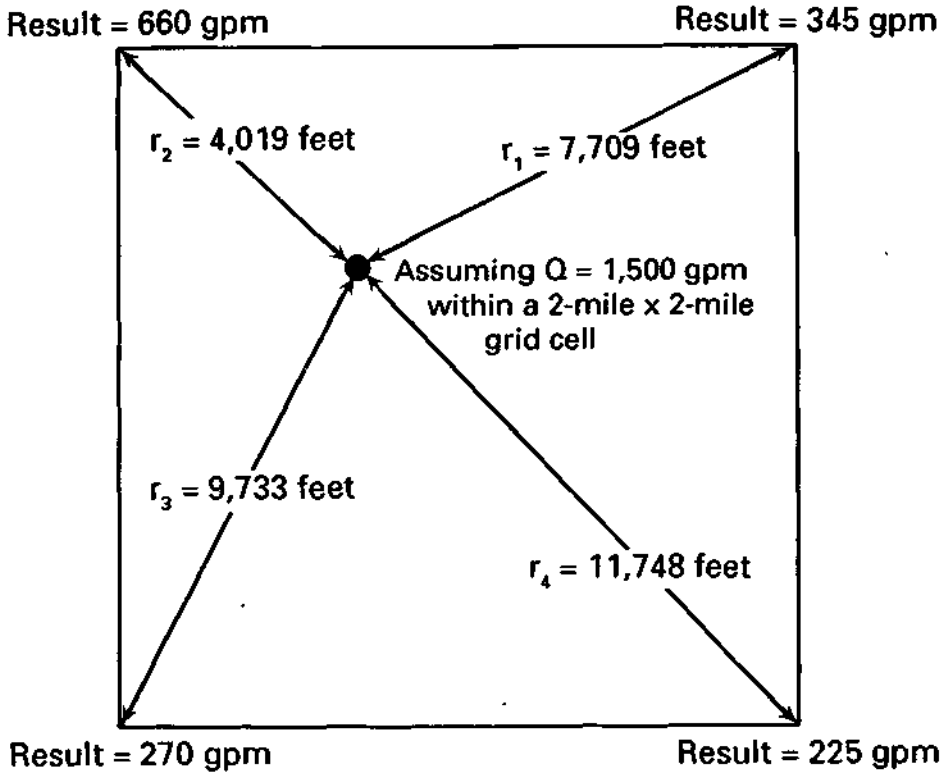
Although this project was primarily concerned with modeling the drawdown effects of sandstone wells, every Water Survey well record in the eight-county northeastern Illinois area was keyed into computer-readable format regardless of well depth. Later, after aquifer codes had been determined and assigned to these records, the sandstone records were selected for use in this project.

Similar well and usage data for Wisconsin were provided by the USGS office in Madison. Many of those data were developed as part of the Northern Midwest Regional Aquifer-System Analysis program. The Wisconsin pumpage data set was reduced to 6,953 records for 344 sandstone wells that were used between 1964 and 1985 and located within the boundaries used in the model.

The accuracy of the Illinois withdrawals can be validated by comparing the published pumpage estimates with tabulations made specially for this project. Generally, the greatest disparity occurs with the oldest records. The difference decreases from about 22 percent in 1964 to only 2 percent in 1980.

The Illinois and Wisconsin pumpage data for the period 1964 to 1985 were then combined. This data set contains information on 1,150 individual wells. The locations of these wells were converted to Lambert feet coordinates. Because the locations of the grid nodes were also known in terms of Lambert feet (appendix B), the distance between each well and its surrounding nodal locations could then be calculated. A distance-weighting program written in QuickBASIC (appendix C) was developed to solve these calculations. [The distance-weighting program is included with the CHI2SURF program on diskette from the Hydrology Division of the Illinois State Water Survey, telephone (217) 333-2210.]

Figure 5 illustrates how the program distre(use) Tj0 Tc(d) Tj-0.342 Tc(percen) TjTc(an) T01-0.092Iu Tw-0.5 Tc(m9(telephon)



	Weighting factor	Distributed Q (gpm)
$\%\ wt_1 = {}^1/r_1 \div \Sigma({}^1/r) = 1/7{,}709 \div (5.666 \times 10^{-4}) =$	0.23	345
$\%\ wt_2 = {}^1/r_2 \div \Sigma({}^1/r) = 1/4{,}019 \div (5.666 \times 10^{-4}) =$	0.44	660
$\%\ wt_3 = {}^1/r_3 \div \Sigma({}^1/r) = 1/9{,}733 \div (5.666 \times 10^{-4}) =$	0.18	270
$\%\ wt_4 = {}^1/r_4 \div \Sigma({}^1/r) = 1/11{,}748 \div (5.666 \times 10^{-4}) =$	0.15	225
	1.00	1,500

Figure 5. Example of the distance-weighting technique used to distribute pumpage to finite-difference grid nodes

An examination of the starting head map reveals a significant and previously unrecognized fact: the Rock River is of great hydrologic importance in any model of the Chicago area because it controls the location of the ground-water divide in DeKalb County. The divide has been shown on maps for more than 30 years and is regarded as the western edge of the Chicago flow regime. However, while calibrating the New Chicago Model, the position of this divide was found to be maintained by ground-water discharges to the Rock River. Consequently its importance has been underestimated.

In this model, the Rock River has been simulated as a series of constant head nodes. Singh and Stall (1973) determined that baseflow figures for the Rock River range from about 900 to 1,200 cubic feet per second (cfs) at these nodes on the model grid. Most of this contribution from the ground-water system probably comes from the Pleistocene sand-and-gravel deposits in the river valley, but some contribution also comes from the discharge of the Cambrian-Ordovician Sandstones. While the exact amount is unknown, it almost certainly should be simulated in regional models, as the next chapter will show.

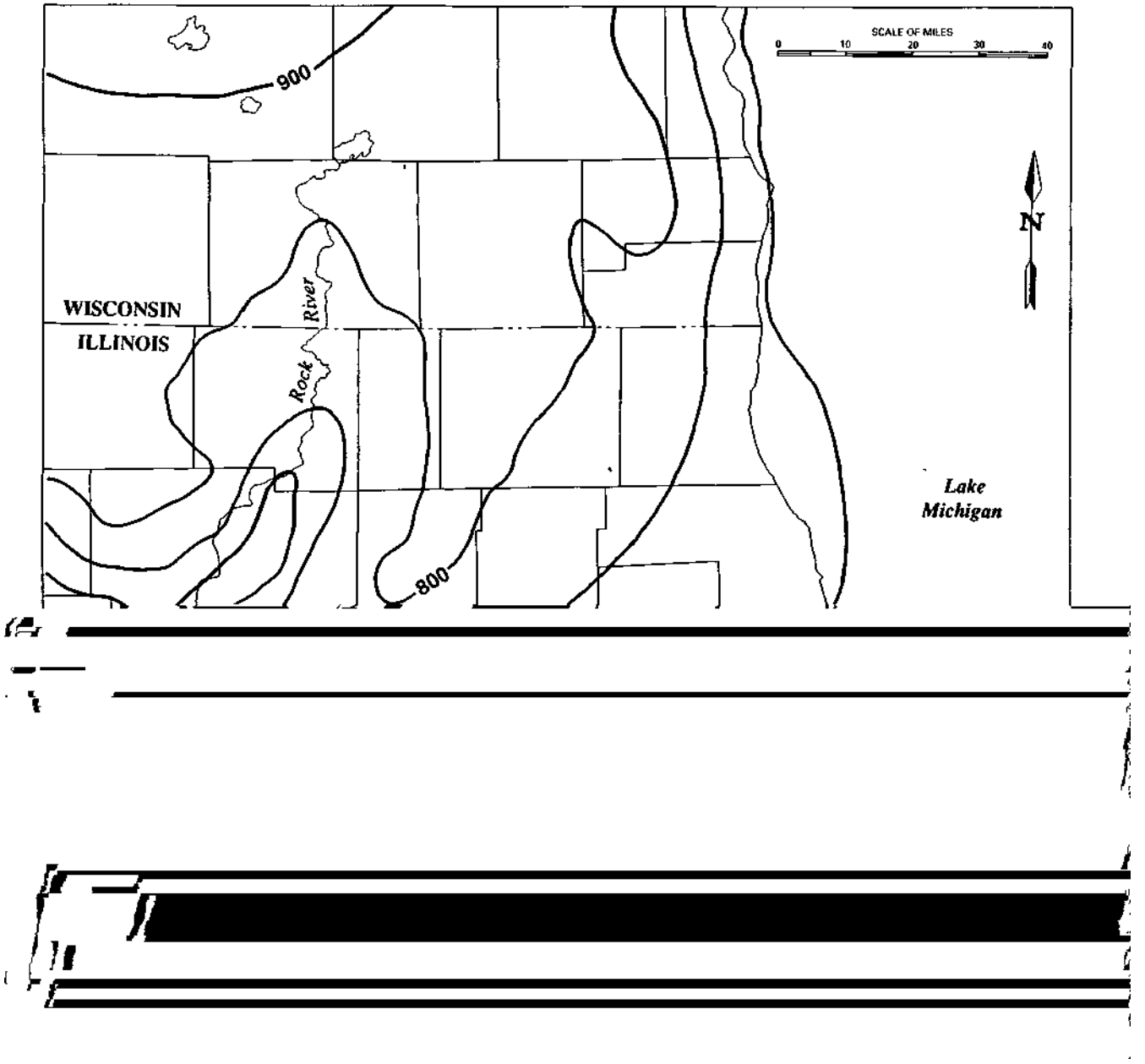


Figure 6. Starting head map showing potentiometric surface (feet msl) in the study area, c. 1865 (after Weidman and Schultz, 1915; Visocky et al., 1985)

3. FLOW SIMULATION AND MODEL CALIBRATION

Traditionally, the eight counties that constitute the focus area of this study have been used to illustrate water-level declines in northeastern Illinois. But to calibrate the parameters used by the model, pumpage simulations were made for the period 1957 through 1985 for the entire study area. Approximately 80 computer runs were made with the model. Various aquifer parameters and boundary conditions were tried until a satisfactory match was made with historic water-level maps. Final calibration of the model was assumed when computed water levels in the Chicago cone of depression closely approximated the values measured by Sasman et al. in 1985 (1986).

The New Chicago Model was successfully used to simulate the 1985 potentiometric surface. The calculated surface for the Chicago region is presented as figure 7. This map was compared to an interpreted map of observed water levels (figure 8) collected by Sasman et al. (1986, figure 11). Particular attention was given to the eight-county Chicago region because the purpose of this investigation was to gauge the impacts of Lake Michigan water deliveries to DuPage and Lake Counties.

Well hydrographs were used to judge the model's ability to predict water levels, particularly within the Chicago cone of influence. Measured levels were compared to calculated values for the node nearest each observation well. This examination indicated that the model converged to a correct solution by 1980, and at that point it was predicting water levels accurately. A regression analysis compiled from eight sites (figure 9) shows that calibration seems to have been achieved because the slope of the regression line is near 1, and the y-intercept for each is near 0.

As a further test, a difference map was prepared to compare the calculated change between 1980 and 1985. Sasman et al. (1986, fig. 12) observed that initial recoveries occurred in southeastern Cook County due to the transition of public supplies from ground water to lake water. At the same time, his map of observed data suggests ground-water declines of more than 100 feet in DuPage County. The model indicated similar results in both areas during calibration runs. Because it can calculate current water levels that agree with observed changes, the model is considered to be capable of producing accurate predictions of future water levels as well.

Model Grid

Finite-difference modeling is based upon solving equations at nodes on a predefined grid. The griw-0.393 Tc(grid)c38 Tw-0.431 Tc(use) Tj0 Tc(d) Tj0.305 Tw-0.413 Tc(a) Tj0 Tc(n) Tj1.852

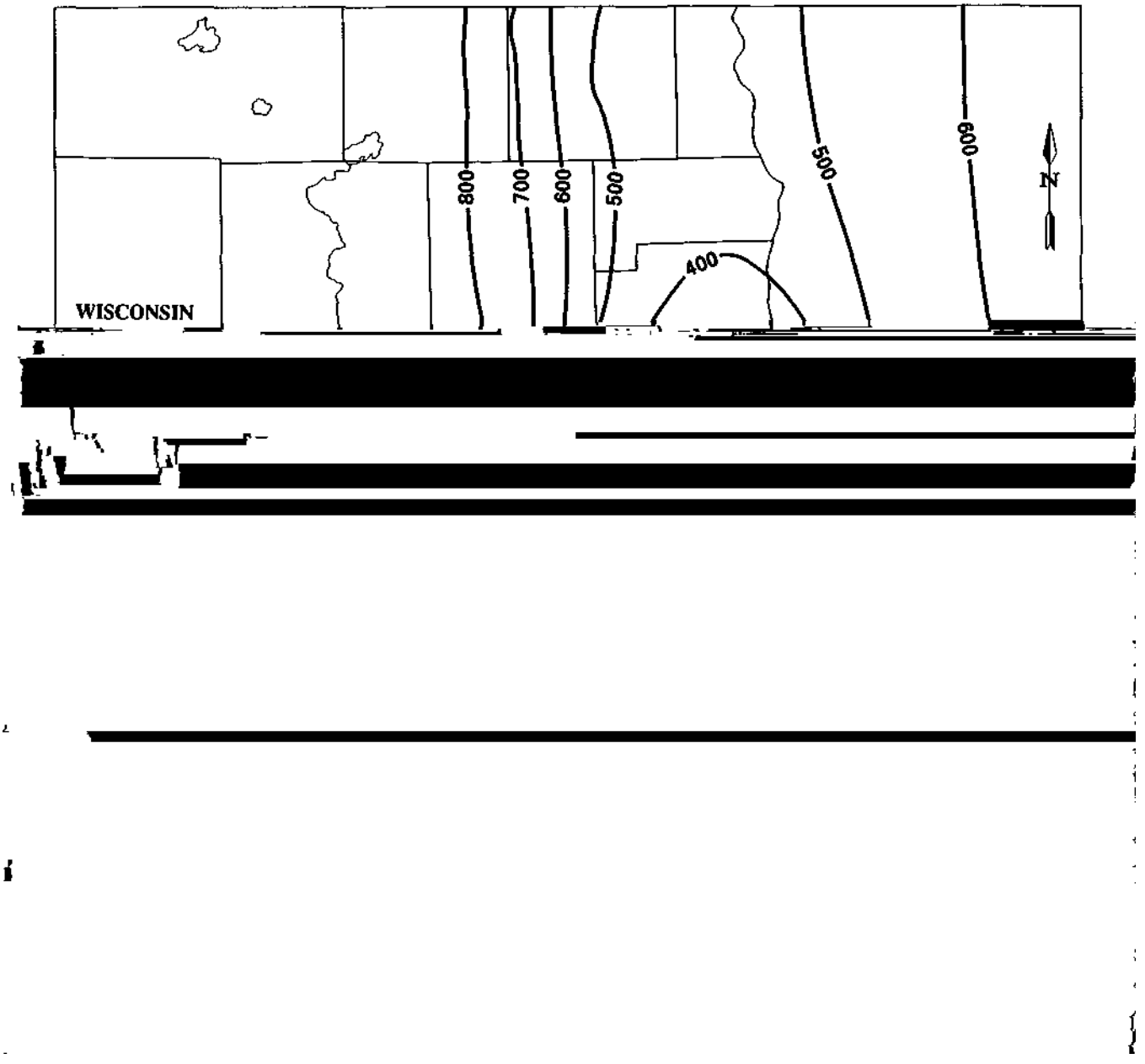


Figure 7. Calculated potentiometric surface in northeastern Illinois for 1985 (feet msl)

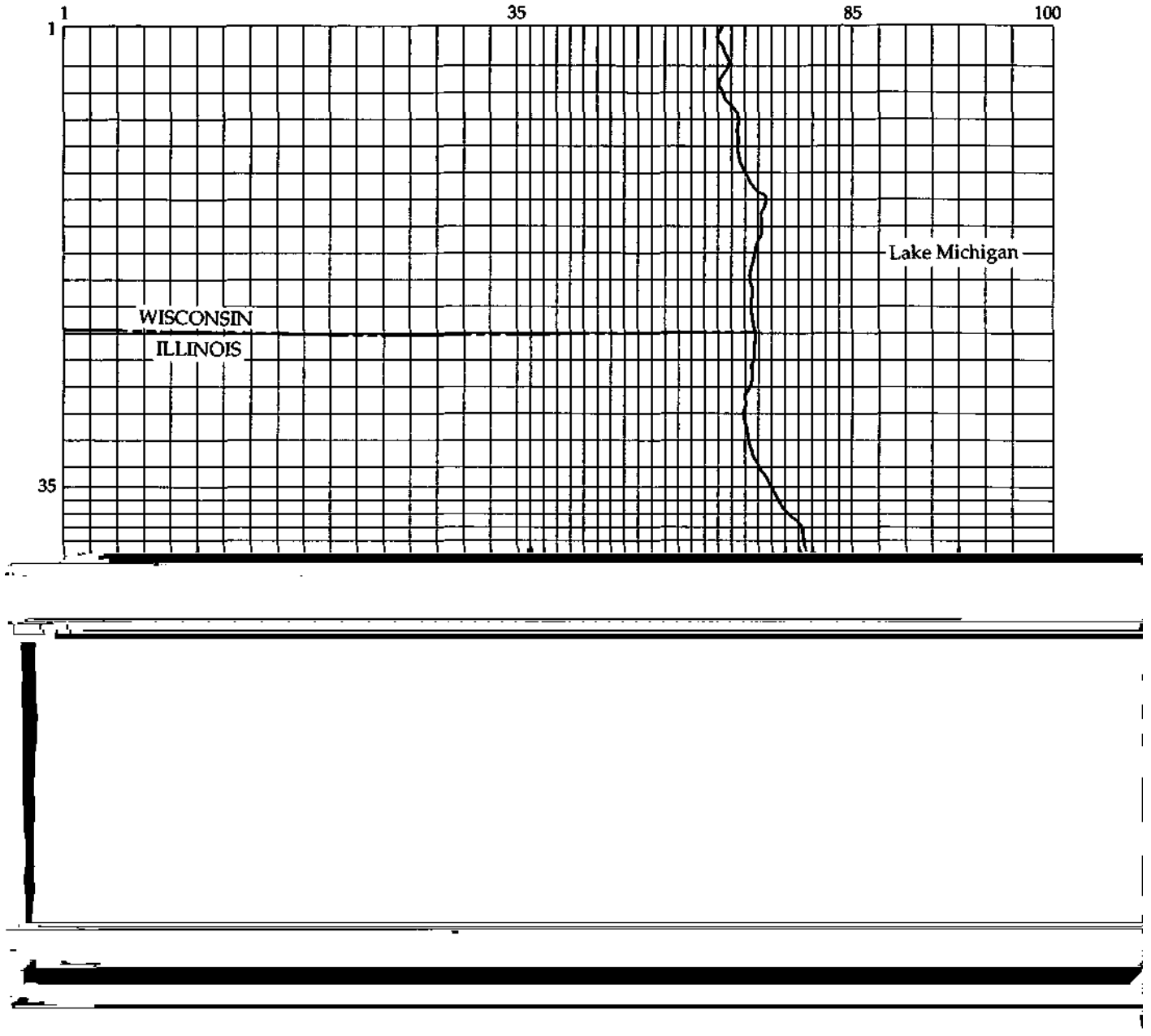


Figure 10. Finite-difference grid used with the New Chicago Model (after Prickett and Lonnquist, 1971)

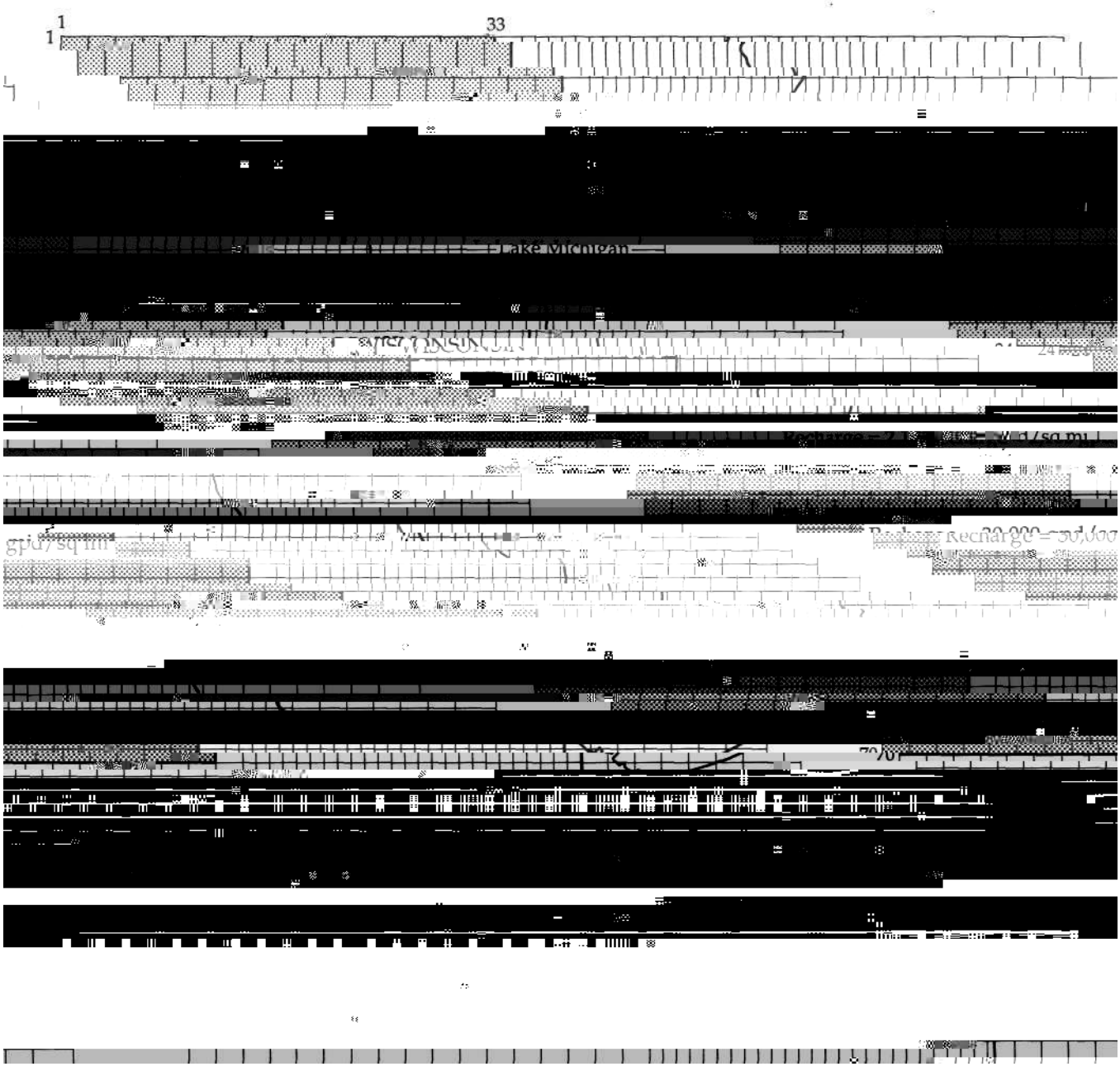


Figure 11. Recharge areas used with the New Chicago Model

flow boundaries were specified along the lower half of the western boundary (rows 36 through 100), along most of the southern boundary (columns 1 through 64 and 81 through 100), and along the lower third of the eastern boundaries (rows 66 through 100). Fewer columns along the northern edge of the model were specified as no-flow boundaries (columns 23 through 44 and 66 through 100).

Constant-head (or specified-value) boundary conditions were also used. These were applied cautiously, and frequently they coincide with permeable boundaries near large volumes of surface water connected to the aquifer system. One important constant-head boundary was intended to correspond with the recharge area in Wisconsin. Another coincides with the eastern edge of the model at Lake Michigan. A third lies within the model grid, instead of on an edge. That boundary represents the Rock River from about Janesville, Wisconsin, downstream to Rock Falls, Illinois.

The first constant-head boundary is located at column 1, rows 1 through 25; and at row 1, columns 1 through 22. In model simulations, these boundary segments serve to dissipate much of the recharge mound applied to the northwest corner of the grid.

The second constant-head boundary is a straight line corresponding to the eastern edge of the grid. It is defined in simulations as column 100, rows 1 through 65. This boundary assumption is perhaps the least likely to be represented in the physical world, because Lake Michigan is not considered to be responsible for maintaining the head condition. On the contrary, the condition is specified for convenience in constructing water-level contours. Without the constant-head boundary, the equipotential lines intersect the edge of the model in an unacceptable fashion. If data were available under the lake, then a better assumption would probably involve a flux out of the model. In the absence of these data, the next best choice is the one assumed: constant head.

The third constant-head boundary defines grid nodes corresponding to the position of the Rock River. Initially, the idea was tested by simulating high-capacity wells at some of these locations. The tests proved so successful that the source code for the simulation was modified to accomplish the constant-head condition. This was done by adding information at the beginning of the pumpage file. This information specifies the nodal location and negative values (e.g., -1) -17-1y

(Buschbach, 1964). Figure 12 illustrates how the fault trends southeast from a point in DeKalb County into Will County. Displacement along the fault is slightly greater than 100 feet, although it appears to diminish at the easternmost extent Its simulation in calibration runs had almost no effect on water levels because the regional flow direction is virtually parallel to the fault trace. If the prevailing direction of ground-water flow were at right angles to the fault, then its impact would be more important. The arbitrary value of zero transmissivity along the trace of the fault does provide a slight kink in the calculated water-level contours. Although the Sandwich Fault has little bearing on regional flow, its inclusion does serve to add an aesthetic quality to the map.

Erosion of the St. Peter Sandstone along the Sandwich Fault

The Sandwich Fault and to a lesser extent the Ashton Arch have brought the St. Peter Sandstone to the surface and subjected,t aEm t doeo at th. Peteds . i thn . oe the fa iV

4. ACTUAL MODEL SIMULATION: FORECAST DEVELOPMENT AND APPLICATION

The New Chicago Model was established as a tool for predicting future ground-water levels. It accurately represents the hydrogeologic system and has demonstrated its capability during the calibration process. It is now ready to simulate future water levels.

The Cambrian-Ordovician aquifer system will respond to future pumpage demands in northeastern Illinois. Therefore, the model user has only to input pumpage forecasts, and the model will calculate corresponding water levels. Specifically, the model makes use of data describing *where* the pumpage will occur, *how much* will occur, and *when* it will occur. The more accurate these data are, the more accurate the predictions will be.

Special Considerations

Because the goal of this investigation has been to determine the impact of the delivery of Lake Michigan water to DuPage and Lake Counties, two simulations were made: one assumed the delivery of lake water in 1992, and the other assumed there would be no delivery. It follows then that the difference in future ground-water levels will represent the impact of the delivery.

Forecasting the amount and location of water demand is an inexact science. Simple forecasts dependent upon variables such as population, economic factors, and other measurable criteria can be made for public water supply demands. But they fail to portray the exact quantity that will be needed from any particular aquifer system.

To be successful, the most effective method should acknowledge that some facilities obtain water from multiple ground-water sources. Some, such as the city of Elgin, might even use combined surface and ground-water sources. The new forecasting method also should recognize the impact of regulations for drinking water quality. For example, to meet the standards for radium in their drinking water, some communities are planning to blend waters. The result, therefore, might be decreased pumpage from the Cambrian-Ordovician aquifer, even though water demand is increasing. Consequently, forecasts extend only to the year 2010, ensuring greater reliability and accommodating the complexity of some situations.

Forecast Development

Forecasts of ground-water demand were made for both Wisconsin and the eight-county Chicago region. Actual observations for 1986 and 1987 were used in Illinois, and predictions were made for the period 1988 through 2010. Predictions for Wisconsin pumpage were made fordo

A special QuickBASIC program was written to display the corresponding pairs of X and Y values on a color monitor. Regression lines were determined for pumpage and displayed with the observed data at each Illinois facility using the Cambrian-Ordovician aquifer. Corrections were made for missing data, and subjective interpretations were imposed on some of the 289 predictions. These judgements typically involved holding industrial pumpages at 1987 levels. A few impositions were made on public water supplies for cases in which planners are attempting to meet radium standards by switching part of their demand to surface water.

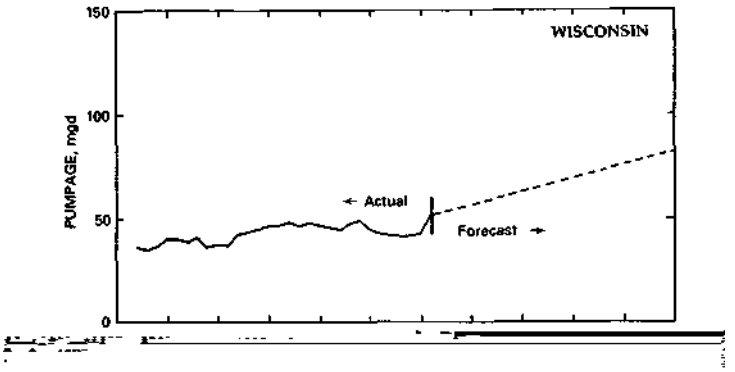


Figure 14. Impact of Lake Michigan water delivery on deep sandstone pumpage in southeastern Wisconsin: actual and forecast

pumpage steady at present levels and meet future growth from shallower aquifers. These communities include Sugar Grove, Cary, and Rockdale.

As a result of these expectations, Cambrian-Ordovician pumpage in northeastern Illinois is expected to fall below the practical sustained yield of the aquifer. If this occurs, it will mark the first time since the late 1950s. However, the pumping center locations will move much further west than those observed previously.

Decrease in the Number of Illinois Pumping Centers

In the next century, the locations of ground-water pumping centers will differ significantly from the pattern observed in the twentieth century. Not only will decreased demand affect the shape of the Chicago pumping cone, but its

Table 2. Illinois Public Water Supply Centers Withdrawing More than 2.0 Million Gallons per Day, 1960-2000

1960	*1970*	*1980*	*1990*	*2000*
Aurora	Arlington Hts.	Arlington Hts.	Aurora	Aurora
Chicago	Aurora	Aurora	Batavia	Crystal Lake
Des Plaines	Elk Grove	Bellwood	Bellwood	Joliet
Elgin	Elgin			

Table 3. (Continued)

Table 3. (Continued)

Facility name

Kane County (continued)
Sugar Grove
West Dundee

Subtotals

Kendall County
Farm Colony
Fox Lawn Utility Co.
Hollis Park Subdivision
Newark
Osweg

Table 3. (Concluded)

Facility name

Will County

Braidwood
Camelot Subd.
Channahon
Imperial Trailer Park
Joliet
Joliet Correctional Center
Lakewood Shores Subdivision
Lewis College
Lockport
Plainfield
Rockdale
Romeoville
Stateville Correctional Center
Will County Water Co.
Wilmington

Table 4. Summary of Industrial, Irrigation, and Public Water Supply Pumpage Demands in the Chicago Region, 1985-2010 (mgd)

Type of pumpage

Industrial

Cook County
DuPage County
Grundy County
Kane County

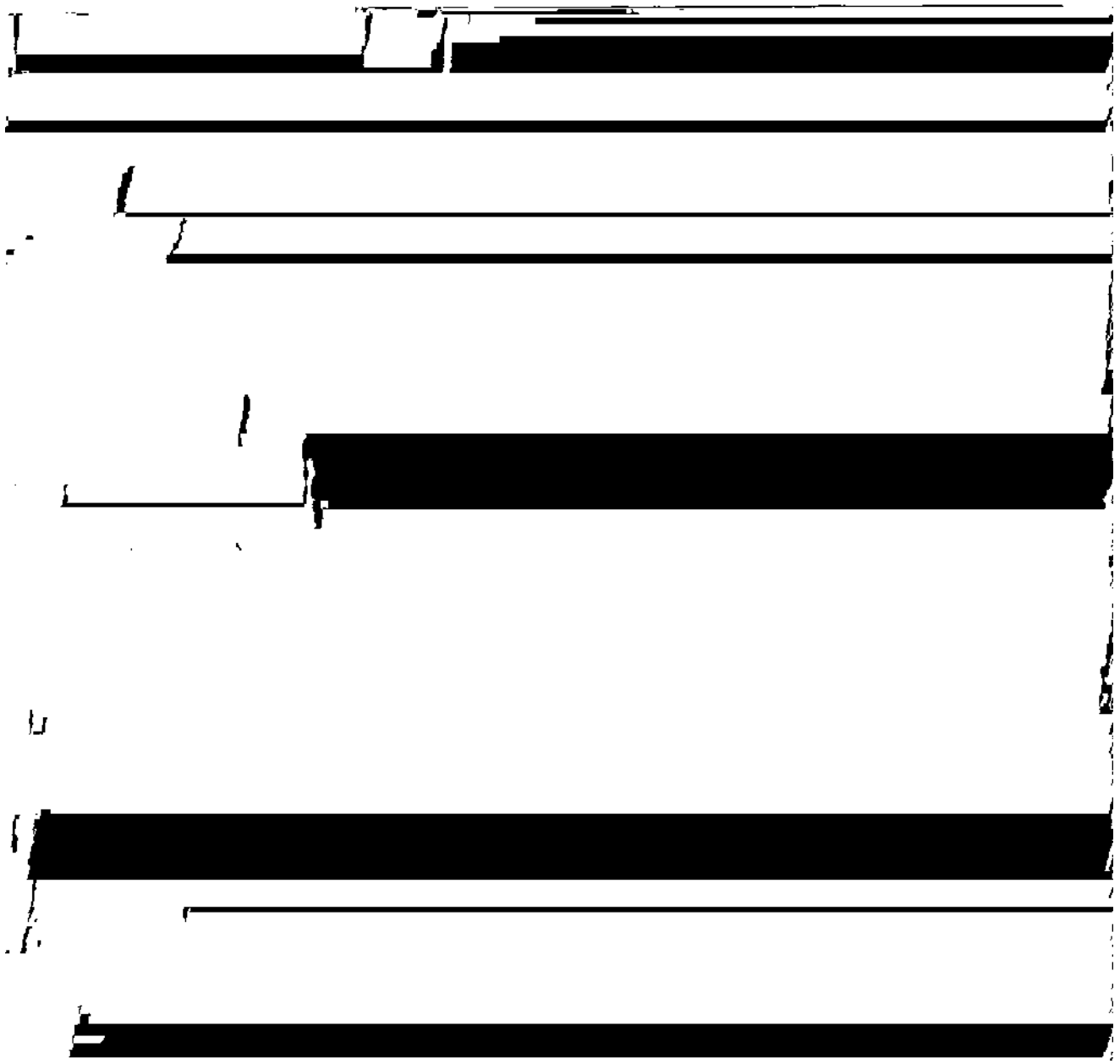


Figure 17. Predicted water-level changes between 1985 and 1992 (feet)

1995

Water levels predicted by the end of the year 1995 are illustrated in figure 18. This map can be considered to represent the first reaction to the 1992 delivery of Lake Michigan water to DuPage and Lake Counties. It is, in fact, a prediction of what might happen during the first four years after the switch.

The model predicts that the Chicago-area regional pumping cone will initially become more shallow without becoming significantly smaller in areal extent. The 100-, 200-, and 300-foot contours will shift southward in Lake County, while most other contours will remain stationary.

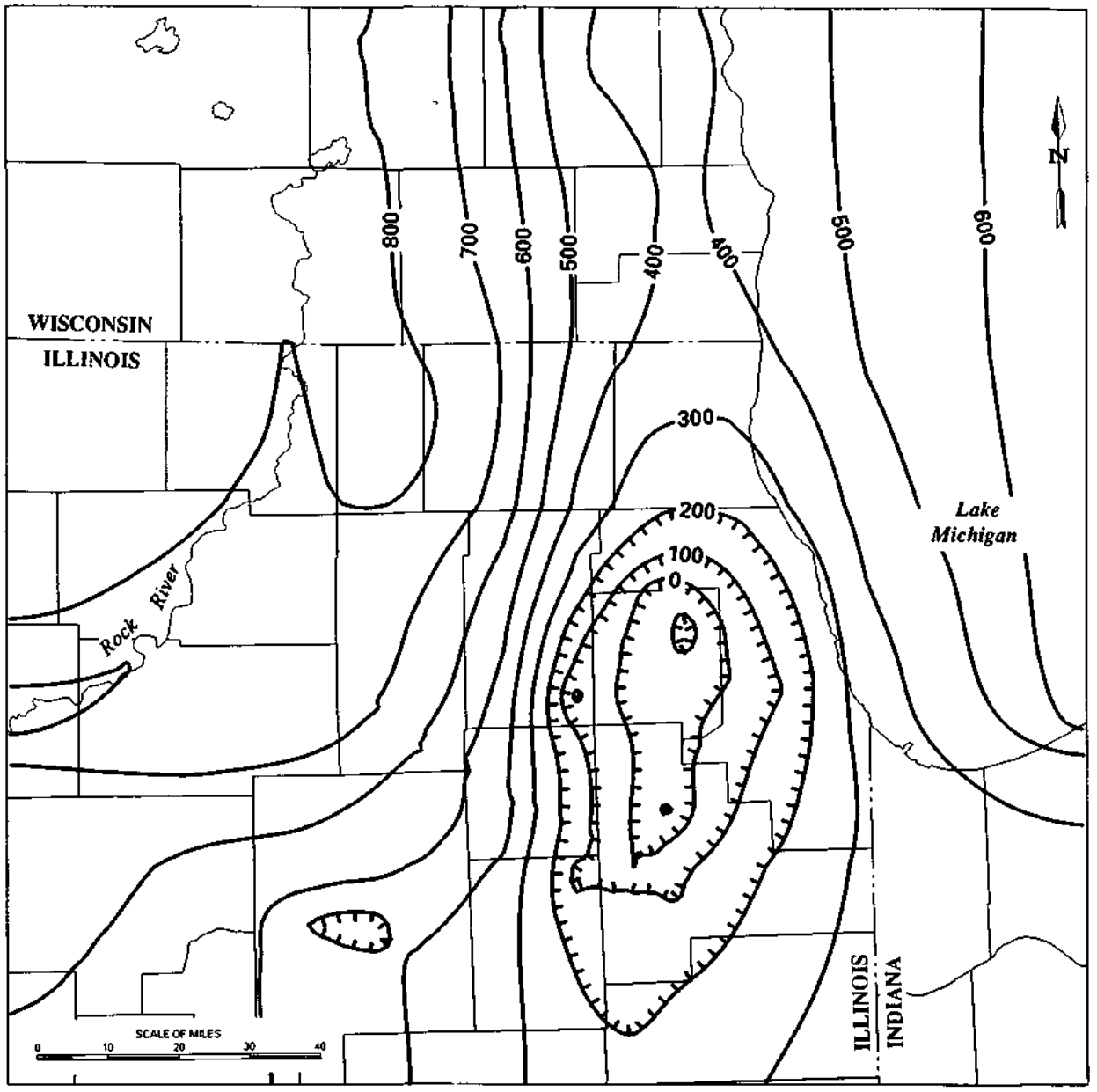


Figure 18. Calculated potentiometric surface for 1995 (feet msl), assuming delivery of Lake Michigan water to DuPage and Lake Counties in 1992

2000

By the end of the year 2000, water levels will have recovered dramatically. Everywhere in DuPage and Cook Counties, levels will rise above the 200-foot elevation, as shown in figure 19. This has not been observed since 1958 when the Water Survey began documenting Chicago's regional water levels. The area encompassed by the pumping cone of depression will shrink rapidly.

Other benefits will also be seen in northeastern Illinois. Water levels in parts of southern Lake County will have risen by more than 150 feet. At Elgin, levels are predicted to rise 200 feet. In fact, Cambrian-Ordovician water levels all along me Fox River Valley in Kane County will improve significantly. Major changes will also be observed at Aurora as that community diversifies its sources of water.

Further south, in Will and southern Cook Counties, significant improvements will also be observed. The Joliet pumping cone will disappear and fade into a more regional cone of depression. Water levels near Bolingbrook will rise by more than 200 feet. Some of this recovery will occur when DuPage County changes to lake water, but it will also result from Joliet diverting 5 to 6 mgd of its demand to surface water sources.

The water levels predicted for the year 2000 represent something of a landmark in charting ground-water manage-

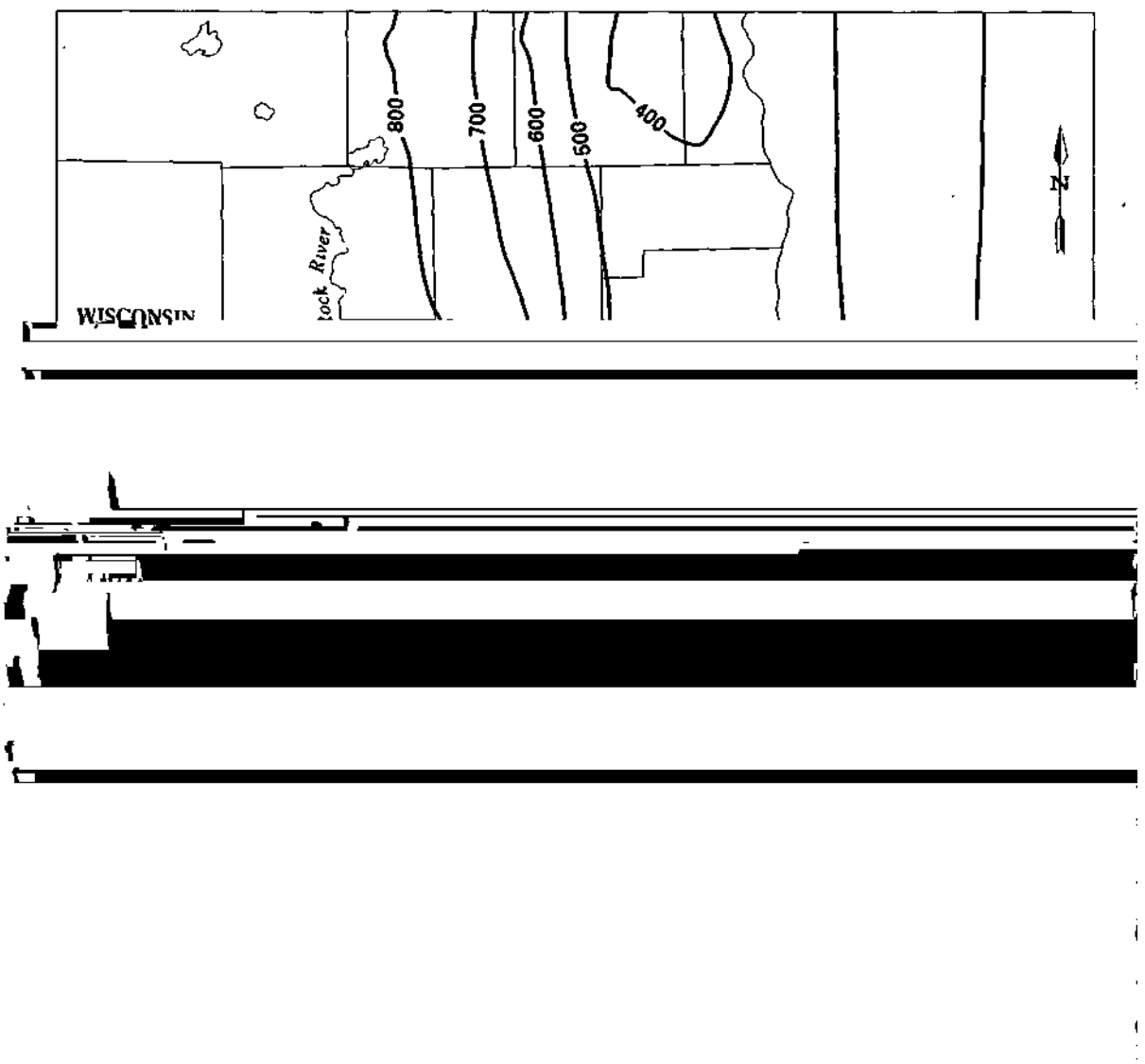


Figure 19. Calculated potentiometric surface for 2000 (feet msl), assuming delivery of Lake Michigan water to DuPage and Lake Counties in 1992

ment: they will be the result of the *projected minimum pumpage* in northeastern Illinois (see forecasts in section 4). Estimates indicate that Cambrian-Ordovician withdrawals will bottom out at about 54 mgd. Beyond

Water lev
depicted in figur
rising, although t

as the last of the

year 2010 represe

Impact of Projected 1992 Lake Michigan Water Deliveries

A major concern of this investigation was to determine how the delivery of Lake Michigan water would impact ground-water levels in DuPage and Lake Counties. The prediction in olved the use of two simulations: one assumed the delivery of lake water in 1992, and the other assumed the water would not be delivered. Water-level predictions were made for both assumptions and extended to the year 2010. The difference represents the impact of the Lake Michigan water deliveries plus other forecasted changes in demand.

The predicted impact of the delivery of lake water is illustrated in figure 22. Ground-water levels in the Cambrian-Ordovician aquifer are expected to rise in northeastern Illinois by almost 650 feet! Levels will also rise in southeastern Wisconsin and northwestern Indiana in response to actions taken in Illinois. The recovery will be centered on Elmhurst, but water levels are predicted to rebound by 350 feet or more throughout DuPage and much of western Cook Counties as well. It is expected that levels will rise by 50 feet or more in areas as far away as Belvidere, DeKalb, Morris, and Kankakee.

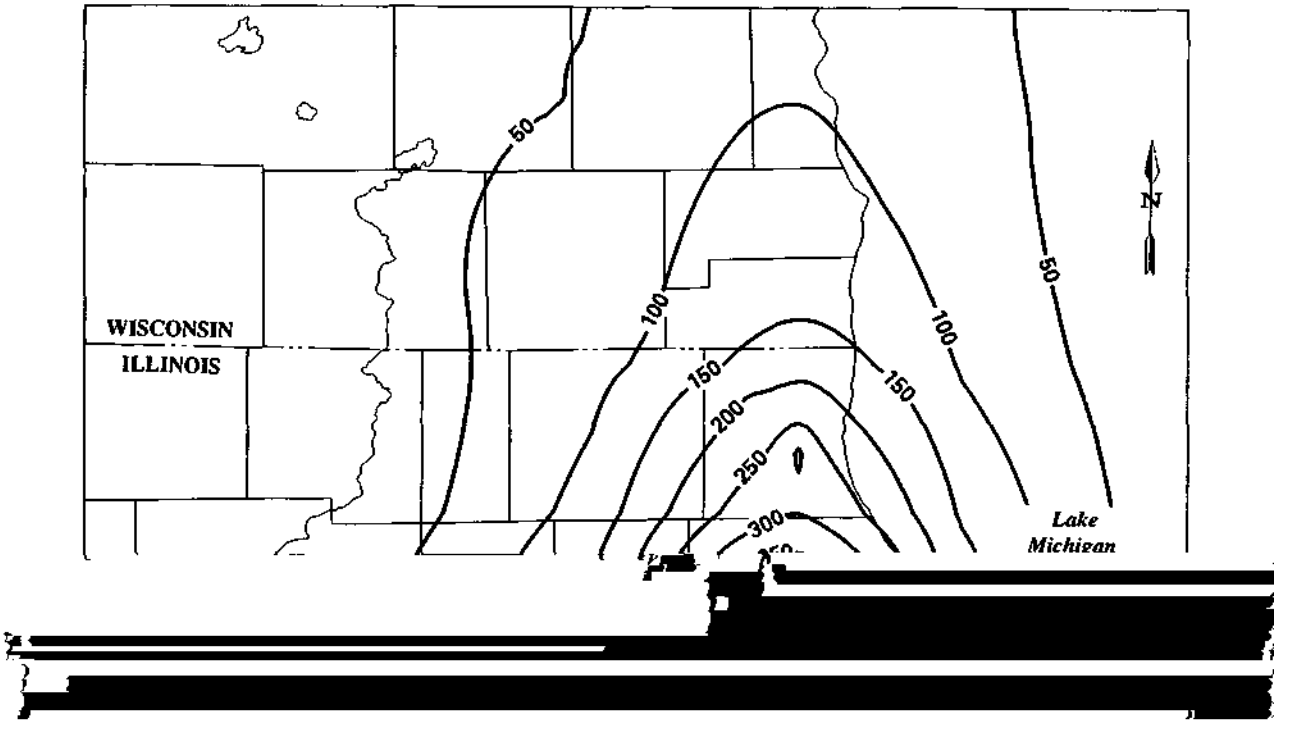


Figure 22. Relative changes in water levels by 2010: impact of the delivery of Lake Michigan water to DuPage and Lake Counties in 1992 (feet)

Conclusions and Restatement of Key Points

An enhanced version of Prickett and Lonnquist's traditional Chicago model was developed for this project The model is a numerical ground-water flow representation of the physical aquifer system that supplies large quantities of water to northeastern Illinois and southeastern Wisconsin.

Hydrogeologic Conditions

This study differs from previous studies in its interpretation of hydrogeologic conditions, and it excludes the Galena-Platteville as part of the aquifer system. Elimination of the Galena-Platteville has implications for the storage coefficient The original model was designed to change storage coefficients when dewatering caused the aquifer to convert from artesian conditions to water-table conditions. The conversion "was keyed to the position of the potentiometric head relative to the top of the Galena-Platteville. Because these formations are no longer considered part of the upper aquifer layer, this criterion is not applicable. Instead, the conversion to

Practical Significance

The recovery of ground-water levels will be important to both users and resource

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Appendix A. Source Code for CHI2SURF:
A Post-Processing Program to Convert Model Calculations to SURFER Format
by Evan P. Mills

```
REM This QuickBasic 4.0 program is used to post-process output from
REM the new Chicago Model.  It inverts the output from the fourth
REM quadrant and writes it in what SURFER (Golden Software, Inc.)
REM recognizes as a *.GRD
```

```
END
```

Appendix A (Concluded)

```
FOR col - 2
```

Appendix B. Grid Location Details

(Lambert feet)

Column (i)	*Row (J)*	*X (Lambert feet)*	*Y (Lambert feet)*
1	1	2911457.5	3681210.5
2	1	2922017.5	3681210.5
3	1	2932577.5	3681210.5
4	1	2943137.5	3681210.5
5	1	2953697.5	3681210.5
6	1	2964257.5	3681210.5
7	1	2974817.5	3681210.5
8	1	2985377.5	3681210.5
9	1	2995937.5	3681210.5
10	1	3006497.5	3681210.5
11	1	3017057.5	3681210.5
12	1	3027617.5	3681210.5
13	1	3038177.5	3681210.5
14	1	3048737.5	3681210.5
15	1	3059297.5	3681210.5
16	1	3069857.5	3681210.5
17	1	3080417.5	3681210.5
18	1	3090977.5	3681210.5
19	1	3101537.5	3681210.5
20	1	3112097.5	3681210.5
21	1	3122657.5	3681210.5
22	1	3133217.5	3681210.5
23	1	3143777.5	3681210.5
24	1	3154337.5	3681210.5
25	1	3164897.5	3681210.5
26	1	3175457.5	3681210.5
27	1	3186017.5	3681210.5
28	1	3196577.5	3681210.5
29	1	3207137.5	3681210.5
30	1	3217697.5	3681210.5
31	1	3228257.5	3681210.5
32	1	3238817.5	3681210.5
33	1	3249377.5	3681210.5
34	1	3259937.5	3681210.5
35	1	3270497.5	3681210.5
36	1	3275777.5	3681210:5
37	1	3281057.5	3681210.5
38	1	3286337.5	3681210.5
39	1	3291617.5	3681210.5
40	1	3296897.5	3681210.5
41	1	3302177.5	3681210.5
42	1	3307457.5	3681210.5
43	1	3312737.5	3681210.5
44	1	3318017.5	3681210.5
45	1	3323297.5	3681210.5
46	1	3328577.5	3681210.5
47	1	3333857.5	3681210.5
48	1	3339137.5	3681210.5
49	1	3344417.5	3681210.5
50	1	3349697.5	3681210.5
51	1	3354977.5	3681210.5
52	1	3360257.5	3681210.5

Appendix B (Continued)

Column (i)	*Row (J)*	X *(Lambert feet)*	*Y (Lambert feet)*
53	1	3365537.5	3681210.5
54	1	3370817.5	3681210.5
55	1	3376097.5	3681210.5
56	1	3381377.5	3681210.5
57	1	3386657.5	3681210.5
58	1	3391937.5	3681210.5
59	1	3397217.5	3681210.5
60	1	3402497.5	3681210.5
61	1	3407777.5	3681210.5
62	1	3413057.5	3681210.5
63	1	3418337.5	3681210.5
64	1	3423617.5	3681210.5
65	1	3428897.5	3681210.5
66	1	3434177.5	3681210.5
67	1	3439457.5	3681210.5
68	1	3444737.5	3681210.5
69	1	3450017.5	3681210.5
70	1	3455297.5	3681210.5
71	1	3460577.5	3681210.5
72	1	3465857.5	3681210.5
73	1	3471137.5	3681210.5
74	1	3476417.5	3681210.5
75	1	3481697.5	3681210.5
76	1	3486977.5	3681210.5
77	1	3492257.5	3681210.5
78	1	3497537.5	3681210.5
79	1	3502817.5	3681210.5
80	1	3508097.5	3681210.5
81	1	3513377.5	3681210.5
82	1	3518657.5	3681210.5
83	1	3523937.5	3681210.5
84	1	3529217.5	3681210.5
85	1	3534497.5	3681210.5
86	1	3545057.5	3681210.5
87	1	3555617.5	3681210.5
88	1	3566177.5	3681210.5
89	1	3576737.5	3681210.5
90	1	3587297.5	3681210.5
91	1	3597857.5	3681210.5
92	1	3608417.5	3681210.5
93	1	3618977.5	3681210.5
94	1	3629537.5	3681210.5
95	1	3640097.5	3681210.5
96	1	3650657.5	3681210.5
97	1	3661217.5	3681210.5
98	1	3671777.5	3681210.5
99	1	3682337.5	3681210.5
100	1	3692897.5	3681210.5

Appendix B (Continued)

Column *(i)*	*Row* *(j)*	*X* *(Lambert feet)*	*Y* *(Lambert feet)*
1	2	2911457.5	3670650.5
1	3	2911457.5	3660090.5
1	4	2911457.5	3649530.5
1	5	2911457.5	3638970.5
1	6	2911457.5	3628410.5
1	7	2911457.5	3617850.5
1	8	2911457.5	3607290.5
1	9	2911457.5	3596730.5
1	10	2911457.5	3586170.5
1	11	2911457.5	3575610.5
1	12	2911457.5	3565050.5.
1	13	2911457.5	3554490.5
1	14	2911457.5	3543930.5
1	15	2911457.5	3533370.5
1	16	2911457.5	3522810.5
1	17	2911457.5	3512250.5
1	18	2911457.5	3501690.5
1	19	2911457.5	3491130.5
1	20	2911457.5	3480570.5
1	21	2911457.5	3470010.5
1	22	2911457.5	3459450.5
1	23	2911457.5	3448890.5
1	24	2911457.5	3438330.5
1	25	2911457.5	3427770.5
1	26	2911457.5	3417210.5
1	27	2911457.5	3406650.5
1	28	2911457.5	3396090.5
1	29	2911457.5	3385530.5
1	30	2911457.5	3374970.5
1	31	2911457.5	3364410.5
1	32	2911457.5	3353850.5
1	33	2911457.5	3343290.5
1	34	2911457.5	3332730.5
1	35	2911457.5	3322170.5
1	36	2911457.5	3316890.5
1	37	2911457.5	3311610.5
1	38	2911457.5	3306330.5
1	39	2911457.5	3301050.5
1	40	2911457.5	3295770.5
1	41	2911457.5	3290490.5
1	42	2911457.5	3285210.5
1	43	2911457.5	3279930.5
1	44	2911457.5	3274650.5
1	45	2911457.5	3269370.5
1	46	2911457.5	3264090.5
1	47	2911457.5	3258810.5
1	48	2911457.5	3253530.5
1	49	2911457.5	3248250.5
1	50	2911457.5	3242970.5
1	51	2911457.5	3237690.5
1	52	2911457.5	3232410.5

Appendix B (Continued)

Column (i)	*Row*	*X*	*Y*

Appendix B (Concluded)
Grid Corners for the New Chicago Model
(in Lambert feet)

xmin = 2911457 ymin = 2899770
xmin = 2911457 ymax = 3681210
xmax = 3692897 ymin = 2899770
xmax = 3692897 ymax = 3681210

In Lambert feet

Lower Left	2911457	2899770
Upper Left	2911457	3681210
Lower Right	3692897	2899770
Upper Right	3692897	3681210

In longitude-latitude

Lower Left	89	49	20.28	40	59	46.	07
Upper Left	89	49	57.78	43	8	57.	05
Lower Right	86	58	41.74	40	58	12.	16
Upper Right	86	53	48.53	43	7	20.	34