a tremendous volume of recharge. In contrast, the high pumping rates and relatively thin sandstone in the Cherokee and Storm Lake zones limit the sustainable pumping rates.

In rural areas outside the major pumping centers the concept of potential safe yields can be a useful planning tool. The potential safe yield distribution is shown on Figure 4, and ranges from greater than 2 mgd in much of Dickinson, O'Brien, Osceola, Plymouth, and Sioux counties, to less than 1 mgd across the southern and eastern regions of the Lower Dakota aquifer. In general, the higher safe yields are found in areas with thicker sandstone.

Local Scale Modeling

The use of the additional groundwater availability map and the potential safe yield map are qualitative tools to evaluate groundwater resources. The regional groundwater flow model can also be used to provide a more quantitative and detailed approach to proposed water use at the local level. Local scale modeling has been used to evaluate a 1.6 mgd water use permit for a new ethanol plant near Hartley, Iowa, and a well interference complaint near LeMars, Iowa, that involved a private well owner and the City of LeMars.

Predictive Modeling

An important use of a calibrated regional groundwater flow model is using it to predict future impacts to an aquifer based on various pumping scenarios. Water usage or pumping rates often double or triple during droughts, which can have a major impact on groundwater head values. Even more important than actual pumping rates is predicting the approximate locations of future wells and permits. Locations for future wells are more likely within the current major producing zones, since industry and population growth generally occur in these areas.

One possible scenario is assuming a 50% increase in pumping rates from the 2006 water usage. Additional ethanol plants are predicted in Ida, Cherokee, Sioux, Plymouth, Clay, and Osceola counties, with an average daily usage at each facility of 1.6 mgd. Irrigation permits are assumed to remain unchanged, and the simulated pumping period is 2008 to 2028.

Figure 5 shows the additional drawdown from current water levels for a 50% increase in pumping rates, six additional ethanol plants, and using a 20-year simulation period. The Hartley, Storm Lake, and Cherokee areas show significant additional drawdown that ranges from 15 to 21 feet. Drawdowns in the LeMars, Sioux Center, and South Sioux Rural Water District zones range from 6 to 15 feet. Additional drawdowns appear to stabilize after 18 years of pumping except in the Cherokee and Storm Lake zones. LeMars and South Sioux Rural Water District appear to be approaching their sustainable pumping rates with the high future use simulation.

Summary

Groundwater availability in the Lower Dakota aquifer was evaluated using the groundwater flow model Visual MODFLOW 4.3. Based on current water use, the Lower Dakota has substantial additional pumping capacity. Additional groundwater availability ranges from greater than 5 mgd in the Sioux City area to less than 1 mgd in the Cherokee and Storm Lake areas. Local scale modeling can also be conducted using the regional groundwater model to evaluate individual permits and potential well interference complaints.

Reference

Rowden, Robert, in Press, *Groundwater Resource Evaluation of the Lower Dakota Aquifer in Northwest Iowa: The Beginning of a New State Water Plan*, Iowa Department of Natural Resources.

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Iowa Department of Natural Resources

Groundwater Modeling as a Predictive Tool to Manage Water Resources in Iowa

Unlike many western states, Iowa has not experienced significant depletion of its groundwater resources from excessive pumping. This does not mean that Iowa has an unlimited supply of groundwater, or that Iowa should not manage this resource in a sustainable manner for future use. Potential well interference issues and complaints have increased in recent years as new water-use permits place stress on local and regional aquifers. The increased use of groundwater for biofuels, power generation, irrigation, food processing, and municipal supplies is essential for economic development. This growth, however, needs to be balanced by the long term availability of our water resources for future generations.

In 2007, the Iowa Legislature began funding a comprehensive Water Resources Management program. A key aspect of the program is to evaluate and quantify the groundwater resources across the state using three-dimensional groundwater flow models. A properly calibrated groundwater model can be used as a predictive tool to estimate the future impact on an aquifer caused by increases in water demand.

The first regional aquifer evaluated under the program was the Lower Dakota aquifer. This aquifer is found primarily in a fifteen-county area in northwest Iowa as shown in Figures 1 through 5. The Lower Dakota aquifer is a confined (buried) sandstone aquifer that varies in thickness and lateral extent. Wells in this aquifer have been in use since the early 1900s.

Using historic (pre-1900) water levels as a baseline, the drop in groundwater levels over time (drawdown in the

Table 1. *Water balance during the summer of 2006.*

Zone	Pumping (mgd)	Recharge (mgd)	Inflow-Outflow (mgd)	From Storage (mgd)
LeMars	4.15	0.21	3.2	0.73
Emmetsburg	0.81	0.22	0.521	0.07
Cherokee	1.32	0.24	0.89	0.2
Hartley	1.9	0.69	1.14	0.08
Estherville	1.2	0.46	0.69	0.05
Sioux City	9.1	14.5		
Sioux Center	0.58	0.27	0.21	0.1
Storm Lake	3.3	0.29	2.1	0.9
S. Sioux RW	1.66	0.26	1	0.4
Sutherland	0.13	0.26	-0.19	0.06
Clasing, Inc.	3	0.4	0.45	2.3
Rural Areas	4.4	20.6		
Total	31.55	38.4		mgd = million gallons per day

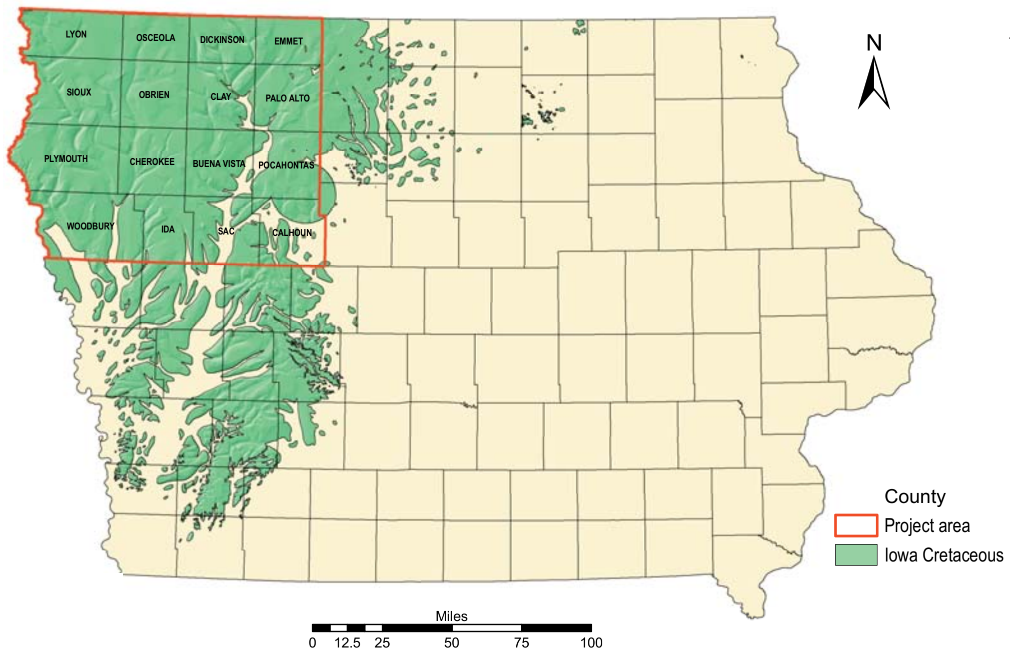

Figure 1. *Occurrence of the Cretaceous in western Iowa (16 county study area of the Lower Dakota aquifer).*

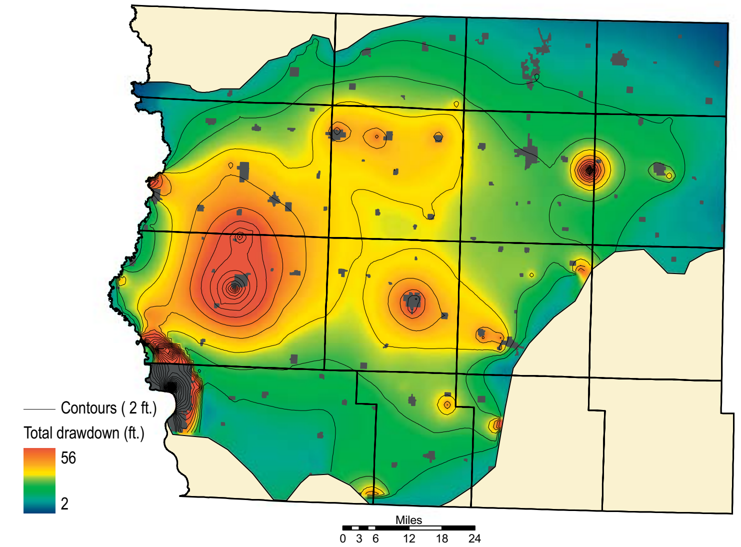

Figure 2. *Drawdown from pre-development historic water levels to present showing major pumping centers.*

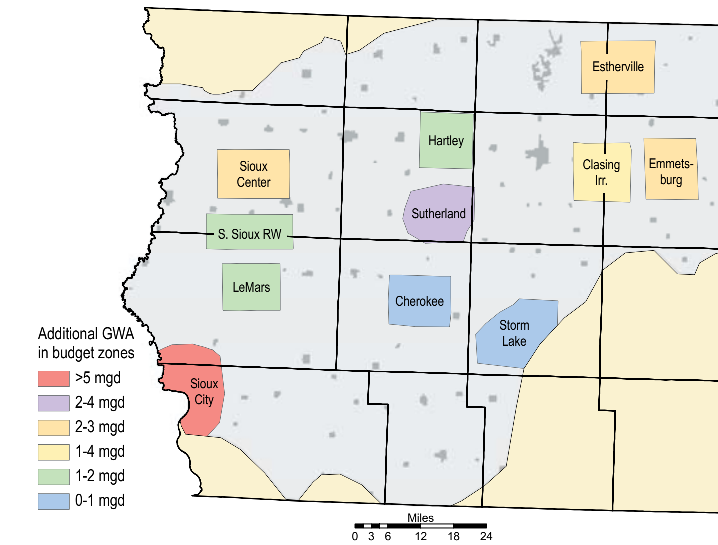

Figure 3. *Zone budget locations and additional groundwater availability*

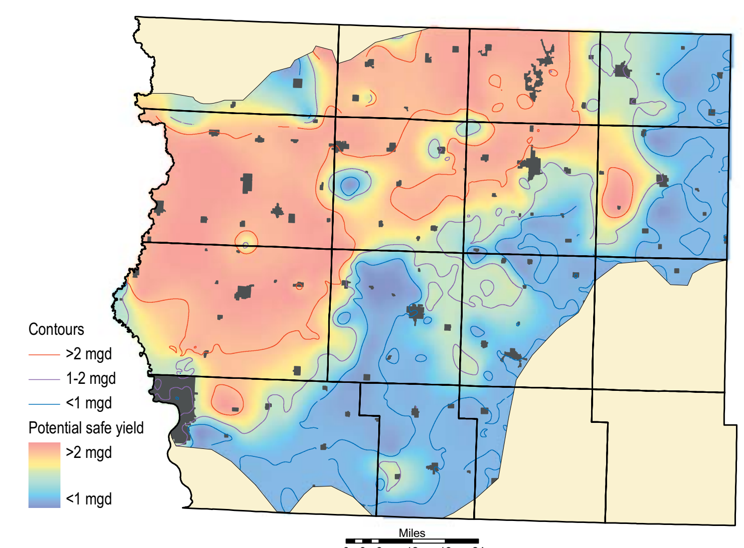

Figure 4. *Potential safe yield map (Rowden, in preparation).*

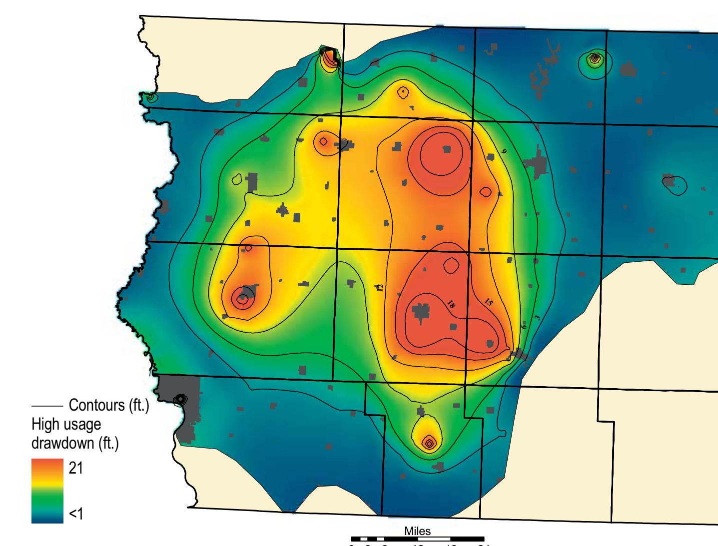

Figure 5. *Additional drawdown in 2028 assuming a 50% increase in water use – (Initial Head Values December 2006).*

aquifer) was evaluated. Figure 2 shows the drawdown from historical pre-development water levels to the present. The largest decreases in water levels are in Plymouth, Sioux, and O'Brien counties with a maximum drawdown of 56 feet. Large drawdowns are attributed to major pumping centers and include: Sioux City, LeMars, Southern Sioux Rural Water District, Sioux Center, Hartley, Sutherland, Cherokee, Storm Lake, Emmetsburg, Estherville, and Clasing (irrigation permit).

Water Balance

The volume of groundwater in an aquifer can also be evaluated using a water balance approach. A water balance looks at pumping rates, inflow of groundwater, outflow of groundwater, and changes in storage. The water balance in the Lower Dakota aquifer was evaluated regionally using a groundwater flow model. Based on the calibrated flow model, the volume of recharge into the Lower Dakota aquifer is approximately 38.4 million gallons per day (mgd). Daily pumping rates in the region range from 20.3 mgd in the winter to 31.6 mgd in the summer. Based on this regional water balance, the Lower Dakota aquifer has substantial additional pumping capacity.

The regional water balance evaluation is useful, but does not indicate changes that may be happening at a local level. Based on the drawdown map shown in Figure 2, zones were established around each of the major groundwater pumping centers (Figure 3). The water balance in each of these zones was calculated to evaluate whether pumping rates were depleting the aquifer, thus causing groundwater mining. Table 1 presents the water balance results for the major pumping centers during the summer of 2006. LeMars, Storm Lake, and Clasing zones all had significant reductions in storage. The reduction in storage in Storm Lake occurred throughout most of the year which suggests that the pumping rates may be near the sustainable rate. The reduction in storage in the Clasing zone only occurred during the 90-day irrigation season, and most of this storage recovered during the non-growing season. The change in storage in the LeMars zone only occurred during the peak summer usage period, and partially recovered during the fall, winter, and spring. The Sioux City zone has the highest pumping rate, but the recharge far exceeds the pumping rate because of the hydraulic connection with the Missouri River alluvium.

Groundwater Availability

The probability of additional water use permits is much higher near cities and current major pumping centers. Using the water balance information, and running the groundwater model using various future water-usage scenarios, an estimate for the additional groundwater availability was generated in the eleven major pumping centers. Additional groundwater availability ranges from greater than 5 mgd in the Sioux City area to less than 1 mgd in the Cherokee and Storm Lake zones (Figure 3). The remaining zones have between 1 and 4 mgd of additional availability. The hydraulic connection between the Lower Dakota aquifer and the Missouri River in the Sioux City area provides