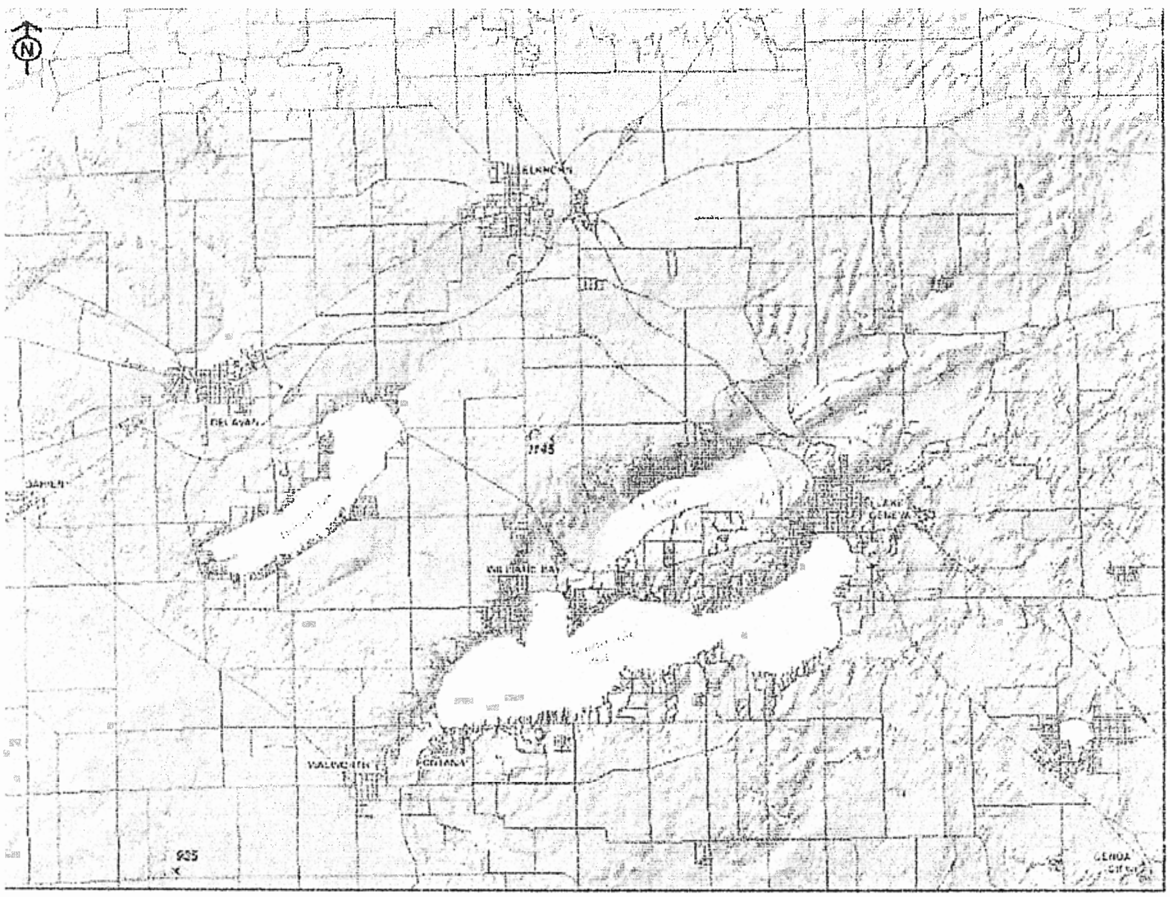
GROUNDWATER DATA COMPILATION FOR THE GENEVA LAKE, WISCONSIN AREA 2006



Prepared by
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For the
Geneva Lake Environmental Agency

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Lake Geneva Garden Club,
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Groundwater Data Compilation for the Geneva Lake, Wisconsin, Area

Prepared for Ted Peters, Geneva Lake Environmental Agency

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Wisconsin Geological and Natural History Survey – University of Wisconsin Extension

May 12, 2006

This report contains a summary of groundwater resources information compiled from WGNHS projects near Geneva Lake, Walworth County, Wisconsin. We present several geologic and hydrogeologic maps printed at a scale useful to the Geneva Lake Environmental Agency (GLEA). The second issue we report on is the suitability of an existing groundwater flow model for simulating surface water and groundwater interactions in the Geneva Lake area.

Map Preparation

The maps prepared for this project were initially compiled for the Southeast Wisconsin Regional Planning Commission (SEWRPC) and were published in "Groundwater Resources of Southeastern Wisconsin", SEWRPC Technical Report No. 37, June 2002. The maps include a regional overview (Plate 1), bedrock geology (Plate 2), bedrock elevation (Plate 3), depth to bedrock (Plate 4), and water table elevation (Plate 5).

Prominent features apparent in the regional overview map include the Darien Moraine, extending north-northwest between Walworth and Darien, and a fan of glacial outwash deposits sloping southward from the western end of Geneva Lake. The depth to bedrock map shows extensive surficial deposits across the region, with a thick sequence of valley fill deposits west of Geneva Lake. A thickening of surficial materials forms a ridge between Como and Geneva Lakes. These features are reflected in the elevation of the bedrock surface, with bedrock valleys apparent between Darien and Walworth, and between Delavan and Elkhorn.

The map of bedrock geology illustrates the location of the subcrop (that is, the subsurface edge) of the Maquoketa Formation. The Maquoketa Formation shale and underlying Sinnipee Group dolomite form the Maquoketa-Sinnipee aquitard, which is a regionally extensive, low-permeability hydrogeologic unit separating the upper aquifer system (glacial deposits and Silurian Group dolomite) from a deep groundwater flow system. The water table map illustrates general directions of shallow groundwater flow from recharge areas at higher elevations in the landscape towards low-lying areas of groundwater discharge such Como and Geneva Lakes and Turtle Creek.

Groundwater Flow Model Review

The regional-scale, three-dimensional groundwater flow model of the SEWRPC region is documented in "A Regional Aquifer Simulation Model For Southeastern Wisconsin," SEWRPC Technical Report No. 41, June 2005. This report also provides an overview of hydrogeologic conditions in the area. Although not published until 2005, the regional model was available in 2002, when the WGNHS refined (that is, modeled at a finer scale) part of this model to simulate municipal well capture zones in Walworth County for the Wisconsin DNR's Source Water Protection Program. The capture zone of a well is the area of the land surface over which recharging precipitation enters a groundwater system and eventually flows to a well. Capture zones are useful to identify potential sources of contamination to wells and for delineating well-head protection areas.

The refined model has a cell size of about 515 ft by 515 ft (about 0.01 square mile of land surface); the model calculates one value of hydraulic head (water table elevation) in every model cell. The model has good vertical resolution, with 12 layers of varying thickness representing unlithified (glacial) deposits, Silurian dolomite, Maquoketa-Sinnipee aquitard, and various sedimentary rock layers that constitute the deep flow system. The Fontana, Williams Bay and City of Lake Geneva municipal wells are completed in unlithified deposits and are represented in the two uppermost model layers.

Representation of Wells and Surface Water Features

Most of the high capacity wells (that is, wells permitted by the DNR to pump in excess of 70 gallons per minute) in the Geneva Lake area are represented in the model (Figures 1 and 2). Table 1 summarizes well names and the pumping rates used in the model. Other wells in the area, a majority of which are shallow domestic wells that pump only a small quantity of groundwater relative to the high capacity wells, provide points at which the model can be calibrated, or matched, to field conditions. There are two monitoring wells, one in Fontana and one in Lake Geneva, that are part of the Wisconsin ground-water observation network maintained by the U.S. Geological Survey and the WGNHS. These wells are not used as calibration points in the model, but could be incorporated at a later time if deemed useful for improved model calibration or validation. The appendix to this report includes historical groundwater levels at the two wells. These are also available from the U.S. Geological Survey internet site at http://wi.water.usgs.gov/public/gw/.

None of the tributaries to Geneva Lake are simulated in the refined model (Figure 1). They were not included because they are depicted as ephemeral steams on 1:24000-scale topographic maps, and they are not significant hydrologic features with respect to the original purpose for this model.

The White River, with headwaters at the spillway of Geneva Lake, is simulated in the model as a river boundary condition. (A boundary condition is a mathematical formulation applied where water enters or exits the modeled system; boundary conditions are necessary to arrive at a model solution or "output".) The river boundary condition is assigned a non-varying stage elevation in each model cell that represents a river reach. In the model, the river cell may gain water from the aquifer or lose water to the aquifer, as determined by the simulated water table elevation, the assigned stage and conductance (that is, permeability of river sediments input by the modeler). The flow rate in the river is not an input to the model, and the river boundary condition does not allow a simulated river to go dry. This representation may not provide an adequate simulation of the natural system if the surface water body undergoes significant temporal changes in stage or flow, and if the primary purpose for the model is to simulate groundwater and surface water interactions.

Lakes in the model are also simulated with the river boundary condition; the model does not simulate changes in lake level. This is a useful approach to modeling Geneva and Como Lakes, in which the maximum lake level is maintained by spillway elevations. Some streams and wetlands, such as the large wetland complexes east of Big Foot Beach State Park, are represented with the drain-type boundary condition. The drain boundary condition permits a model cell to receive groundwater discharge when the simulated water table elevation exceeds the modeler-defined drain elevation. The drain cell remains dry (that is, disconnected from the groundwater system) if the water table elevation is below the drain elevation. Figure 1 shows the location of river and drain boundary conditions in the model.

As currently developed, this model is useful for simulating changes in the water table elevation, horizontal and vertical hydraulic gradients in the aquifer, and volumetric fluxes within the groundwater system due to changes in well locations, pumping rates, or recharge. Where drains represent streams and wetlands, the model can be used to simulate the effect of near-by pumping wells on groundwater discharge to those surface water features.

Demonstration Simulations

The flow model was run several times for the purposes of this report to demonstrate potential uses for the model, in particular illustrating some of the impacts of pumping. Figure 3 shows the simulation of the water table elevation and the five-year capture zones for municipal wells determined for the DNR. These time-delineated capture zones illustrate the area of the land surface over which recharge to the water table will reach the well within five years. The shape and size of the capture zone are generally determined by the permeability and type of aquifer (confined or unconfined), and the pumping rate. The DNR requested that capture zones be simulated with pumping rates overestimated by a factor of about 2, which results in a simulated capture zone larger than the actual capture zone. Note the capture zones of the Lake Geneva municipal wells intersect the White River and are hydraulically down gradient of the lake. This suggests that some lake and river water infiltrates to the aquifer and is captured by the pumping wells.

The model was run with no pumping from wells to provide a sense of pre-development conditions in the aquifer. The simulated water table elevation is shown in Figure 4, and this can be compared to the simulated water table under pumping conditions (Figure 3). With pumping, the groundwater divide west of the lake shifts away from the lake, increasing the size of the "groundwater shed" of the lake. This illustrates the effect of wells in Walworth and Fontana, which lower the water table and move the divide to the west.

In a subsequent model simulation, all wells were turned back on at the rates listed in Table 1, with the exception of Fontana, Williams Bay and Lake Geneva municipal wells. These wells were set at the average pumping rates reported by these water utilities for 2005 (the volume of water pumped by each utility on an annual basis is available from the Public Service Commission of Wisconsin's web site). The simulation (Figure 5) shows that current pumping at these wells results in appreciable drawdown of water levels. Figure 6 illustrates the change in water levels, or drawdown, from predevelopment (that is, non-pumping) conditions attributable to current pumping at Fontana, Williams Bay and Lake Geneva municipal wells.

The final model simulation evaluates the effect of Lake Geneva waste water treatment infiltration ponds on the groundwater system. The ponds, located near the intersection of Highways 12 and 51, are used to dispose of treated effluent. In the model, they are represented by an area assigned an increased rate of recharge. Seven model cells representing an area of about 1,856,575 ft^2 are assigned a recharge rate of 0.0825 ft/day. This rate was calculated by assuming that 80% of the water pumped in 2005 by the Lake Geneva municipal wells is discharged to the ponds. The simulation further assumes that the wastewater is discharged at a steady rate over time. Results of this run show that a groundwater mound develops under the ponds (Figure 7). Under these conditions, the 40 year capture zone of Lake Geneva municipal Well 5 extends to the ponds. This suggests that at the 2005 pumping rate, treated effluent discharged to the ponds will reach Well 5 in about 40 years. The model does not account for subsurface processes (dilution, mixing and biological and chemical reactions) that will reduce the impact of effluent on groundwater quality.

Effect of municipal pumping on Geneva Lake

A mass balance approach can be used to estimate the significance of groundwater pumping with respect to the lake system. Wells completed in glacial deposits within the groundwater shed of the lake capture groundwater that would otherwise discharge to the lake. When lake stage is sufficiently high to flow over the spillway, additional groundwater discharge to the lake would not affect lake stage but would presumably increase the volume of flow through the lake and over the spillway. For example, Fontana and Williams Bay pumped about 263 million gallons of water in 2005. Their sewage treatment effluent is diverted outside of the lake watershed, and pumping from the village wells is therefore a net loss to the watershed. Based on a lake volume of 403,000,000 m^3, the pumped volume is less than 0.5% of the lake volume. From a mass balance approach, this suggests that the primary consequence of municipal pumping from the two villages is to divert 263 million gallons annually from discharging to the lake and the White River. A second case to consider is when lake stage remains below the elevation of the spillway. Based on a lake surface area of 21,200,000 m^2, the volume of water pumped by the villages in a year would raise the lake stage by about 4.7 cm (about 1.9 inches).

Lake Geneva's municipal wells pumped about 529 million gallons of water in 2005. The wells are east and downgradient of the lake, near the White River. Based on the model-simulated capture zones (figure 2) and water table (figures 2 and 4), these wells primarily capture groundwater that has discharged from the lake to the groundwater system, that would otherwise flow down valley and discharge to the White River. Therefore, pumping from the Lake Geneva municipal wells presumably has no effect on lake stage or the volume of flow through the lake. Pumping from the wells removes about 529 million of gallons from the hydrologic system, but a similar volume of treated wastewater is returned to the groundwater system through the infiltration ponds.

Improving model simulation of surface water-groundwater systems

The model could be refined to simulate tributaries to the lakes by replacing river boundary conditions with stream boundary conditions. This requires that measured or estimated stream flows be entered in the model. The stream boundary condition causes a stream reach to go dry when the simulated flux from the stream to the aquifer exceeds flow in the stream. This prevents the modeled stream from allowing too much water to flow to the aquifer from a loosing stream reach.

Another option to improve simulation of surface water-groundwater interactions is to convert this three-dimensional model to a two-dimensional model using a computer code such as GFLOW. This modeling approach would simplify vertical representation in the model, limiting it to the glacial aquifer system. The GFLOW model code is flexible and "user-friendly"; it allows for easy representation of, and changes to, streams, wells and other discharge and recharge features in a single aquifer.

Conclusions

Collection of regional geologic and hydrogeologic information for SEWRPC resulted in an extensive, high quality data set for the Geneva Lake area. The groundwater flow model is useful to investigate impacts of pumping wells on water table elevations, and to identify wellhead protection areas for wells. The model does not represent small streams, springs or wetland complexes that are likely valued ecological resources near Geneva and Como Lakes. The model could be refined to improve simulation of surface water and groundwater resources.

Mass balance calculations may provide a useful way for concerned citizens to think about effects of groundwater withdrawals near the lake. Wells situated upgradient of the lake capture water that would otherwise discharge to the lake. This reduces volumetric flow through the lake. When lake levels fall below the elevation of the spillway, groundwater pumping captures water that would otherwise discharge to the lake. Current groundwater withdrawal in the area has a relatively small effect on lake stage.

Modeling efforts are time-consuming, and data collection and associated modeling should be guided by a specific purpose. The existing model is detailed and calibrated to local water level elevations. Further refinement of the model may be useful if it is motivated by questions about a specific feature or scenario in the hydrologic system.

The GLEA would be well–served by continuing data collection efforts. For example, if the model were used to evaluate new high capacity wells proposed for the area, historic flow measurements from nearby streams will provide reliable surface water calibration points. Depth to groundwater measurements from shallow monitoring wells near the lake edge would also be useful. These wells would need to be installed and monitored by the GLEA or another interested party. The wells would provide measurements of vertical gradients below the lake and would be an important supplement to data from the two existing monitoring wells that are part of the ground-water observation network (see appendix). The name "Fontana" translates from "spring" in Italian, suggesting that there are, or were at one time, springs near the lake. A spring inventory, including a map of locations and flow measurements, would also be valuable for future discussions of water resources near the lake.

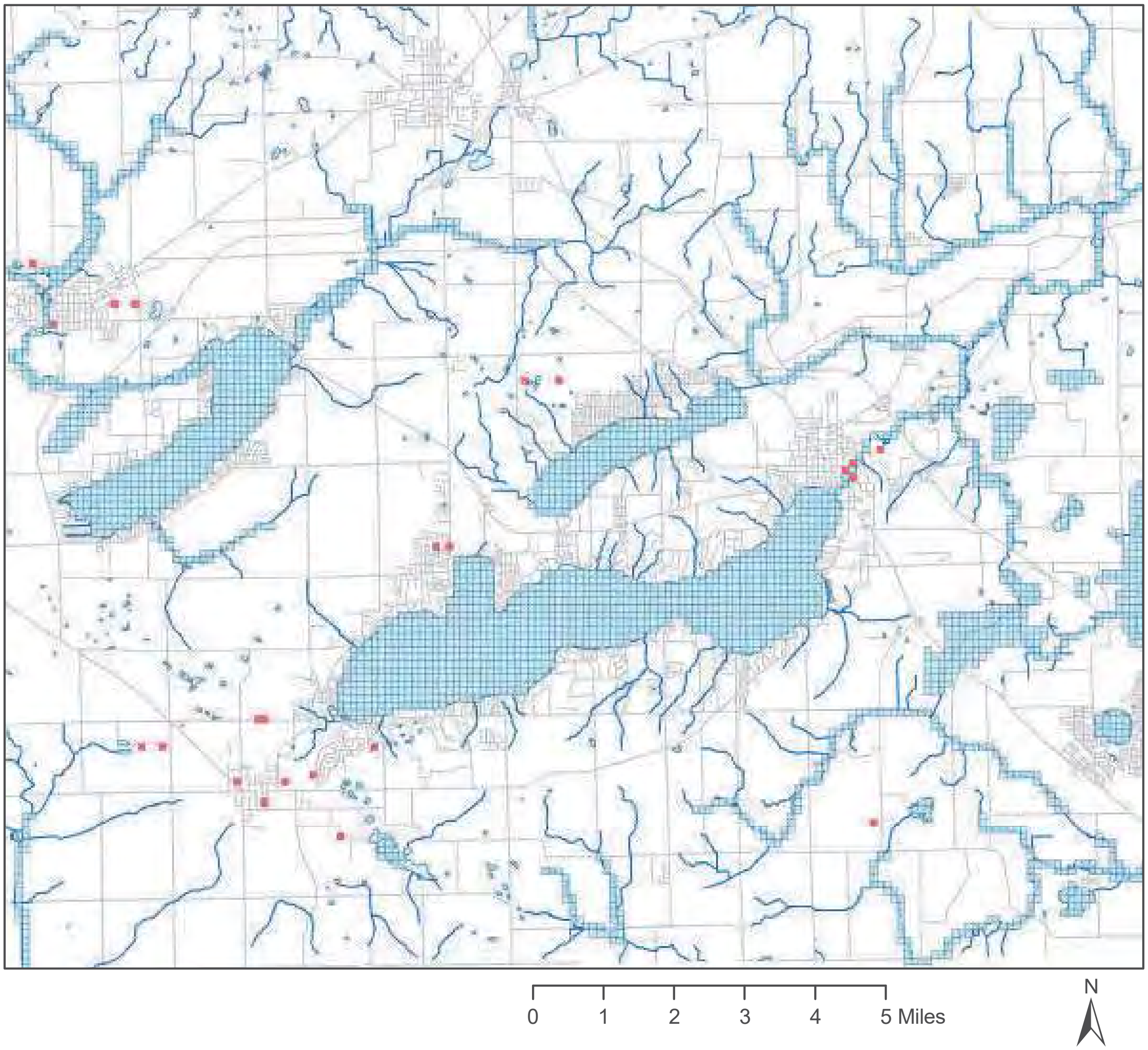


Figure 1. River and drain boundary conditions are shown in light blue. Red squares represent locations of pumping wells. The streams shown as dark blue lines are not represented in the model.

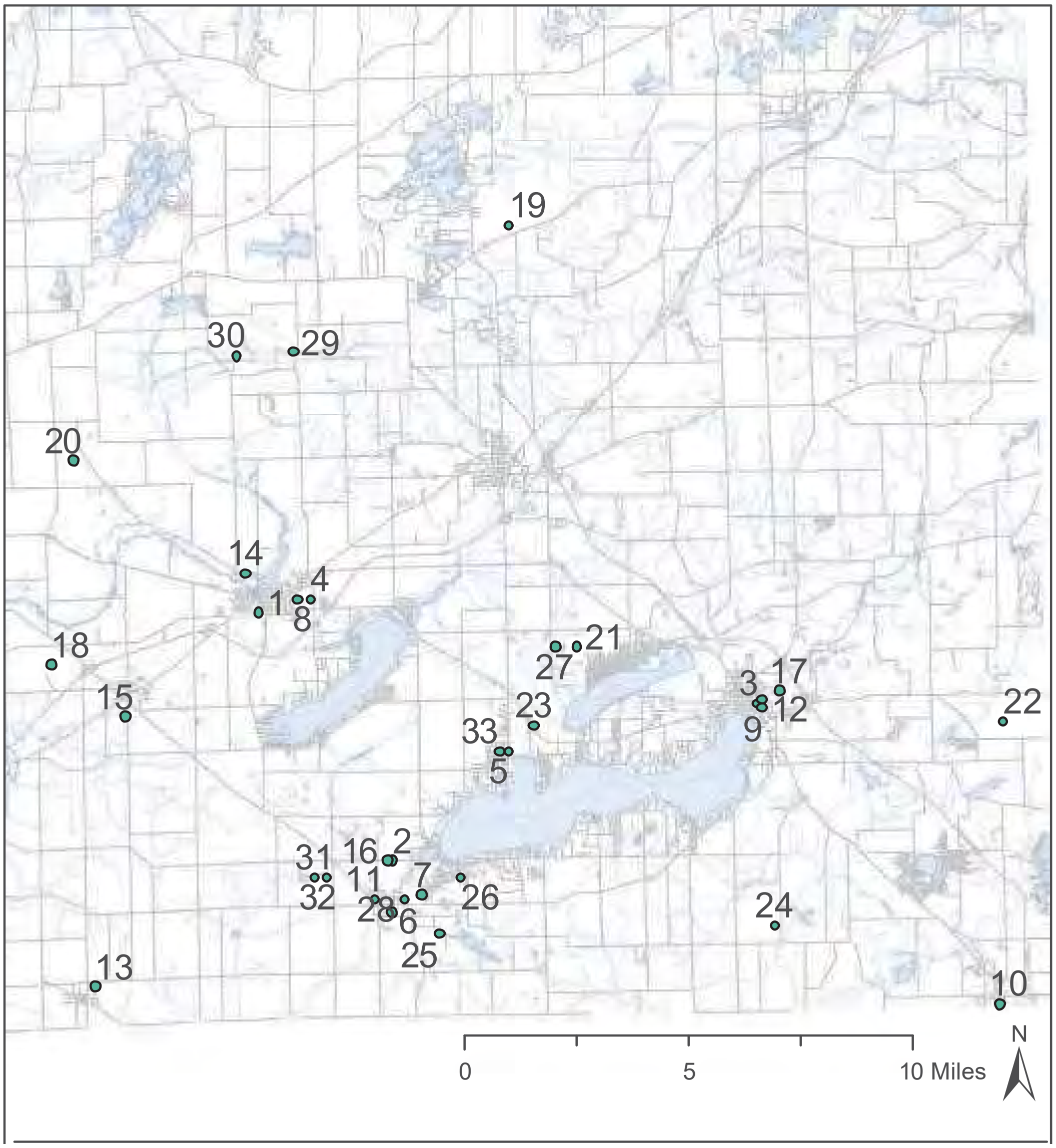


Figure 2. Locations of wells represented in the model. See Table 1 for well names.

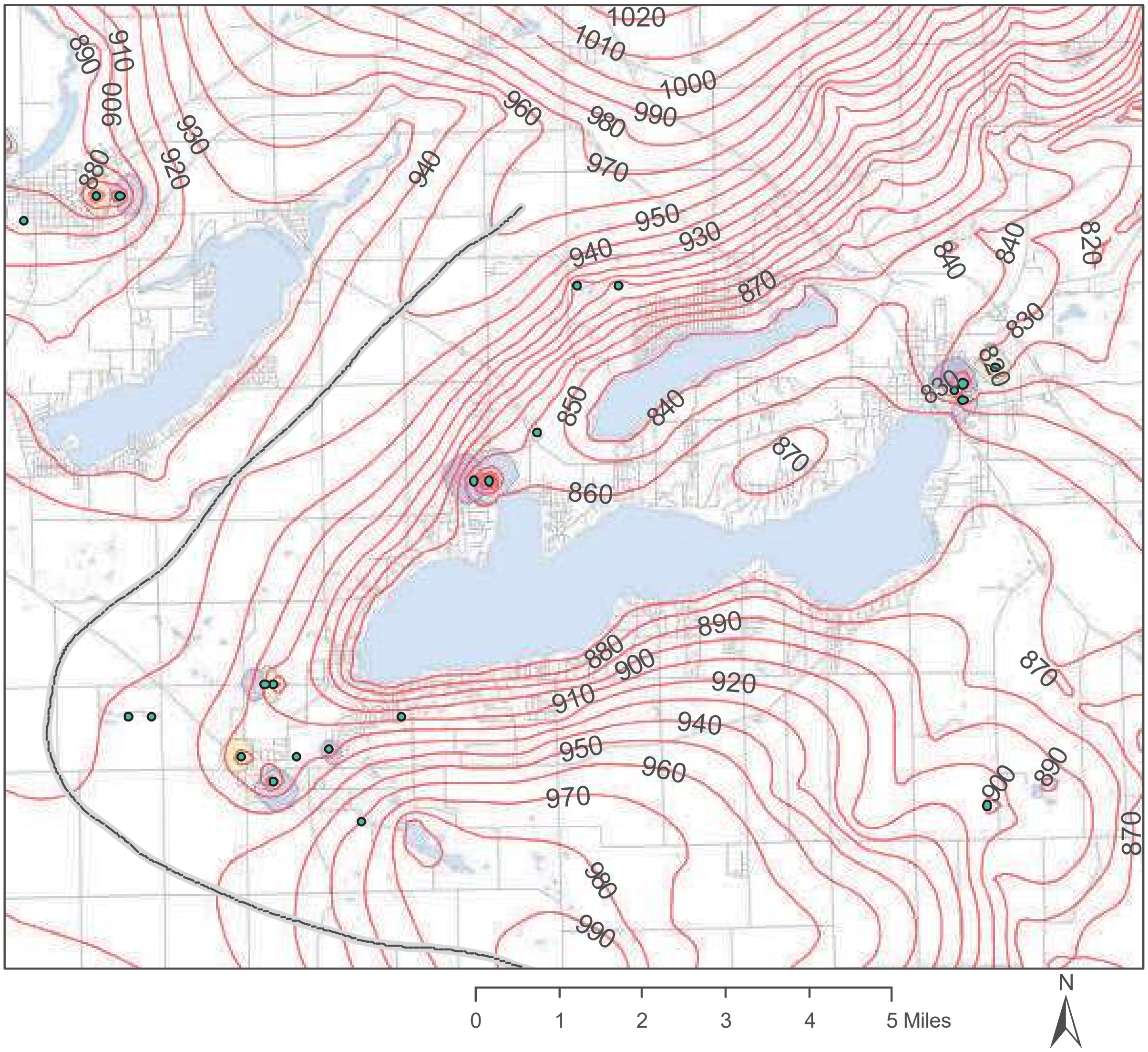


Figure 3. Water table elevation in feet, mean sea level, 10-foot contour interval. Municipal well capture zones are shown as colored areas around wells. Pumping rates at these wells (Table 1) were determined by the DNR and exceed actual pumping rates by about two times, resulting in simulated capture zones that are larger than actual, and water levels that are lower than actual. The gray line is the approximate location of the groundwater divide west of Geneva Lake.

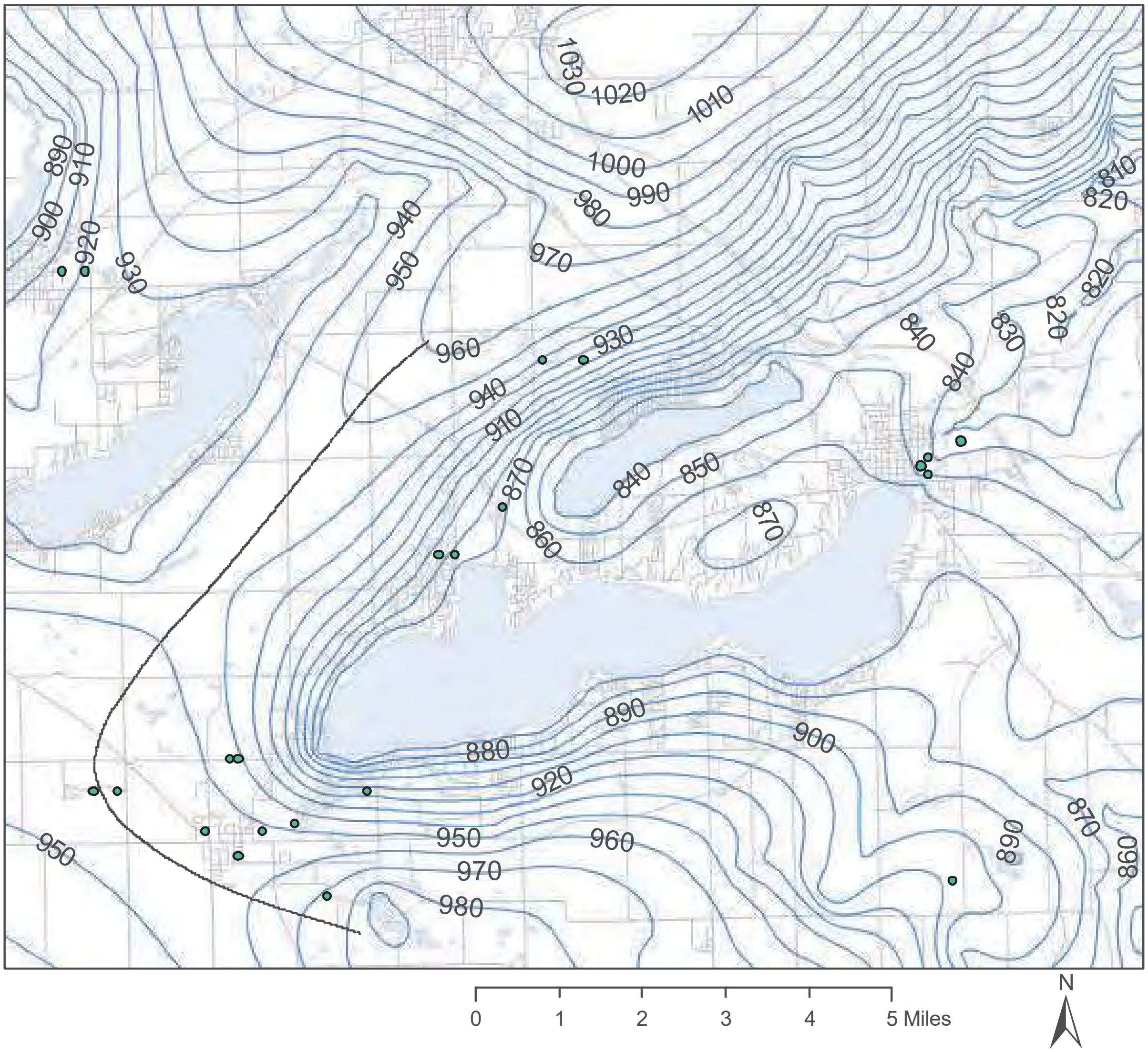


Figure 4. Simulated water table with no pumping. The water table elevation is in feet, mean sea level, 10-foot contour interval. The gray line is the approximate location of the groundwater divide west of Geneva Lake.

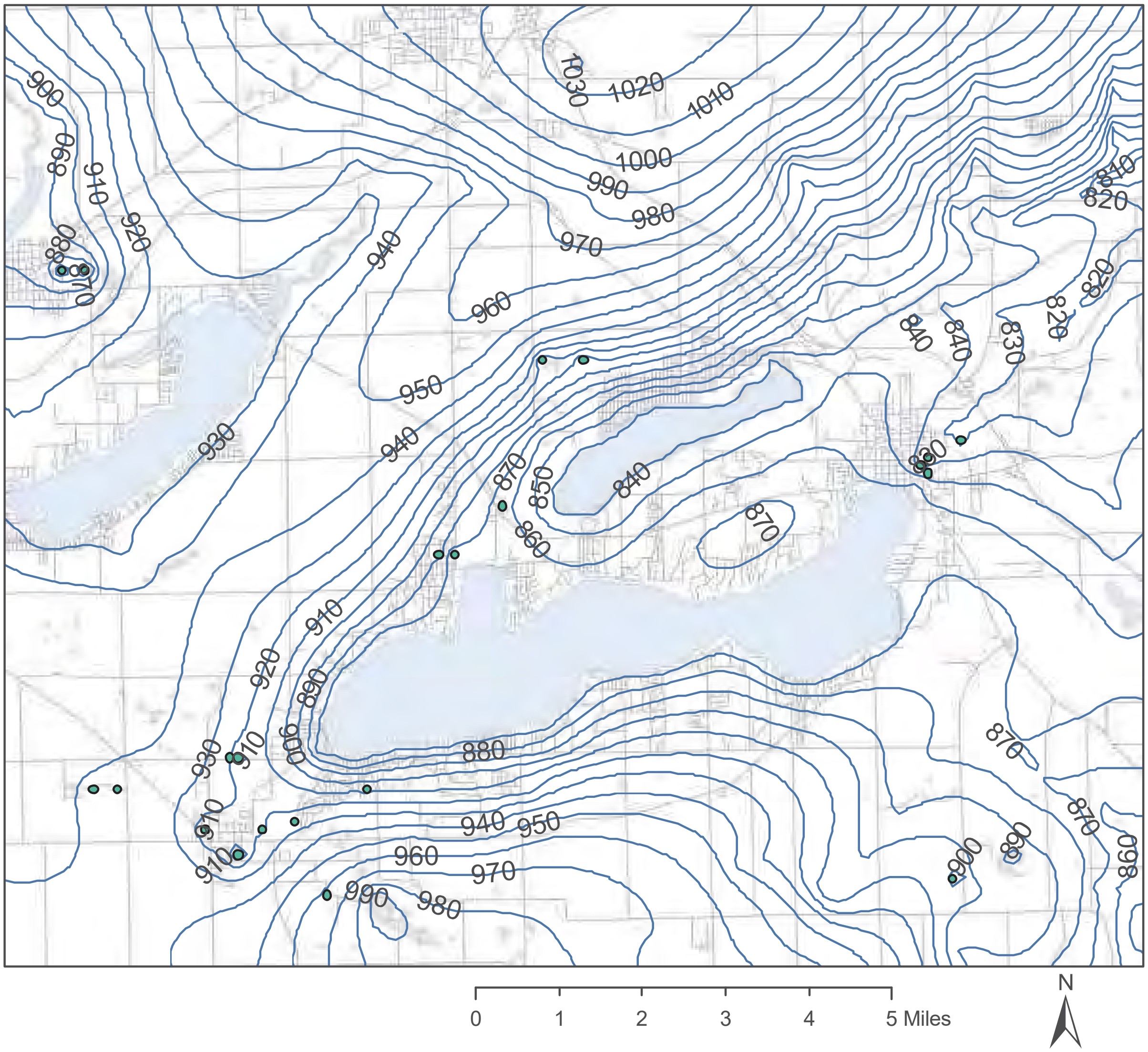


Figure 5. Simulated water table with Fontana, City of Lake Geneva and Williams Bay wells pumping at average rates reported for 2005. The water table elevation is in feet, mean sea level, 10-foot contour interval.

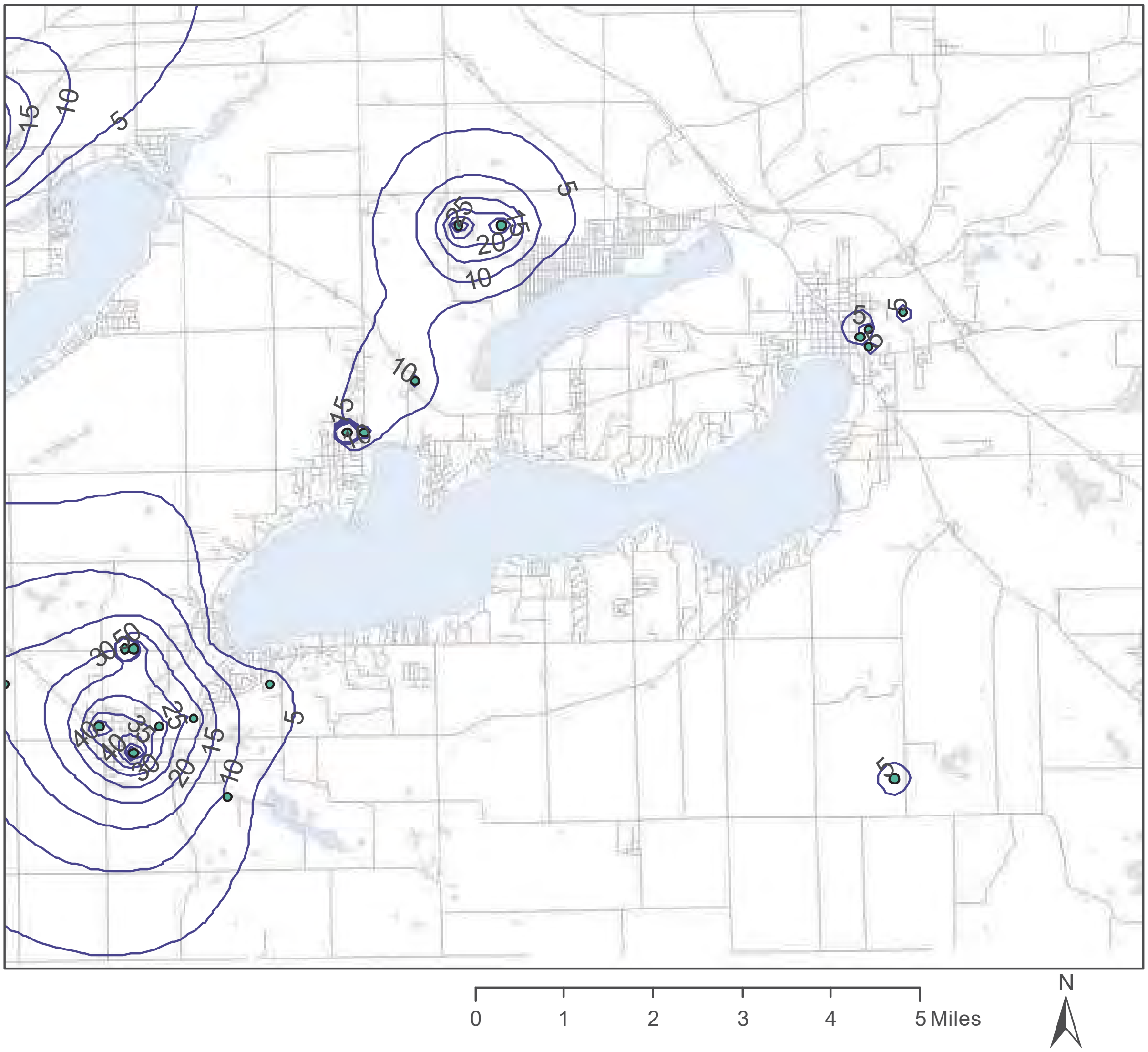


Figure 6. Simulated drawdown due to pumping at rates described in Figure 5. The contour interval is five feet.

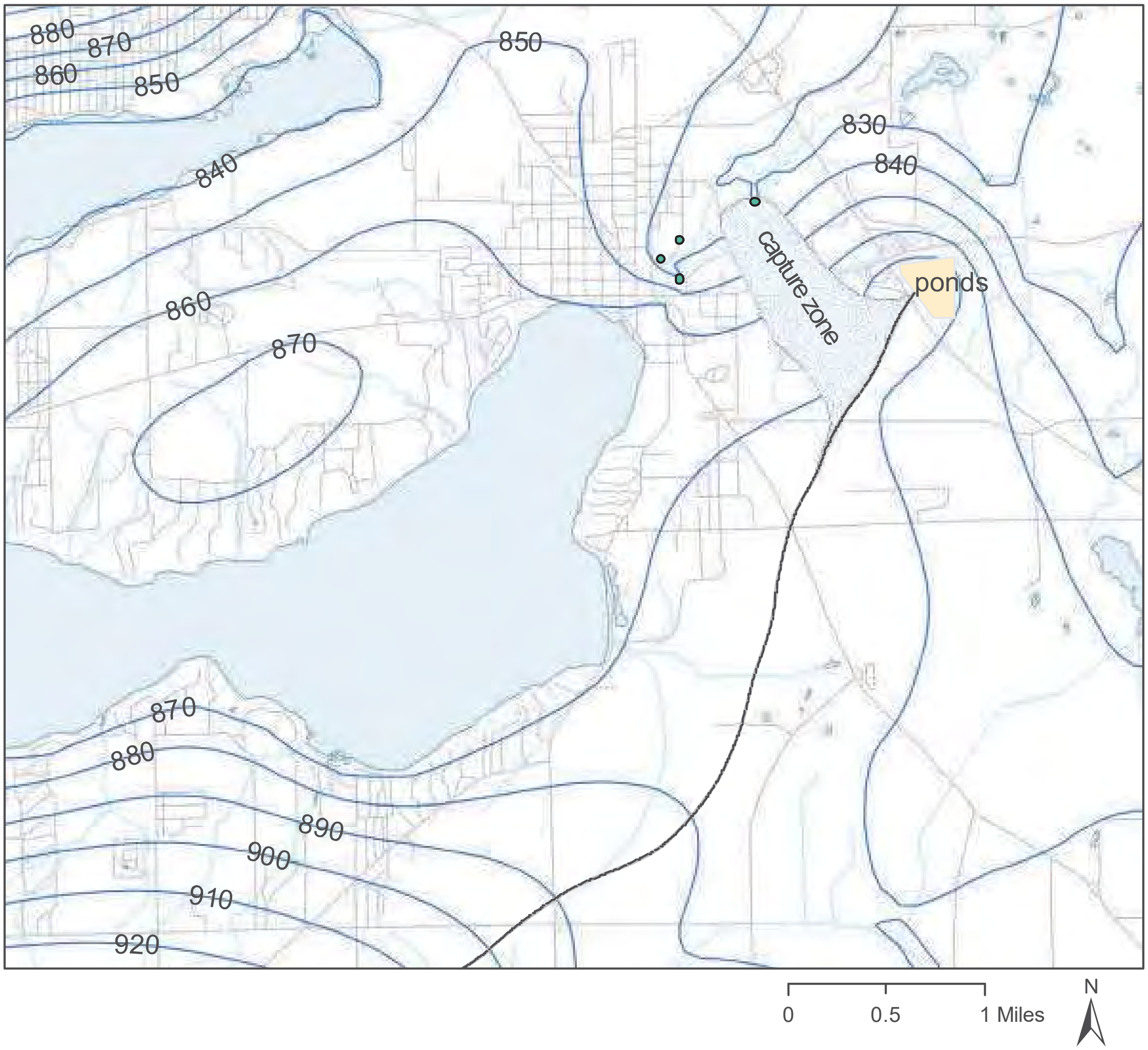


Figure 7. Simulated water table with Lake Geneva municipal wells pumping at average rates reported for 2005 and treated wastewater discharged to infiltration ponds. The water table elevation is in feet, mean sea level, 10-foot contour interval. Location of the ponds, the 40-year capture zone of Lake Geneva Well 5, and the groundwater divide southwest of the ponds are shown.

Table 1. Well name and identification number. See Figure 2 for well locations.

Identification number	Well Name, permit number, WUWN[1]	Q[2] (gallons / minute)	Q[2] (ft^3/day)
33	Williams Bay # 2	392	75416.26
1	Delavan # 2	90	17280.00
2	Fontana # 1	209	40141.00
3	Lake Geneva # 3	590	113575.00
4	Delavan # 4	340	65450.00
5	Williams Bay # 1	440	84680.45
6	Walworth # 3	270	51965.00
7	Fontana # 2	108	20767.00
8	Delavan # 3	300	57750.00
9	Lake Geneva # 2	500	96250.00
10	Genoa City # 2	150	28875.00
11	Walworth # 4	180	34650.00
12	Lake Geneva # 4	675	129938.00
13	Sharon # 3	300	57750.00
14	Delavan # 5	350	67375.00
15	Darien # 2	250	48125.00
16	Fontana # 3	243	46699.00
17	Lake Geneva # 5	260	50000.00
18	Kincaid Farm 701	92	17648.83
19	Lauderdale Farm; 389	30	5814.68
20	Boss, Daniel; 33004	68	13098.23
21	Poloma Development 379	96	18510.52
22	Schwind, Dennis; FN862; 85	100	19252.80
23[3]	Poloma Development 2752 & 3020	105	20215.44
24	Leedle, William; OT683	100	19252.80
25	Bog Foot Farm; 771	25	4813.10
26	Abbey Springs Condo. Assoc.; 938	33	6417.60
27[3]	Geneva National 883 & Poloma Development 377	109	20976.70
28	Big Foot Corp; 33017	45	8690.50
29	Vanderveen, Curt; 33008	85	16364.88
30	Vanderveen, Curt; BD658; 33001	200	38505.60
31[3]	Kikkoman 631 & 47212	98	18878.44
32	Kikkoman, 47217	50	9626.40

Notes:

[1] WUWN = Wisconsin unique well number assigned by WDNR consists of two letters followed by three numbers. High capacity permit application numbers are also provided for some wells.

[2] Q = pumping rates assigned in the regional model for delineating well capture zones

[3] In the model, wells 23, 27 and 31 represent two real wells that are located within one model cell.

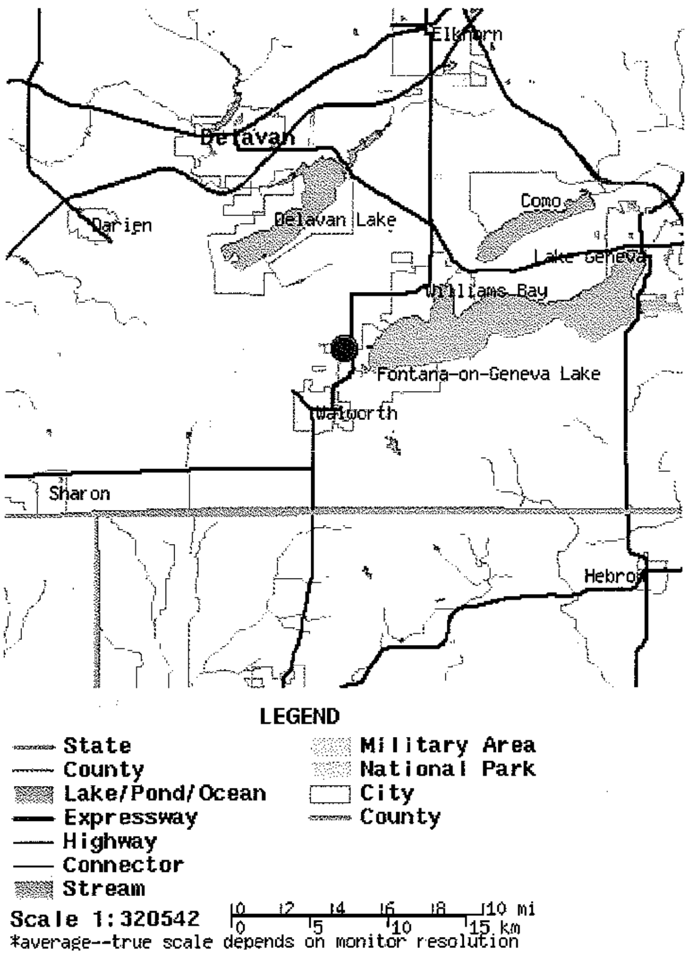
Appendix

Information from the Wisconsin ground-water observation network
Downloaded on April 19, 2006 from the U.S. Geological Survey internet site:
http://wi.water.usgs.gov/public/gw/

USGS

WELL WW-0083

Map of Area Surrounding WW-0083



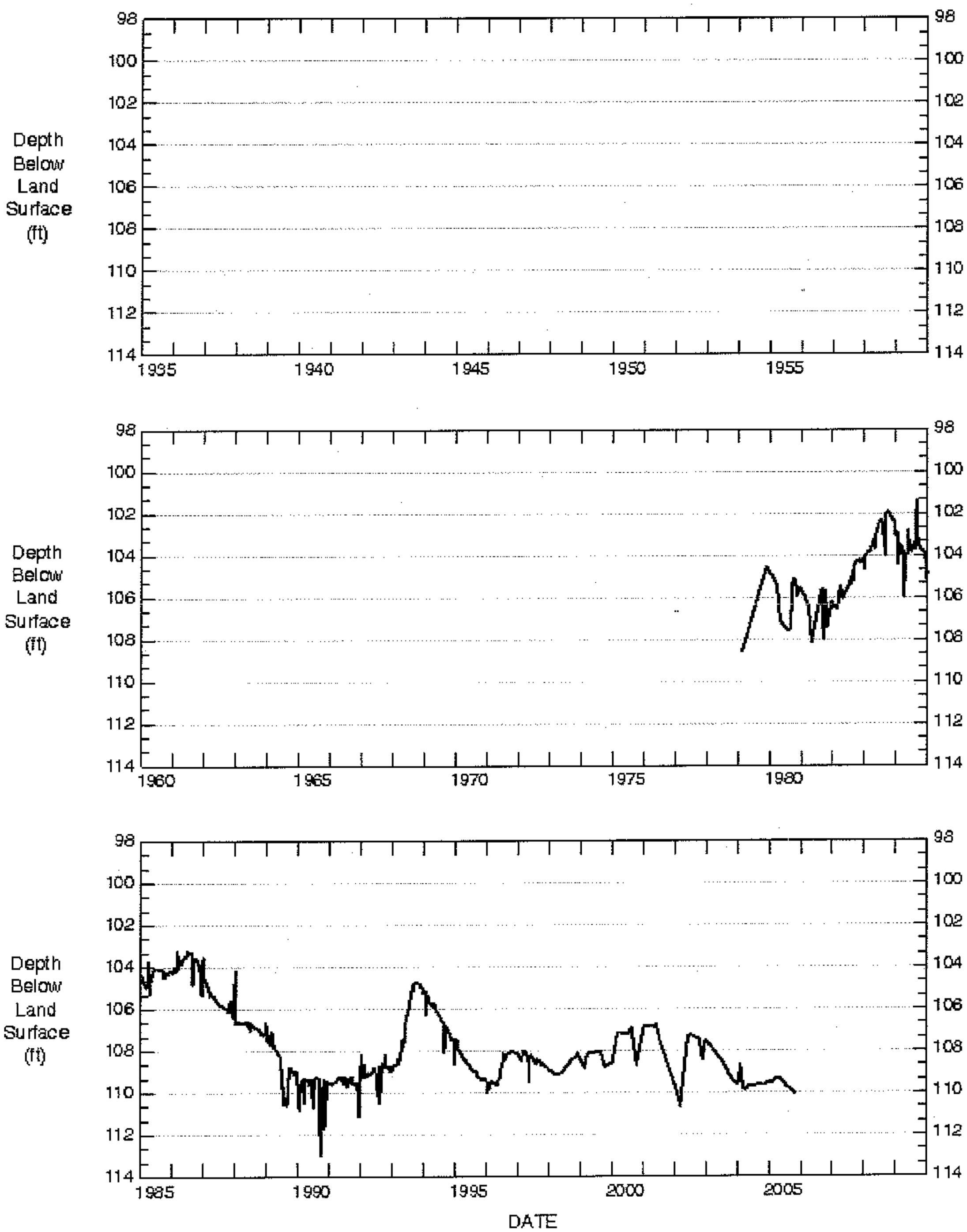
[Zoom In On Well Site]

Hydrograph of Well WW-0083

Sand & gravel aquifer

WW-01/16E/10-0083

Revised:
Nov 17, 2005



Latitude: 42°33'15"N   Longitude: 088°35'03"W

Click here for more information on WW-0083

USGS Water Resources of Wisconsin Homepage
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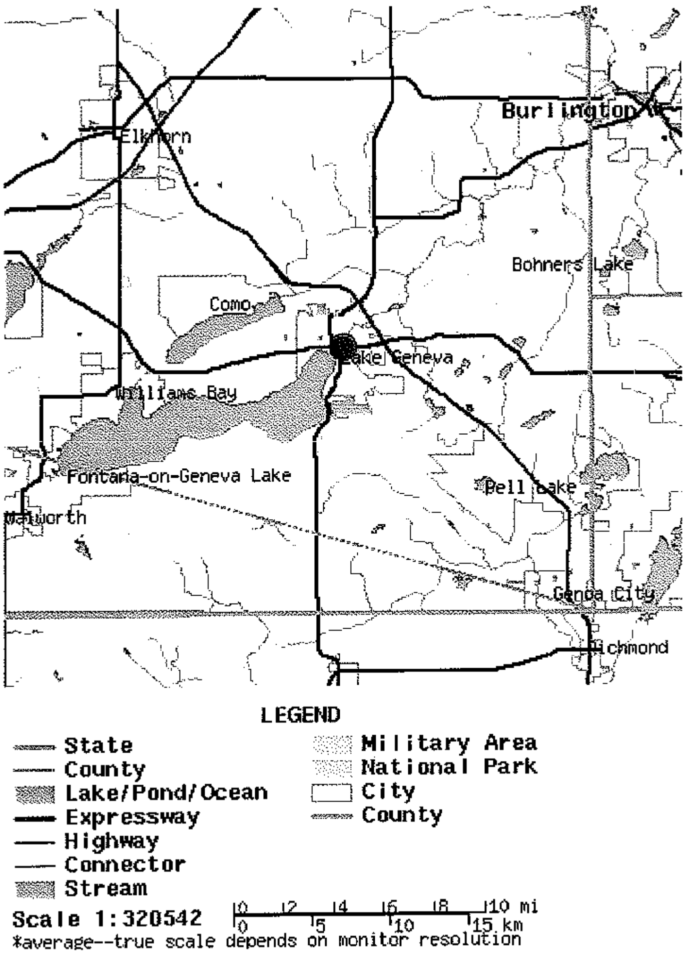
USGS

WELL WW-0037

Map of Area Surrounding WW-0037

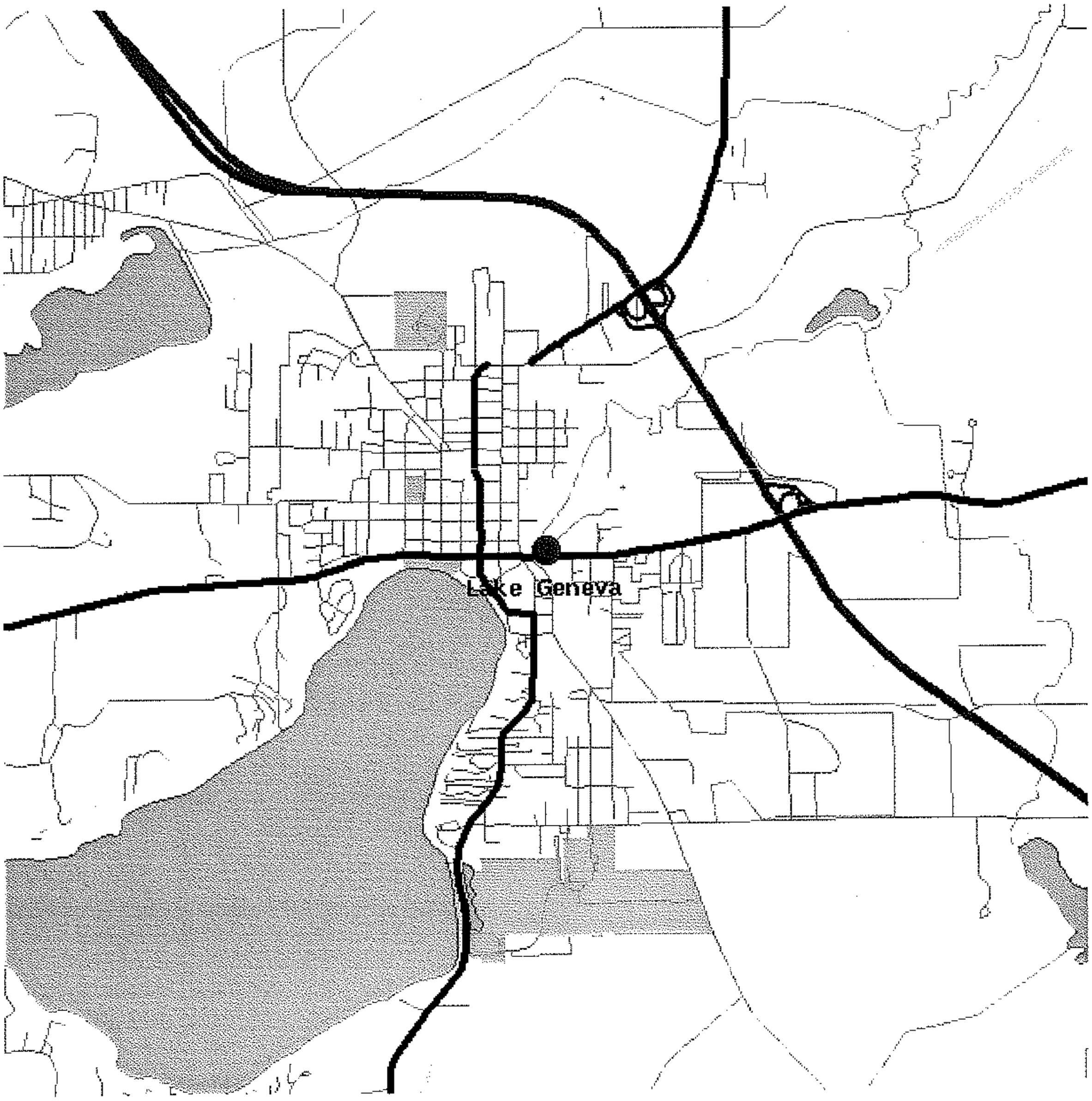


Zoom In On Well Site

Hydrograph of Well WW-0037

USGS

WELL WW-0037



[USGS Water Resources of Wisconsin Homepage]
[U.S. Department of the Interior], [U.S. Geological Survey]
URL: http //wi.water usgs.gov/public/gw/HISTORICAL/WW-0037zm html

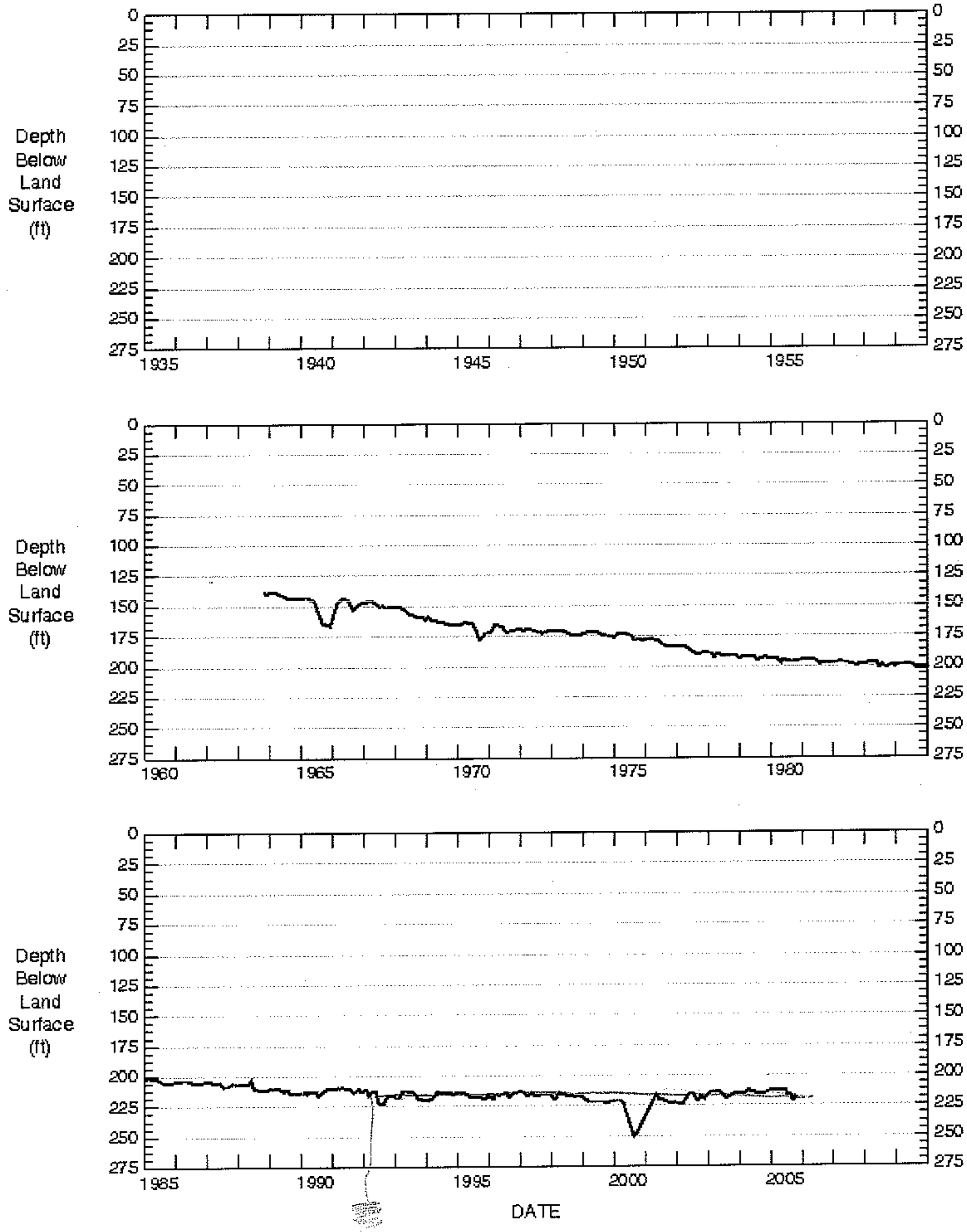
Maintainer: gmueller@usgs.gov
Email [The GW Observation Network] with comments and questions about the Ground-Water Network
[Privacy Statement] | [Disclaimer]
Last update April 15, 2005

A-4

SANDSTONE aquifer

WW-02/17E/36-0037

Revised: Nov 17, 2005



Latitude: 42°35'32"N Longitude: 088°25'46"W

Click here for more information on WW-0037

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