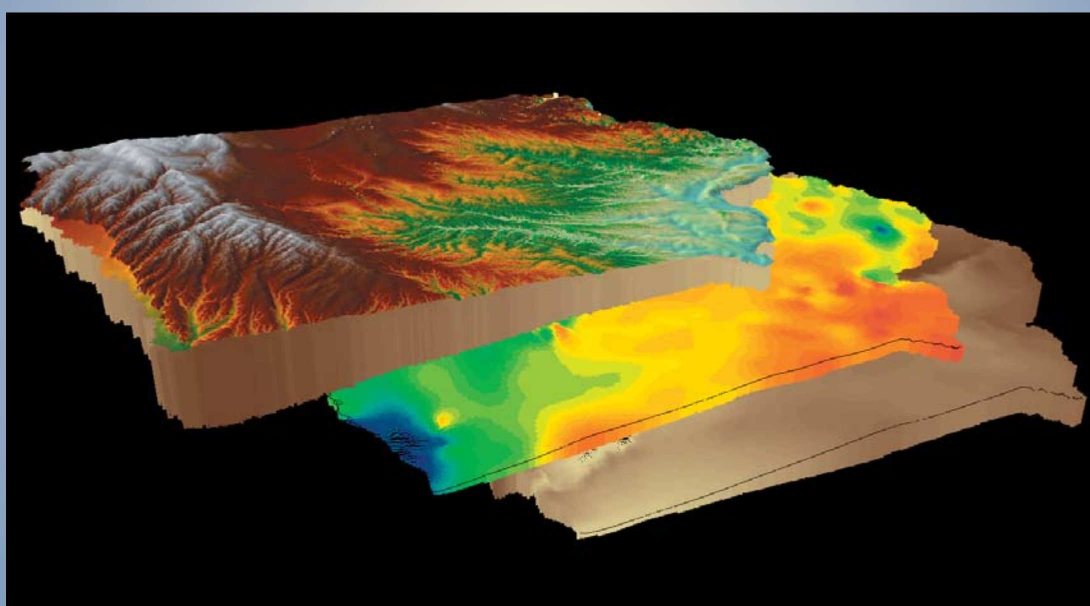
Groundwater Availability Modeling of the Cambrian-Ordovician Aquifer in Iowa

Iowa Geological and Water Survey
Water Resources Investigation Report No. 2A



Iowa Department of Natural Resources
Richard Leopold, Director
July 2009

COVER

Hydrogeologic conceptual model of the
Cambrian-Ordovician aquifer in Iowa.

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Groundwater Availability Modeling of the Cambrian-Ordovician Aquifer in Iowa

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Water Resources Investigation Report No. 2A

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EXECUTIVE SUMMARY

Increased demand for groundwater by agriculture, industries, and municipalities has raised concerns for the long-term sustainability of the resource. However, the information necessary for decision makers to answer basic questions regarding how much water can be withdrawn from Iowa's aquifers on a sustainable basis was not available. The 2007 Iowa General Assembly, recognizing this lack of information, began funding a multi-year evaluation and modeling of Iowa's major bedrock aquifers by the Iowa Geological and Water Survey (IGWS).

This report documents an intensive one-year investigation of the hydrogeology of the Cambrian-Ordovician aquifer and construction of a groundwater flow model that can be used as a planning tool for future water resource development. Iowa Administrative Code Chapter 52.4(3) states that water levels are not to decline more than 200 feet from the 1975 baseline in any high-use area (State Of Iowa, 1998). The potentiometric surface map of the Cambrian-Ordovician aquifer prepared by Horick and Steinhilber (1978) is currently used as the baseline.

The hydrologic characteristics of the geologic layers included in the modeling of the Cambrian-Ordovician aquifer were investigated. An important component of this study was a network of approximately 51 wells, which were used to evaluate water levels. Key to the investigation were 11 observation wells which had time series data. These data were used for the transient model development.

A total of 49 aquifer pump tests and recovery tests and 38 specific capacity tests were used to calculated the aquifer parameters. The majority of the recovery tests were evaluated for the first time. The hydraulic properties of the Cambrian-Ordovician aquifer were shown to vary considerably in both the lateral and vertical direction. The hydraulic conductivity of the aquifer ranges from 0.3 to 20.9 feet per day, with an arithmetic mean of 4.6 feet per day. Transmissivity values range from 150 to 8,500 feet squared per day. The storage coefficient of the Cambrian-Ordovician aquifer ranges from 10^{-6} to 10^{-3}. The arithmetic mean storage coefficient is 3.3×10^{-4}.

Recharge to most of the Cambrian-Ordovician aquifer is through relatively thick confining beds that include glacial till and various shale units. Due to the relatively thick confining units, the rate of recharge to the Cambrian-Ordovician aquifer is very small. Calibrated recharge rates range from 10^{-5} inches per year to 0.02 inches per year over the study area. With this information a numerical groundwater flow model of the Cambrian-Ordovician aquifer was developed using three hydrogeologic layers. The model was created using Visual MODFLOW version 4.3. Hydrologic processes examined in the model include net recharge, hydraulic conductivity, specific storage, flow through boundaries, no flow boundaries, well discharge, and groundwater upwelling.

The modeling approach involved the following components:

1. Calibrating a pre-development steady-state model using water level data from historic records.
2. Calibrating a transient model using water-use data from 1901 through 2007. Simulated water levels were compared to observed time-series water level measurements.
3. The calibrated model was used to predict additional drawdowns through 2029 for future water usage simulations.

The calibrated model provided good correlation for both steady-state and transient conditions. Root mean square errors of 18.3 and 34.8 feet were relatively small errors for an aquifer that covers most of the state of Iowa. Simulated water level changes are most sensitive to recharge in the steady-state model, and hydraulic conductivity in the transient model.

Based on this model, and maintaining current withdrawal rates, the Cambrian-Ordovician aquifer will likely exceed the 200-foot regulatory limit in the Fort Dodge-Webster City area by 2029. If pumping rates increase by 25% above 2007 rates, the 200-foot regulatory limit will likely be exceeded in the Marion-Cedar Rapids and Des Moines areas in 20 years.

INTRODUCTION

The Cambrian-Ordovician aquifer is one of the most dependable sources of groundwater in Iowa. Wells drilled into the Cambrian-Ordovician aquifer supply large volumes of water to both industry and municipalities across the state. It is the most widespread regional aquifer in the state and is only absent in extreme northeast and northwest Iowa. As a major regional aquifer, concerns have been raised related to its long-term sustainability. Groundwater level declines, or drawdown, of 50 to 150 feet have been recorded in major pumping centers throughout Iowa (Horick and Steinhilber, 1978, and Steinhilber and Young, 1979). Futhermore, major pumping centers may alter the natural groundwater flow direction and cause poorer quality water to move into the pumped area (Burkart and Buchmiller, 1990).

Efforts have been made to quantify the water balance of the Cambrian-Ordovician aquifer. A two-layered groundwater flow model was developed and calibrated by the United States Geological Survey (USGS) (Burkart and Buchmiller, 1990). This model was further evaluated in 1997 using observed groundwater elevations measured in wells open in the Cambrian-Ordovician aquifer (Turco, 1999). Maximum regional water level declines of between 60 and 120 feet were observed between 1975 and 1997.

The purpose of this study was to provide an updated, comprehensive, and quantitative assessment of groundwater resources in the Cambrian-Ordovician aquifer in Iowa. The assessment included the development of a three-dimensional groundwater flow model to guide future development and utilization of the aquifer. The study included the following tasks:

- Collecting, compiling, and analyzing available hydrogeologic and hydrologic data;

- Collecting, compiling, and estimating the location and amounts of groundwater withdrawals within the study area;

- Constructing and calibrating a groundwater flow model for the Cambrian-Ordovician aquifer;

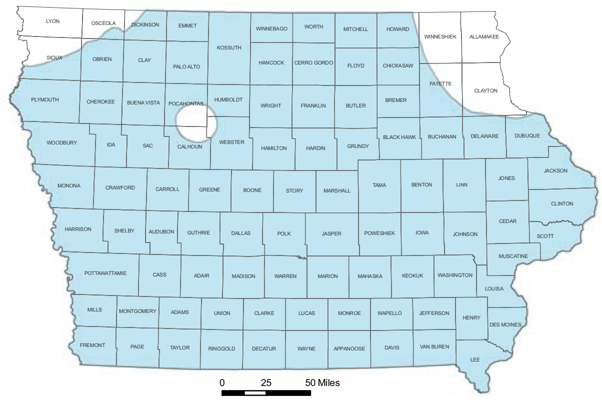

Figure 1. Project study area for the Cambrian-Ordovician aquifer in Iowa.

- Simulating future water-use scenarios and the overall groundwater availability within the aquifer;

- Documenting the data used and the model simulations.

GEOLOGY

The study area for the Cambrian-Ordovician aquifer includes most of the state of Iowa as shown in Figure 1. The stratigraphic and hydrogeologic units for the study area are shown in figures 2 and 3. Unconsolidated materials overlie most of Iowa and are grouped together as Quaternary materials. This grouping includes youngest to oldest: Holocene (modern) river deposits, Pleistocene loess (wind-blown silt), Pleistocene glacial materials (including glacial till and related deposits), buried bedrock valley fill materials, and Tertiary "Salt and Pepper" sands.

Beneath the Quaternary units are various consolidated units that include both regional aquifers and confining beds. These aquifers and confining units can be grouped by system, and include: Cretaceous, Pennsylvanian, Mississippian, Devonian-Silurian, Ordovician, Cambrian,

System	Rock-Stratigraphic Unit		Maximum Thickness	Physical Characteristics	Hydrologic Units	Model Layer
ORDOVICIAN	Maquoketa Formation		300’	Mostly shale, grayish green, with dolomite beds in upper and lower part in east-central Iowa; mostly dolomite, brown, with chert in north-central and western Iowa; thin red shale with limonite or hematite pellets (Neda) at top.	Confining bed (locally water bearing in north-central Iowa)	Layer 1
	Galena Group		230’	Dolomite, minor limestone, minor chert in lower half.	Water Bearing	
	Decorah Formation		170’	Limestone and dolomite, tan to brown; grayish green and brown shales at top and base.	Confining Bed	
	Platteville Formation			Limestone, gray, and dolomite, brown, fossiliferous; shale, grayish-green at base (Glenwood). Sandstone, fine-to-medium grained above the shale in southeast Iowa only.		
	St. Peter Formation		110’	Sandstone, coarse to fine, rounded and frosted grains, loosely cemented, minor green shale stringers.	Cambrian-Ordovician Aquifer	Layer 2
	Prairie du Chien Group	Shakopee Formation	650’	Dolomite, sandstone.		
		Oneota Dolomite Formation		Dolomite, crystalline, contains chert.		
CAMBRIAN	Trempealeau Group	Jordan Sandstone	145’	Sandstone, fine-to medium-grained, well-sorted and frosted grains; contains sandy dolomite beds in upper (Madison) and basal (Lodi) units.		
		St. Lawrence Dolomite	260’	Dolomite, coarsely crystalline, gray, silty, commonly containing glauconite.	Confining Bed	Layer 3
	Lone Rock Formation		280’	Dolomitic siltstone, glauconitic shale, and glauconitic sandstone.		
	Dresbach Group	Wonewoc Formation	200’	Sandstone, medium- to coarse-grained, white to gray.	Dresbach Aquifer	
		Eau Claire Formation	260’	Shale, silty, gray, fissile; siltstone; dolomitic; sandstone, fine-grained; some dolomite.		
		Mt. Simon Sandstone	825’	Sandstone, medium-to coarse-grained with minor shale stringers.		

Figure 2. Stratigraphic and hydrogeologic units of the Cambrian-Ordovician aquifer system in Iowa (modified from Olcott, 1992, and Burkart and Buchmiller, 1990).

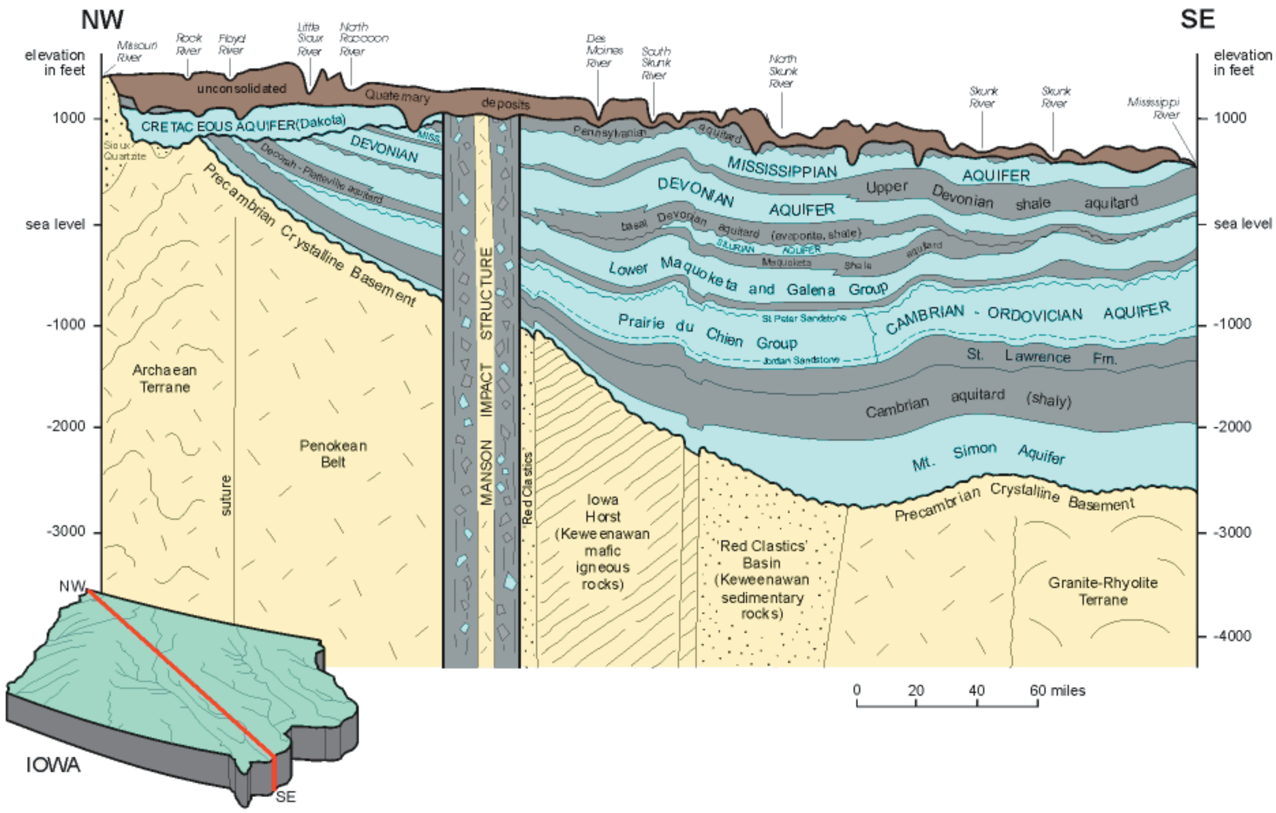

Figure 3. Generalized hydrogeologic cross-section from northwestern to southeastern Iowa (modified from Prior and others, 2003).

and Precambrian. The lateral extent of each of these units varies, and with the exception of the Precambrian, none of the units exist statewide.

The Cambrian-Ordovician aquifer is confined above by a series of laterally extensive shales, shaley-dolomite, and dolomite units, and includes the Maquoketa Formation, Galena Group (an aquifer in Northeast Iowa), Decorah Formation, and Platteville Formation (including the Glenwood Shale). This series of confining units control the downward leakage of groundwater or net recharge that enters the Cambrian-Ordovician aquifer.

The Cambrian-Ordovician aquifer, which is sometimes referred to as the Jordan aquifer, consists of three primary stratigraphic units (figures 2 and 3). The uppermost unit is the St. Peter Formation, which consists primarily of fine to coarse grained, poorly cemented sandstone. Beneath the St. Peter Formation is the Prairie du Chien Group, which consists of the Shakopee Formation (dolomite and sandstone), and the Oneota Formation (primarily dolomite). The base of the aquifer is the Jordan Sandstone, which consists of fine to medium grained, well sorted sandstone and dolomite.

The Cambrian-Ordovician aquifer is confined below by the St. Lawrence and Lone Rock formations. The lithology of both of these formations consists of siltstone, dolomite, and glauconitic sandstone. Beneath the St. Lawrence and Lone Rock formations is the Dresbach aquifer. The Dresbach aquifer consists of the Wonewoc Formation, Eau Claire Formation, and the Mt. Simon Sandstone. The Dresbach Group is used as an aquifer along the Mississippi River, but the water quality is poor to very poor over most of Iowa. It is used in central Iowa as a reservoir to store natural gas.

HYDROGEOLOGY

Hydrostratigraphic Units

Three distinct hydrostratigraphic layers were identified for groundwater flow modeling of the Cambrian-Ordovician aquifer. Each of the layers consists of various geologic formations that include both confining units and local and regional aquifers. The geologic complexity was simplified in order to focus the modeling efforts on the hydrology of the Cambrian-Ordovician aquifer. The stratigraphic, formational, and hydrostratigraphic units are presented in Figure 2.

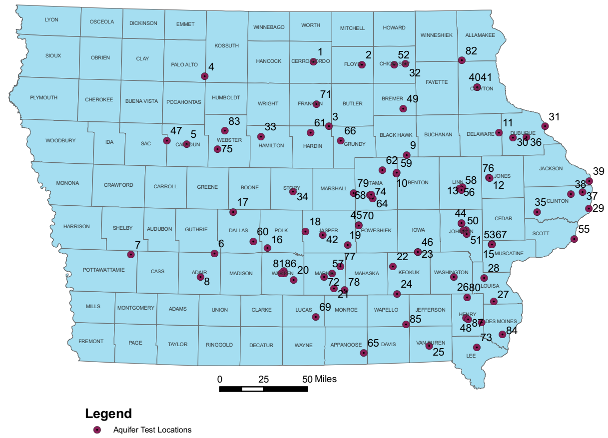

Figure 4. Location of aquifer tests conducted in the Cambrian-Ordovician aquifer. Map locations referenced in tables 1 and 2.

Hydrostratigraphic Layer 1

The uppermost hydrostratigraphic layer (Layer 1) includes the following systems, groups, or formations lumped together as a single unit: Quaternary System or undifferentiated deposits, Cretaceous System, Pennsylvanian System, Mississippian System, Devonian and Silurian Systems, Maquoketa Formation, Galena Group, Decorah Formation, and Platteville Formation.

Layer 1 varies in thickness from a few feet in northeast Iowa to over 2,000-feet in southwest Iowa, and for the purposes of the groundwater flow model behaves as a regional confining layer. Layer 1 is the source of net recharge for the Cambrian-Ordovician aquifer. No attempt was made to model groundwater flow within the various aquifers and confining beds in Layer 1. The primary purpose of this layer was to provide a long-term source of recharge for Layer 1, and to create confining conditions within Layer 2. Wells in this layer were used to calibrate vertical gradients and make estimates regarding leakage. The potentiometric elevation of the Silurian-Devonian System was used to calculate vertical gradients in both the steady-state (non-pumping) model and the transient (pumping) model. The impact of these vertical gradients on leakage will be discussed later in the report.

The Decorah and Platteville formations, some of the Galena Group, and Maquoketa Formation create a relatively low permeability layer over most of the Cambrian-Ordovician aquifer (figures 2 and 3). The exception is in northeast Iowa, where the top of the Cambrian-Ordovician aquifer is the bedrock surface. The lateral extent and thickness of these units creates a regional confined or leaky confined aquifer system. The horizontal hydraulic conductivity of Layer 1 was estimated using data gathered from multiple sites. Hydraulic testing of Maquoketa Shale cores collected in Minnesota estimated horizontal hydraulic conductivities between 10^{-4} and 10^{-9} meters/day (Eaton and others, 2007). Horizontal hydraulic conductivity values based on single well aquifer tests in the Decorah and Platteville formations in De Pere, Wisconsin, range from 5×10^{-4} to 3.4×10^{-3} feet/day (Batten and others, 1999). Additional field studies at the University of Minnesota St. Paul Campus estimated vertical hydraulic conductivities in the Decorah and Platteville Formations, and Glenwood Shale of 10^{-5} ft/day (University of Minnesota St. Paul Campus Ecological Master Plan, 2002).

Hydrostratigraphic Layer 2 (Cambrian-Ordovician Aquifer)

The Cambrian-Ordovician aquifer, which includes the St. Peter Sandstone, the Prairie du Chien Group, and the Jordan Sandstone, comprises Layer 2. Very little is known of the hydraulic properties of each separate unit. Most wells drilled into the aquifer penetrate all three units, and aquifer pump test results provide an average value of transmissivity for the entire layer.

The uppermost unit is the St. Peter Sandstone, which is poorly cemented and is cased-off in most high capacity production wells. It is hydraulically connected to the underlying Prairie du Chien Group in most of Iowa. An unconformity exists in the Cambrian-Ordovician aquifer in eastern Dubuque County where much of the St. Peter Sandstone and Prairie du Chien Group pinches out. This unconformity is related to a bedrock valley that extends from Dubuque County in Iowa into southwest Wisconsin.

The Prairie du Chien Group consists of two separate formations. The upper-most unit is the Shakopee Formation, which varies from a dolomite to a sandy dolomite. Beneath the Shakopee Formation is the Oneota Formation, which consists primarily of dolomite. The permeability within the Prairie du Chien Group varies considerably. Much of this variability can be attributed to the secondary permeability, which is related to fractures and solution openings (Burkart and Buchmiller, 1990).

The oldest unit within the Cambrian-Ordovician aquifer is the Jordan Sandstone. The Jordan is a fine to medium grained, well-sorted sandstone that is present across much of Iowa. In northeast Iowa, the aquifer consists primarily of sandy dolomite and dolomite beds.

The most reliable hydraulic properties are those obtained from controlled aquifer tests with known pumping rates, pumping duration, accurate well locations, and accurate water level measurements. Seven aquifer pump tests conducted in wells open in the Cambrian-Ordovician aquifer were found in Iowa. In addition to the aquifer pump tests, a total of 42 aquifer recovery tests and 38 specific capacity tests were made available by various consultants, well drillers, and communities. The distribution of these tests is shown in Figure 4. Tables 1 and 2 list the pump/recovery test results and the specific capacity results for each test, the method of analyses, transmissivity values, aquifer thickness, hydraulic conductivity values, storativity values (aquifer pump test results only), and who collected the data. Appendix A contains the original data and graphs.

Based on aquifer test results, the transmissivity of the Cambrian-Ordovician aquifer was found to range from 150 ft^2/day in Indianola to 8,500 ft^2/day in Tama County. The arithmetic mean is 2.3×10^3 ft^2/day. Much of the variability in the transmissivity is related to the secondary permeability found within the dolomite and sandy dolomite units. The regional transmissivity distribution is shown on Figure 5 and is based on data found in tables 1 and 2. Local transmissivity may be much higher than that shown on Figure 5. This is largely due to the fractures and voids found in the Prairie du Chien Group. These fractures and voids have limited lateral extent, and may not be representative of the regional permeability distribution.

Hydraulic conductivity is considered an intrinsic parameter, which means that it is independent of the thickness of the formation, and can be calculated by dividing the transmissivity by the overall aquifer thickness. Hydraulic conductivity is also the input variable used in the groundwater model. Hydraulic conductivity was found to range from 0.3 to 20.9 feet/day, with an arithmetic mean of 4.6 feet/day. The standard deviation of the hydraulic conductivity was 3.7. The regional horizontal hydraulic conductivity distribution is shown on Figure 6 and is based on data found in tables 1 and 2.

Similar permeability values were found in the Cambrian-Ordovician aquifer near Oak Creek, Wisconsin. Based on five aquifer recovery tests, transmissivity values ranged from 2,300 ft^2/day to 3,400 ft^2/day, and the corresponding hydraulic conductivity values ranged from 4.6 to 6.7 feet/day (Miller, 2001).

Another important aquifer parameter measured during an aquifer test is the dimension-

Table 1. Aquifer pump test results for wells open in the Cambrian-Ordovician aquifer. ID# corresponds to the well location on Figure 4.

Location	ID #	W Number	Aq. Thickness	Transmissivity	Transmissivity	Hyd. Cond.	Storage Coef.	Method
			(feet)	(gpd/ft)	(ft2/day)	(ft/day)		
Mason City Golden Grains[6]	1	63761	700	55,352	7,400	10.6	1×10^{-6}	Cooper/Jacobs
Rockwell City[3]	5	59068	380	9,275	1,240	2.6		Recovery Test
Dyersville[6]	11	66011	440	27,676	3,700	3.2		Recovery Test
Anamosa	12	21773	463	18,700	2,500	5.4		Recovery Test
Iowa City[4]	14	37000	628	9,724	1,300	2.1		Recovery Test
Sully	19	16827	541	8,228	1,100	2.0		Recovery Test
Clinton[2]	29	NA	515	11,220	1500	2.9		Recovery Test
Farley[6]	30	63719	438	8,976	1200	2.7		Recovery Test
Dubuque[1]	31		327	12,118	1620	4.9		Recovery Test
Homeland Ethanol Lawler[6]	32	NA	500	15,708	2100	4.2		Cooper Jacob
Webster City[3]	33	45712	463	10,996	1470	3.2		Recovery Test
Neveda[3]	34	22721	523	8,228	1100	2.1		Recovery Test
Calamus[1]	35	64546	480	15,035	2010	4.2		Recovery Test
Peosta[1]	36	56720	445	11,370	1520	3.4		Recovery Test
Andover[1]	37	NA	300	7,555	1,010	3.4		Recovery Test
Goose Lake[1]	38	59412	345	30,294	4050	11.7		Recovery Test
Sabula[1]	39	41725	425	37,624	5030	11.8		Recovery Test
Elkader[1]	40	62661	480	45,628	6100	12.7	2×10^{-4}	Cooper Jacob
Elkader[1]	41	62662	450	70,162	9380	20.9		Cooper Jacob
North Liberty[4] #5	43	35258	523	22,664	3030	5.8		Recovery Test
North Liberty[4] #6	44	55191	528	14,960	2000	3.8		Recovery Test
Grinnell #5	45	1571	550	15,259	2040	3.7		Cooper Jacob
North English Well 2	46	2910	570	27,078	3620	6.4		Recovery Test
Lytton	47	2018	355	4,488	600	1.7		Recovery Test
Mount Pleasant	48	52	695	28,349	3790	5.5		Recovery Test
Readlyn	49	1544	202	9,799	1310	6.5		Recovery Test
Coralville	50	17262	524	5,715	764	1.2		Recovery Test
Iowa City Jordan	51	14453	620	47,872	6400	10.0		Recovery Test
West Liberty Well 4	53	16614	550	28,723	3840	7.0		Recovery Test
Indianola	54	16662	528	5,610	750	1.4	1×10^{-6}	Cooper Jacob
Dysart	59	23326	581	8,976	1200	2.1		Recovery Test
Waukee Well 2	60	23434	470	18,700	2500	5.3		Recovery Test
Farmbest Iowa Falls	61	14410	533	2,543	340	0.6		Recovery Test
Toledo	64	12687	560	8,602	1150	2.1		Recovery Test
Dysart Park Well	10	12665	565	6,732	900	1.6		Recovery Test
Wellsburg (Grundy Co.)	66	10984	570	14,436	1930	3.4		Recovery Test
West Liberty Well 2	67	10351	560	23,188	3100	5.5		Recovery Test
Central Fiber (Tama Co.)	68	10070	572	63,580	8500	14.9	1×10^{-3}	Theis
Grinnell #7	70	6931	554	32,912	4400	7.9		Recovery Test
Toledo Well 2	74	24528	545	11,220	1500	2.8		Recovery Test
Anamosa Well 5	76	31624	485	11,968	1600	3.3		Recovery Test
Pella	77	30179	530	39,644	5300	10.0		Recovery Test
Bussey #4	78	26319	477	8,228	1100	2.3		Recovery Test
LeGrand	79	24635	605	13,464	1800	3.0		Recovery Test
Olds	80	24356	546	8,228	1100	2.0		Recovery Test
Indianola #11	81	23702	487	59,092	7900	16.2		Recovery Test
Postville	82	23398	451	9,724	1300	2.9		Recovery Test
Fort Dodge	83	21118	435	12,716	1700	3.9		Recovery Test
Indianola #9	86	6995	490	1,122	150	0.3		Recovery Test
footnotes								
1		Data Provided by IIW Engineers and Surveyors						
2		Data Provided by Layne Christensen						
3		Data Provided by Fox Engineering						
4		Data Provided by H.R. Green Engineering						
5		Data Provided by USGS						
6		Shawver Drilling Company						

Table 2. Specific capacity test results for wells open in the Cambrian-Ordovician aquifer. ID# corresponds to the well location on Figure 4.

Location	ID #	W Number	Aq. Thickness	Transmissivity	Transmissivity	Hydr. Cond.	Method
			(feet)	(gpd/ft)	(ft2/day)	(ft/day)	
Charles City[1]	**2**	**6987**	**545**	**17,300**	**2,310**	**4.5**	**Specific Capacity**
Ackley[1]	**3**	**8169**	**550**	**11,220**	**1,500**	**2.7**	**Specific Capacity**
West Bend[1]	**4**	**10712**	**415**	**8,228**	**1,100**	**2.7**	**Specific Capacity**
Stuart[1]	**6**	**13454**	**425**	**9,275**	**1,240**	**2.9**	**Specific Capacity**
Walnut[1]	**7**	**22927**	**NA**	**3,291**	**440**	**NA**	**Specific Capacity**
Greenfield[1]	**8**	**33**	**455**	**8,228**	**1,100**	**2.4**	**Specific Capacity**
La Porte City[1]	**9**	**23018**	**585**	**7,480**	**1,000**	**1.8**	**Specific Capacity**
Marion	**13**	**8478**	**480**	**21,692**	**2,900**	**6.0**	**Specific Capacity**
West Liberty[1]	**15**		**560**	**8,976**	**1,200**	**2.4**	**Specific Capacity**
West Des Moines	**16**	**22808**	**486**	**29,920**	**4,000**	**8.2**	**Specific Capacity**
Perry[1]	**17**		**382**	**11,220**	**1,500**	**3.9**	**Specific Capacity**
Mitchellville[1]	**18**		**523**	**14,212**	**1,900**	**3.6**	**Specific Capacity**
Milo[1]	**20**		**542**	**8,303**	**1,110**	**2.0**	**Specific Capacity**
Attica[1]	**21**		**550**	**14,212**	**1,900**	**3.5**	**Specific Capacity**
What Cheer[1]	**22**	**15298**	**554**	**10,472**	**1,400**	**2.6**	**Specific Capacity**
North English[1]	**23**		**570**	**11,220**	**1,500**	**2.6**	**Specific Capacity**
Hedrick[1]	**24**		**570**	**6,732**	**900**	**1.6**	**Specific Capacity**
Keosaqua[1]	**25**		**623**	**10,472**	**1400**	**2.2**	**Specific Capacity**
Washington[1]	**26**		**602**	**22,440**	**3000**	**5.0**	**Specific Capacity**
Morning Sun[1]	**27**		**655**	**9,724**	**1300**	**2.0**	**Specific Capacity**
Columbus Junction[1]	**28**		**500**	**19,448**	**2600**	**5.3**	**Specific Capacity**
Newton[1]	**42**	**53097**	**500**	**23,562**	**3150**	**6.3**	**Specific Capacity**
New Hampton #4A	**52**	**15936**	**515**	**24,684**	**3300**	**6.4**	**Specific Capacity**
Le Claire	**55**	**17974**	**540**	**3,740**	**500**	**1.0**	**Specific Capacity**
Marion Well 4	**56**	**17979**	**480**	**8,228**	**1100**	**2.3**	**Specific Capacity**
Red Rock J-2	**57**	**23178**	**460**	**25,432**	**3400**	**7.4**	**Specific Capacity**
Marion Well 5	**58**	**23249**	**480**	**5,834**	**780**	**1.6**	**Specific Capacity**
Traer	**62**	**14136**	**562**	**11,220**	**1500**	**2.7**	**Specific Capacity**
New London	**63**	**12683**	**680**	**7,480**	**1000**	**1.5**	**Specific Capacity**
Moulton	**65**	**12035**	**530**	**3,964**	**530**	**1.0**	**Specific Capacity**
Russell (Lucas Co.)	**69**	**7948**	**506**	**7,480**	**1000**	**2.0**	**Specific Capacity**
Hampton #3	**71**	**5443**	**510**	**13,464**	**1800**	**3.5**	**Specific Capacity**
Knoxville #3	**72**	**23922**	**455**	**44,880**	**6000**	**13.2**	**Specific Capacity**
West Point #3	**73**	**24442**	**760**	**31,416**	**4200**	**5.5**	**Specific Capacity**
Callender Well 2	**75**	**25484**	**392**	**6,358**	**850**	**2.2**	**Specific Capacity**
West Burlington #4	**84**	**14131**	**687**	**8,228**	**1100**	**1.6**	**Specific Capacity**
Eldon	**85**	**12922**	**610**	**34,408**	**4600**	**7.5**	**Specific Capacity**
Mt. Pleasant Hosp.	**87**	**6674**	**691**	**14,960**	**2000**	**2.9**	**Specific Capacity**
footnotes							
1		Data Provided by USGS					
		NA - Not Available, Partially completed in Cambrian-Ordovician aquifer					

less storage coefficient. The storage coefficient or storativity, is equal to the volume of water released from a vertical column of the aquifer per unit surface area of the aquifer and unit decline in water level (Freeze and Cherry, 1979). Based on aquifer pump test data, the storage coefficient of the Cambrian-Ordovician aquifer ranged from 10^{-6} near Indianola, to 10^{-3} in West Liberty, with an arithmetic mean of 3 x 10^{-4}.

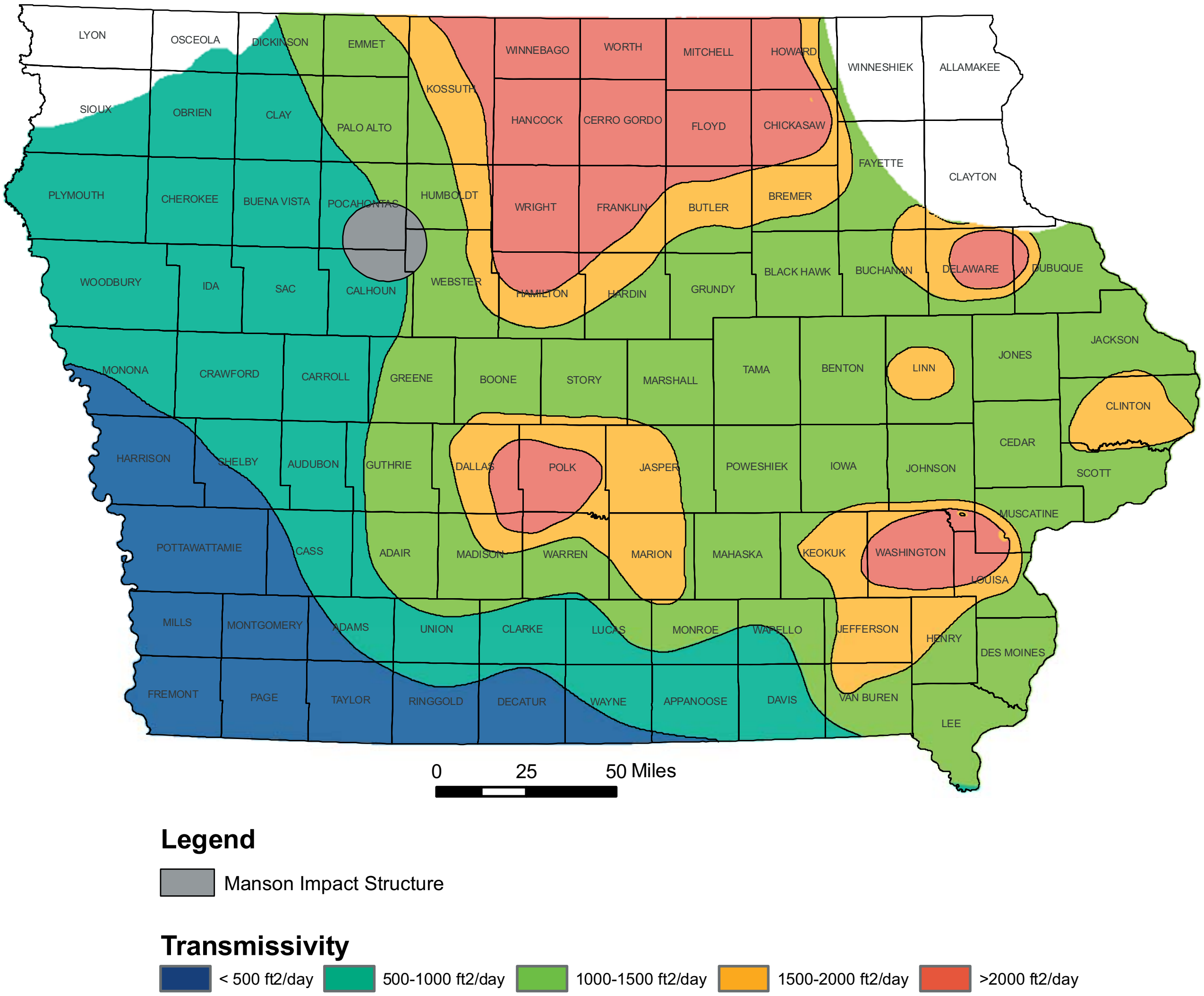

Figure 5. Transmissivity distribution within active model area of the Cambrian-Ordovician aquifer based on data found in tables 1 and 2.

Hydrostratigraphic Layer 3

The stratigraphic units below the Cambrian-Ordovician aquifer, including the St. Lawrence and Lone Rock formations, comprise Layer 3. These units consist of siltstone, dolomite, or sandstone, and create either a lower confining boundary or a semi-confining boundary depending on the lithology. Both were classified as confining layers by Horick and Steinhilber (1978) and Burkart and Buchmiller (1990). The St. Lawrence and Lone Rock formations are an effective lower confining unit in southeastern Minnesota, much of Iowa, and southern and eastern Wisconsin (Olcott, 1992). Very little is known about the actual permeability or vertical hydraulic conductivity of these units, or their lateral extent.

GROUNDWATER RECHARGE AND DISCHARGE IN THE CAMBRIAN-ORDOVICIAN AQUIFER

The Cambrian-Ordovician aquifer is confined throughout most of Iowa except for a small region in Allamakee and Clayton counties where

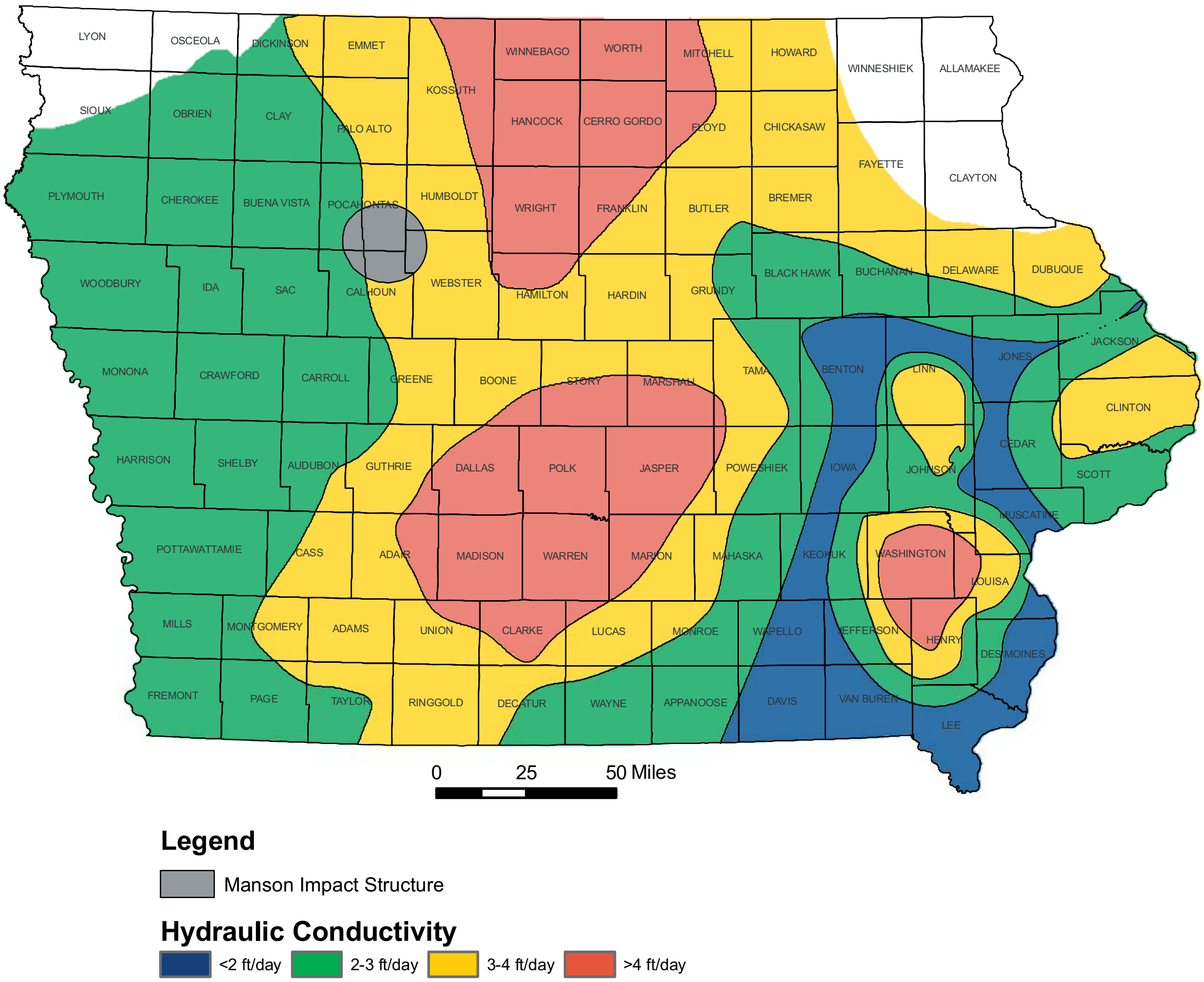

Figure 6. Hydraulic conductivity distribution within active model area of the Cambrian-Ordovician aquifer based on data found in tables 1 and 2.

it is hydraulically connected to the Upper Iowa River, Yellow River, and their various tributaries. In addition, much of Winneshiek, Fayette, Clayton, and all of Allamakee counties lie within the Paleozoic Plateau. These are upland areas lacking substantial glacial drift, which allows direct recharge into the aquifer (Burkart and Buchmiller, 1990). These areas of direct recharge and discharge form localized flow systems within individual watersheds. For these reasons, this portion of northeast Iowa was not included in our study area (Figure 7).

The Cambrian-Ordovician aquifer is also directly recharged in northwest Iowa where the Lower Dakota Sandstone directly overlies the St. Peter Sandstone (Burkart, 1984). Field measurements indicate a downward vertical gradient of -0.03 ft/ft in Osceola County (Munter and others, 1983).

Areas of pre-development recharge and discharge (Figure 8) were estimated by comparing the potentiometric surface of the overlying Silurian-Devonian as shown in Figure 9 with the pre-development (pre-1900) potentiometric surface

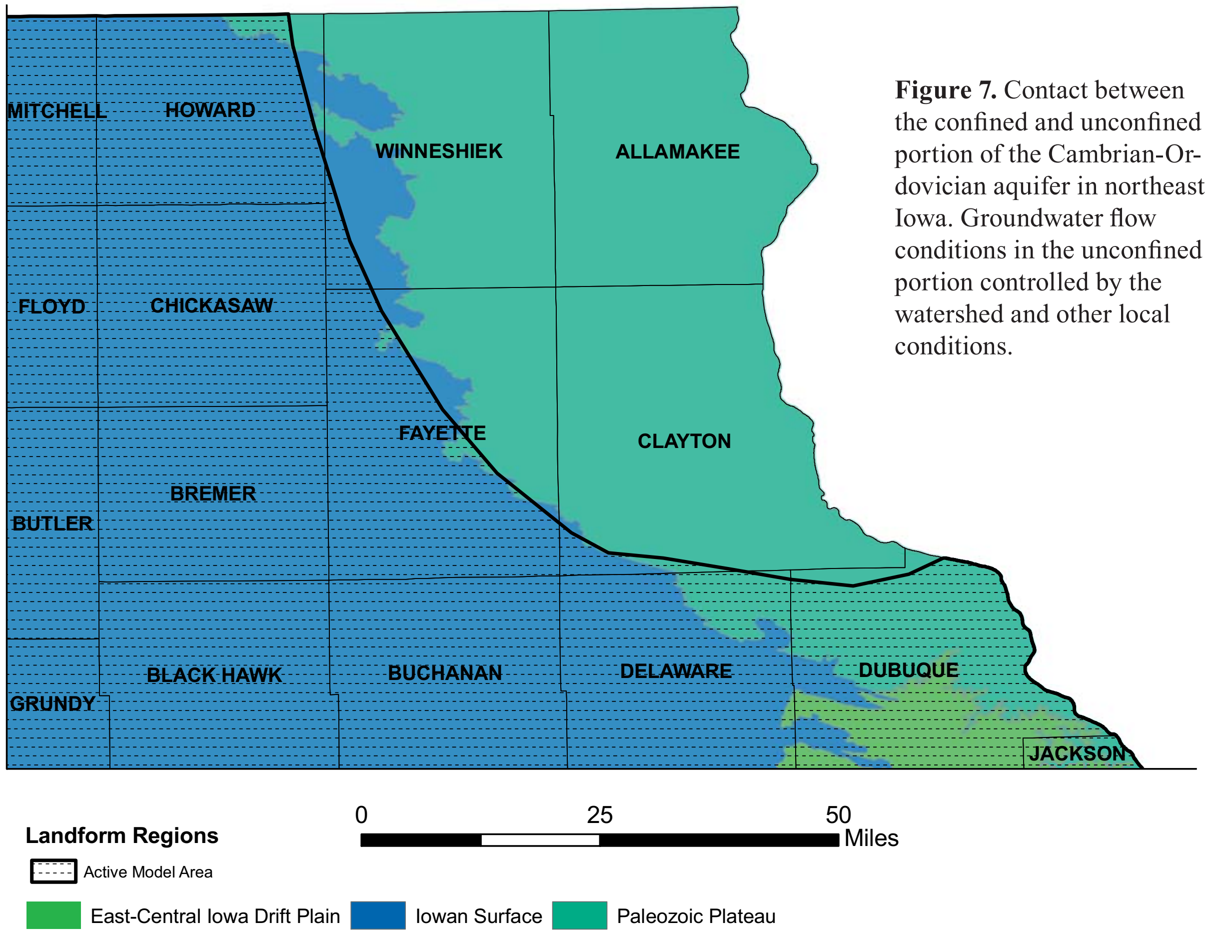

Figure 7. Contact between the confined and unconfined portion of the Cambrian-Ordovician aquifer in northeast Iowa. Groundwater flow conditions in the unconfined portion controlled by the watershed and other local conditions.

elevation in the Cambrian-Ordovician aquifer as shown on Figure 10. Figure 8 indicates that a substantial area of east-central and southeast Iowa had upward vertical gradients prior to 1900, and under steady-state conditions, groundwater from the Cambrian-Ordovician aquifer discharged into the overlying Silurian-Devonian. With the development of the Cambrian-Ordovician aquifer, and the rapid drawdown caused by pumping, vertical gradients in these areas have reversed and are now downward.

Throughout the remainder of the state, recharge into the Cambrian-Ordovician aquifer is vertically downward through overlying confining beds (Burkart and Buchmiller, 1990). This is shown by comparing modern potentiometric surfaces in the Cambrian-Ordovician aquifer with that of the Silurian-Devonian (Figure 9), and are quantified in the modeling sections of this report.

The term recharge as defined in this report is simply the downward leakage into the St. Peter Sandstone from the overlying confining unit, and is also referred to as the net recharge. Even though the net recharge or leakage is relatively small, the long-term sustainability of the aquifer is directly dependent on the recharge value. The following equation represents the water balance formula for a confined aquifer:

$$Q(t) = R(t) - O(t) + dS/dt$$

Where

Q = Volume of pumpage over time

R = Recharge over time

O = Outflow-Inflow over time

dS/dt = Change in storage over time

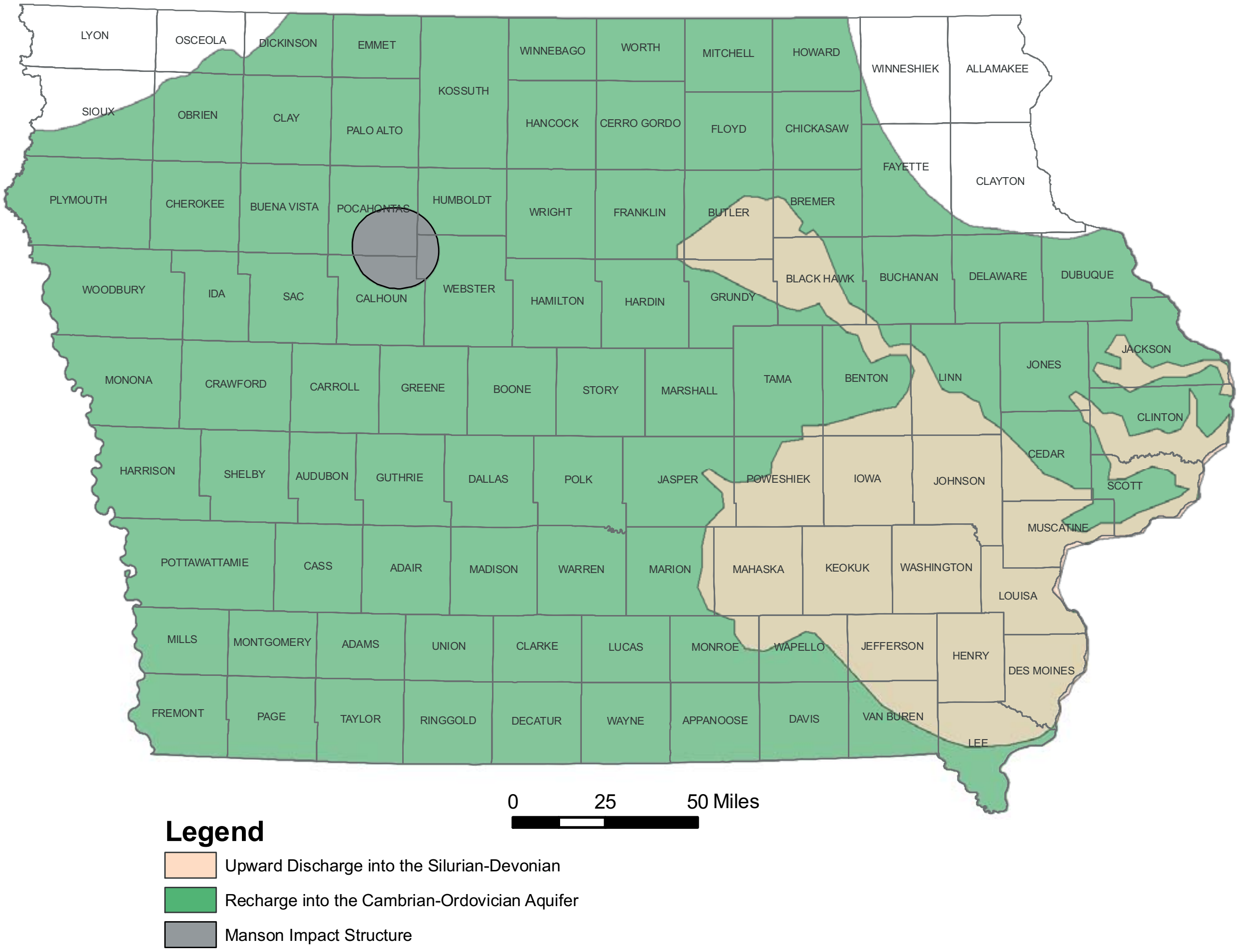

Figure 8. Distribution of the predevelopment recharge and discharge conditions in the Cambrian-Ordovician aquifer prior to pumping.

The confining units above the St. Peter Sandstone create extremely slow vertical groundwater velocities or leakage. The following equation represents the vertical groundwater velocity, and can also be used to estimate leakage or net recharge:

$V_v = -K_v \, dh/dL$

Where

V_v = vertical groundwater velocity

K_v = vertical hydraulic conductivity

dh/dL = vertical hydraulic gradient

Estimates of vertical hydraulic conductivity in the Decorah and Platteville formations in Wisconsin were made by Batten and others (1999) and Dunning and Yeskis (2007). If a reported value of vertical hydraulic conductivity of 10^{-5} ft/day is used, and a vertical hydraulic gradient of between -0.04 and -1.25 ft/ft are inserted into the above equation, the following estimates of net recharge are calculated:

$V_v = (10^{-5}$ ft/day) (-0.04 ft/ft) = -4×10^{-7} feet/day = 2×10^{-3} inches/year

$V_v = (10^{-5}$ ft/day) (-1.25 ft/ft) = -1.25×10^{-5} feet/day = 0.05 inches/year

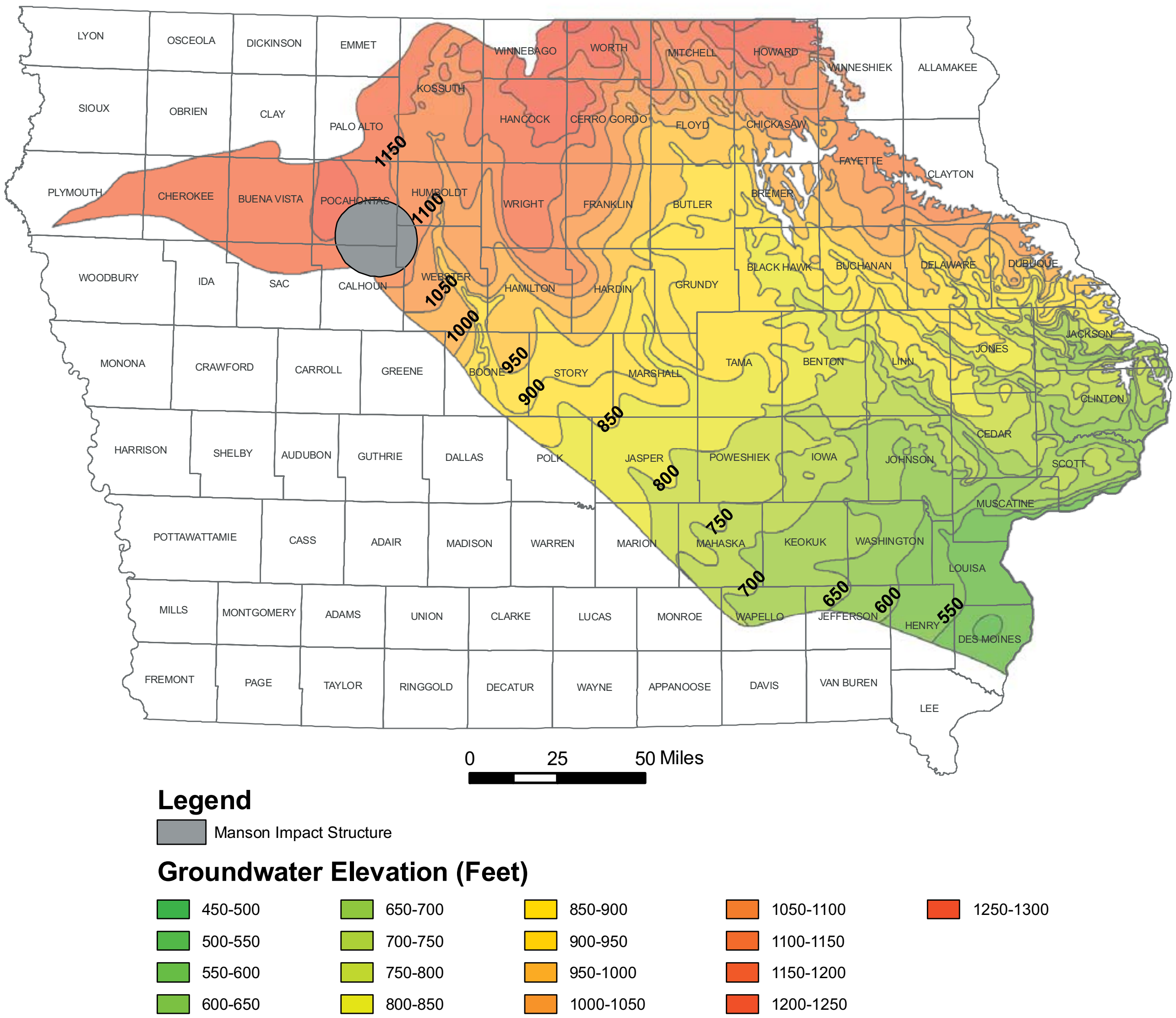

Figure 9. Potentiometric elevation in the Silurian-Devonian (modified from Horick, 1984).

Additional estimates of vertical hydraulic conductivity in the Maquoketa Shale in Illinois were made by Walton and Walker (1961) and ranged from 10^{-5} to 10^{-6} feet/day. If we assume the same vertical gradient as Dunning and Yeskis (2007) (-0.04 and -1.25 ft/ft), recharge was estimated to be between 10^{-4} and 0.06 inches per year.

GROUNDWATER FLOW

Groundwater elevation contours or potentiometric surfaces in the Cambrian-Ordovician aquifer were estimated using water level measurements collected from various historic periods. The potentiometric surfaces were contoured for four time periods; pre-1900, 1975, 1990-1999, and 2000-2008, and are shown in figures 10, 11, 12, and 13. Regional groundwater flow is generally from northwest to southeast. Based on the potentiometric surfaces, groundwater flows into the state from southern Minnesota and parts of eastern Nebraska, and exits the state into north-

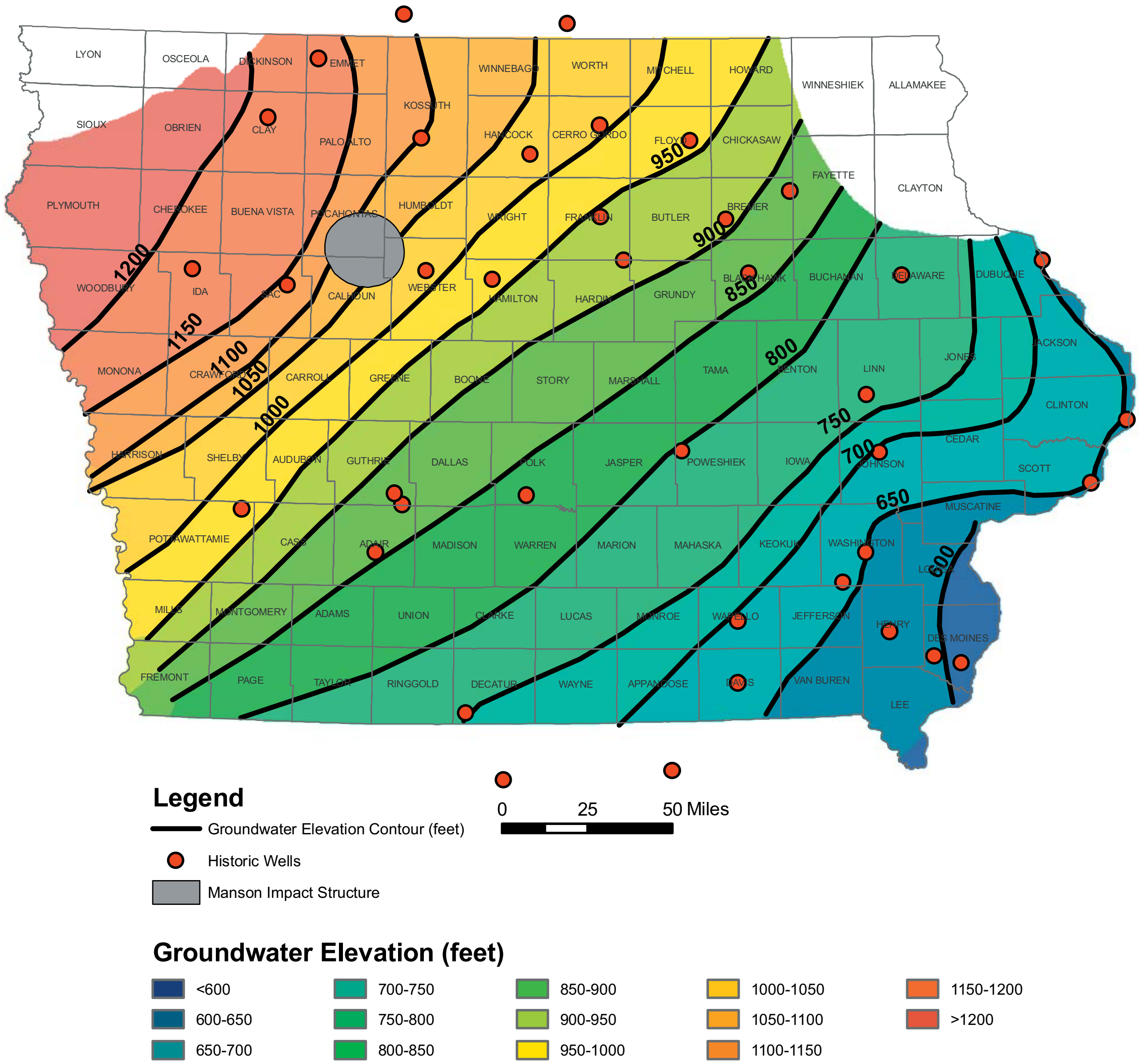

Figure 10. Predevelopment potentiometric elevation of the Cambrian-Ordovician aquifer based on observed groundwater elevation data found in Table 3.

ern Missouri and western Illinois. Groundwater contours have been strongly influenced by the major pumping centers in central and eastern Iowa. Much of the groundwater that used to discharge to Missouri and Illinois is now partially diverted back toward the major pumping centers in east-central Iowa and southeast Iowa.

CONCEPTUAL GROUNDWATER MODEL

A conceptual model represents our best understanding of the three-dimensional geology and hydrogeology. A conceptual model does not necessarily use formations or stratigraphic units,

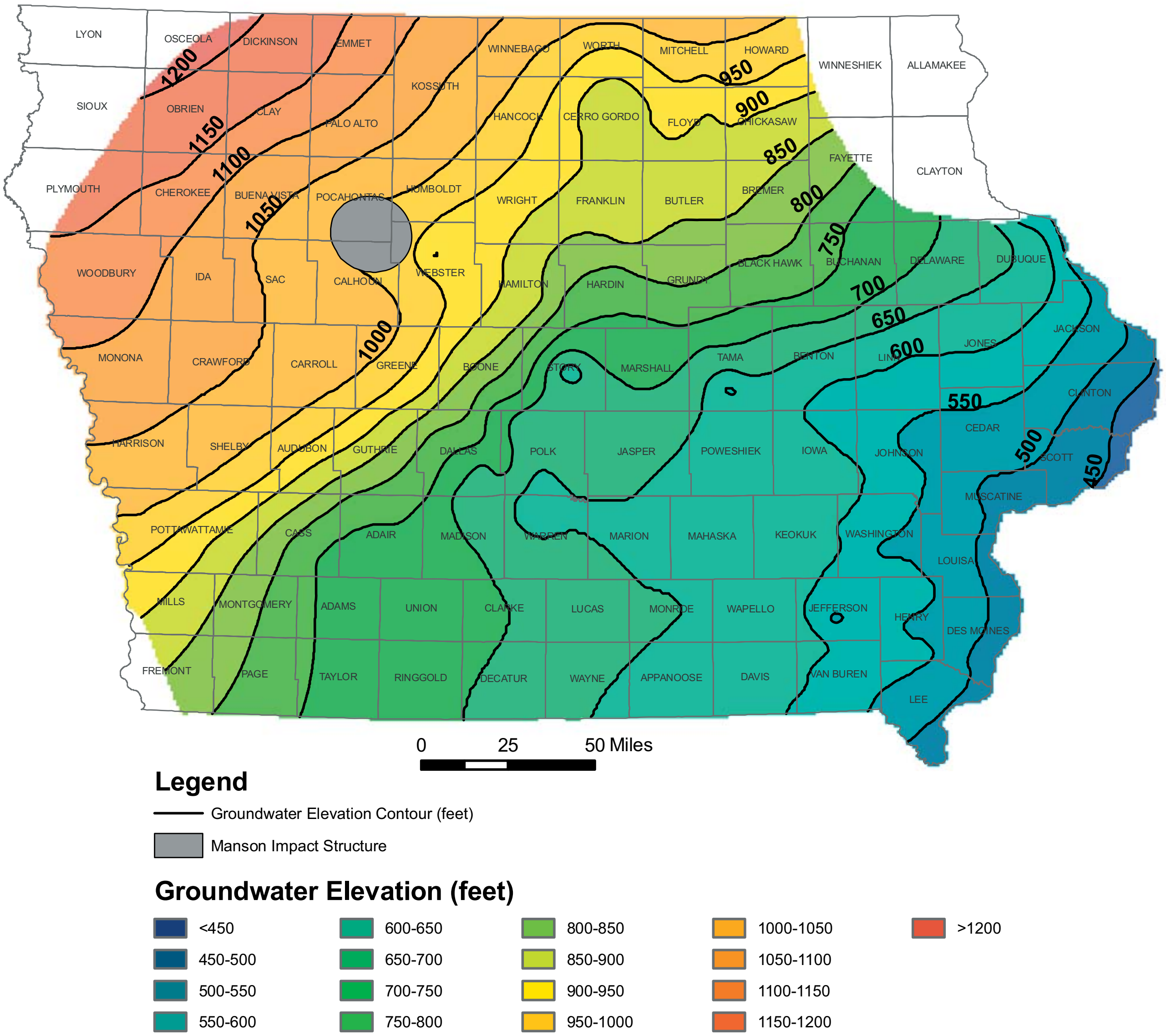

Figure 11. Potentiometric elevation of the Cambrian-Ordovician aquifer based on observed groundwater elevation data from Horick and Steinhilber (1978).

but relies primarily on variations in lithology and hydraulic parameters to represent groundwater flow conditions. The following items represent the basic elements of the conceptual model of the Cambrian-Ordovician aquifer:

- The Cambrian-Ordovician aquifer was modeled using three layers based on the hydrostatic units discussed earlier in this report. Figure 14 gives a graphical representation of each of these layers.

- The base of the model (Layer 3) represents the St. Lawrence and Lone Rock formations. Layer 3 is considered a no flow boundary or semi-confining unit.

- The Cambrian-Ordovician aquifer is repre-

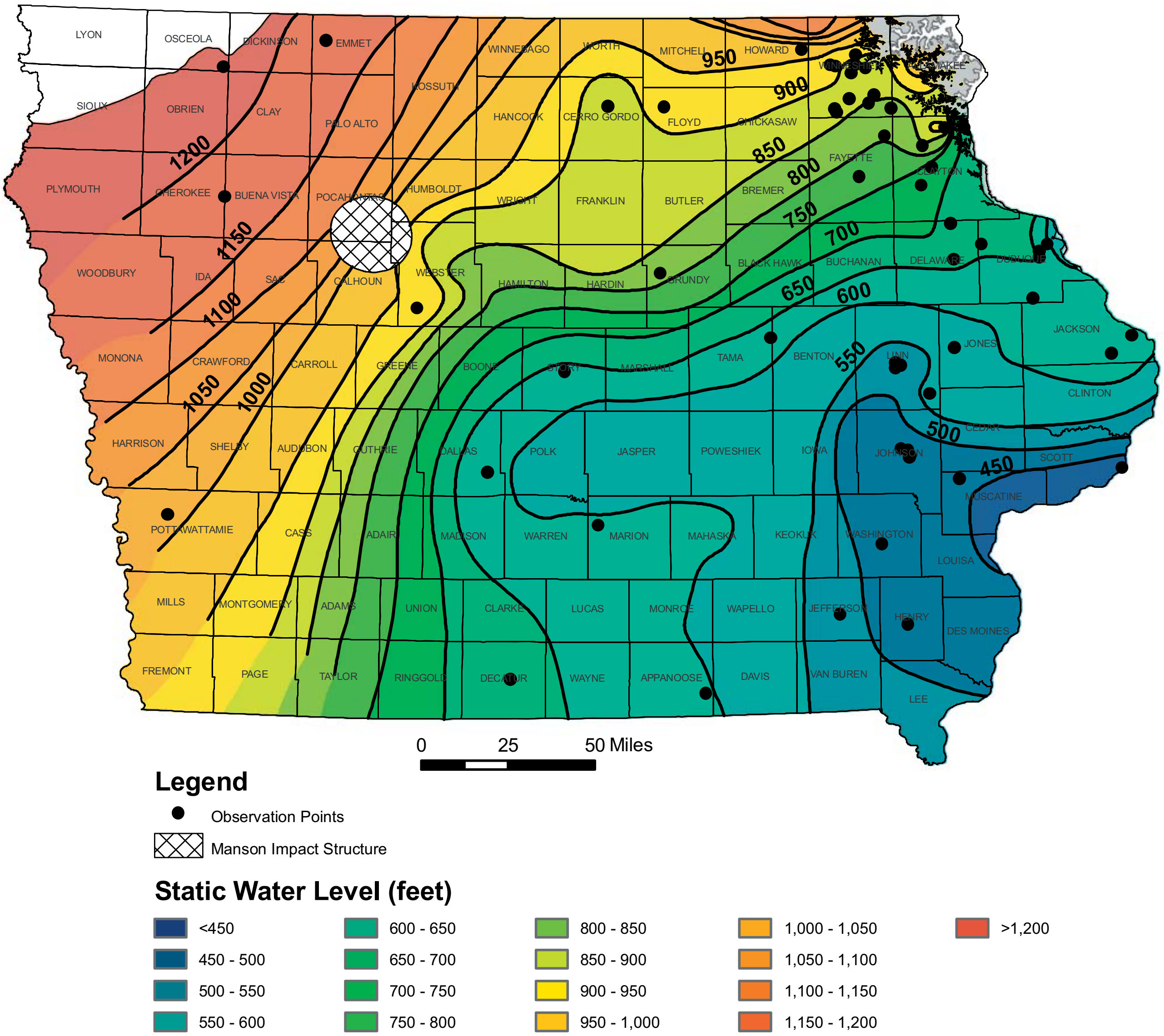

Figure 12. Potentiometric elevation of the Cambrian-Ordovician aquifer based on observed groundwater elevation data from 1990 to 1999. Gray area in Northeast Iowa shows where the aquifer is unconfined and water levels are more variable because of the local topography.

sented by Layer 2 and is confined above by various shale units. Flow-through boundaries are assumed to be along the northwest, north, southwest, south, and eastern study area.

- The regional confining beds and aquifers above the Cambrian-Ordovician aquifer comprise Layer 1.
- Due to the relatively thick shale units in Layer 1, recharge enters the top of the St. Peter Sandstone from the overlying shale.
- To evaluate predevelopment or steady-state conditions, the static water level from the first recorded well in a community was used.

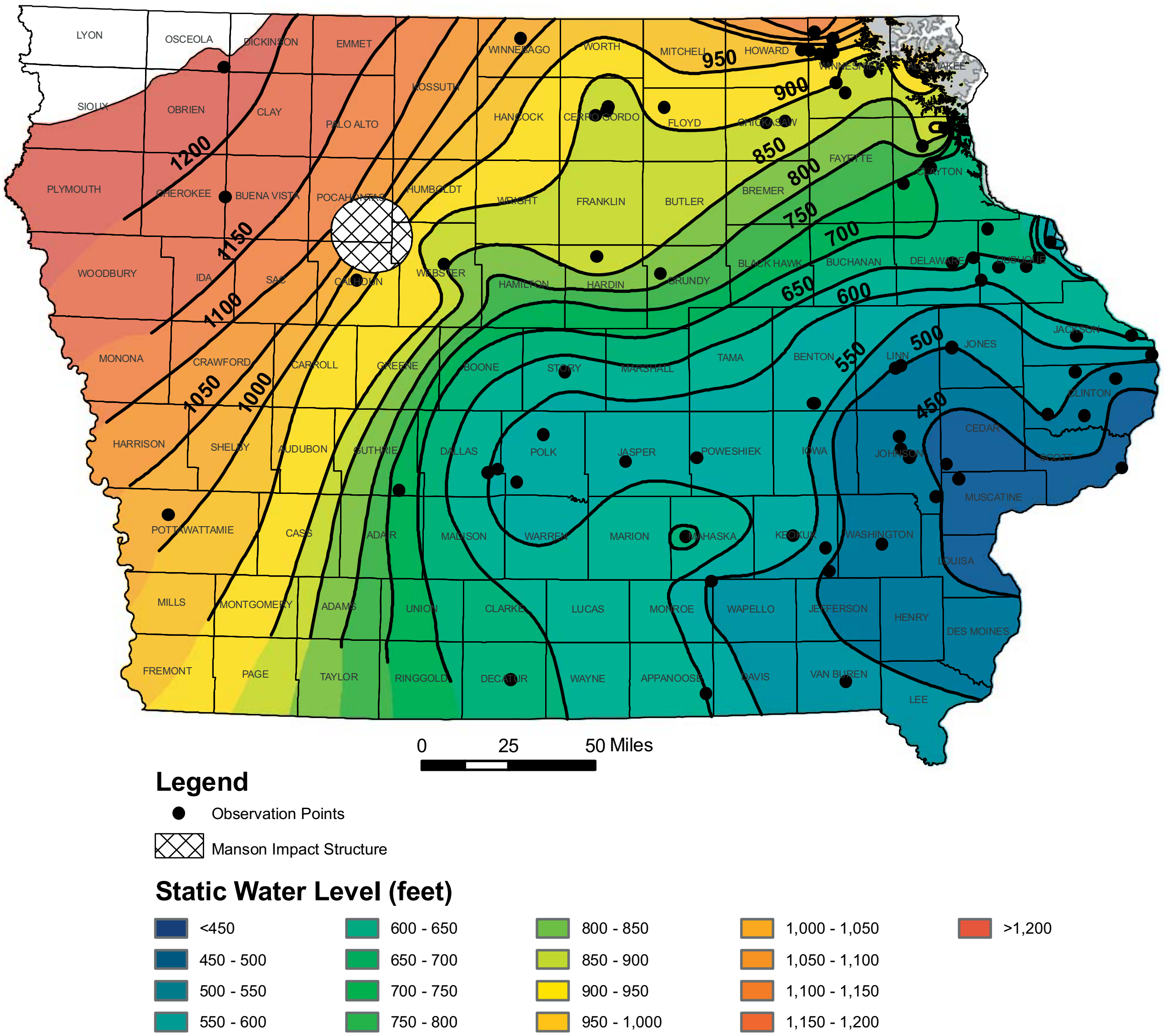

Figure 13. Potentiometric elevation of the Cambrian-Ordovician aquifer based on observed groundwater elevation data from 2000 to 2008. Gray area in Northeast Iowa shows where the aquifer is unconfined and water levels are more variable because of the local topography.

- Drawdown in static water levels since predevelopment has been caused by pumping. Areas with the greatest drawdown are the result of the distribution of wells, pumping rates, and aquifer properties.

- Upward pre-development vertical hydraulic gradients from the Cambrian-Ordovician aquifer into the Silurian-Devonian aquifer exist in areas based on Figure 9.

Model Design

A numerical model of the Cambrian-Ordovician aquifer was developed to evaluate groundwater availability and sustainability using historical water use, current usage, and several future usage scenarios. The future use scenarios involve a static, low, medium, and high water-use. In addition, the concept of zone budgeting was used

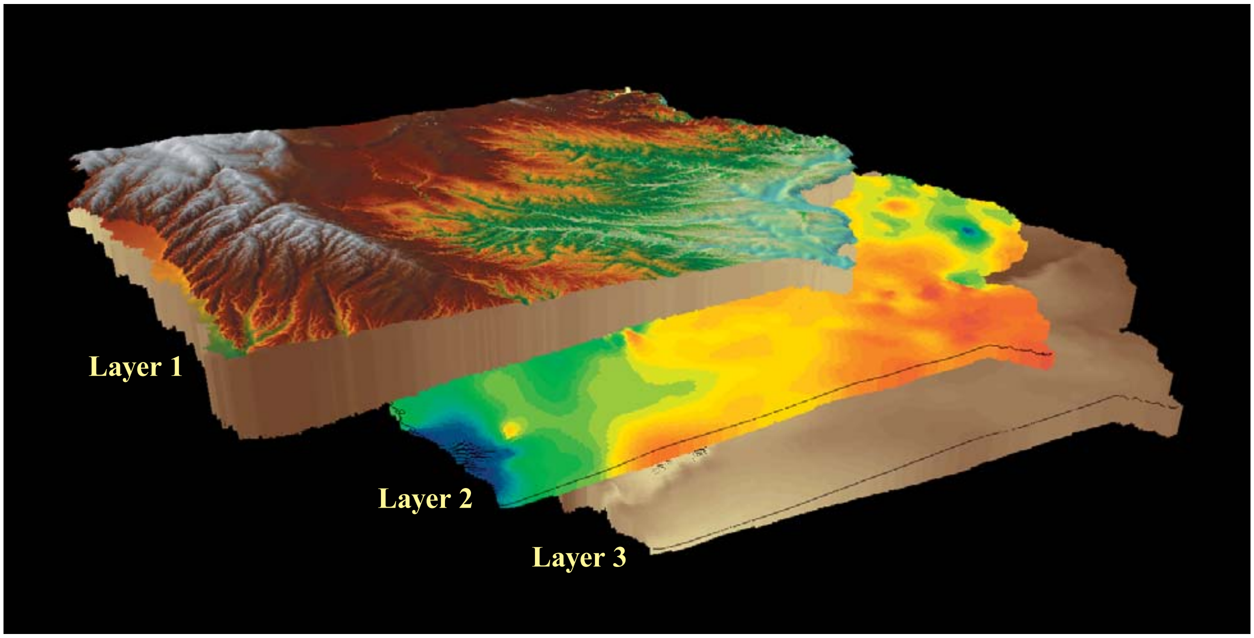

Figure 14. Hydrogeologic conceptual model of the Cambrian-Ordovician aquifer.

within high usage areas to evaluate the local water budget. A total of seven zones were used, which allowed a much better indication of the current water balance in high usage areas. Zone budgeting was also used to evaluate how much water is available in these zones for future development.

Code and Software

Groundwater flow in the Cambrian-Ordovician aquifer was simulated using Visual MODFLOW Version 4.3 (Waterloo Hydrogeologic Inc. 2008). The preconditioned conjugate-gradient method was used to solve the linear and non-linear flow conditions (Hill, 1990). MODFLOW is a widely used finite difference groundwater modeling program originally developed by the United States Geological Survey.

Model Parameters

The following model parameters were included in Visual MODFLOW:

- The model consisted of three layers as described in the conceptual model.
- The top surface for each of the three layers was entered using 1,600 by 1,600 meter grids. The top of Layer 1 was the ground-surface elevation. The top surfaces for Layers 2 and 3 were derived from geologic grid surfaces.
- Layer 1 consisted of various confining units, primarily shale, and shallower regional aquifers. Because the various shale units dominate the vertical movement of groundwater to the Cambrian-Ordovician aquifer, the aquifer parameters assigned to this unit are those typical of shale. Layer 1 was modeled as one continuous confining unit.
- The horizontal hydraulic conductivity of Layer 1 was assigned a value of 3.28×10^{-4} feet/day based on data from previous studies (Eaton and others, 2007). The vertical hydraulic conductivity was assigned a value of 3.28×10^{-5} feet/day.

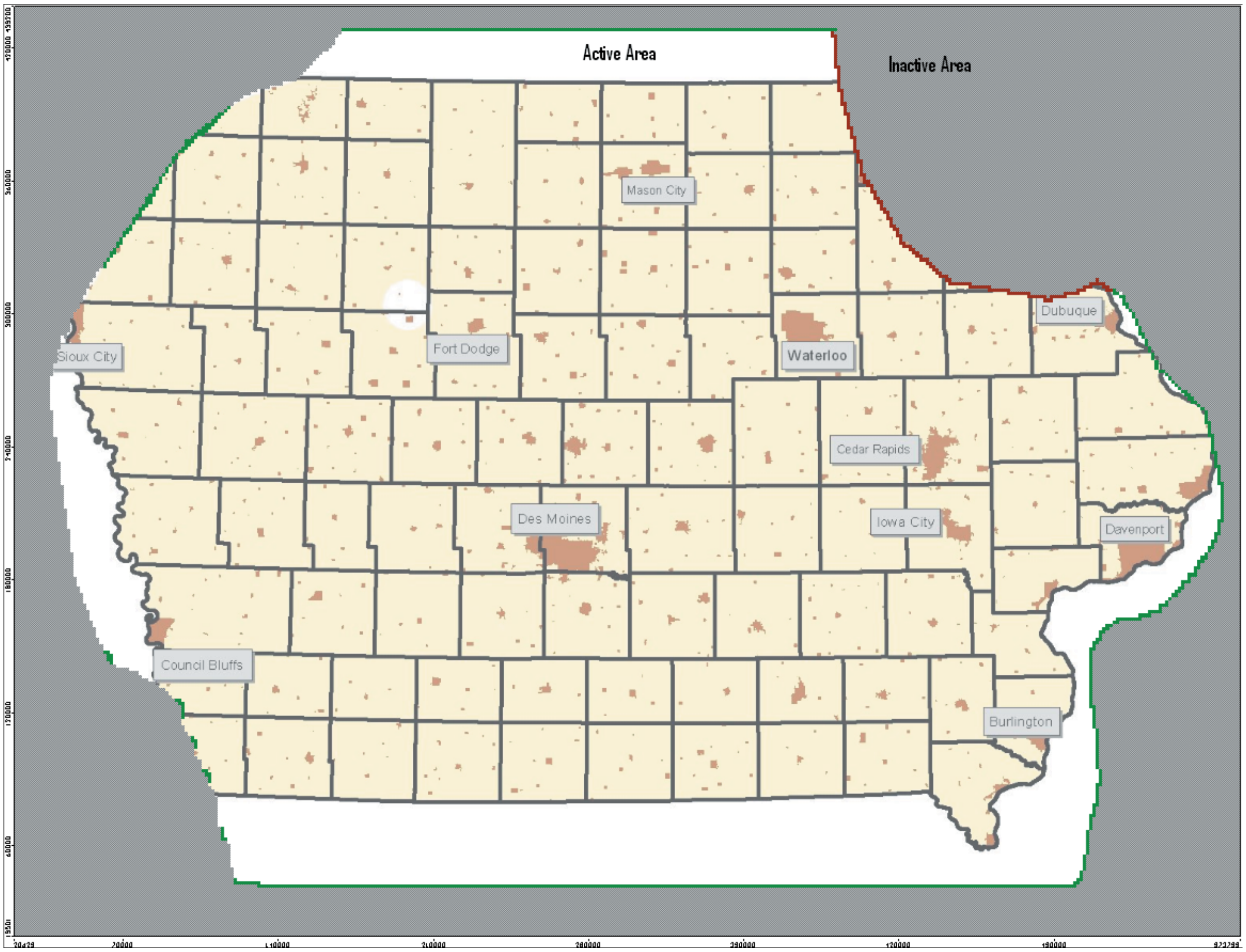

Figure 15. Active-Inactive model area of the Cambrian-Ordovician aquifer. Discharge boundaries represented by constant head cells shown in red. Flow-through boundaries are represented by general head cells shown in green.

- The modeled region included approximately 20 to 30 miles of both Minnesota and Missouri, parts of western Illinois, and eastern Nebraska. Portions of the aquifer are discontinuous in northwest and southwest Iowa. Local flow conditions are dominant in extreme northeast Iowa. To represent this discontinuity, model cells were de-activated within Visual MODFLOW. The final active portion of the model is shown in Figure 15.

- Horizontal hydraulic conductivity values in the Cambrian-Ordovician aquifer are shown in Figure 6. The vertical hydraulic conductivity was assigned a value that was 1/10th the horizontal.

- Visual MODFLOW uses the parameter specific storage (S_s), which is defined by the following equation:

S_s = S/B

Where:
S = Storativity
B = aquifer thickness

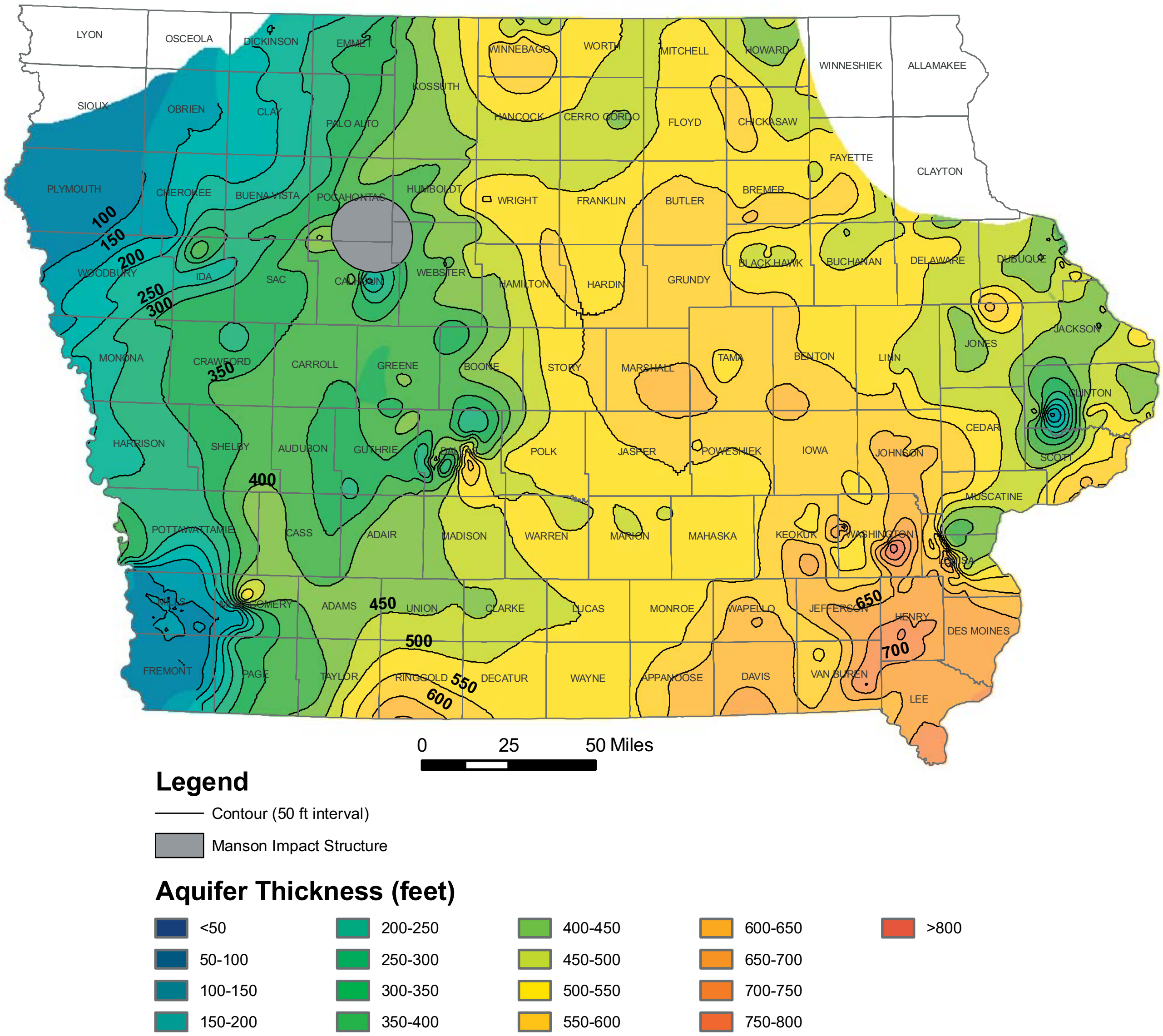

Figure 16. Isopach (thickness) map of the Cambrian-Ordovician aquifer in Iowa.

The specific storage distribution was calculated by taking the average storativity value of 3×10^{-4} from Table 1, and dividing this by the thickness of the Cambrian-Ordovician aquifer (Figure 16). The specific storage distribution used in the model is shown on Figure 17.

- A horizontal hydraulic conductivity value of 3.28×10^{-3} ft/day was assigned to Layer 3 to represent the semi-confining nature of this boundary. A vertical hydraulic conductivity of 3.28×10^{-4} ft/day was also assigned.

MODFLOW Grid

The model grid for the Cambrian-Ordovician aquifer was defined by 400 columns and 300 rows. Rows were aligned east to west, and columns were aligned north to south. Each cell has dimensions of 1,600 meters east-west, and 1,600

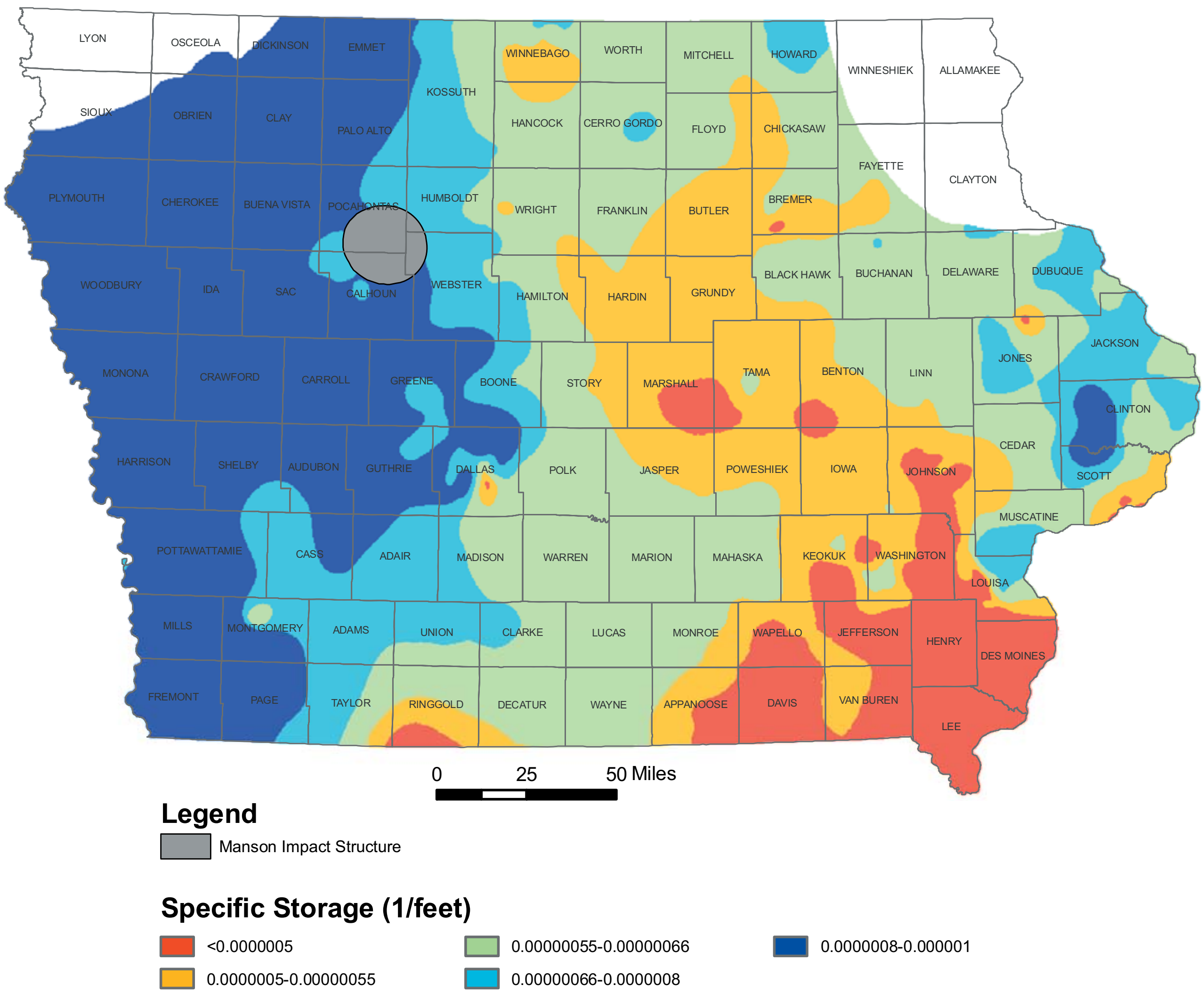

Figure 17. Specific storage distribution in the Cambrian-Ordovician aquifer in Iowa.

meters north to south. In the future, the model grid size may be reduced by simply adding more columns or rows, which is highly recommended for local-scale modeling.

Model Boundary Conditions

The model perimeter for the Cambrian-Ordovician aquifer was assigned using a combination of physical and hydraulic boundaries. Figure 15 shows the boundary conditions and includes the following:

- Flow-through boundaries were designated in southern Minnesota, northern Missouri, southwest Iowa, and western Illinois. These were represented by general head boundaries in the model. The general head values were based on the pre-development potentiometric map. General head boundaries were used in the model to represent the fluctuations in groundwater elevation over time.

- The model boundary in northeast Iowa was represented by using a constant head boundary. The values used for constant head were based on observed groundwater elevations (Figure 10).

- The direct recharge from the Lower Dakota aquifer into the St. Peter Sandstone in northwest Iowa was modeled using a general head boundary. The values used for general head were based on observed groundwater elevations (Figure 10).

- An upward hydraulic gradient from the Cambrian-Ordovician aquifer into Layer 1 was simulated using general head boundaries. The starting values for general head were assigned based on the potentiometric contour elevations shown on Figure 9.

- Net recharge values were used to simulate the recharge that passes through the base of the Layer 1. This method avoided the task of trying to include the alluvial and glacial drift hydrology, losing and gaining streams, evapotranspiration, and the large withdrawals in shallow aquifers.

Steady-State Conditions

Steady-state or pre-development conditions represent the original potentiometric elevation in the Cambrian-Ordovician aquifer prior to the installation and pumping of production wells. Thirty-nine historic water levels were found in the GEOSAM database (Iowa Geological and Water Survey sample database) and an Iowa Geological Survey Annual Report (Norton, 1927), and are assumed to represent predevelopment steady-state conditions (Table 3). The locations of these wells are shown on Figure 18. Each of these water levels was converted to elevation. If more than one water level was recorded, the oldest measured value was used.

Steady-State Calibration

Steady-state model calibration involved adjusting hydraulic properties and recharge rates to reduce model calibration error. There were no pumping wells activated during the calibration period in order to represent pre-development conditions. The calibrated recharge distribution is shown in Figure 19. The higher recharge values occur in north-central Iowa, northwest Iowa, and northeast Iowa, where the confining beds are thinner or the St. Peter Sandstone is the upper most bedrock surface. The lower recharge values in central and southwest Iowa are indicative of the thicker Pennsylvanian confining beds, and the increased depth to the Cambrian-Ordovician aquifer.

A total of thirty-nine observation wells (Table 3 and Figure 18) screened in the Cambrian-Ordovician aquifer were used in the calibration. In order to evaluate model results, the root mean square error (RMSE) of the residuals between observed and simulated water levels were used based on the following equation:

$$RMSE = \sqrt[N]{\sum (M - S)^2 / N}$$

Where

N = number of observations

M = the measured head value in meters

S = the simulated head value in meters

The smaller the RMSE value, the closer the overall match is between the simulated and observed heads. The calibration method consisted of adjusting model input parameters within hydrologically justifiable limits to minimize the RMSE values. The primary parameters that were adjusted were net recharge and hydraulic conductivity.

The hydraulic conductivity values used in the final calibration were the values obtained from aquifer pump tests (tables 1 and 2). Figure 20 shows the observed pressure head levels versus simulated values for the final steady-state calibration. The lowest value for the RMSE during the steady-state calibration was 18.3 feet. This error was considered to be relatively small compared to the size of the Cambrian-Ordovician aquifer modeled. For comparison, the RMSE for the Ogallala aquifer in north Texas was 36 feet for steady-state conditions (Anderson and Woessner, 1992), 13.6 feet for the Silurian-Devonian aquifer in Johnson County, Iowa (Tucci and McKay, 2005), and 14.8 feet for the Lower Dakota aquifer in Iowa (Gannon and others, 2008).

Table 3. Historic water levels used for pre-development calibration.

Location	W Number	Screen depth (feet)	Date	Head Elevation (feet AMSL)
Holstein	10	1465	1897	1163
Sac City	84	1211	1934	1152
Algona	175	1150	1947	1109
Klemme	265	980	1934	1037
Mason City	828	--	1939	1011
Waverly	70	742	1899	916
Sumner	24	--	1902	876
Waterloo	106	--	1905	867
Manchester	88	--	1896	773
Hampton	21	1191	1900	945
Fort Dodge	74	1431	1907	1023
Cedar Rapids #1	15	--	1888	761
Greenwood Park	248	--	1901	827
Guthrie Co.	1025	--	1942	880
Stuart #1	80	1938	1916	861
Lamoni	50	1200	1889	756
Ottumwa (Morrell)	35719	1320	1892	688
Mt. Pleasant	52	1689	1935	613
Brighton	12	1492	1923	662
Davenport	Woolen Mill	--	1890	651
Clinton	Lamb&Sons	--	1890	648
Grinnell	32	1185	1901	798
Oakdale Campus	51	1140	1928	688
Dubuque	39386	952	1924	657
Bloomfield	48628	1445	1900	660
Ackley	8169	1429	1957	915
Webster City	43	1513	1925	967
Spencer	10400	790	1959	1155
Estherville	1243	461	1941	1179
Charles City	20	787	1928	979
West Burlington	576	730	1939	575
Donnellson	184	708	1925	623
Walnut	22927	2250	1971	987
Homestead	33148	--	1895	751
Sigourney	30862	--	1901	759
Primghar	USGS point	--	--	1220
Minnesota 1	USGS point	--	--	1105
Minnesota 2	USGS point	--	--	1040
Missouri 1	USGS point	--	1940	736
Missouri 2	USGS point	--	--	669

The correlation coefficient between observed and simulated pressure head values was 0.986. The range of errors was 44.8 feet in well W-84 to 0.29 feet in Missouri Well #2, with an absolute error of 15 feet. Of the 39 measured water levels used for comparison to simulated water levels, 21 were lower than simulated values, and 18 were higher than simulated values.

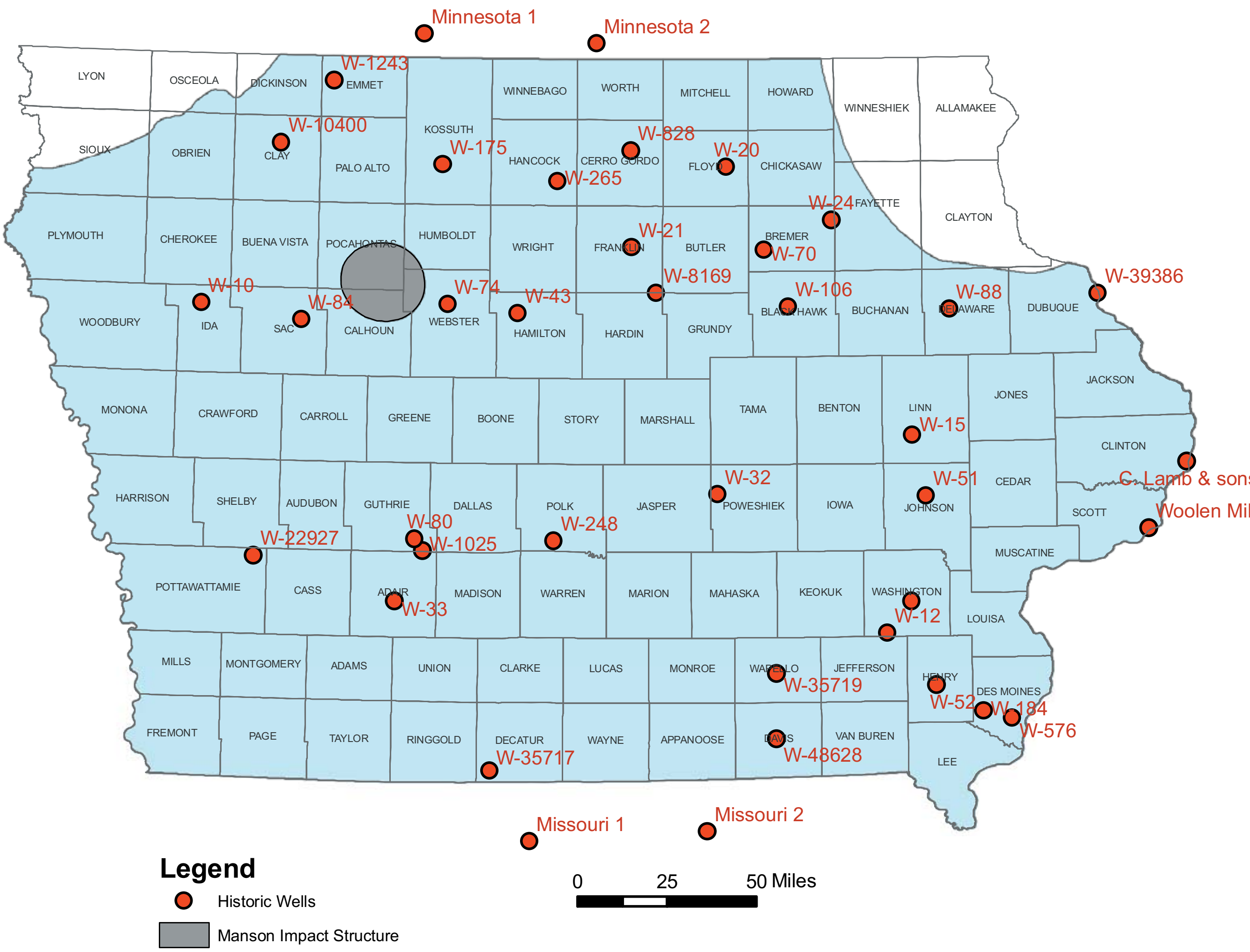

Figure 18. Observation wells used for pre-development steady-state calibration are shown in red. Well numbers correspond to W Numbers found in the GEOSAM database and Table 3.

Figure 21 represents the observed and simulated potentiometric surfaces for the Cambrian-Ordovician aquifer for steady-state, or pre-development conditions. The observed and simulated potentiometric contours were very similar in elevation.

Steady-State Sensitivity Analysis

A sensitivity analysis was conducted to observe the relative impact on the RMSE by adjusting one parameter and holding the other parameters constant. The approach used in the Cambrian-Ordovician aquifer was to vary one parameter by a certain percentage from the calibrated values and evaluate the RMSE. Table 4 presents the changes in RMSE for recharge and hydraulic conductivity based on this approach. The steady-state model appears to be much more sensitive to changes in recharge than hydraulic conductivity when the small percentages of change are used, and more sensitive to hydraulic conductivity at larger percentages of change.

The final calibrated recharge and hydraulic conductivity values were held constant in both the steady-state and transient models.

Steady-State Mass Balance Results

Groundwater enters the Cambrian-Ordovician

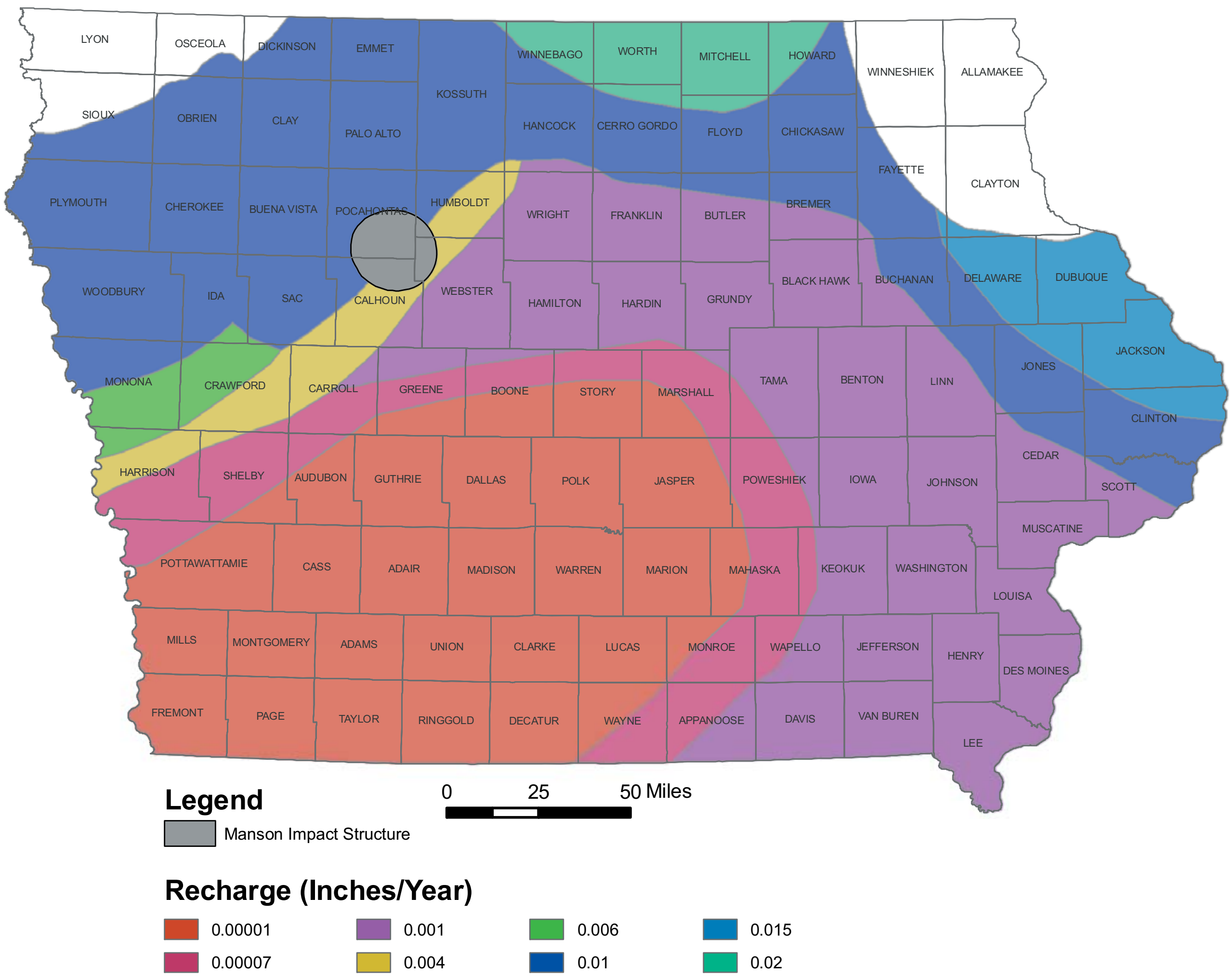

Figure 19. Net recharge or leakage into the Cambrian-Ordovician aquifer.

aquifer vertically though infiltration or leakage from overlying confining beds located throughout most of the state of Iowa. Groundwater also enters the St. Peter Sandstone directly from the overlying Lower Dakota Sandstone in northwest Iowa. Groundwater flows into (inflow) the state from Minnesota and from part of Nebraska, and exits the state (outflow) into Illinois and Missouri. The head relationships between the Cambrian-Ordovician aquifer and the underlying St. Lawrence Formation are unclear. In the model, Layer 3 was simply designated as a semi-confining bed. Groundwater discharged from the Cambrian-Ordovician aquifer into the overlying Silurian-Devonian prior to 1900s. The approximate region of upward flow is shown in Figure 8.

Figure 22 is a schematic that represents the model simulated water balance in the Cambrian-Ordovician aquifer for steady-state or pre-development conditions. Approximately 4.2 billion gallons of water per year (bgy) were recharged from overlying strata in Iowa, 2.8 bgy flowed into the state (primarily through Minnesota, and 7 bgy flowed out of the state into Illinois and Missouri, or upward into the Silurian-Devonian. Based on the vertical gradients and hydraulic conductivity of the upper confining beds, approximately 1 bgy discharged upward into the Silurian-Devo-

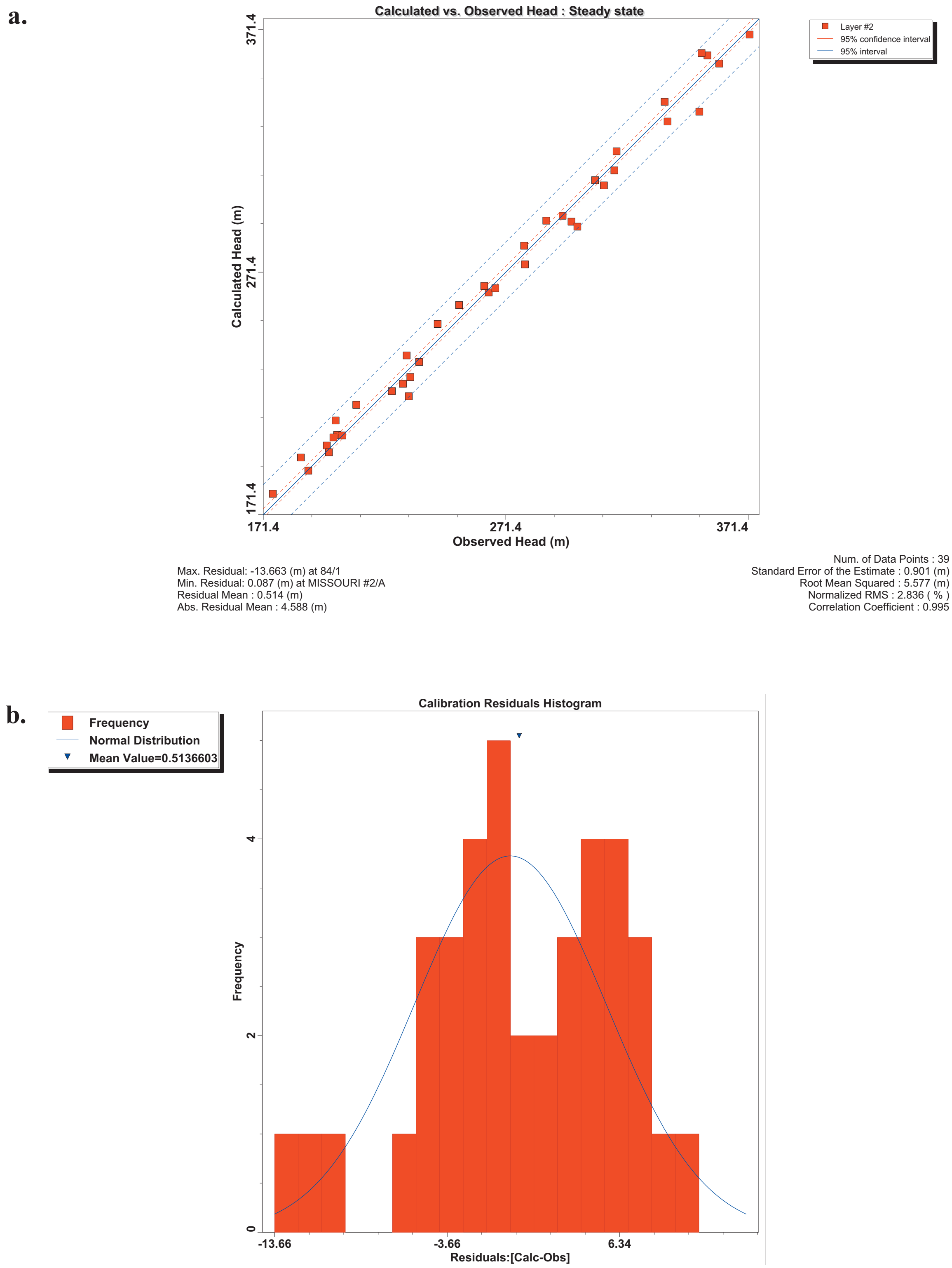

Figure 20. Steady-state (predevelopment) calibration results and distribution of simulated versus observed groundwater elevations.

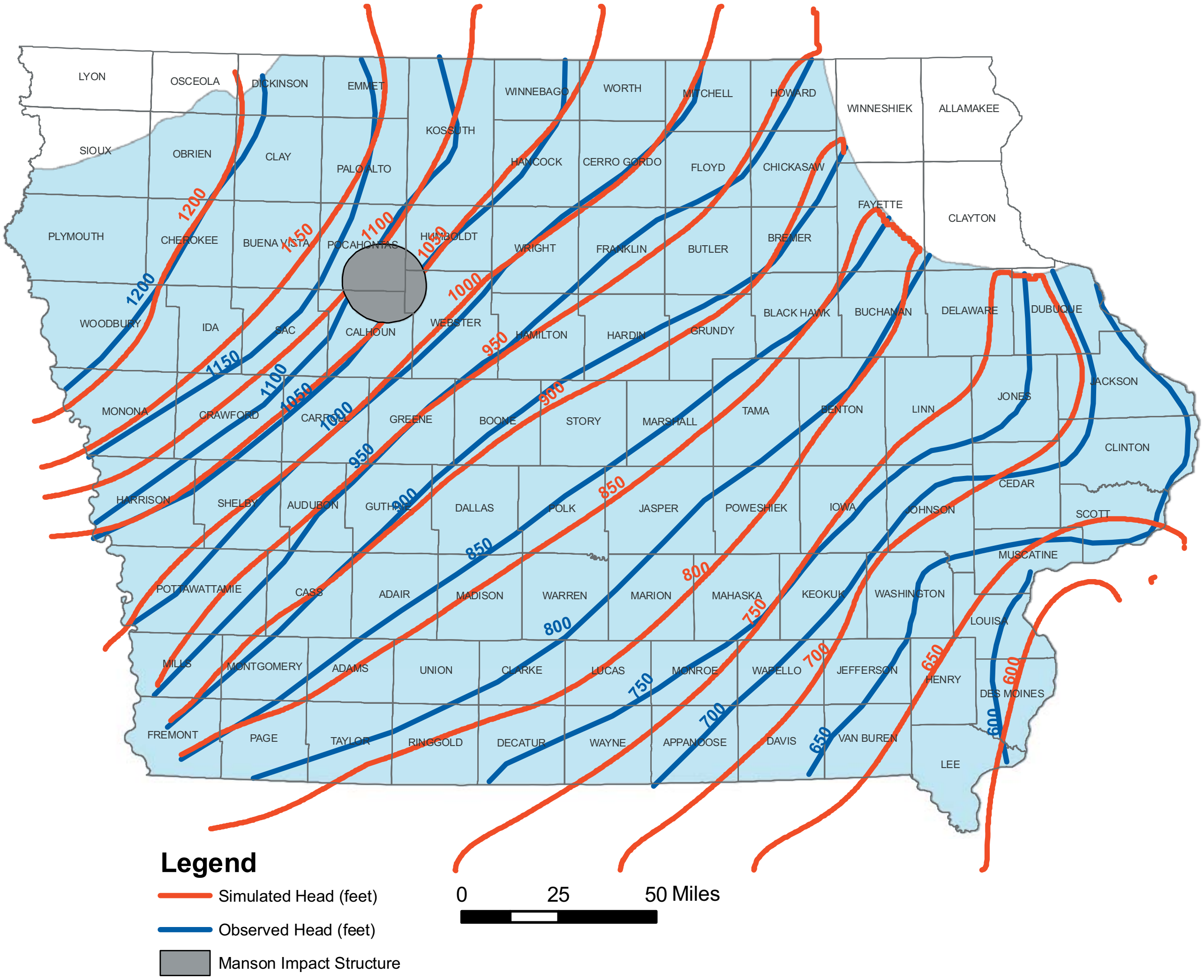

Figure 21. Steady-state (predevelopment) potentiometric surface elevations observed versus simulated.

nian, and 6 bgy flowed out of the state. Horick and Steinhilber (1978) estimated the combined recharge and inflow at between 6.5 bgy and 7.5 bgy, and the outflow at -6.5 bgy and -7.5 bgy, which are very similar to the Visual MODFLOW simulation.

Transient Model

The transient model was identical to the steady-state model except for the addition of transient production well data. The historical pumping data from 1901 to 1990 was obtained from the USGS model produced by Burkart and Buchmiller (1990). The pumping data and observation well results were divided into 10-year time periods starting in 1901. The pumping data from year 1990 through 2007 included public wells, industrial wells, and other permitted users with daily usage greater than 25,000 gallons. This data was downloaded from the IDNR Water Use Database and included a total of 148 water-use permits. If a permit had multiple active wells the pumping rate was equally assigned to each well. Yearly averages were used for pumping rates in the model to evaluate the over all groundwater availability of the regional Cambrian-Ordovician aquifer in Iowa. In the future, seasonal or monthly pumping

Table 4. Sensitivity analyses for steady-state model.

Calibration Parameter	Percent Adjustment	RMSE (meters)	RMSE (feet)	Change From Calibrated (feet)
Recharge	0%	5.58	18.29	0
	10%	6.16	20.21	1.87
	-10%	6.06	19.87	1.54
	25%	6.95	22.78	4.43
	-25%	7.63	25.04	6.69
	50%	10.60	34.77	16.43
	-50%	11.29	37.02	18.70
Hydraulic Conductivity	0%	5.58	18.29	0
	10%	5.94	19.47	1.15
	-10%	5.76	18.90	0.56
	25%	6.90	22.65	4.30
	-25%	7.84	25.71	7.38
	50%	8.60	28.22	9.87
	-50%	18.68	61.25	42.90

rates can easily be added to evaluate local well interference and sustainability issues. The spatial distribution of the water use permits are shown in Figure 23. The production data can be found in appendices B and C.

The increase in pumping rates over time is shown in Figure 24. The totals include water-use from wells completed in two or more aquifers. The leveling off of water use from 1990 to 2000 is related to the reduction in water-use in the Des Moines metro area and Dubuque. The drop in the Des Moines area is related to the cities of Waukee, Grimes, and Ankeny purchasing some or all of their water from Des Moines Water Works. City of Ankeny Well 4 is currently being used as an aquifer storage and recovery well (ASR). A notable increase in water use was reported in Coralville, North Liberty, Marion, Fairfield, Washington, Fort Dodge, and Mount Pleasant, which off-set the stabilization in Des Moines. An increase of almost 3 billion gallons per year (bgy) was observed from 2000 to 2007 (13% increase). Much of this increase is related to new water use permits issued to ethanol plants in the Mason City, Dyersville, Fairbanks, Cedar Rapids, Ackley, and Albia areas. From 1990 to 2007, the Fort Dodge-Webster City area had a 54% increase in water use, and the Johnson-Linn County area had a 46% increase.

Time Series Data

The use of time series water level data is extremely valuable for evaluating the transient response of groundwater flow models to pumping stress. For the Cambrian-Ordovician aquifer model, a total of eleven (11) observation wells had time series water level data (Figure 25). One of the difficulties in obtaining time series data was finding a representative observation well with historical water level measurements. Many potential observation wells are also used as production wells. The use of production wells as observation wells can potentially over-estimate the decline in water levels in a regional aquifer by adding extra drawdown caused by a production well itself. Figure 26 illustrates the influence of pumping on the time series data in the City of Iowa City well W-13136, which was used extensively by Iowa City from 1990 to 2004. Approximately 134 feet of drawdown was observed in W-13136 from 1990 to 1999, and almost 82 feet of recovery was observed from 1999 to 2004. Compare the time series data from Well W-13136 with that of University of Iowa Well W14453, which is located less than one-half mile to the south (Figure 27). Well W-14453 is used very infrequently by the University of Iowa, and is much more representative of

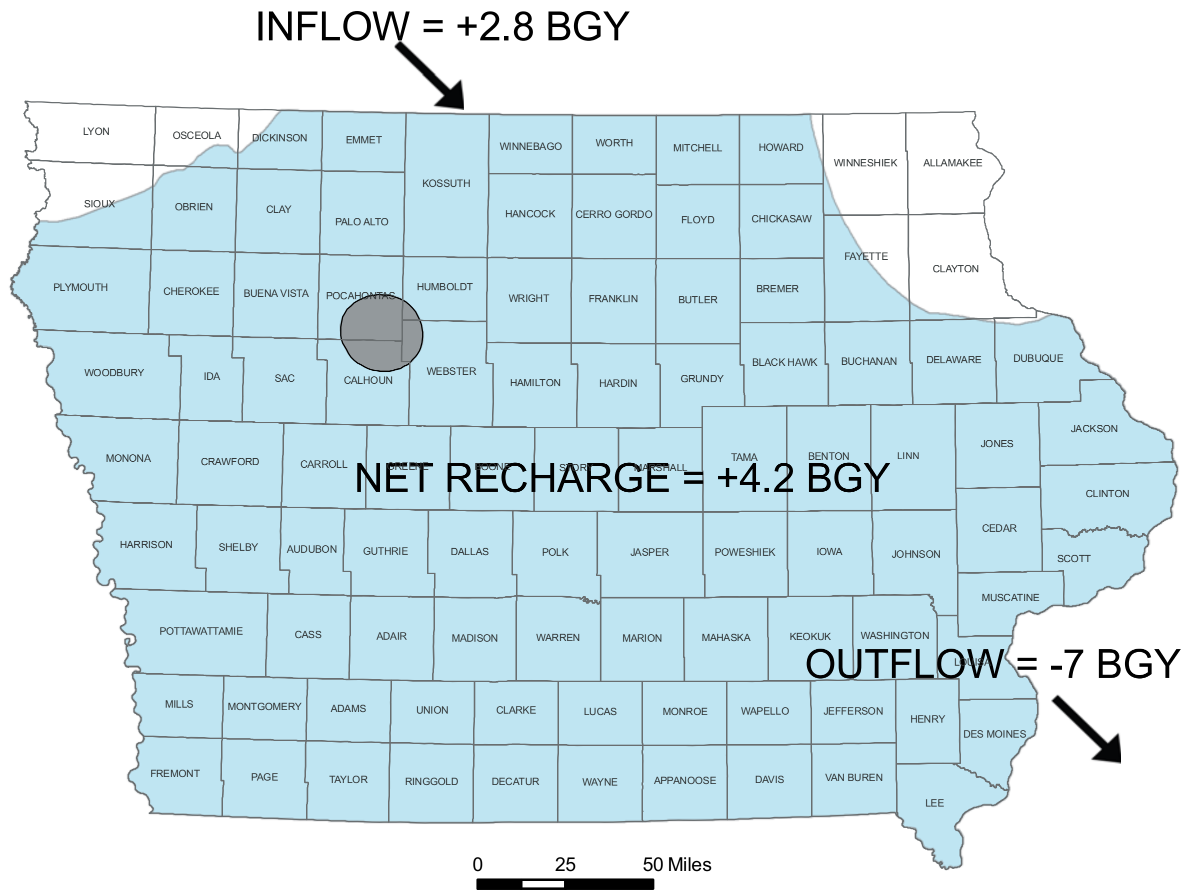

Figure 22. Water balance map for steady-state (predevelopment) conditions.

the drawdown in the aquifer versus production well W-13136.

The graphs of the times series data can be found in Appendix D. Based on the time series data, the simulated results of the transient model correlate relatively well with the observed results. The drawdown responses in the simulated results were very similar to the observed results in most of the observation wells. Some of the differences in elevation may be related to well location and groundwater surface elevation. Datum elevation differences of plus or minus 25 feet or more may simply be related to inaccuracies in well location. Some of the other differences may also be attributed to active production wells being used as observation wells.

In addition to the time series data, individual static water levels were obtained from the GEOSAM database. Most of the GEOSAM data provided a one-time groundwater elevation value at the time the wells were drilled. Figures 28, 29, 30, and 31 show the observed versus the simulated head values for 1960, 1980, 1997, and 2007. The correlation coefficients in 1997 and 2007 are both approximately 0.98, and the RMSEs are 9.45 meters (31.0 feet) in 1997 versus 10.61 meters (34.8 feet) in 2007.

Simulated potentiometric maps for 1960, 1980, 1997, and 2007 are shown in figures 32, 33, 34, and 35. These simulated potentiometric maps correlate well to the observed data from 1975, 1990s, and 2000s (figures 11 through 13). The potentiometric maps show steady decline in water levels caused by the increase in pumping rates

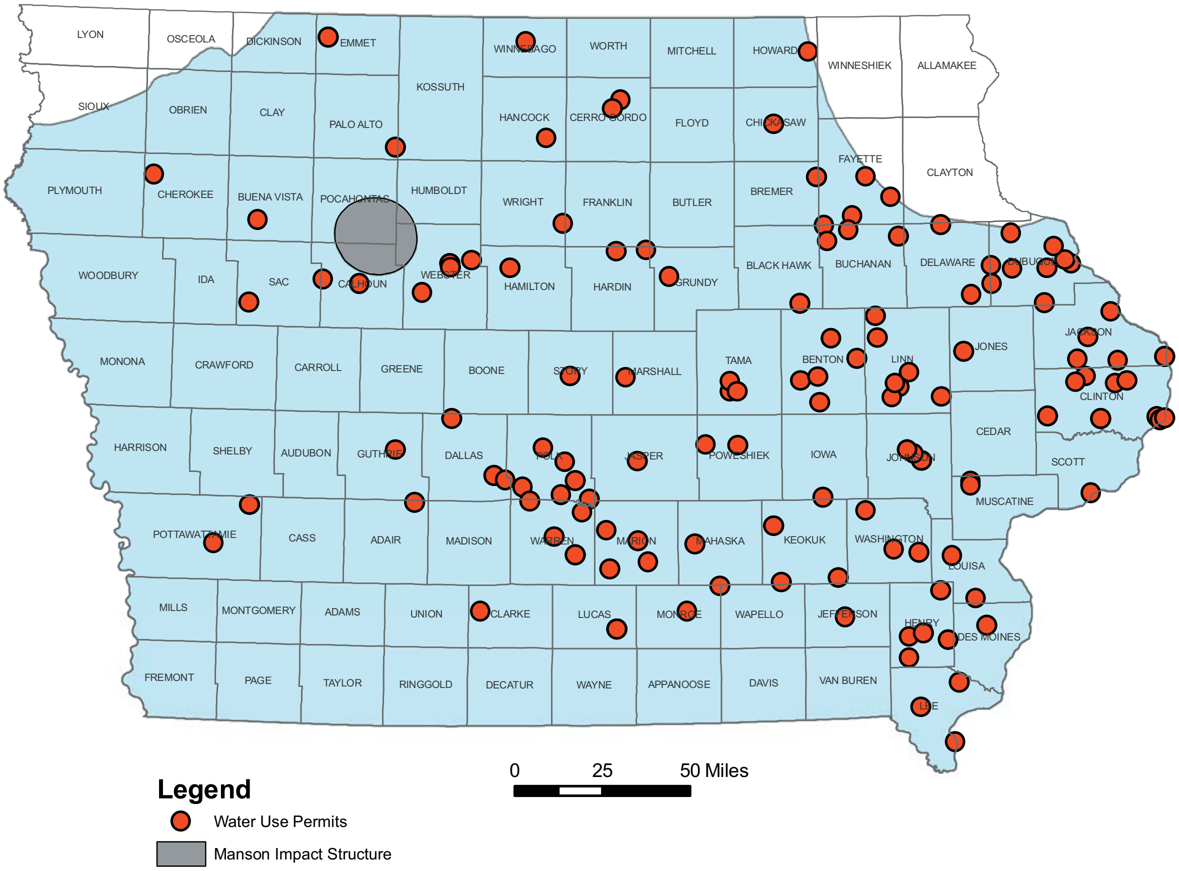

Figure 23. Water-use permits used for transient simulation.

over time. The most prominent zones of drawdown occur in Des Moines, Fort Dodge, Mason City, east-central Iowa, and southeast Iowa.

Transient Sensitivity Analysis

A sensitivity analysis was conducted to observe the relative impact on the RMSE by adjusting one parameter and holding the other parameters constant. The approach used in the Cambrian-Ordovician aquifer was to vary one parameter by a certain percentage from the calibrated values and evaluate the RMSE. Table 5 presents the changes in RMSE for recharge and hydraulic conductivity based on this approach. The transient model appears to be much more sensitive to changes in hydraulic conductivity than recharge.

Decline in Water Levels (Drawdown) Over Time

Iowa Administrative Code Chapter 52.4(3) states that water levels are not to decline more than 200 feet from the 1975 baseline in any high-use area (State Of Iowa, 1998). The potentiometric surface map of the Cambrian-Ordovician aquifer prepared by Horick and Steinhilber (1978) is currently used as the baseline. Figures 36 and 37 show the drawdown from the 1975 baseline based on the simulated potentiometric maps from 1997 and 2007. Increased pumping rates have resulted in drawdowns that exceed 120 feet in Johnson-Linn counties and Fort Dodge/Webster City regions for 2007. The pumping rates in the Fort Dodge/Webster City and Linn-Johnson County areas have increased by 54% and 46% respectively, from 1990 to 2007.

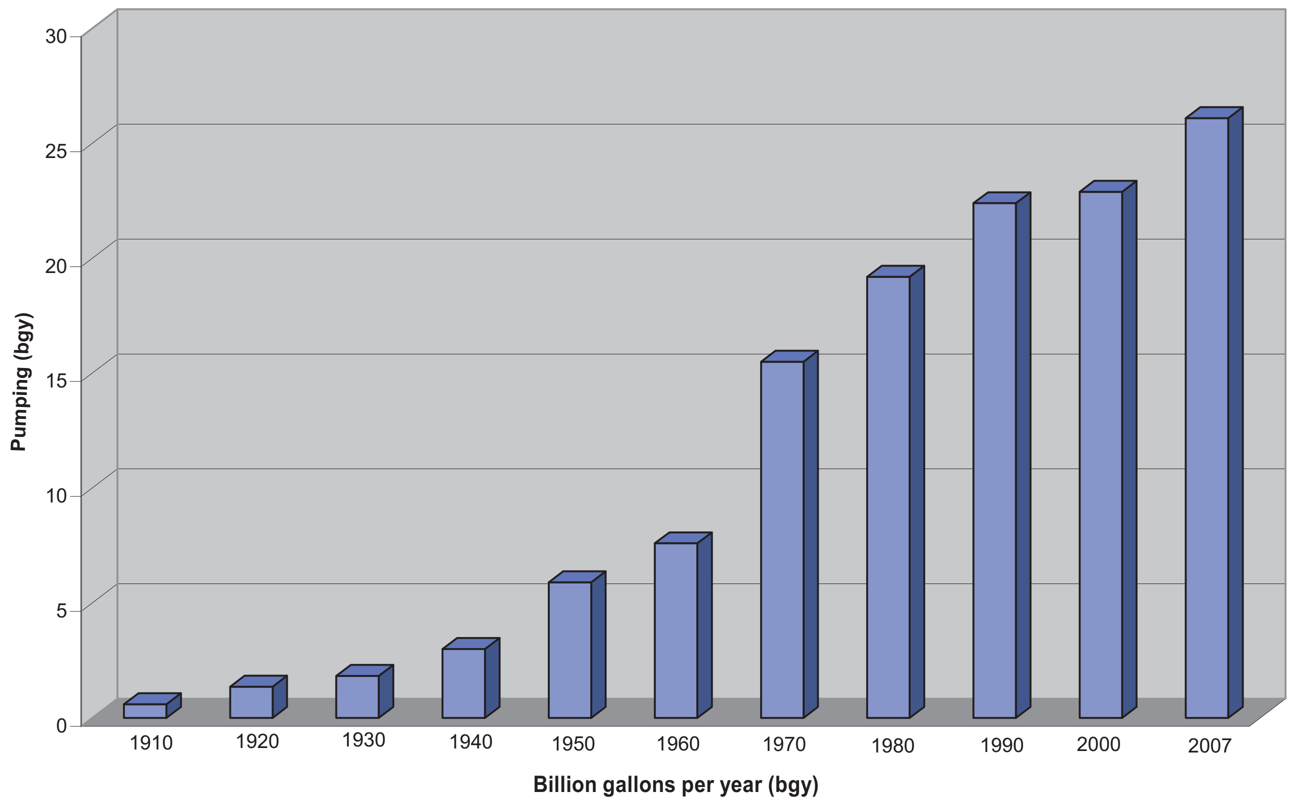

Figure 24. Water-use data for the Cambrian-Ordovician aquifer from 1910 to 2007. Data includes total yearly volume pumped in billion gallons per year (bgy). Totals include wells completed in more than one aquifer.

Figures 38 and 39 show the drawdown from the 1975 baseline based on potentiometric maps generated from data collected in observation wells from 1990-1999 (Figure 12) and 2000-2008 (Figure 13). Figures 38 and 39 correlate well with the simulated drawdowns shown in figures 36 and 37. Figures 38 and 39 represent observed groundwater level data collected during non-pumping periods (representing static water levels). Figures 36 and 37 represent simulated groundwater elevations with continuous average daily pumping rates from wells open in the Cambrian-Ordovician aquifer.

The additional drawdown in the Estherville area shown in figures 36 and 37 is mostly a false drawdown that was not observed in figures 38 and 39. The City of Estherville has been pumping from the Cambrian-Ordovician aquifer since 1941. The estimated daily pumping rate in 1977 in Estherville from wells open in the Cambrian-Ordovician aquifer was 1.9 million gallons per day (mgd). The difference in observed versus simulated groundwater elevations in the Estherville area is most likely related to pumping versus static water level readings.

Based on the drawdown contours in the Nevada and Tama areas, a rebound of approximately 20 feet occurred from 1977 to 2007. The Mason City area had 40 feet of rebound in the potentiometric surface from 1977 to 1997, but from 1997 to 2007 the increased pumping from Interstate Power and Golden Grains Ethanol caused most of this rebound to disappear.

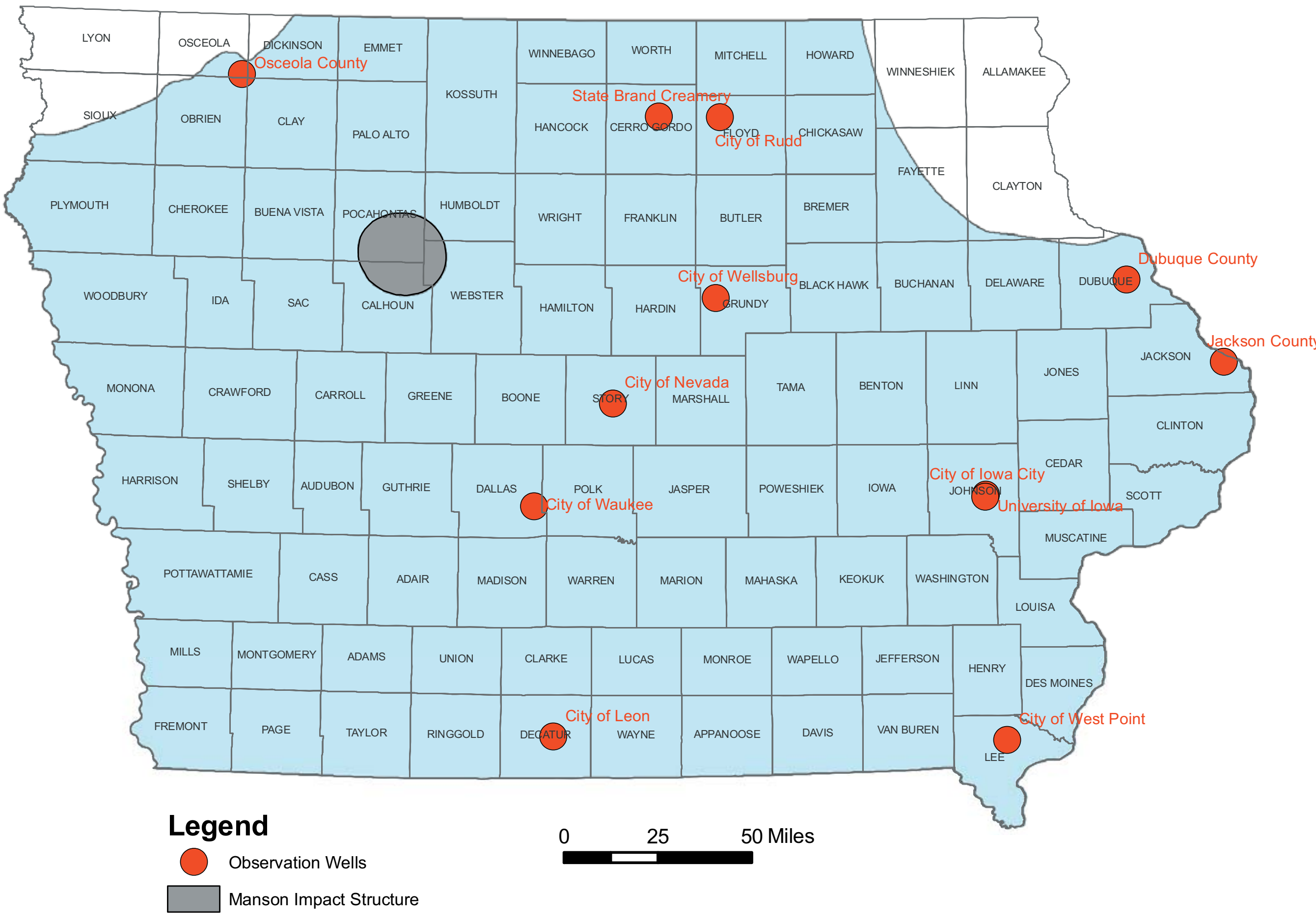

Figure 25. Observation well locations for time series data wells.

Transient Mass Balance Results

Figure 40 is a schematic that represents the model simulated water balance in the Cambrian-Ordovician aquifer for the year 2007. Approximately +4.3 billion gallons per year (bgy) were leaked vertically downward into the system, +15.1 bgy flowed into the state (primarily through Minnesota), -4.5 bgy flowed out of the state into Illinois and Missouri, -20.1 bgy were removed by pumping, and 5.2 bgy were derived from storage. The following equation can be used to estimate the regional loss in head:

$V_s = S (A) \Delta H/\Delta t$ ***(Equation 1)***

Where:

V_s=Volume released from storage (feet cubed per year)

S=Storage coeffient (dimensionless)

A=Area (feet squared)

ΔH=Change in head (feet)

Δt=Change in time (1 year)

Solving for ΔH gives us:

$\Delta H= (V_s)(\Delta t)/(S)(A)$ ***(Equation 2)***

Using a storage coefficient of 3×10^{-4} corresponds to a regional head loss of approximately -2.1 feet per year (2007). Horick and Steinhilber (1978) estimated a regional head loss of between -1.8 and -2.4 feet per year in 1975.

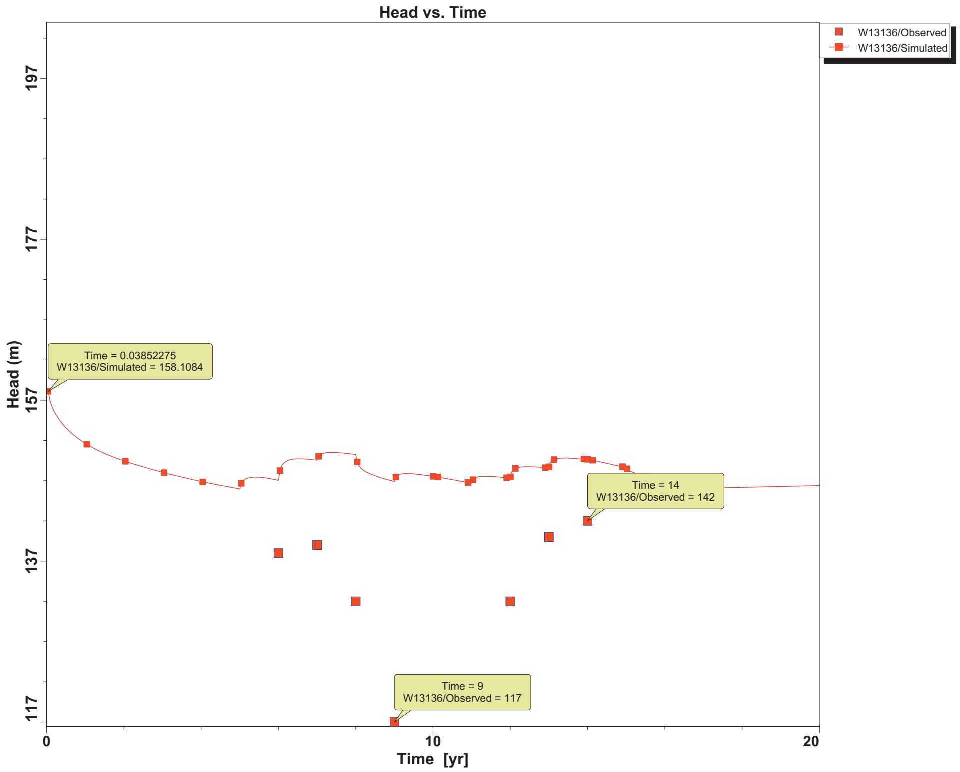

Figure 26. Time series data for observation well W-13136 (City of Iowa City) showing the influence of active pumping on the groundwater elevation.

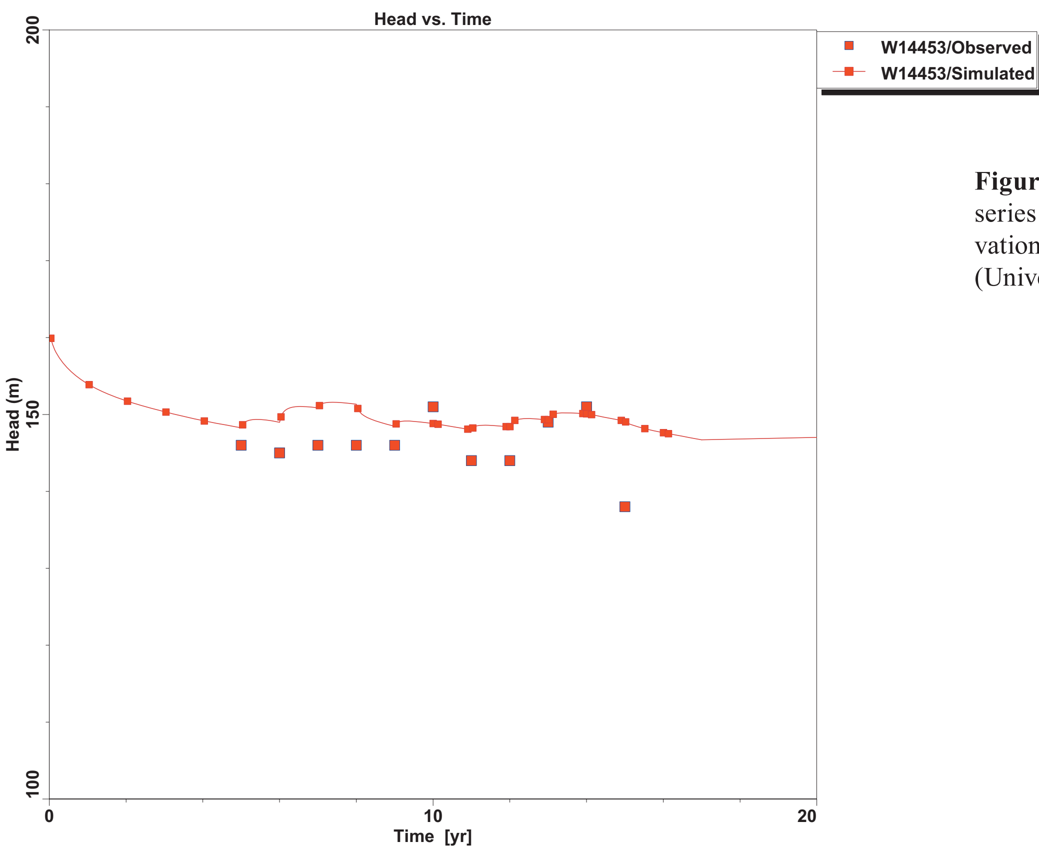

Figure 27. Time series data for observation well W-14453 (University of Iowa).

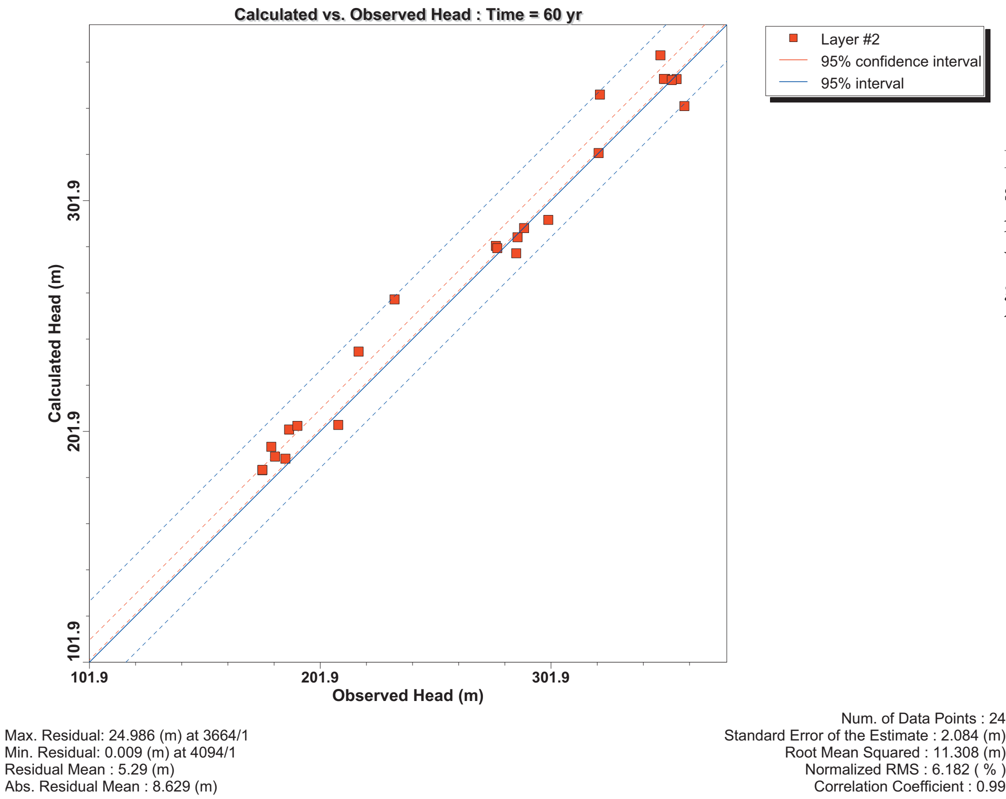

Figure 28. Transient calibration results of simulated versus observed groundwater elevations for 1950 to 1960.

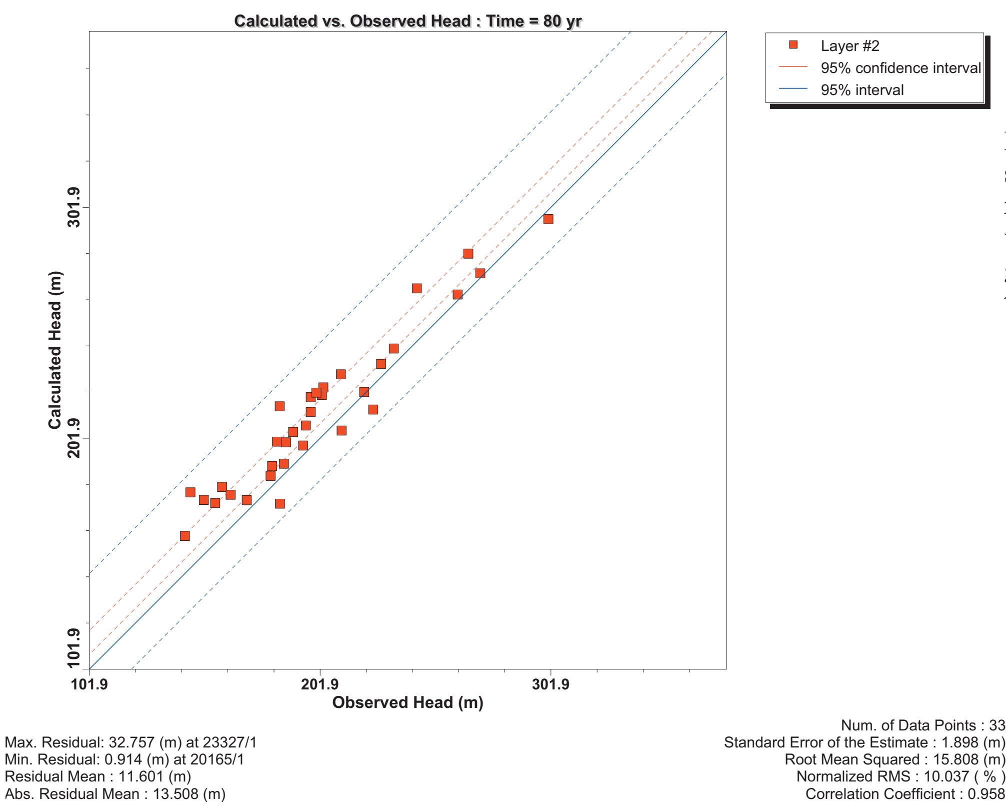

Figure 29. Transient calibration results of simulated versus observed groundwater elevations for 1970 to 1980.

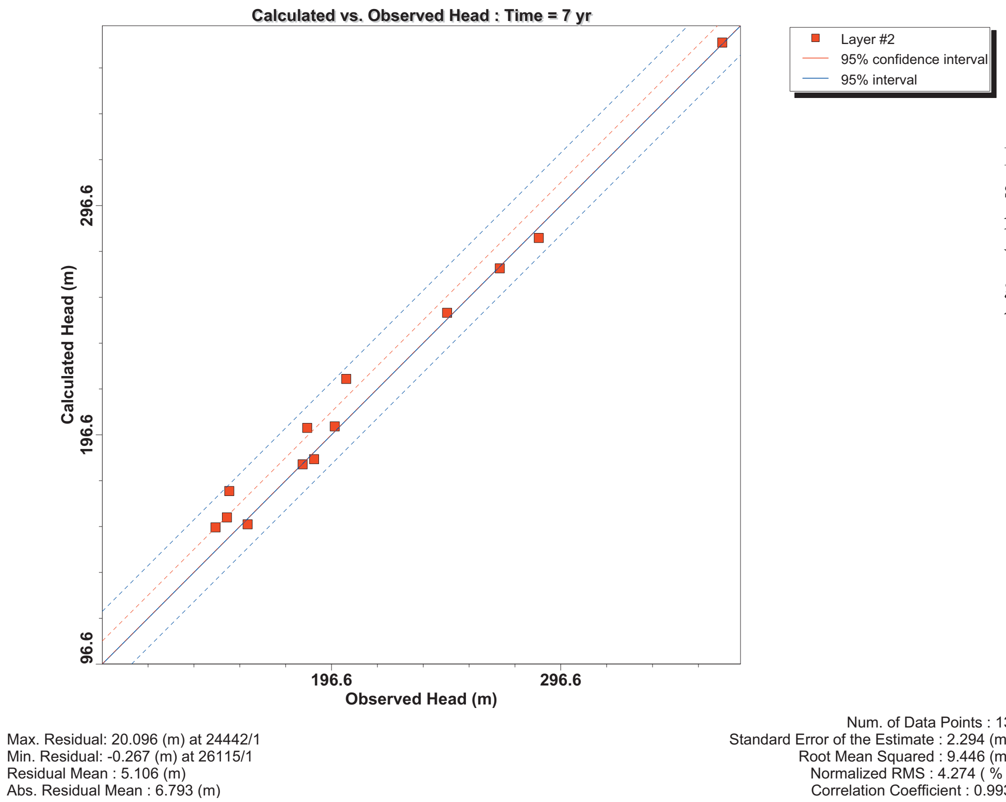

Figure 30. Transient calibration results of simulated versus observed groundwater elevations for 1997.

ZONE BUDGETING

Zone budgeting is a powerful management tool in Visual MODFLOW Version 4.3 that allows the user to conduct water balance analyses within specified zones or areas. This is especially useful in major producing areas to evaluate permit allocation questions and to assess the groundwater available for future development. The use of zone budgeting reduces the risk of over-allocation and the potential for severe well interference and/or groundwater mining.

Zone Locations

A total of seven zones were delineated in the Cambrian-Ordovician aquifer as shown in Figure 41. The zones were chosen for their relatively high current pumping rate. The shape of each polygon was drawn to include the various water use permits in each zone. An attempt was made to try and make the area of each zone approximately equal.

Table 6 summarizes the water budgets for each of the seven zones for water year 2007. The top three water usage zones include:

Cedar Rapids/Marion/Iowa City – 3.1 bgy
Des Moines – 2.46 bgy
Clinton – 2.1 bgy (does not include pumpage from other aquifers)

The pumping rates in the Mason City, Fort Dodge, Clinton, and Dubuque pumping centers were adjusted based on whether the wells in each zone were dual completion wells (open or screened in more than one aquifer). In addition to the Cambrian-Ordovician aquifer, some of the wells in each of these zones were open in the deeper Cambrian sandstones. The Mason City Zone also had wells open in the Devonian, Ordovician, and Cambrian aquifers in addition to the Cambrian-Ordovician aquifer.

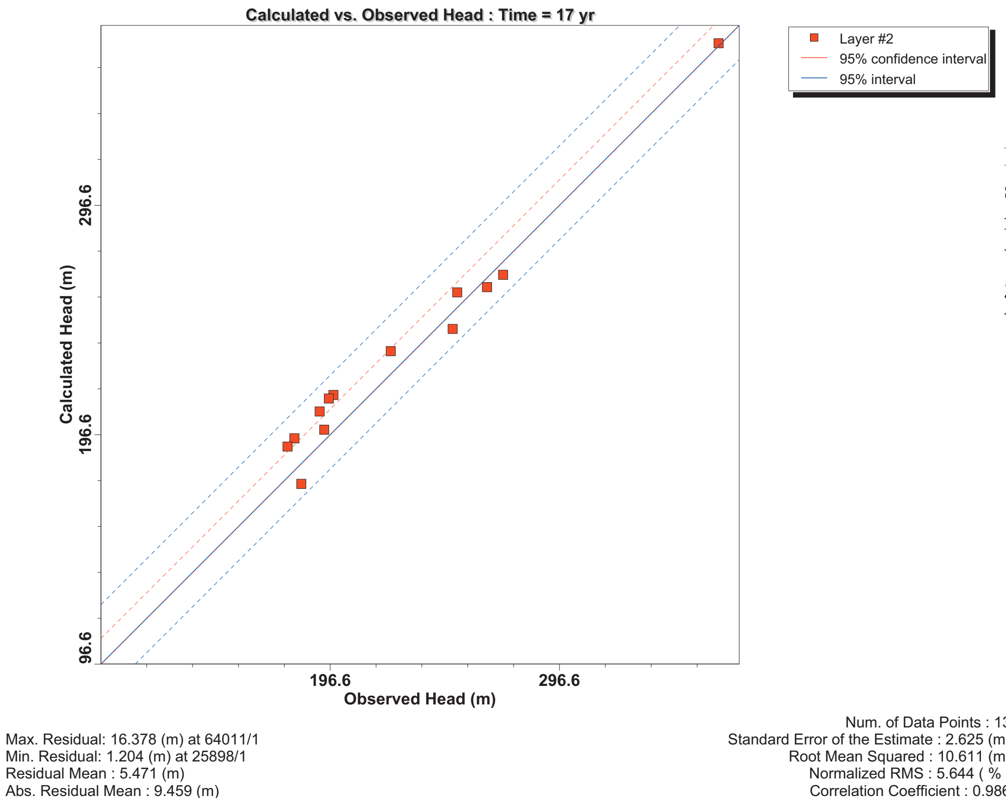

Figure 31. Transient calibration results of simulated versus observed groundwater elevations for 2007.

From Equation 2 (described earlier), and the calculated storage obtained from the model, the decline in pressure head per year for water year 2007 can be estimated. The average drop in head was highest in the Cedar Rapids/Marion/Iowa City Zone with 7.7 feet. This is followed by Fort Dodge/Webster City at 5.6 feet, and Des Moines at 4.7 feet. If the pumping rates remain constant, the rate of drawdown will decrease over time. The next section will address future head loss and drawdown based on various pumping rate scenarios over a 20-year period.

Equation 2 does not reflect the possible upward contribution of groundwater from the underlying St. Lawrence and Lone Rock formations. In addition, cascading water from dual completion wells, poorly constructed wells, damaged wells, and possible fractures in the overlying and underlying confining units, may all reduce the head loss in the Cambrian-Ordovician aquifer.

PREDICTIONS FOR FUTURE WATER USAGE

One of the most powerful uses of a calibrated regional groundwater flow model is using the model to predict future impacts to an aquifer based on various pumping scenarios. The uncertainty in projected pumping rates may be the most important factor in determining the accuracy of the flow model (Konikow, 1986). Calibration error that is related to allocating pumping from too many or too few wells is compounded if the projection of total future pumping does not prove accurate (Dutton and others, 2001).

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.

Four different future water usages scenarios

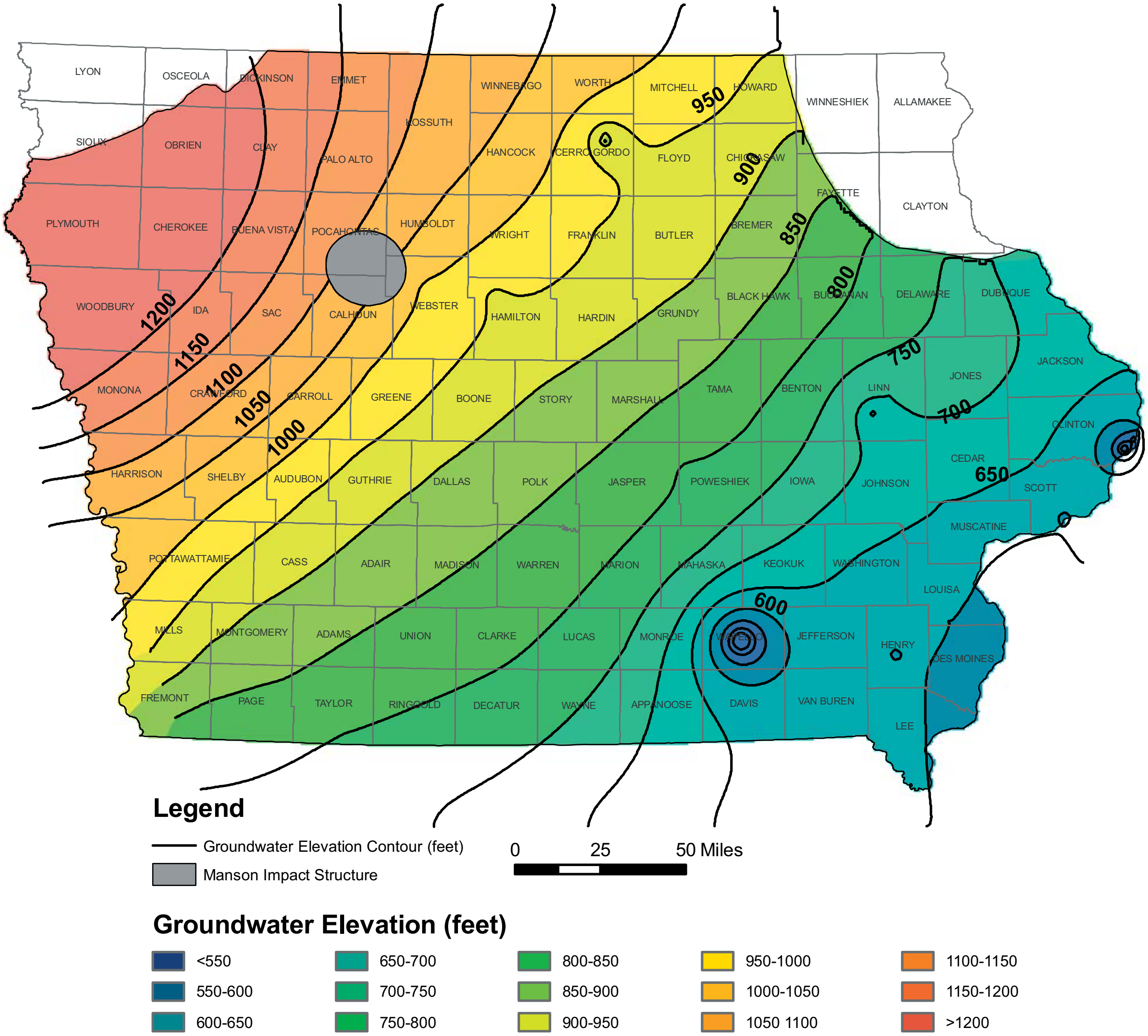

Figure 32. Simulated (modeled) potentiometric surface elevation 1960.

were simulated using the calibrated transient model. Each of these simulations and the assumptions that were used are described in the following sections.

Future Usage

The first water usage scenario assumes a constant or static pumping rate for 20 years based on 2007 values. The "low future" usage prediction assumes a relatively slow population and industrial growth, which limits the future usage to a 25% increase in pumping rates compared to 2007 values. The "medium future usage" prediction assumes a 50% increase in pumping rates from 2007 values, and the "high future usage" prediction assumes a 100% increase in pumping rates. The simulated pumping period is 2009 to 2029 for all four scenarios.

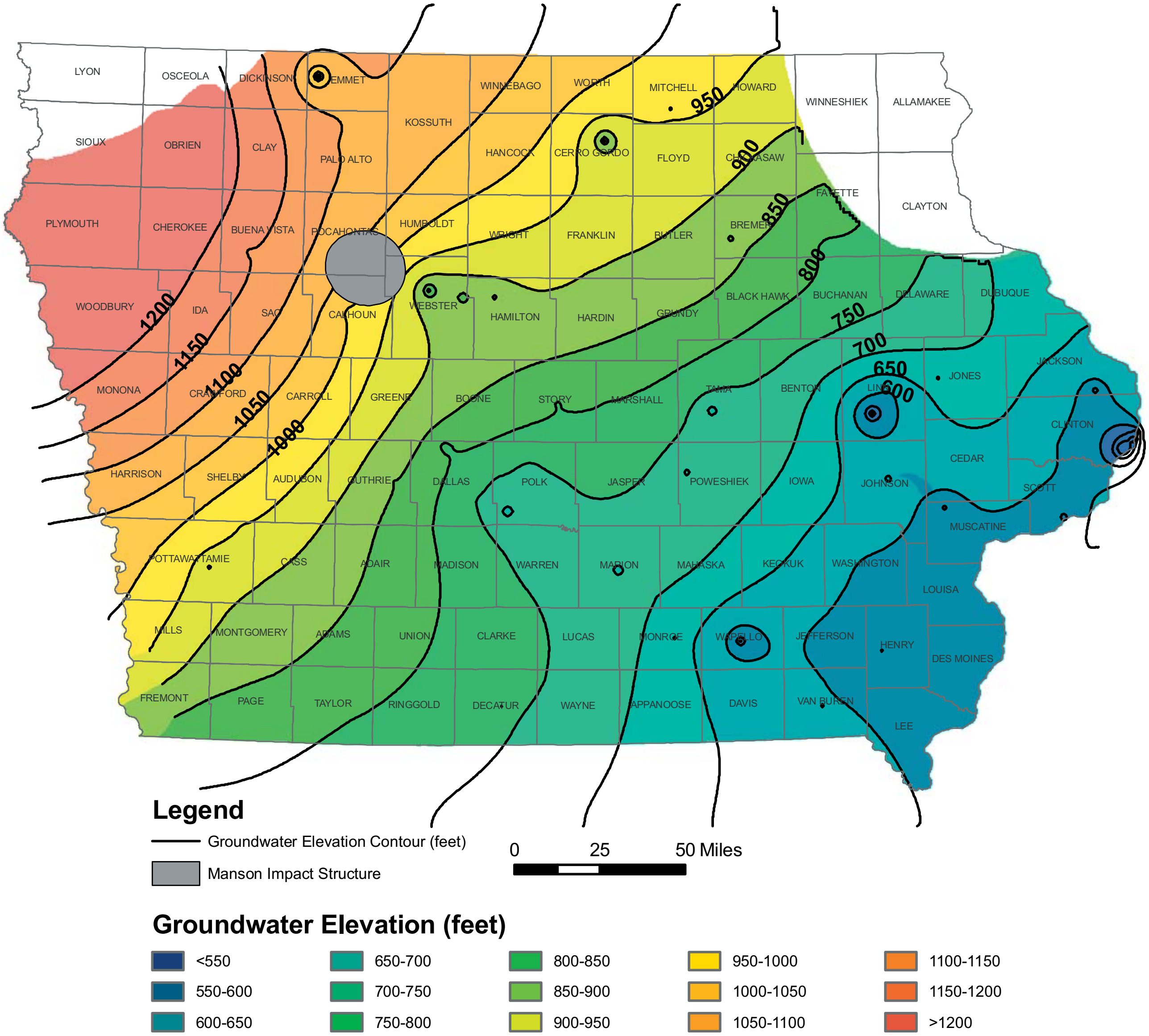

Figure 33. Simulated (modeled) potentiometric surface elevation 1980.

Prediction Results

For comparison purposes additional drawdown maps were used for each of the four predictive scenarios. The initial head values used in each model simulation were the calculated head values from December 2007.

Constant Future Water-use Results

Figure 42 shows the simulated additional drawdown for the constant future usage prediction in 2029 compared to 2009, and Figure 43 shows the simulated additional drawdown compared to the Horick and Steinhilber (1978) potentiometric map. The most significant areas of drawdown occur in the Fort Dodge/Webster City area, Cedar Rapids/Marion area, Iowa City/Coralville/North Liberty area, and Grinnell area. Even with constant pumping rates, the drawdown would likely exceed the 200-foot limit established in Iowa Administrative code Chapter 52.4(3)

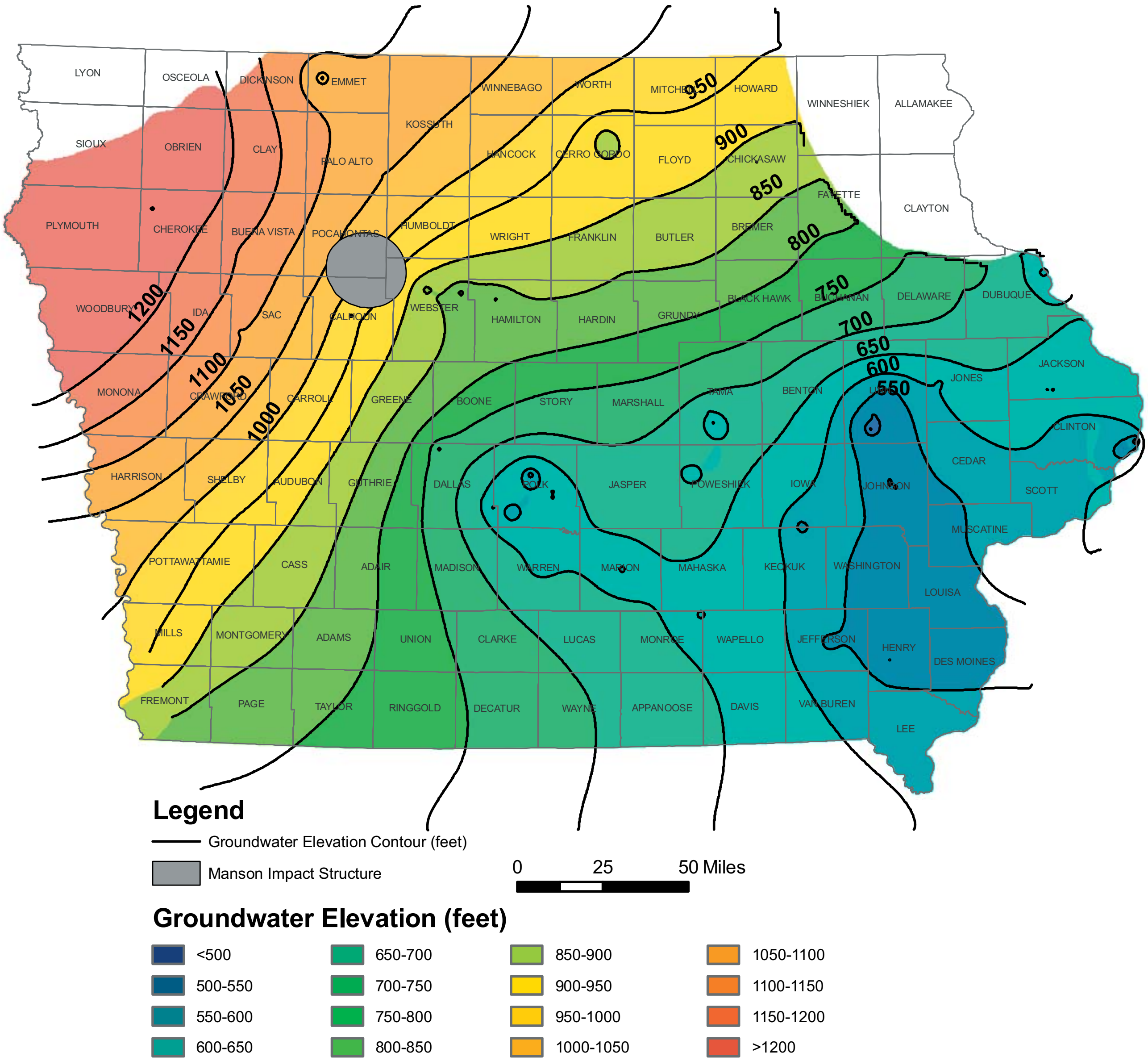

Figure 34. Simulated (modeled) potentiometric surface elevation 1997.

in the Fort Dodge area. There is some additional expansion of pumping rates in the other areas.

Low Future Water-use Results

Figure 44 shows the simulated additional drawdown for the low future usage prediction in 2029 compared to 2009, and Figure 45 shows the simulated additional drawdown compared to Horick and Steinhilber (1978) potentiometric map. The most significant areas of drawdown occur in the Fort Dodge/Webster City area, Cedar Rapids/Marion area, Iowa City/Coralville/North Liberty area, Knoxville, Albia, West Des Moines, and Grinnell area. Even with relatively slow growth in the pumping rates, the drawdown would likely exceed the 200-foot limit established in Iowa Administrative code Chapter 52.4(3) in the Fort Dodge/Webster City and Marion areas.

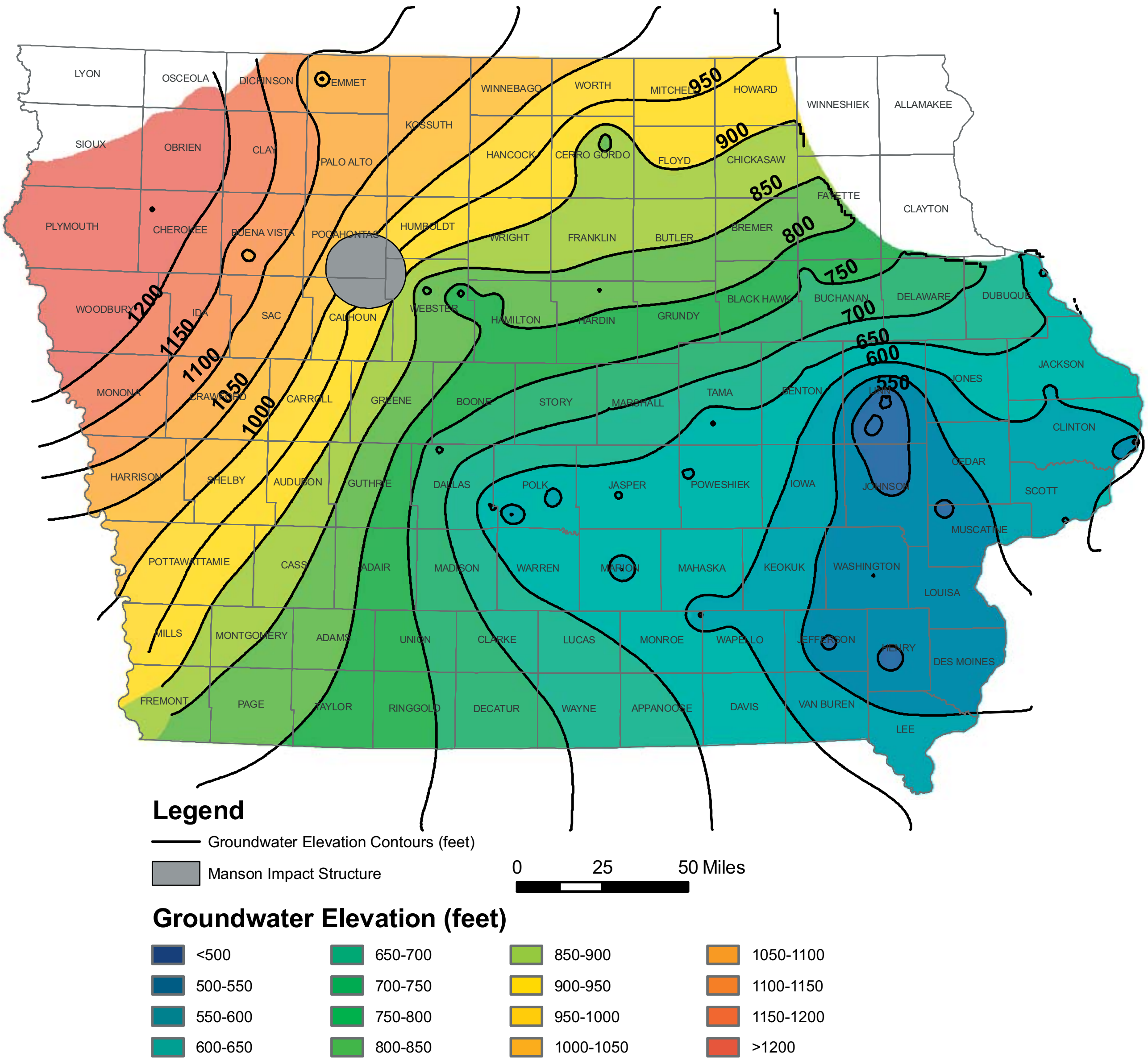

Figure 35. Simulated (modeled) potentiometric surface elevation 2007.

Medium Future Water-use Results

Figure 46 shows the simulated additional drawdown for the medium future usage prediction in 2029 compared to 2009, and Figure 47 shows the simulated additional drawdown compared to the Horick and Steinhilber (1978) potentiometric map. In addition to the Cedar Rapids/ Marion, and Fort Dodge/Webster City areas, the Iowa City/Coralville/North Liberty, West Des Moines, Perry, Knoxville, Albia, and Grinnell areas would also likely exceed the Iowa Administrative Code 200-foot drawdown limit.

High Future Water-use Results

Figure 48 shows the simulated additional drawdown for the high future usage prediction in 2029 compared to 2009, and Figure 49 shows the simulated additional drawdown compared to

Table 5. Sensitivity analyses for transient model.

Calibration Parameter	Multiplier Adjustment	RMSE (meters)	RMSE (feet)	Change From Calibrated (feet)
Recharge	none	10.94	35.88	0
	2 X	11.36	37.26	1.38
	0.5 X	11.35	37.23	1.35
	10 X	28.49	93.45	57.57
	0.1 X	11.64	38.19	2.31
Hydraulic Conductivity	none	10.94	35.88	0
	2 X	12.44	40.80	4.92
	0.5 X	15.95	52.32	16.44
	10 X	21.36	70.06	34.18
	0.1 X	49.29	161.67	125.79

the Horick and Steinhilber (1978) potentiometric map. In addition to the exceedences previously mentioned, the Fairfield, Washington, Mount Pleasant, Mason City, Fairbanks, Newton, West Liberty, and Tama areas would likely exceed the Iowa Administrative Code 200-foot drawdown limit.

Groundwater Availability Map

Using the combined results for zone budgeting and the various future water use predictive scenarios, an evaluation of future groundwater available was estimated for the Cambrian-Ordovician aquifer. Figure 50 and Table 6 represent the potential additional groundwater availability for the Cambrian-Ordovician aquifer. The Fort Dodge/Webster City area will exceed the Iowa Administrative Code Chapter 52.4(3) 200-foot drawdown limit in 2029 based on Figure 43 and has limited future groundwater availability. The Cedar Rapids/Marion/Iowa City and Des Moines areas have some groundwater availability, but may need to rely on other sources of water to meet future population and industrial growth. Northeast and north-central Iowa, because of the high recharge rates, have additional groundwater availability that ranges between 1 and 1.6 bgy.

LIMITATIONS OF THE MODEL

As with all models, limitations exist regarding the evaluation of potential future use scenarios. Models are tools to assist with water use planning and water allocations. The following are known limitations:

- A few of the production wells used in the model are open in multiple aquifers (Mason City, Clinton, and Dubuque). The actual pumping rates that could be attributed solely to the Cambrian-Ordovician aquifer were based on pump test results at one location in Clinton, Iowa. Site specific withdrawals may vary from the values used in our model.

- Additional production wells may need to be added if local scale model simulations are conducted. Many of the water use permits do not specify the total number of wells screened in the Cambrian-Ordovician aquifer, or the percentage of water pumped from each well. A centroid point was used to represent a water use permit with multiple wells and little or no information concerning the actual number, specific locations, or specific production by well. When an actual number of wells and locations were known, but the percentage of water use was unknown, pumping rates were

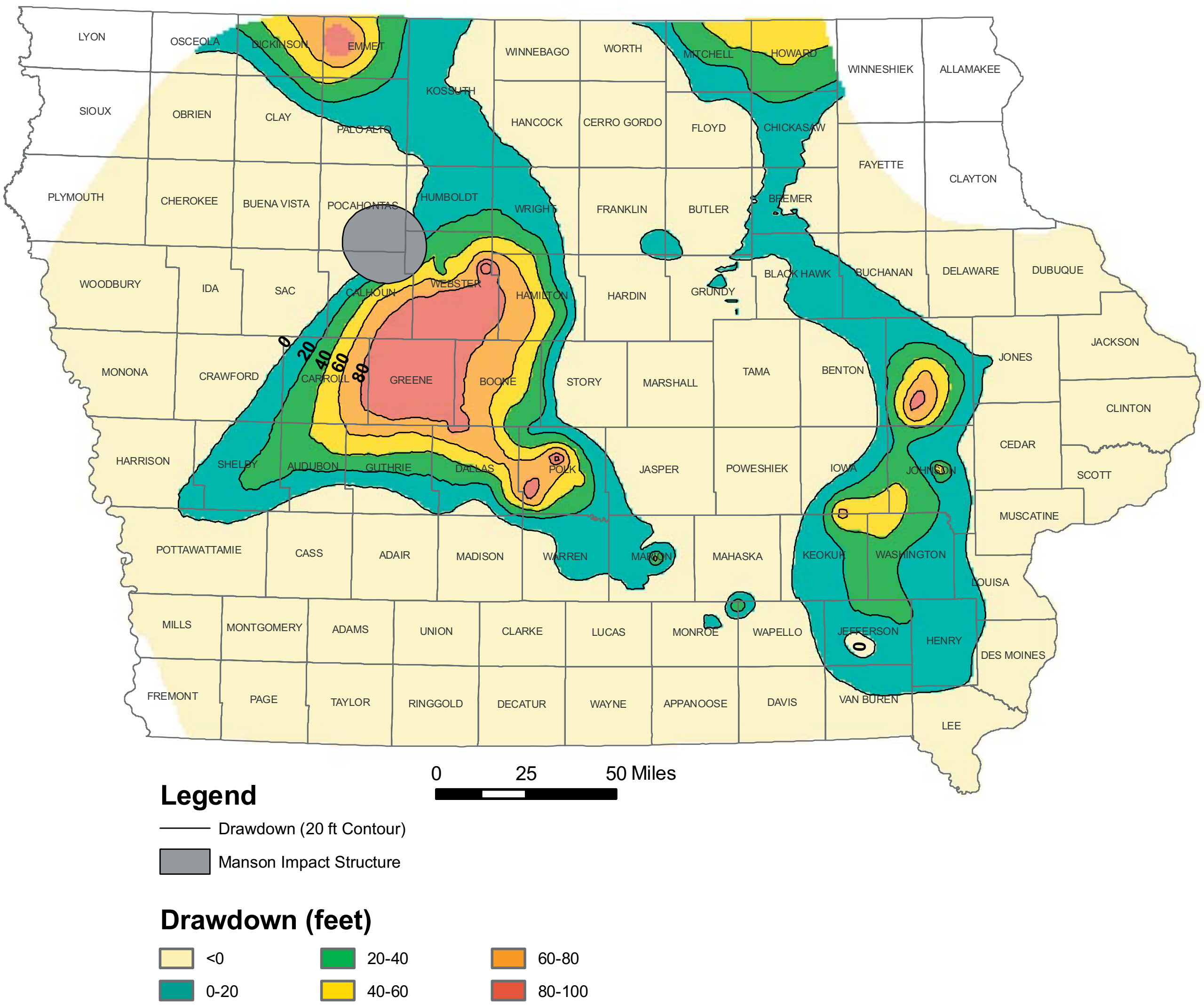

Figure 36. Additional drawdown in feet from Horick and Steinhilber (1978) compared to simulated results 1997.

equally divided among the active wells. Improvements in monthly water use reporting would be extremely useful for transient model simulation.

- Head values near flow-through boundaries may not accurately represent observed values. This error increases at higher pumping rates and the closer the wells are to the actual flow-through boundary. General-head boundaries were used to minimize this error.
- Because the recharge was entered as net recharge, water level values in layer 1 were not simulated, and do not represent actual conditions.

FUTURE DATA NEEDS

Additional data would improve our understanding of the hydrogeology and future water availability, and provide more accurate input parameters for our model. Future improvements in

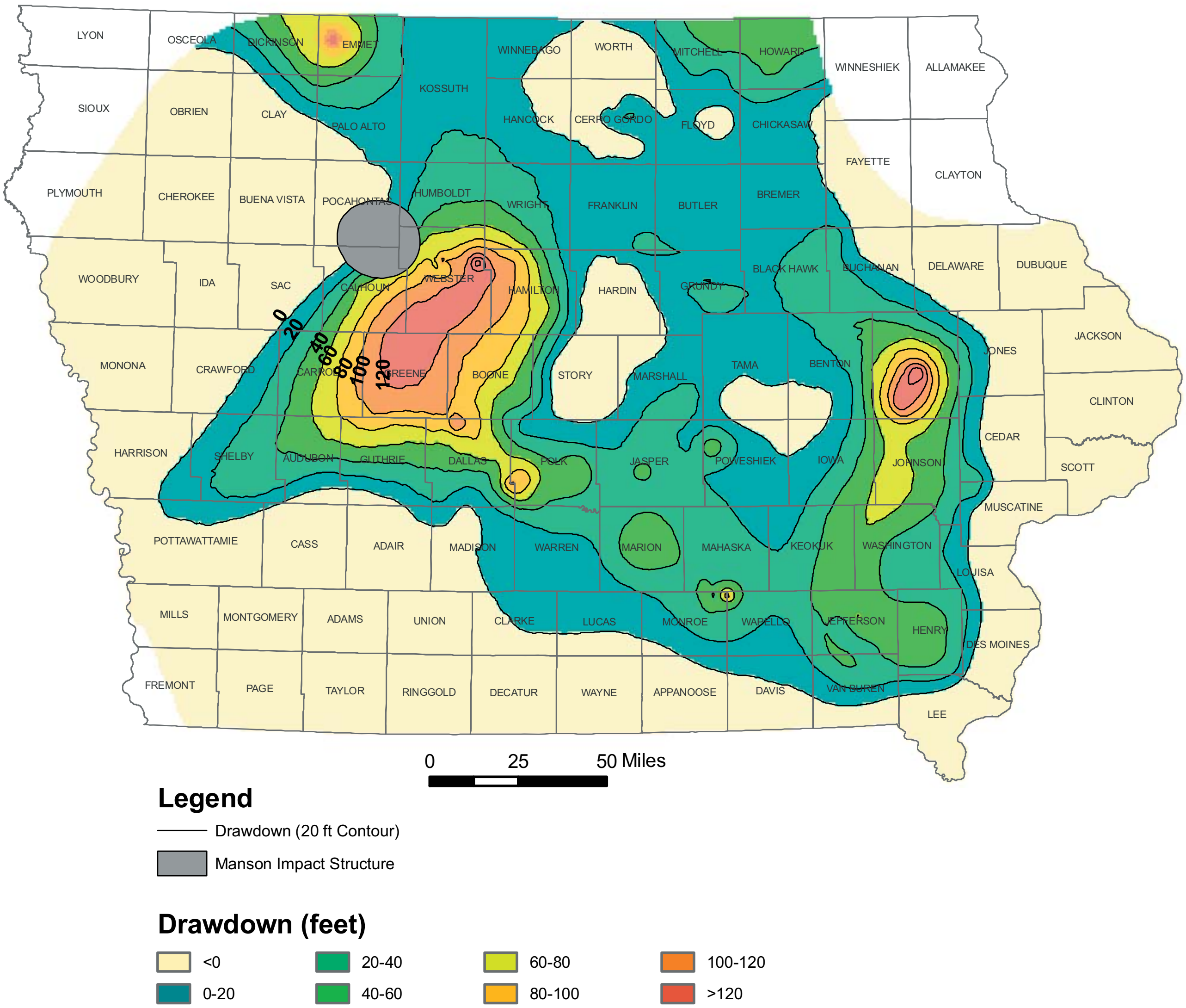

Figure 37. Additional drawdown in feet from Horick and Steinhilber (1978) compared to simulated results 2007.

aquifer parameters, water level data, storage coefficients, and water use information would provide more confidence in future predictions. The following is a short list of recommendations:

- At least one 24-hour pump test should be conducted in each of the high usage areas to calculate a more accurate storage coefficient and transmissivity value.

- Continuing and expanding the monitoring well network is crucial for the future evaluation of the Cambrian-Ordovician aquifer model as a predictive tool.

- Time series water level readings should be collected in one or more observation wells in the Fort Dodge, Mason City, Des Moines, and Washington areas. Additional time series water level data would be beneficial in the Cedar Rapids, Grinnell, Knoxville, Iowa City, Dubuque, and Clinton areas.

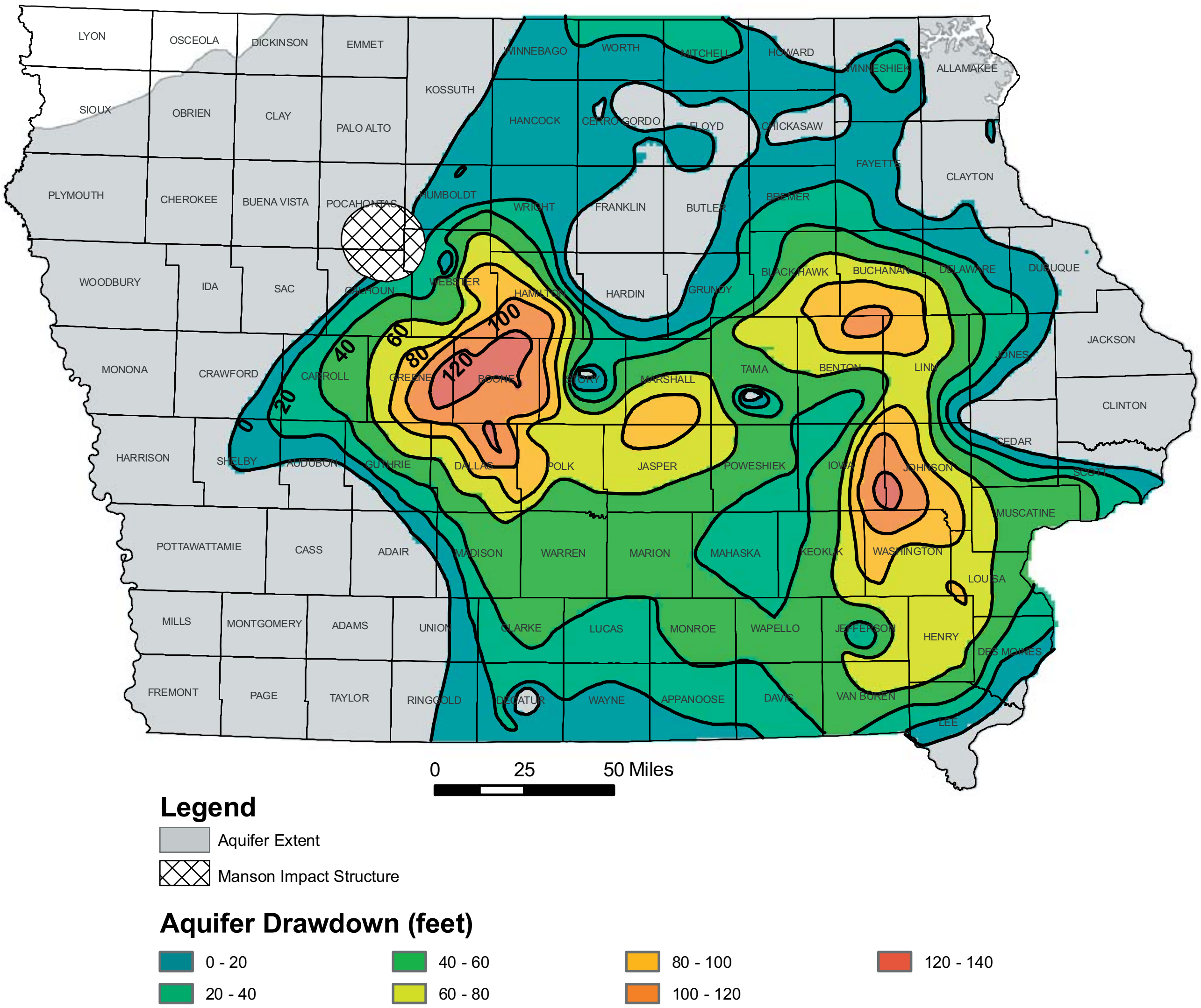

Figure 38. Additional drawdown in feet from Horick and Steinhilber (1978) compared to observed results 1990-1999.

- Down-hole geophysical logs are needed for wells that are thought to be dual completions. Electrical-resistivity, gamma, and caliber logs could be generated to evaluate casing intervals and determine the aquifer that a particular well is drawing water.

- Packer tests should be performed to evaluate the aquifer properties of individual units or aquifers. Water quality data should also be collected from each unit or aquifer.

CONCLUSIONS

Although Iowa is not facing an immediate water shortage, increased demand for groundwater by agriculture, industries, and municipalities has raised concerns for the future of the resource. However, the information necessary for decision makers to answer basic questions regarding how much water can be withdrawn from Iowa's aquifers on a sustainable basis was not readily available. The 2007 Iowa General Assembly rec-

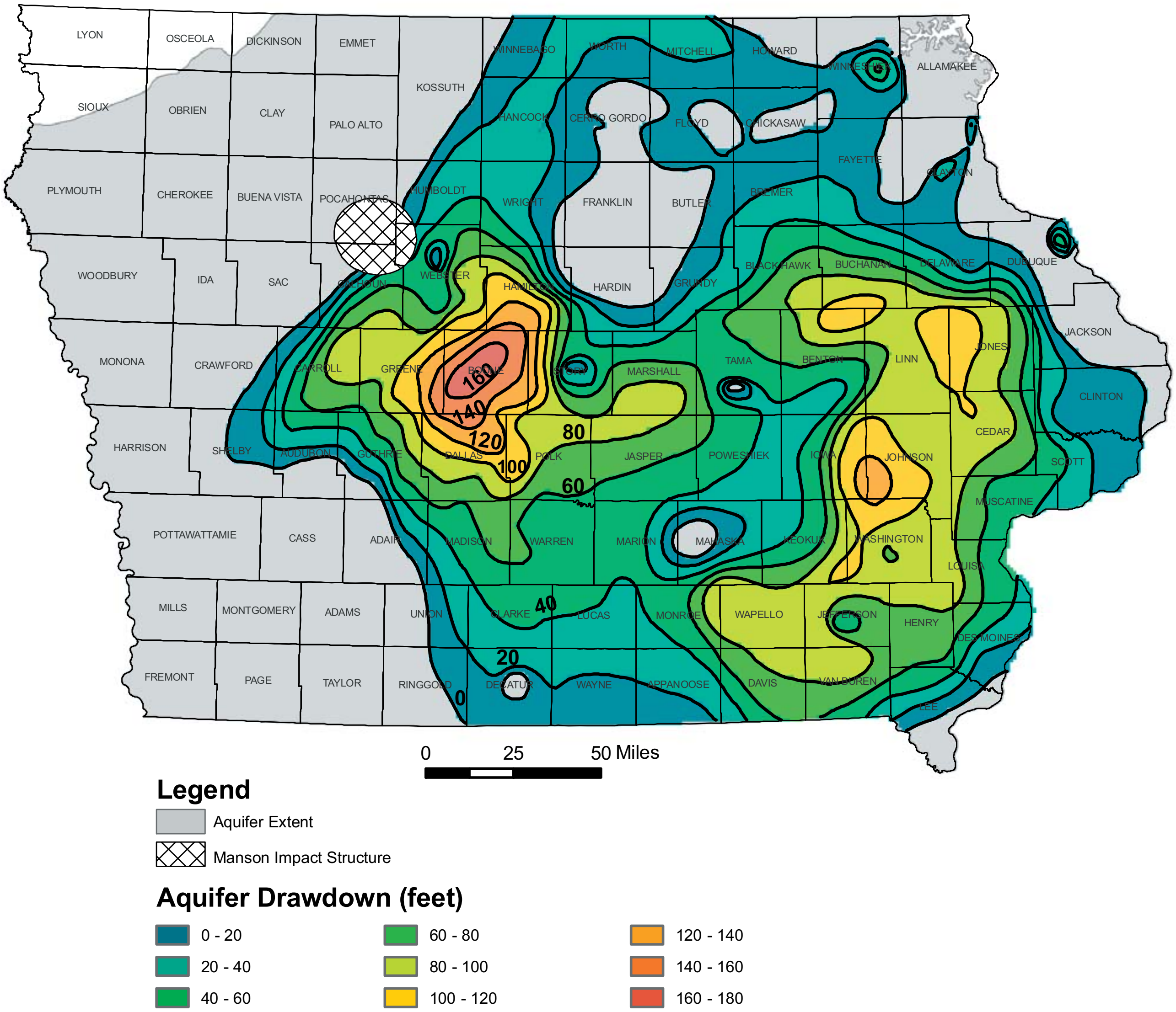

Figure 39. Additional drawdown in feet from Horick and Steinhilber (1978) compared to observed results 2000-2008.

ognized this lack of information and approved funding for the first year of a multi-year evaluation and modeling of Iowa's major bedrock aquifers by the Iowa Geological and Water Survey (IGWS).

An intensive one-year investigation was undertaken to provide a more quantitative assessment of the Cambrian-Ordovician aquifer. A groundwater flow model was developed to provide a planning tool for future water resource development.

The hydrologic characteristics of the Cambrian-Ordovician aquifer were investigated. An important component of this study was a network of approximately 51 wells used to evaluate water levels. Key to the investigation were eleven observation wells which had time series data. These data were used for the transient model development.

A total of 49 aquifer pump tests and recovery tests and 38 specific capacity tests were used to calculate the aquifer parameters. The majority

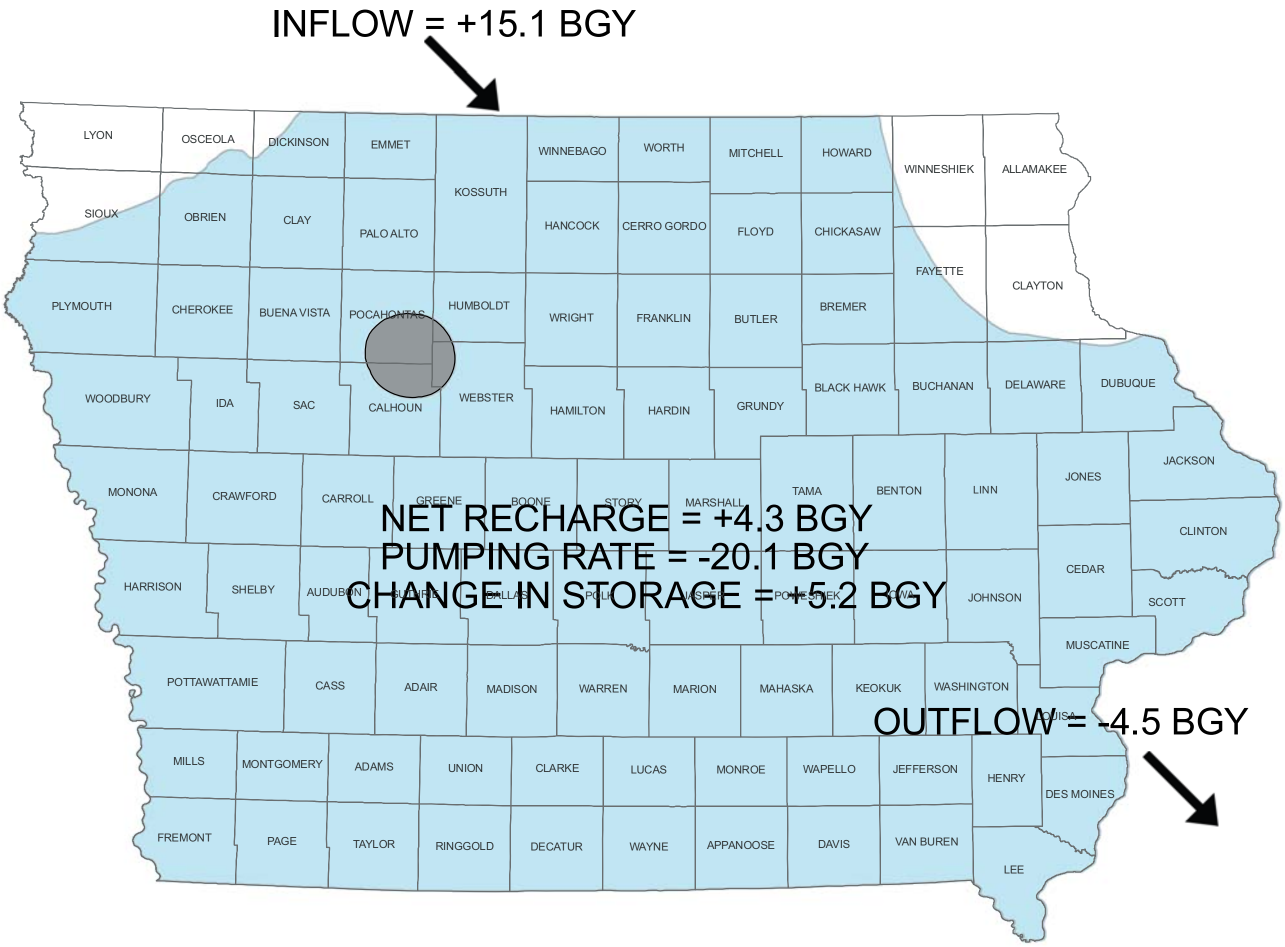

Figure 40. Water balance map for transient conditions in 2007.

of the recovery tests were evaluated for the first time. The hydraulic properties of the Cambrian-Ordovician aquifer were shown to vary considerably both laterally and vertically. The hydraulic conductivity of the aquifer ranged from 0.3 to 20.9 feet per day, with an arithmetic mean of 4.6 feet per day. Transmissivity values ranged from 150 to 8,500 feet squared per day. The storage coefficient of the Cambrian-Ordovician aquifer ranged from 10^{-6} to 10^{-3} with an arithmetic mean storage coefficient of 3.3 x 10^{-4}.

Recharge to most of the Cambrian-Ordovician aquifer is through relatively thick confining beds that include glacial till and various shale units. Due to the relatively thick confining units, the rate of recharge to the Cambrian-Ordovician aquifer is very small. Calibrated recharge rates ranged from 10^{-5} to 0.02 inches per year.

With this information a numerical groundwater flow model of the Cambrian-Ordovician aquifer was developed using three hydrogeologic layers. The model was created using Visual MODFLOW version 4.3. Hydrologic processes examined in the model include net recharge, hydraulic conductivity, specific storage, flow through boundaries, no flow boundaries, well discharge, and groundwater upwelling.

The modeling approach involved the following components:

1. Calibrating a pre-development steady-state model using water level data from historic records.

2. Calibrating a transient model using water-use

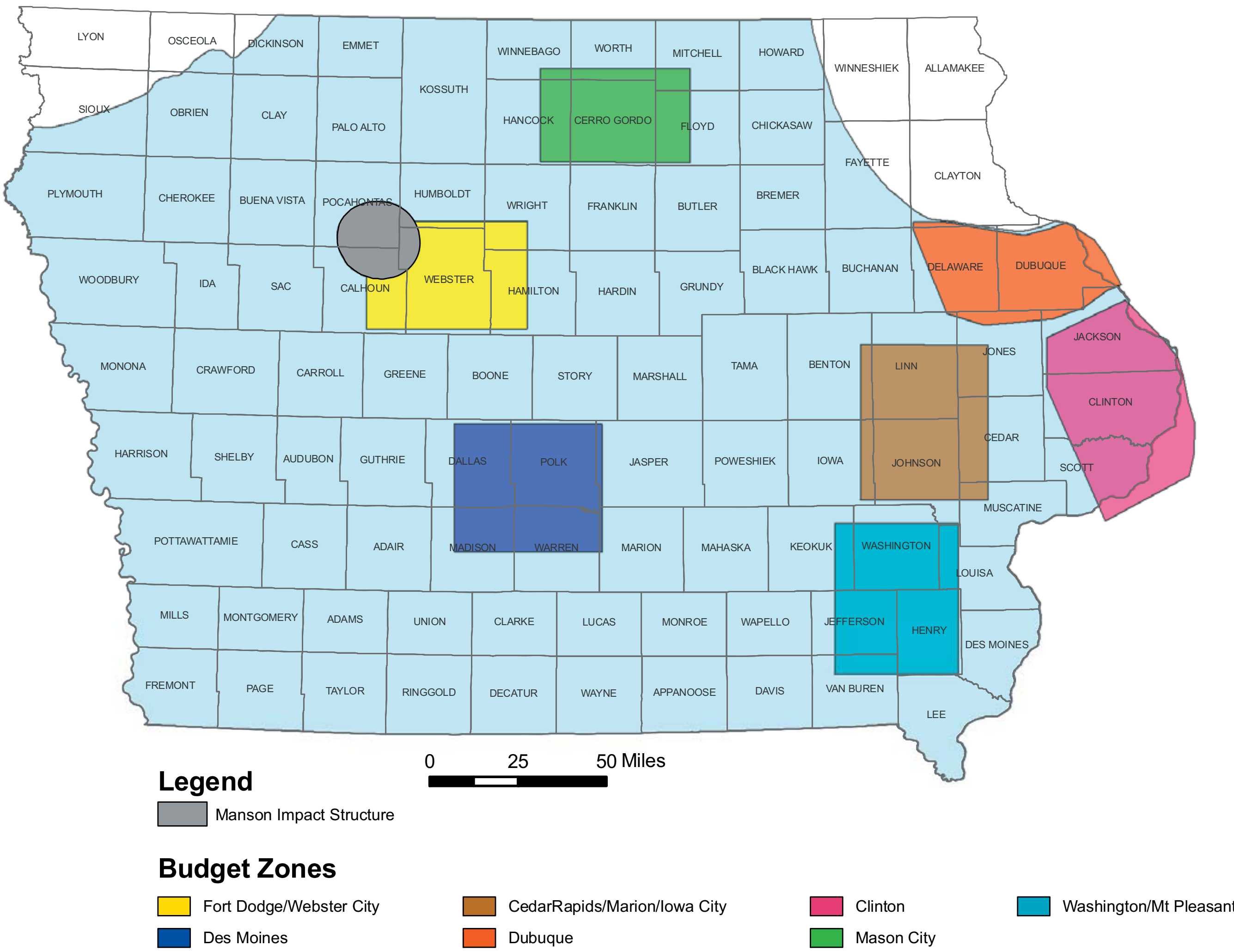

Figure 41. Zone budget locations used in localized water balance evaluation.

Table 6. Water balance for budget zones shown on Figure 50 based on model results for 2007. Pumping rates in Mason City, Fort Dodge, Clinton, and Dubuque are estimates based on the withdrawal from the Cambrian-Ordovician aquifer only. Some of the wells in these zones are open in more than one aquifer.

	Water Balance for Cambrian-Ordovician Aquifer					
Zone	**Pumping (Q)**	**Recharge (R)**	**Inflow-Outflow**	**From Storage**	**Change**	**GWA**
	(bgy)	**(bgy)**	**(bgy)**	**(bgy)**	**in Head (ft/year)**	**(bgy)**
Outside Budget Zones	6.60	3.2000	5.98	4.14	-1.3	
Mason City*	1.40	0.2400	0.92	0.25	-2.4	1.4
Fort Dodge/Webster City*	1.80	0.0460	1.17	0.58	-5.6	0.0 to 0.5
Des Moines	2.46	0.0003	1.96	0.50	-4.7	0.6 to 1.2
Cedar Rapids/Marion/Iowa City	3.10	0.0560	2.28	0.80	-7.7	0.75
Washington/Mt. Pleasant	1.60	0.0260	1.27	0.34	-3.3	1.6
Clinton*	2.10	0.3400	1.74	0.03	-0.3	1.1
Dubuque*	0.90	0.3000	0.40	0.20	-1.92	1.0
Total	**19.96**	**4.2083**				
** estimated pumpage from the Cambrian-Ordovician aquifer only*						

data from 1901 through 2007. Simulated water levels were compared to observed time-series water level measurements.

3. The calibrated model was used to predict additional drawdowns through 2029 for future water usage simulations.

The calibrated model provided good correlation for both steady-state and transient conditions. Root mean square errors of 18.3 and 34.8 feet, respectively, were considered relatively small errors for an aquifer that covers most of the state of Iowa. Simulated water level changes were most sensitive to recharge in the steady-state model and hydraulic conductivity in the transient model.

Model simulations suggest that the Cambrian-Ordovician aquifer will likely exceed the 200-foot regulatory limit in Fort Dodge-Webster City area by 2029 based on current water usage. If pumping rates increase by 25% above 2007 rates, the 200-foot regulatory limit will likely be exceeded in the Marion-Cedar Rapids and Des Moines areas in 20 years.

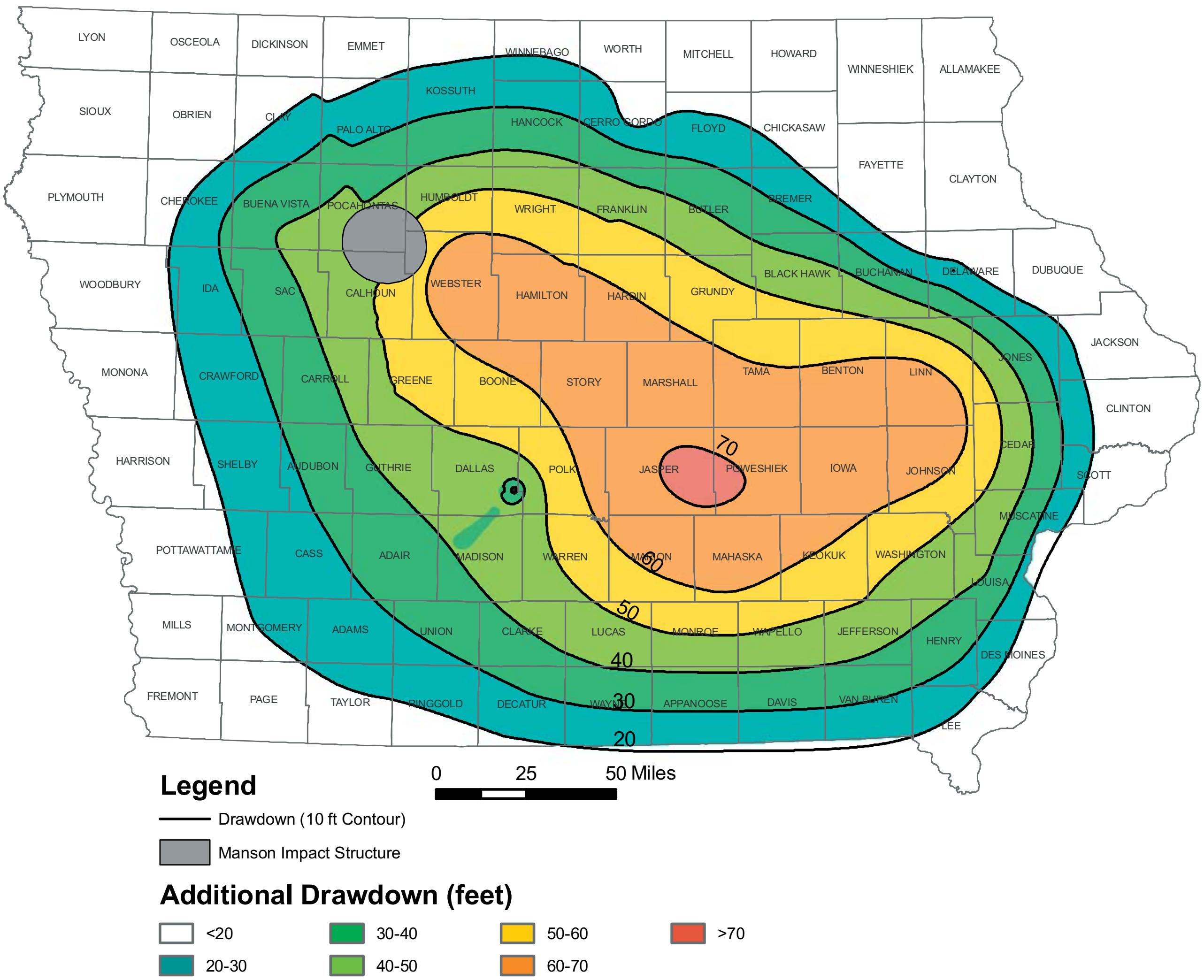

Figure 42. Predicted (simulated) additional drawdown in feet from 2009 to 2029 for zero or stagnant growth in pumping rates.

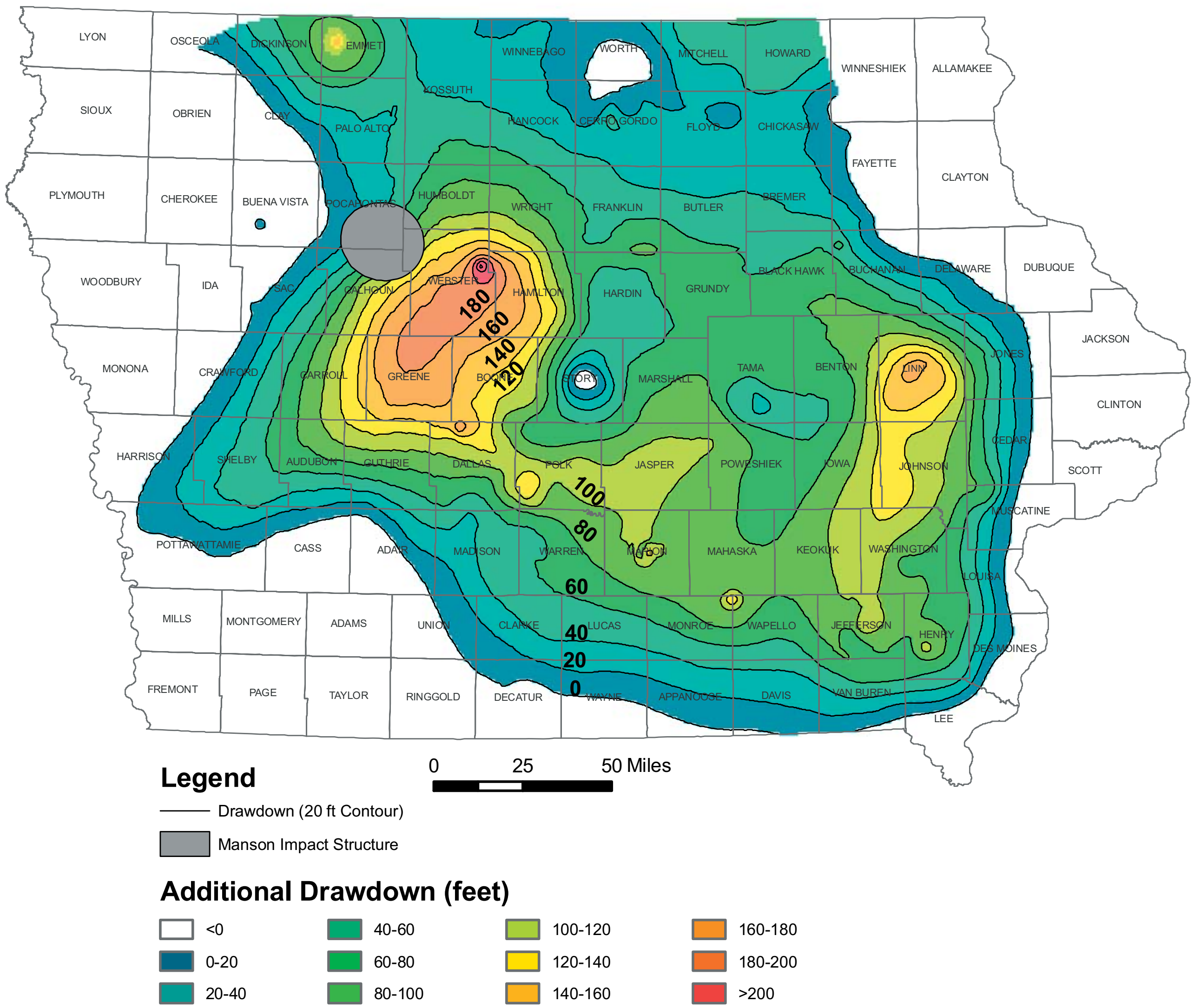

Figure 43. Additional drawdown in feet from Horick and Steinhilber (1978) compared to simulated results 2029 for zero or stagnant growth in pumping rates.

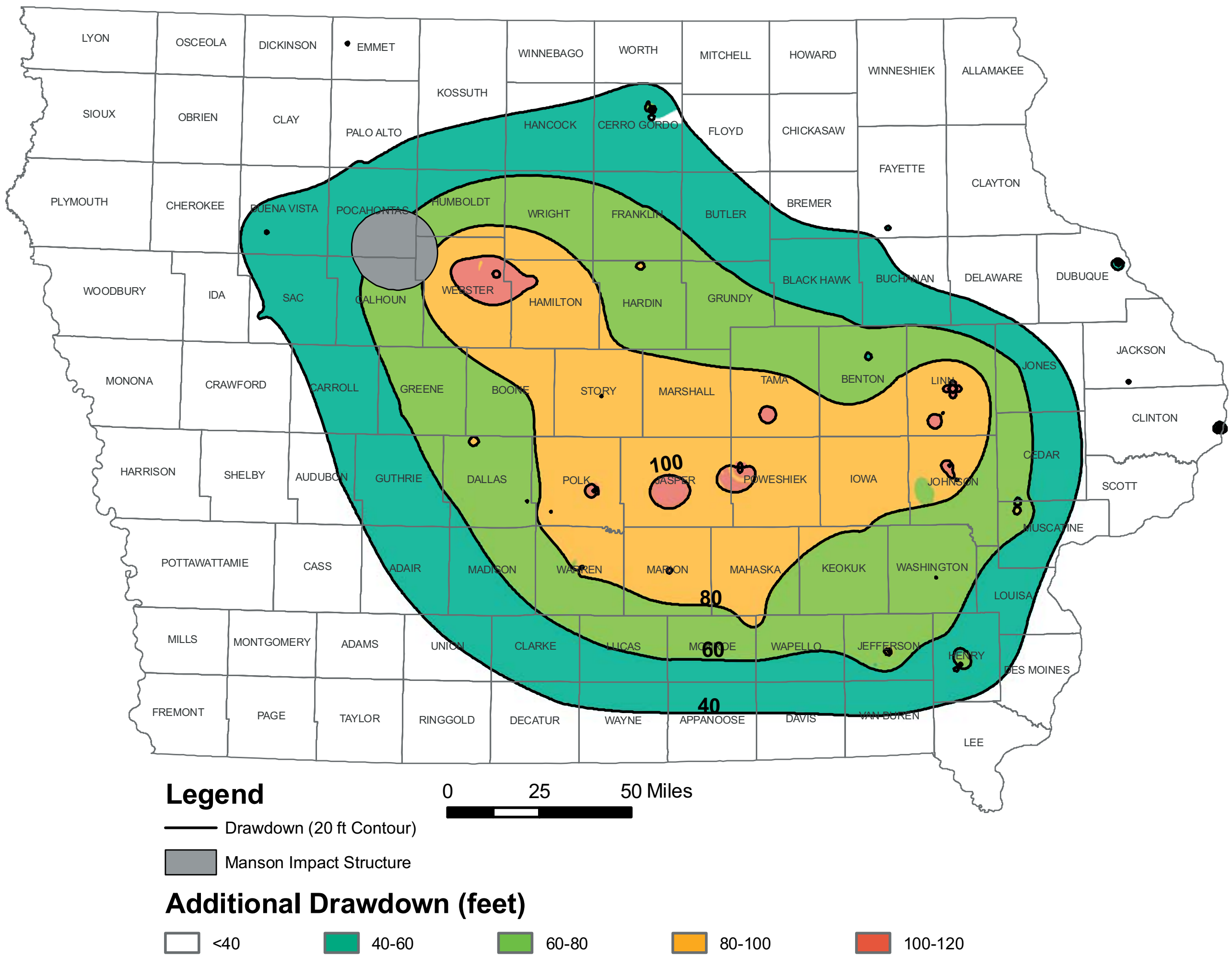

Figure 44. Predicted (simulated) additional drawdown in feet from 2009 to 2029 for 25% growth in pumping rates.

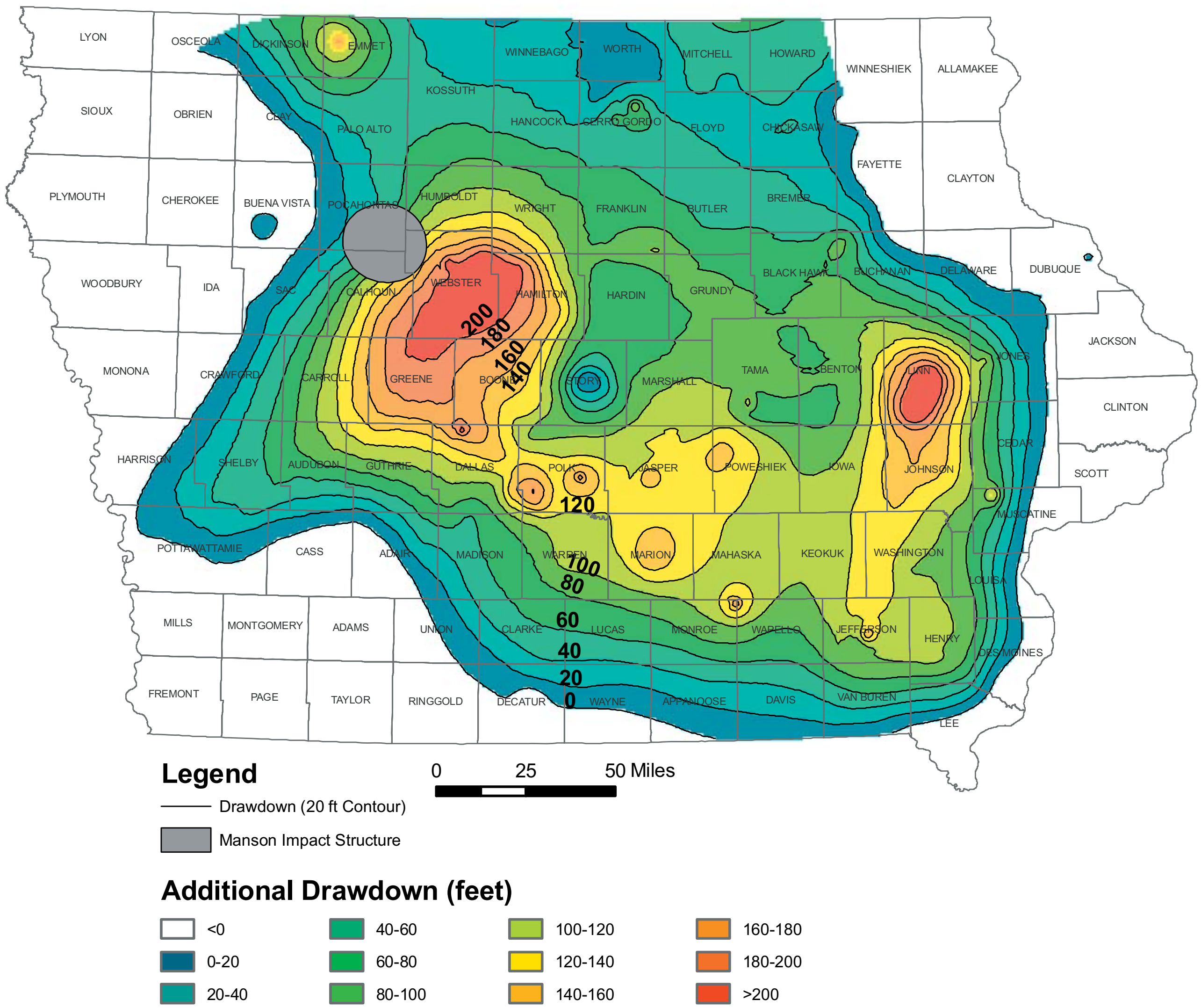

Figure 45. Additional drawdown in feet from Horick and Steinhilber (1978) compared to simulated results 2029 for 25% growth in pumping rates.

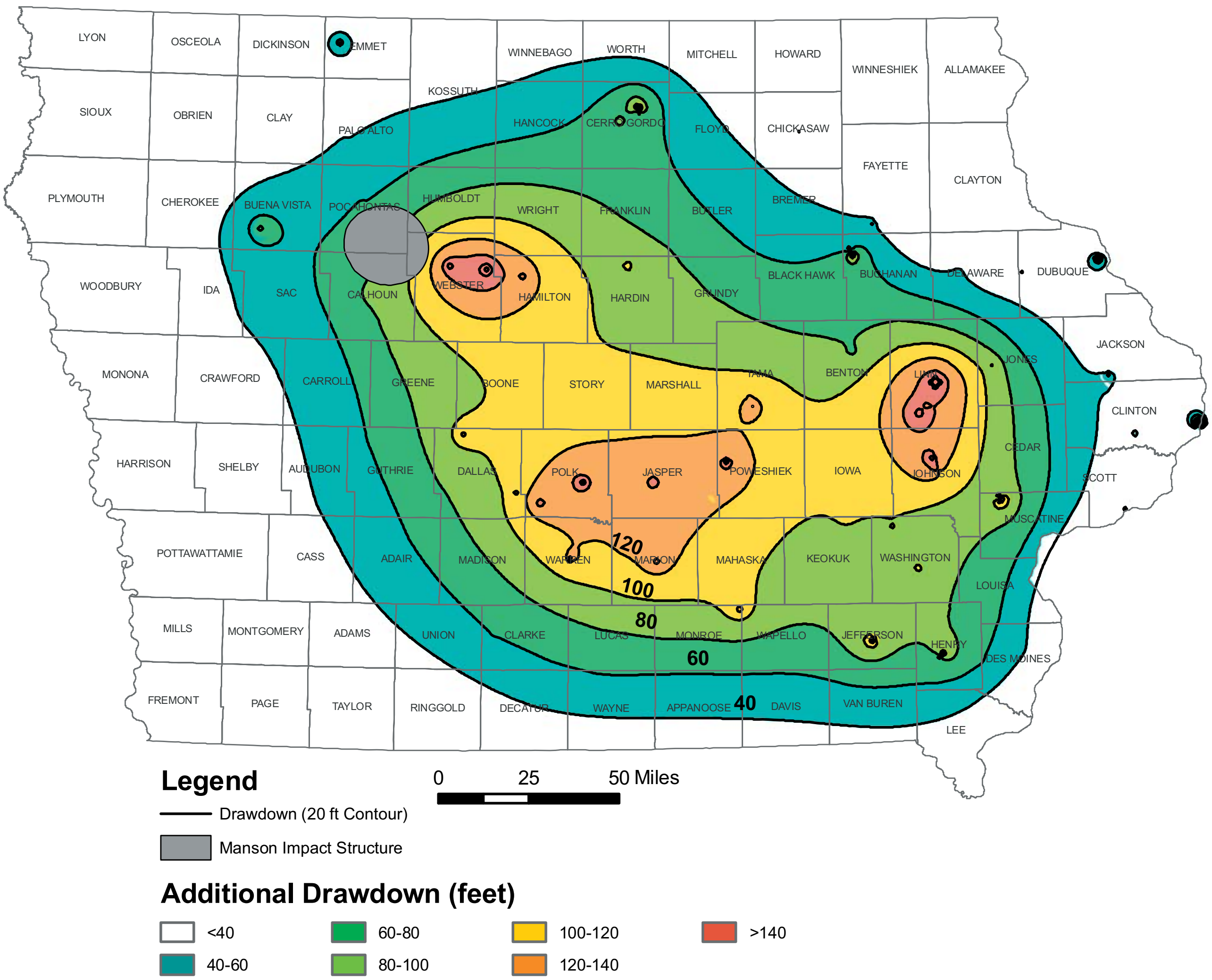

Figure 46. Predicted (simulated) additional drawdown in feet from 2009 to 2029 for 50% growth in pumping rates.

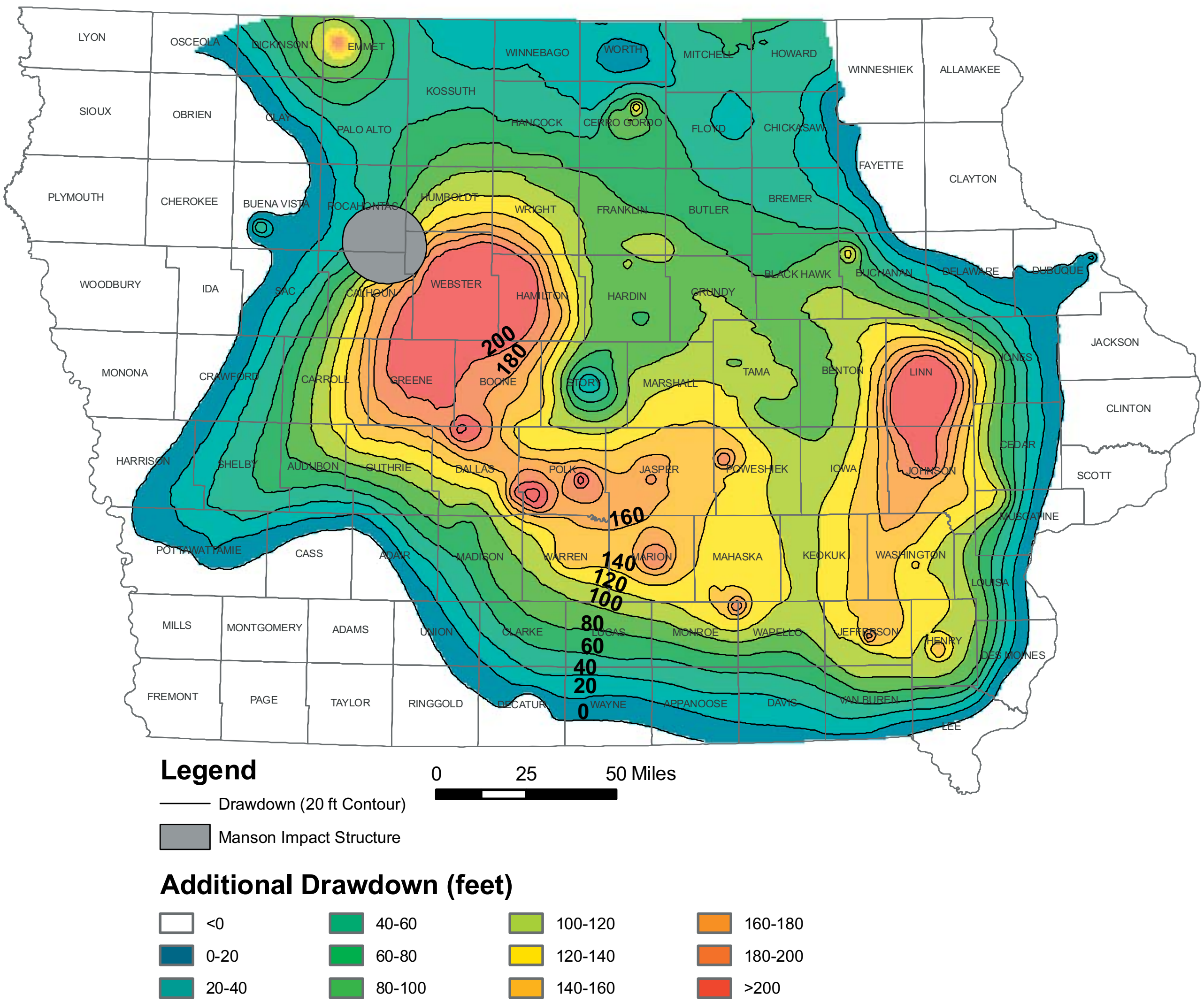

Figure 47. Additional drawdown in feet from Horick and Steinhilber (1978) compared to simulated results 2029 for 50% growth in pumping rates.

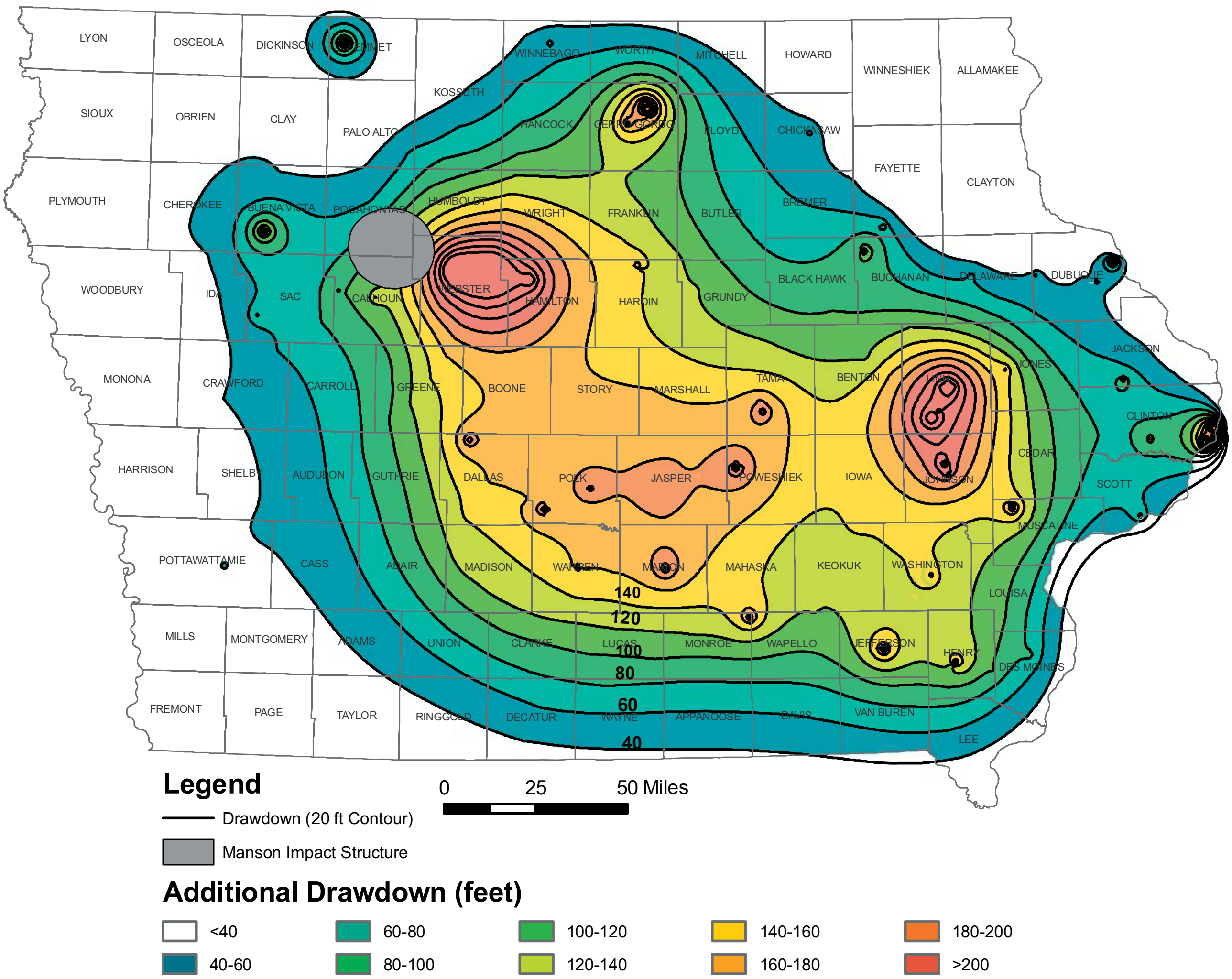

Figure 48. Predicted (simulated) additional drawdown in feet from 2009 to 2029 for 100% growth in pumping rates.

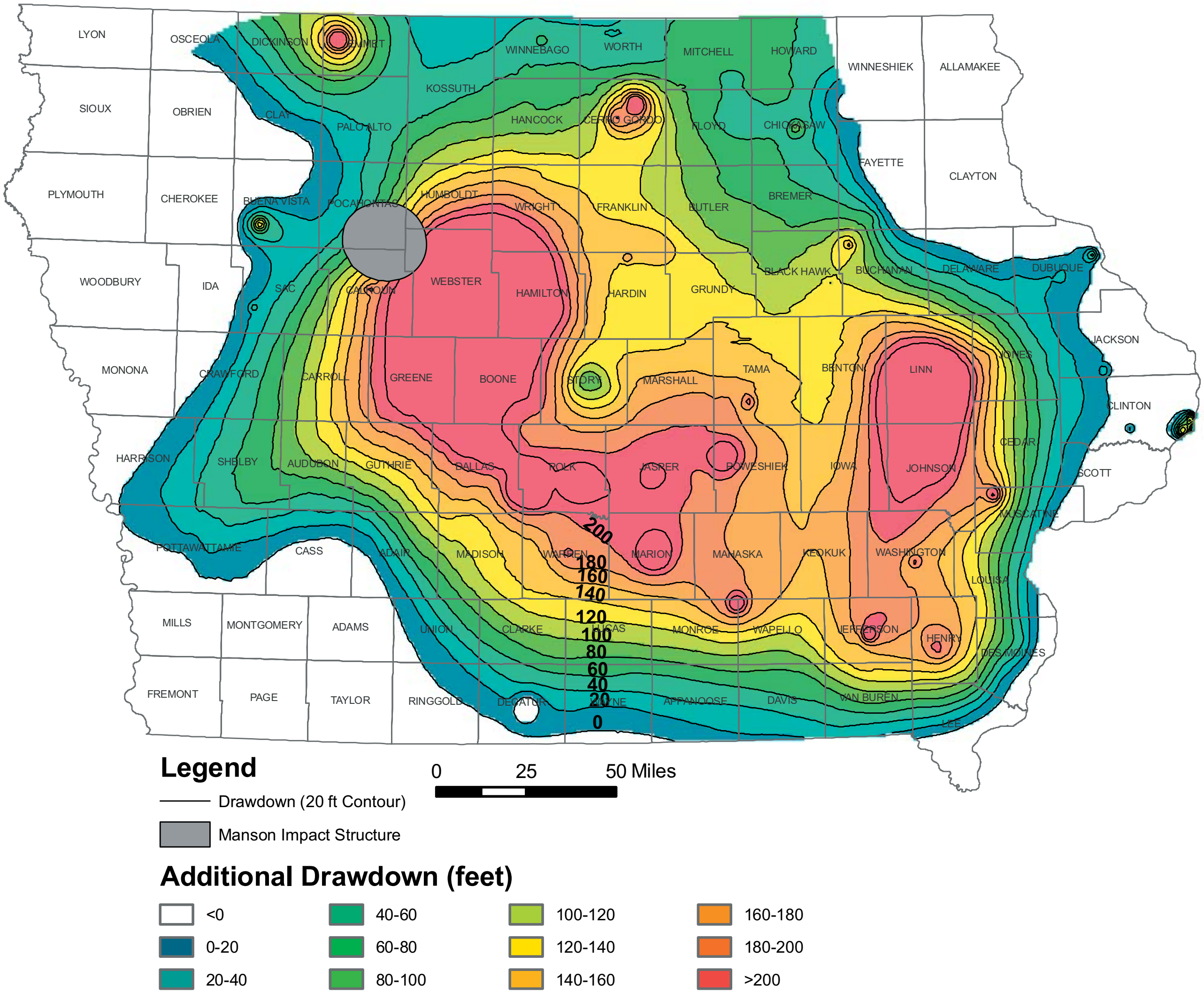

Figure 49. Additional drawdown in feet from Horick and Steinhilber (1978) compared to simulated results 2029 for 100% growth in pumping rates.

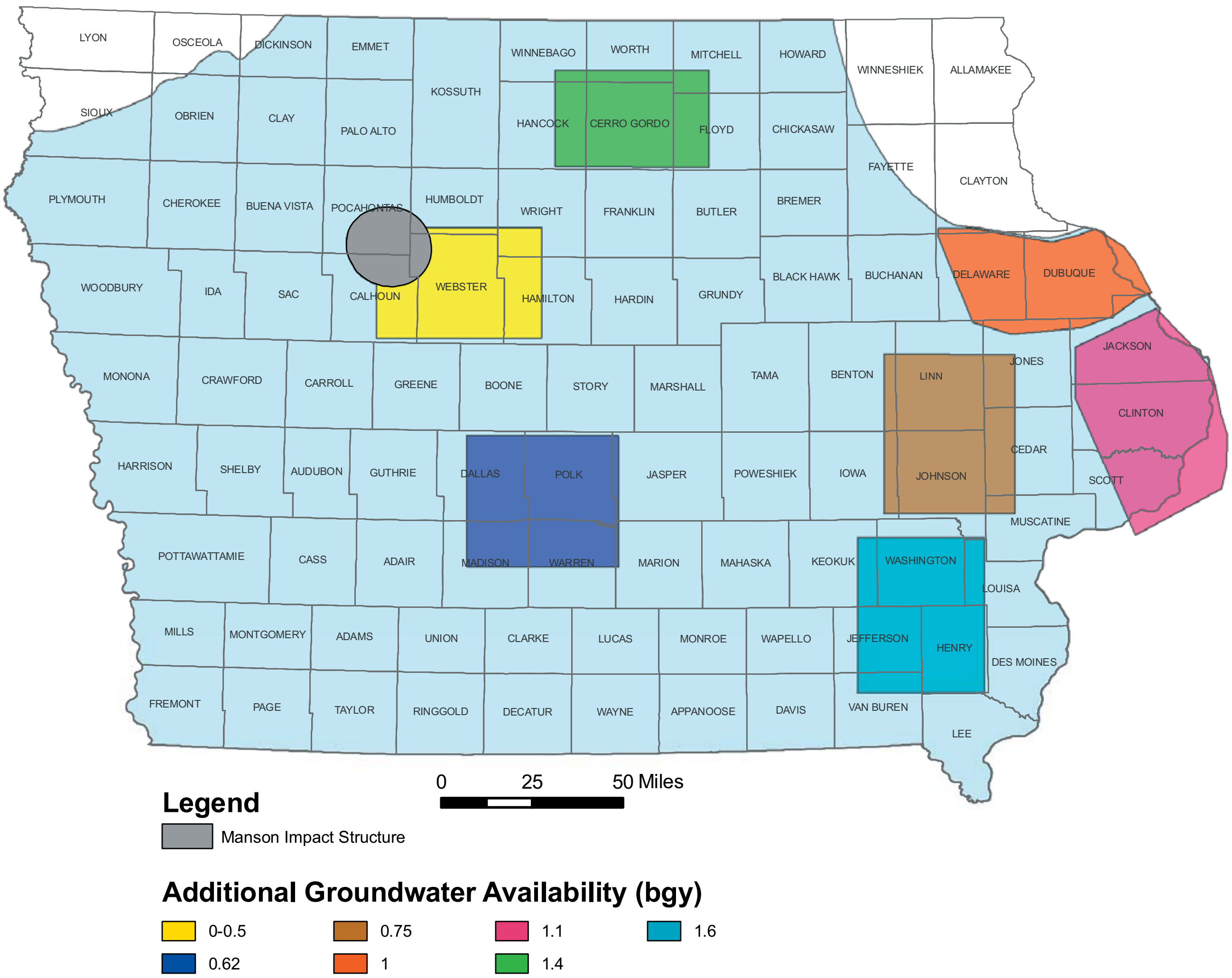

Figure 50. Groundwater availability (GWA) map based on Zone Budget Analyses and Predictive Modeling.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the contributions of the many individuals who assisted in the production of this report. First, much of our understanding of the Cambrian-Ordovician aquifer in Iowa is built on the work of previous Iowa Geological Survey geologist Paul Horick and United States Geological Survey geologists Walter Steinhilber, Michael Burkart, and Robert Buchmiller. Current Iowa Geological and Water Survey geologists Robert McKay, Brian Witzke, and Ray Anderson provided input on the geology and conceptual model. Various companies supplied pump test and recovery test data including Fox Engineering, H. R. Green Engineers, IIW Engineers and Surveyors, Layne Christiensen, and Shawver Well Company. Chad Fields, Bob Libra, Keith Schilling, and Lynette Seigley provided editorial support. Pat Lohmann compiled the various components and was the publication designer. A special thank you goes to University of Iowa student Jason Vogelgesang for evaluating the current and historical water-use data.

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APPENDIX A.

AQUIFER TEST DATA

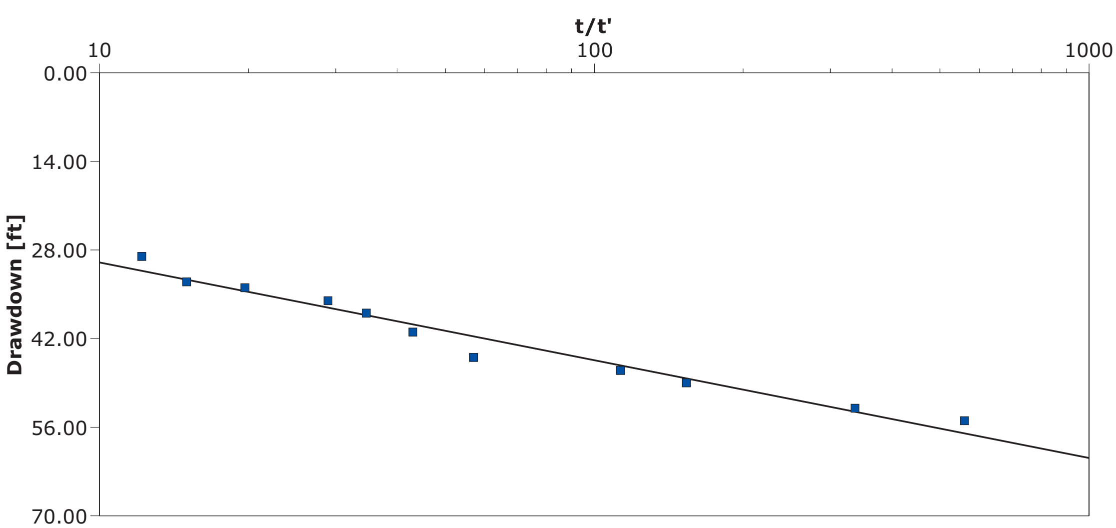
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data**	Page 1 of 1
	Project: Anamosa Well 5 Recovery Test	
	Number:	
	Client:	

Location: Anamosa, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 5
Test Conducted by:	Test Date: 10/10/1990	Discharge: variable, average rate 700.21 [U.S. gal/min]
Observation Well: Well 5	Static Water Level [ft]: 272.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1683	327.00	55.00
2	1685	325.00	53.00
3	1691	321.00	49.00
4	1695	319.00	47.00
5	1710	317.00	45.00
6	1720	313.00	41.00
7	1730	310.00	38.00
8	1740	308.00	36.00
9	1770	306.00	34.00
10	1800	305.00	33.00
11	1830	301.00	29.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**	
	Project: Anamosa Well 5 Recovery Test	
	Number:	
	Client:	

Location: Anamosa, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 5
Test Conducted by:		Test Date: 10/10/1990
Analysis Performed by:	New analysis 2	Analysis Date: 10/23/2008
Aquifer Thickness: 1591.21 ft	Discharge: variable, average rate 700.21 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 5	1.60×10^3	1.00×10^0	0.5

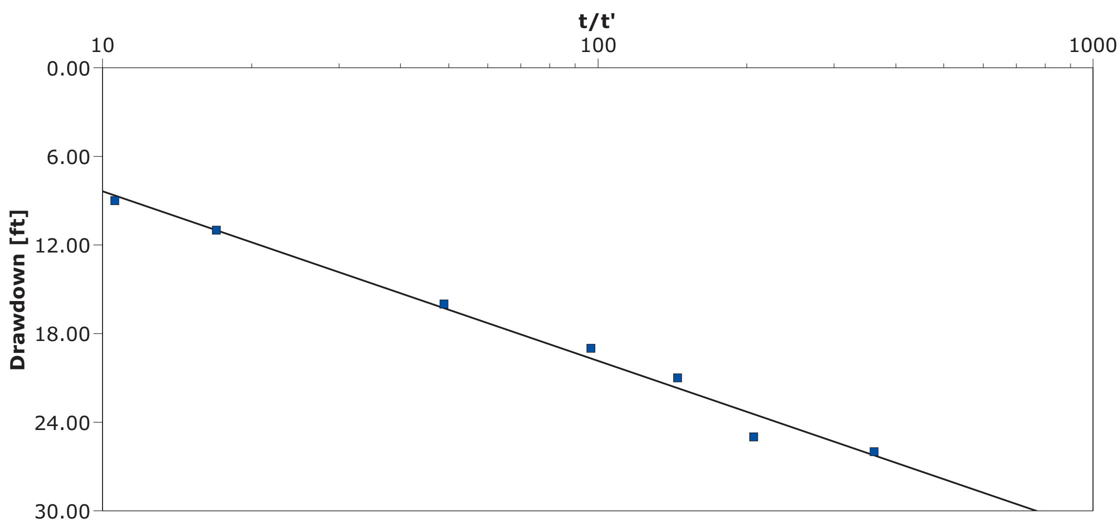
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data**	Page 1 of 1
	Project: Anamosa Recovery Test	
	Number:	
	Client:	

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 10/20/2008	Discharge: variable, average rate 815.08 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 307.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1444	333.00	26.00
2	1447	332.00	25.00
3	1450	328.00	21.00
4	1455	326.00	19.00
5	1470	323.00	16.00
6	1530	318.00	11.00
7	1590	316.00	9.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**	
	Project: Anamosa Recovery Test	
	Number:	
	Client:	

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 10/20/2008
Analysis Performed by:	New analysis 2	Analysis Date: 10/20/2008
Aquifer Thickness: 463.00 ft	Discharge: variable, average rate 815.08 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	2.50×10^3	5.40×10^0	0.33

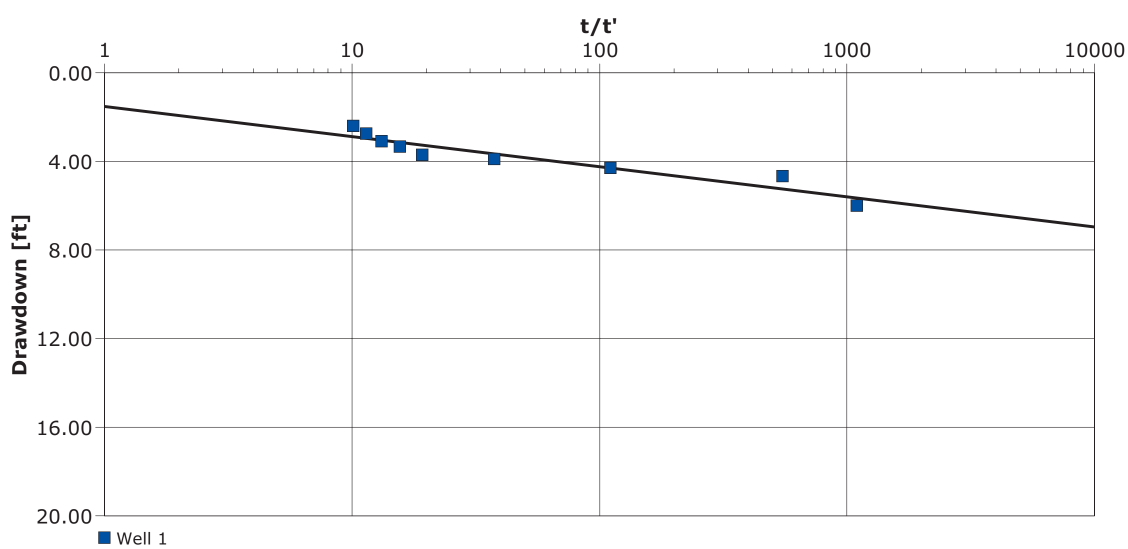
Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test - Water Level Data**	Page 1 of 1
	Project: Andover Recovery Test	
	Number:	
	Client:	

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 7/22/2008	Discharge: variable, average rate 39 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 233.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1095	244.50	11.50
2	1096	239.00	6.00
3	1097	237.67	4.67
4	1105	237.30	4.30
5	1125	236.90	3.90
6	1155	236.70	3.70
7	1170	236.33	3.33
8	1185	236.10	3.10
9	1200	235.75	2.75
10	1215	235.40	2.40

Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test Analysis Report**
	Project: Andover Recovery Test
	Number:
	Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 7/22/2008
Analysis Performed by:	New analysis 1	Analysis Date: 9/8/2008
Aquifer Thickness: 300.00 ft	Discharge: variable, average rate 39 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	1.01×10^{3}	3.37×10^{0}	1.0

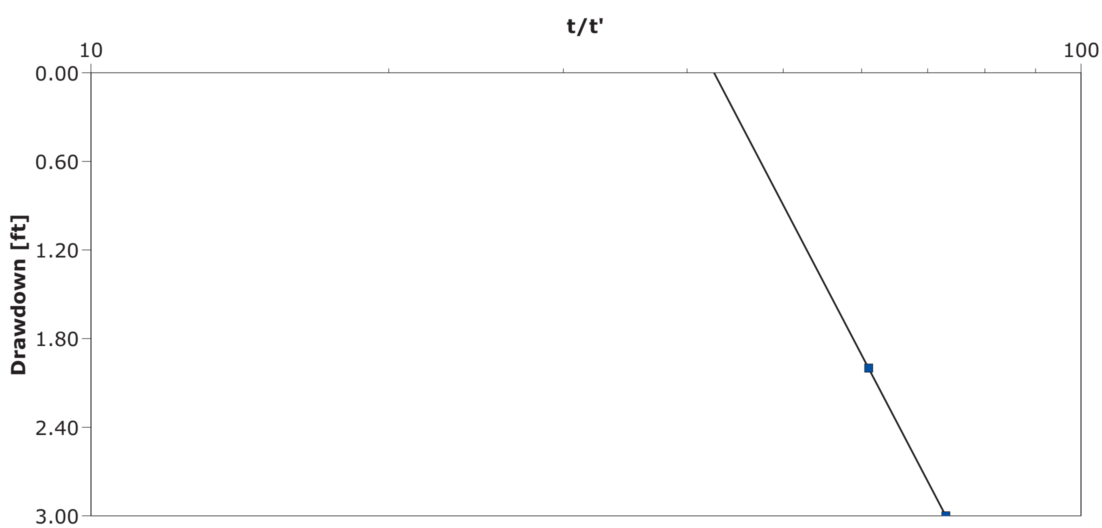
	Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
		Project: Bussey Recovery Test
		Number:
		Client:

Location: Bussey, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 7/9/1981	Discharge: variable, average rate 400 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 238.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	730	241.00	3.00
2	732	240.00	2.00

	Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
		Project: Bussey Recovery Test
		Number:
		Client:

Location: Bussey, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 7/9/1981
Analysis Performed by:	New analysis 5	Analysis Date: 11/3/2008
Aquifer Thickness: 477.00 ft	Discharge: variable, average rate 400 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
Well 1	1.10×10^{3}	2.30×10^{0}	0.33	

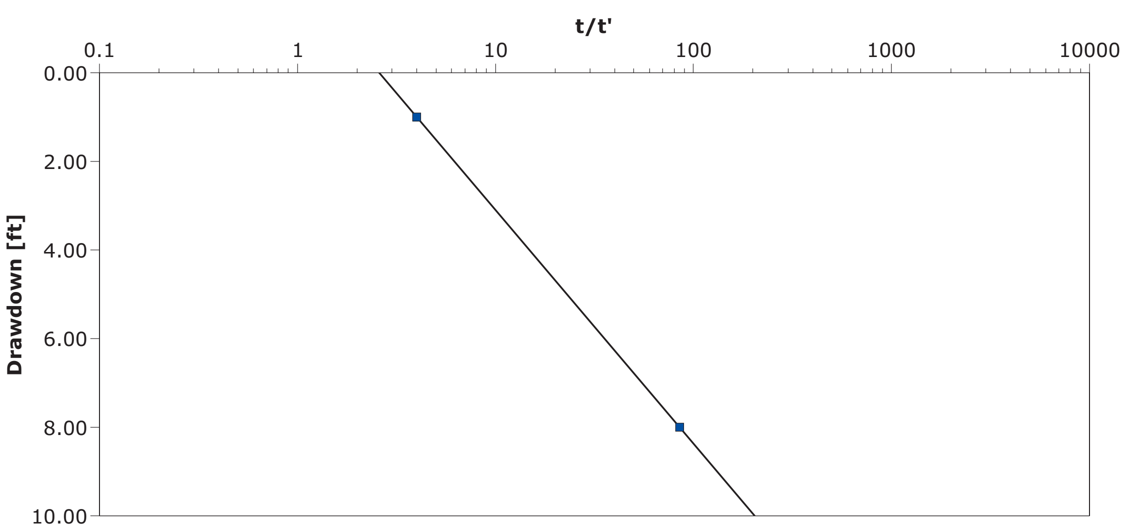
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
	Project: Calamus Recovery Test
	Number:
	Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by: Shawver	Test Date: 3/14/2006	Discharge: variable, average rate 301.28 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 184.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	425	192.00	8.00
2	560	185.00	1.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
	Project: Calamus Recovery Test
	Number:
	Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by: Shawver		Test Date: 3/14/2006
Analysis Performed by:	New analysis 1	Analysis Date: 9/10/2008
Aquifer Thickness: 480.00 ft	Discharge: variable, average rate 301.28 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	2.01×10^3	4.19×10^0	1.0

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
	Project: Central FiberTama County
	Number:
	Client:

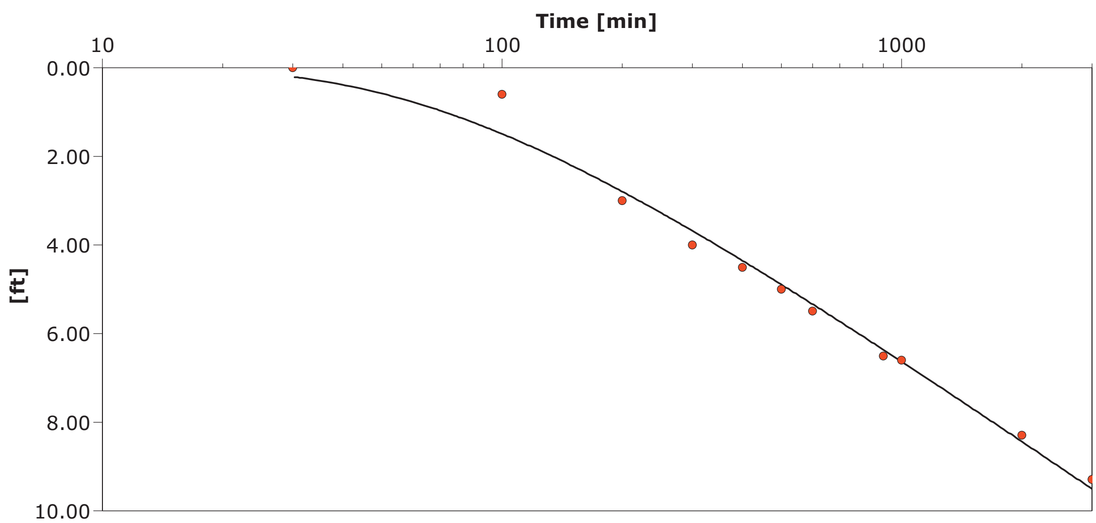
Location:	Pumping Test: Pump Test 1	Pumping Well: Well 2
Test Conducted by:	Test Date: 4/11/1960	Discharge: variable, average rate 1500 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 92.00	Radial Distance to PW [ft]: 1000

	Time [min]	Water Level [ft]	Drawdown [ft]
1	30	92.00	0.00
2	100	92.60	0.60
3	200	95.00	3.00
4	300	96.00	4.00
5	400	96.50	4.50
6	500	97.00	5.00
7	600	97.50	5.50
8	900	98.50	6.50
9	1000	98.60	6.60
10	2000	100.30	8.30
11	3000	101.30	9.30

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

	Pumping Test Analysis Report
	Project: Central FiberTama County
	Number:
	Client:

Location:	Pumping Test: Pump Test 1	Pumping Well: Well 2
Test Conducted by:		Test Date: 4/11/1960
Analysis Performed by:	New analysis 6	Analysis Date: 10/22/2008
Aquifer Thickness: 572.00 ft	Discharge: variable, average rate 1500 [U.S. gal/min]	



Calculation after Theis

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]
Well 1	8.51×10^{3}	1.49×10^{1}	1.20×10^{-3}	1000.0

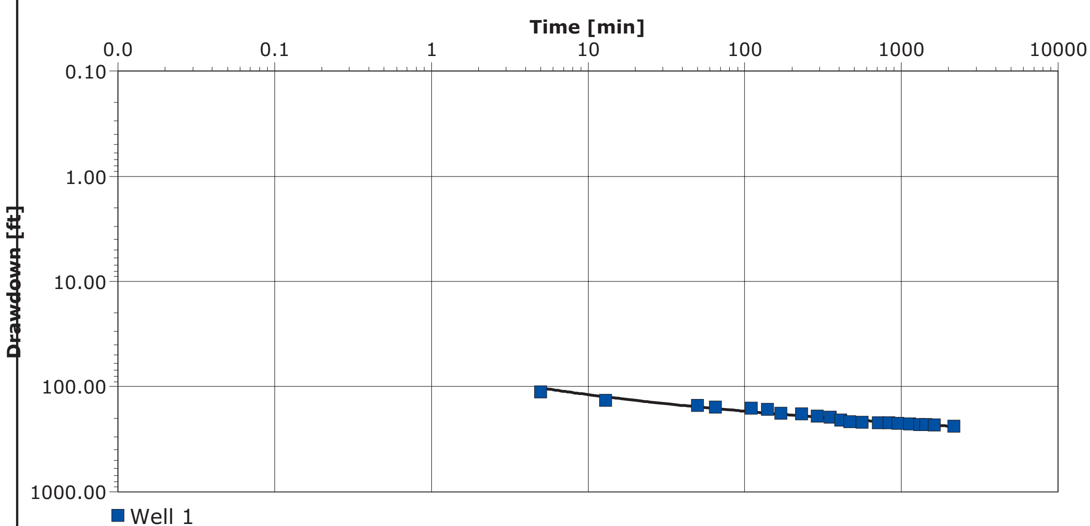
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
	Project: Layne-Northwest Clinton ADM
	Number:
	Client:

Location: Clinton, Iowa	Pumping Test: Jordan	Pumping Well: Well 1
Test Conducted by: Layne Northwest	Test Date: 11/1/2006	Discharge: variable, average rate 1519 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 190.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	5	303.00	113.00
2	13	325.00	135.00
3	50	340.00	150.00
4	65	347.00	157.00
5	110	350.00	160.00
6	140	355.00	165.00
7	170	370.00	180.00
8	230	372.00	182.00
9	290	380.00	190.00
10	350	385.00	195.00
11	410	398.00	208.00
12	470	405.00	215.00
13	560	407.00	217.00
14	710	410.00	220.00
15	830	412.00	222.00
16	950	414.00	224.00
17	1130	416.00	226.00
18	1310	418.00	228.00
19	1440	420.00	230.00
20	1620	422.00	232.00
21	2160	428.00	238.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
	Project: Layne-Northwest Clinton ADM
	Number:
	Client:

Location: Clinton, Iowa	Pumping Test: Jordan	Pumping Well: Well 1
Test Conducted by: Layne Northwest		Test Date: 11/1/2006
Analysis Performed by:	Well 1 - with Well Effects	Analysis Date: 8/6/2008
Aquifer Thickness: 530.00 ft	Discharge: variable, average rate 1519 [U.S. gal/min]	



Calculation after Papadopulos & Cooper

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]	
Well 1	1.06×10^{3}	1.99×10^{0}	8.56×10^{-2}	1.0	

Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test - Water Level Data**	Page 1 of 1
	Project: Coralville Recovery Test	
	Number:	
	Client:	

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 10/16/2008	Discharge: variable, average rate 400 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 175.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	450	194.00	19.00
2	451	190.00	15.00
3	453	186.00	11.00
4	454	184.00	9.00
5	455	183.00	8.00
6	456	182.00	7.00
7	458	181.00	6.00
8	460	180.00	5.00

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

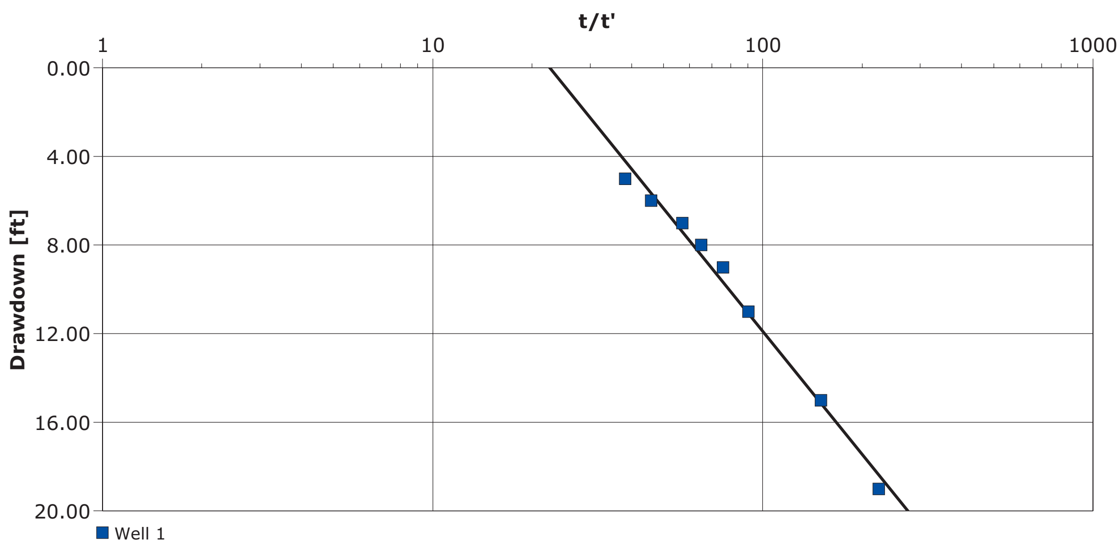
Pumping Test Analysis Report

Project: Coralville Recovery Test

Number:

Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 10/16/2008
Analysis Performed by:	New analysis 1	Analysis Date: 10/16/2008
Aquifer Thickness: 624.00 ft	Discharge: variable, average rate 400 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	7.64×10^2	1.22×10^0	0.3

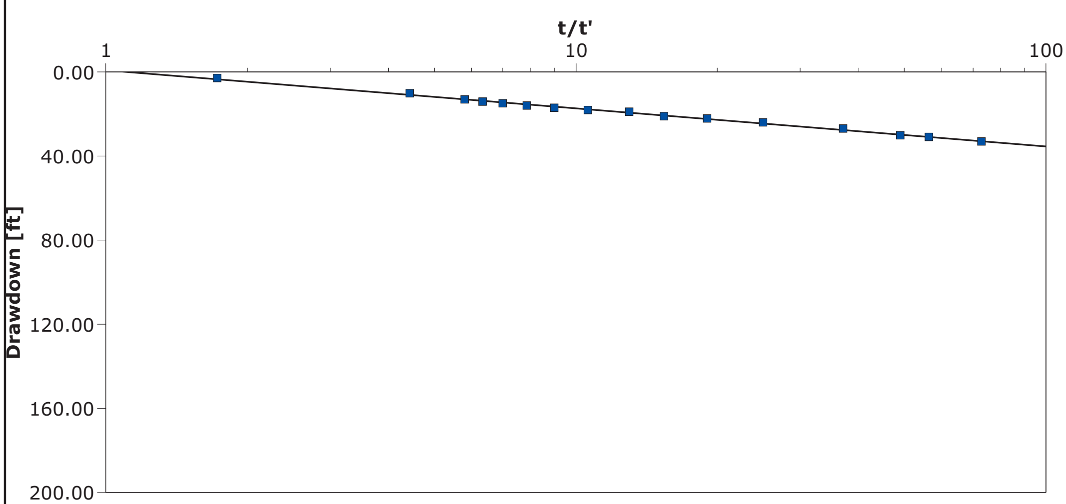
Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test - Water Level Data** Page 1 of 1 Project: Dysart Recovery Number: Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 10/20/2008	Discharge: variable, average rate 600 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 259.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	720	399.00	140.00
2	730	292.00	33.00
3	733	290.00	31.00
4	735	289.00	30.00
5	740	286.00	27.00
6	750	283.00	24.00
7	760	281.00	22.00
8	770	280.00	21.00
9	780	278.00	19.00
10	795	277.00	18.00
11	810	276.00	17.00
12	825	275.00	16.00
13	840	274.00	15.00
14	855	273.00	14.00
15	870	272.00	13.00
16	930	269.00	10.00
17	1710	262.00	3.00

Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test Analysis Report** Project: Dysart Recovery Number: Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 10/20/2008
Analysis Performed by:	New analysis 2	Analysis Date: 10/20/2008
Aquifer Thickness: 581.00 ft	Discharge: variable, average rate 600 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
Well 1	1.16×10^{3}	2.00×10^{0}	0.4	

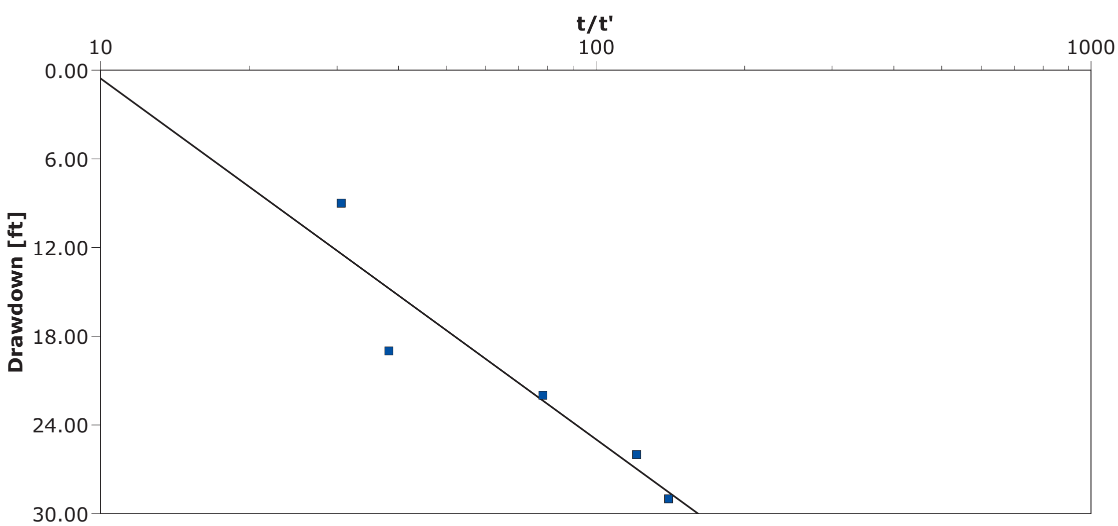
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
	Project: Dysart Park Well
	Number:
	Client:

Location: Dysart, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 6/22/1961	Discharge: variable, average rate 600 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 221.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	4351	250.00	29.00
2	4356	247.00	26.00
3	4376	243.00	22.00
4	4436	240.00	19.00
5	4466	230.00	9.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
	Project: Dysart Park Well
	Number:
	Client:

Location: Dysart, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 6/22/1961
Analysis Performed by:	New analysis 2	Analysis Date: 10/21/2008
Aquifer Thickness: 565.00 ft	Discharge: variable, average rate 600 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
Well 1	8.66×10^2	1.53×10^0	0.4	

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

Pumping Test - Water Level Data Page 1 of 1

Project: Edgewood Recovery Test

Number:

Client:

Location: Edgewood, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 5/21/1985	Discharge: variable, average rate 168.82 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 465.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	675	490.00	25.00
2	690	488.00	23.00
3	735	480.00	15.00
4	750	477.00	12.00
5	765	474.00	9.00
6	780	471.00	6.00
7	840	465.50	0.50

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

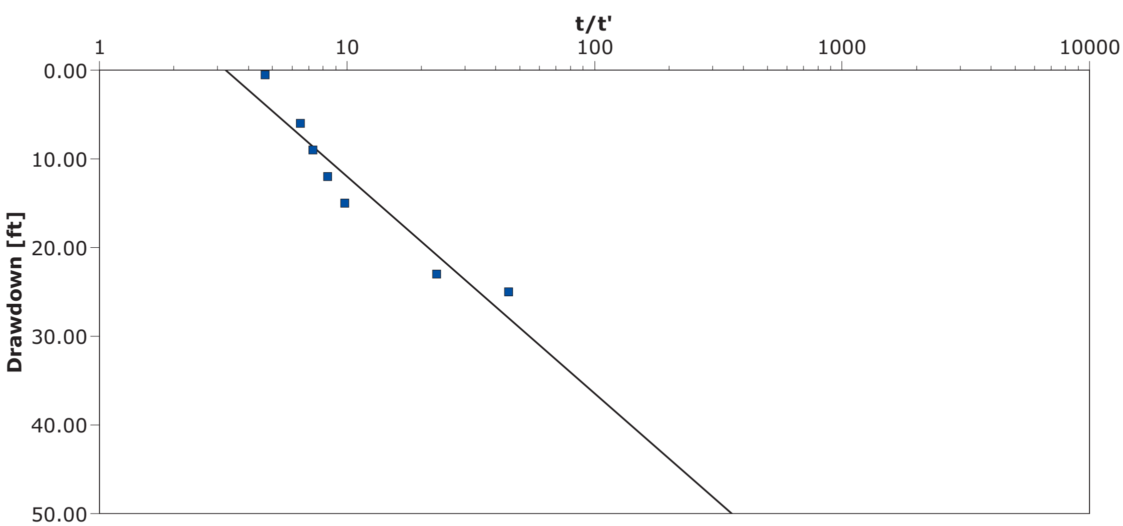
Pumping Test Analysis Report

Project: Edgewood Recovery Test

Number:

Client:

Location: Edgewood, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 5/21/1985
Analysis Performed by:	New analysis 2	Analysis Date: 11/3/2008
Aquifer Thickness: 432.00 ft	Discharge: variable, average rate 168.82 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	2.43×10^{2}	5.63×10^{-1}	0.33

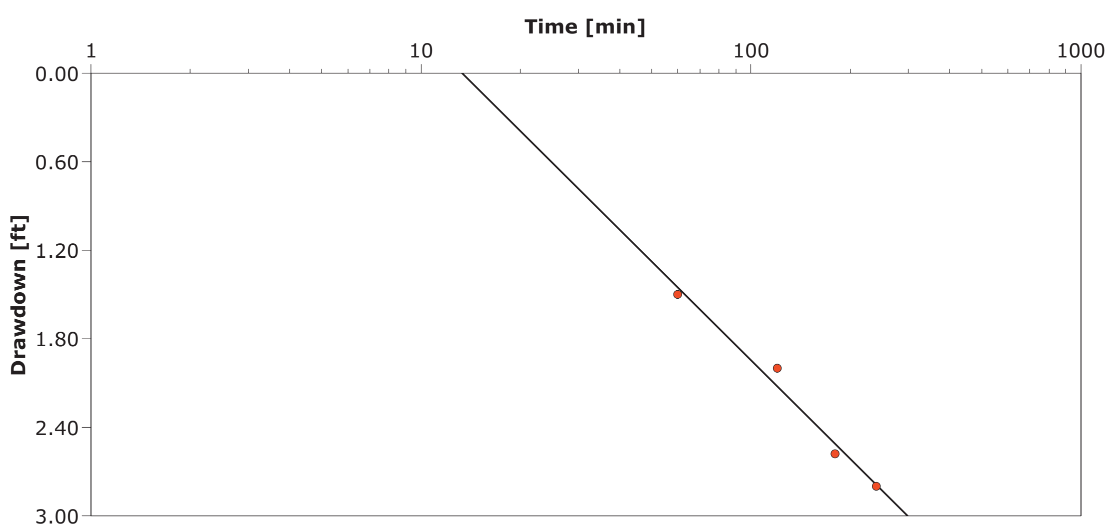
Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test - Water Level Data** Page 1 of 1 Project: Elkader Well 6 Pump test Number: Client:

Location:	Pumping Test: Recovery Test Well 6	Pumping Well: Well 6
Test Conducted by: Peerless	Test Date: 4/27/2005	Discharge: variable, average rate 592.27 [U.S. gal/min]
Observation Well: Well 7	Static Water Level [ft]: 109.00	Radial Distance to PW [ft]: 261

	Time [min]	Water Level [ft]	Drawdown [ft]
1	0	109.00	0.00
2	60	110.50	1.50
3	120	111.00	2.00
4	180	111.58	2.58
5	240	111.80	2.80

Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test Analysis Report** Project: Elkader Well 6 Pump test Number: Client:

Location:	Pumping Test: Recovery Test Well 6	Pumping Well: Well 6
Test Conducted by: Peerless		Test Date: 4/27/2005
Analysis Performed by:	New analysis 3	Analysis Date: 5/19/2009
Aquifer Thickness: 450.00 ft	Discharge: variable, average rate 592.27 [U.S. gal/min]	



Calculation after Cooper & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]
Well 7	9.38×10^{3}	2.09×10^{1}	2.87×10^{-3}	261.0

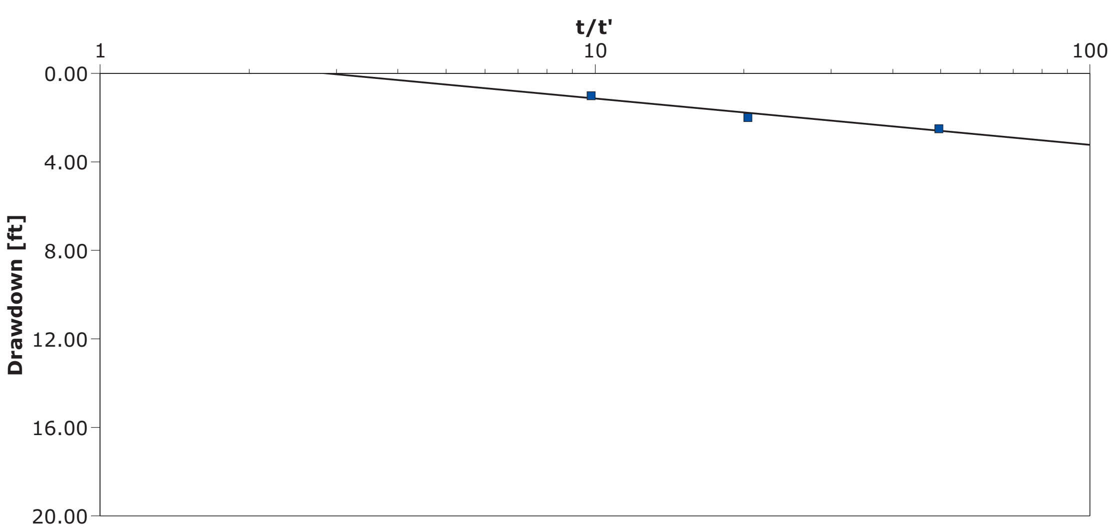
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data**	Page 1 of 1
	Project: Elkader Well 6 Pump test	
	Number:	
	Client:	

Location:	Pumping Test: Recovery Test Well 6	Pumping Well: Well 6
Test Conducted by: Peerless	Test Date: 4/27/2005	Discharge: variable, average rate 592.27 [U.S. gal/min]
Observation Well: Well 6	Static Water Level [ft]: 95.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	480	112.00	17.00
2	481	99.00	4.00
3	485	98.00	3.00
4	495	97.50	2.50
5	510	97.00	2.00
6	540	96.00	1.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**	
	Project: Elkader Well 6 Pump test	
	Number:	
	Client:	

Location:	Pumping Test: Recovery Test Well 6	Pumping Well: Well 6
Test Conducted by: Peerless		Test Date: 4/27/2005
Analysis Performed by:	New analysis 2	Analysis Date: 9/5/2008
Aquifer Thickness: 450.00 ft	Discharge: variable, average rate 592.27 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 6	9.91×10^3	2.20×10^1	1.0

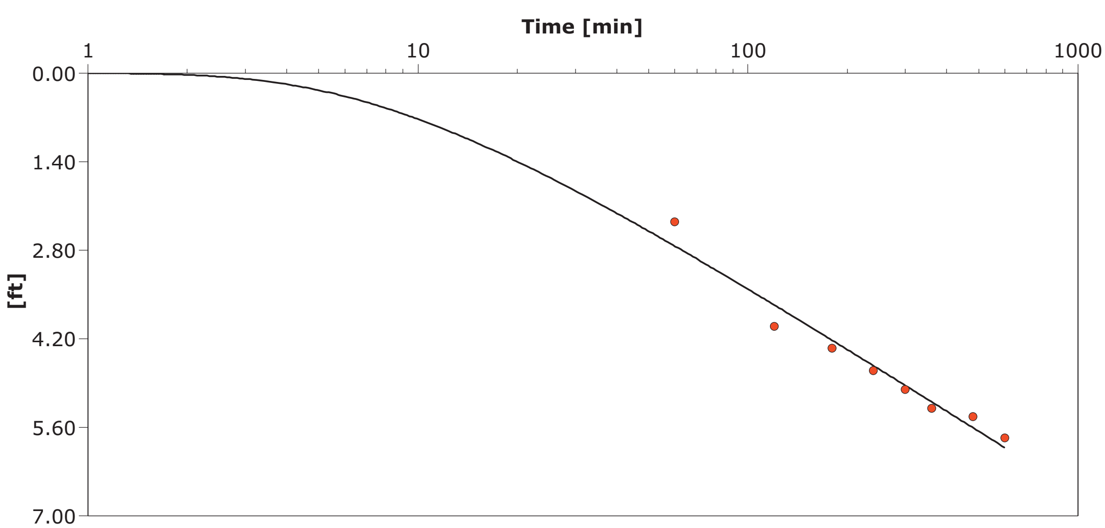
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1 Project: Elkader Well 7 Number: Client:

Location:	Pumping Test: Recovery Test Well 7	Pumping Well: Well 7
Test Conducted by: Peerless	Test Date: 4/25/2005	Discharge: variable, average rate 587.27 [U.S. gal/min]
Observation Well: Well 6	Static Water Level [ft]: 94.90	Radial Distance to PW [ft]: 261

	Time [min]	Water Level [ft]	Drawdown [ft]
1	0	94.90	0.00
2	60	97.25	2.35
3	120	98.90	4.00
4	180	99.25	4.35
5	240	99.60	4.70
6	300	99.90	5.00
7	360	100.20	5.30
8	480	100.33	5.43
9	600	100.67	5.77

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report** Project: Elkader Well 7 Number: Client:

Location:	Pumping Test: Recovery Test Well 7	Pumping Well: Well 7
Test Conducted by: Peerless		Test Date: 4/25/2005
Analysis Performed by:	New analysis 1	Analysis Date: 9/5/2008
Aquifer Thickness: 480.00 ft	Discharge: variable, average rate 587.27 [U.S. gal/min]	



Calculation after Theis

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]	
Well 6	6.27×10^{3}	1.31×10^{1}	1.40×10^{-3}	261.0	

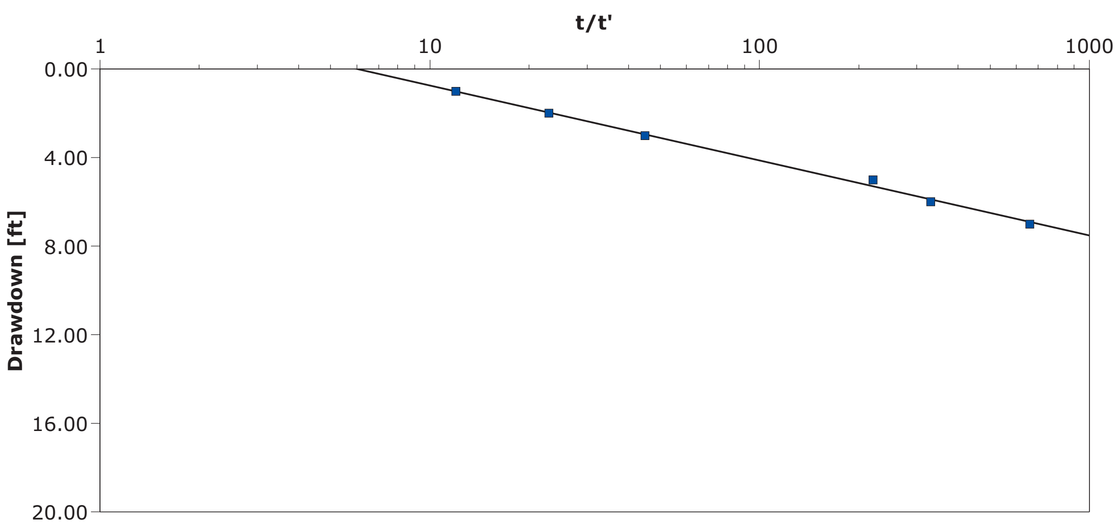
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
	Project: Elkader Well 7
	Number:
	Client:

Location:	Pumping Test: Recovery Test Well 7	Pumping Well: Well 7
Test Conducted by: Peerless	Test Date: 4/25/2005	Discharge: variable, average rate 587.27 [U.S. gal/min]
Observation Well: Well 7	Static Water Level [ft]: 109.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	660	126.00	17.00
2	661	116.00	7.00
3	662	115.00	6.00
4	663	114.00	5.00
5	675	112.00	3.00
6	690	111.00	2.00
7	720	110.00	1.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
	Project: Elkader Well 7
	Number:
	Client:

Location:	Pumping Test: Recovery Test Well 7	Pumping Well: Well 7
Test Conducted by: Peerless		Test Date: 4/25/2005
Analysis Performed by:	New analysis 3	Analysis Date: 9/5/2008
Aquifer Thickness: 480.00 ft	Discharge: variable, average rate 587.27 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 7	6.11×10^3	1.27×10^1	1.0

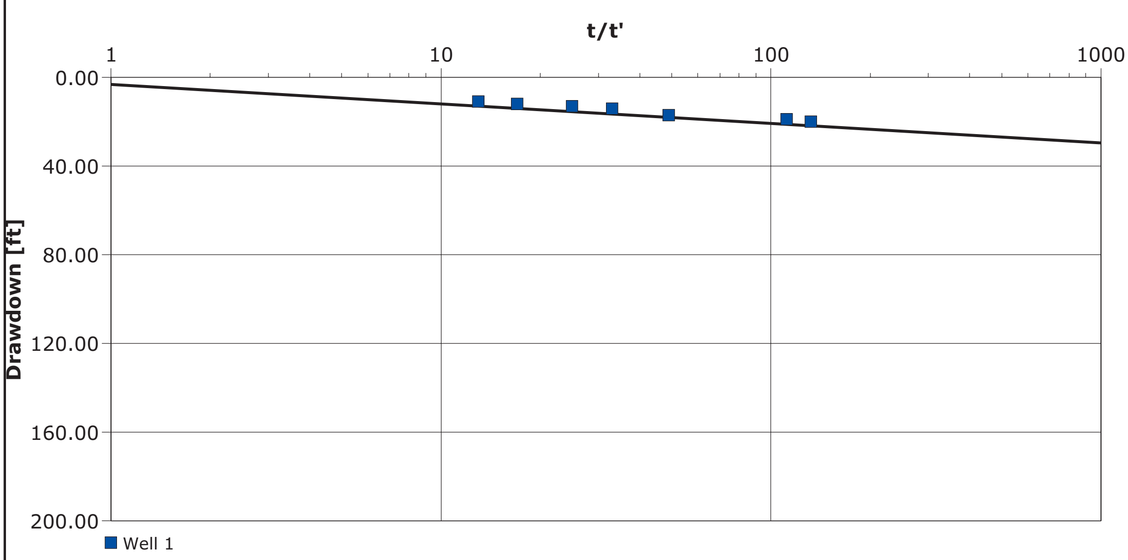
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
	Project: Farley
	Number:
	Client:

Location: Farley, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 3/20/2008	Discharge: variable, average rate 299.79 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 473.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1440	605.00	132.00
2	1441	581.00	108.00
3	1451	493.00	20.00
4	1453	492.00	19.00
5	1470	490.00	17.00
6	1485	487.00	14.00
7	1500	486.00	13.00
8	1530	485.00	12.00
9	1560	484.00	11.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
	Project: Farley
	Number:
	Client:

Location: Farley, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 3/20/2008
Analysis Performed by:	New analysis 2	Analysis Date: 8/28/2008
Aquifer Thickness: 438.00 ft	Discharge: variable, average rate 299.79 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	1.20×10^{3}	2.74×10^{0}	1.0

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Pumping Test - Water Level Data	Page 1 of 1
Project: Farm Best	
Number:	
Client:	

Location: Iowa Falls, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 8/29/2008	Discharge: variable, average rate 324.77 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 250.12	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1440	287.17	37.05
2	1441	266.12	16.00
3	1575	262.54	12.42
4	1739	259.50	9.38
5	1904	257.50	7.38
6	1934	257.20	7.08
7	1994	256.63	6.51
8	2114	255.61	5.49

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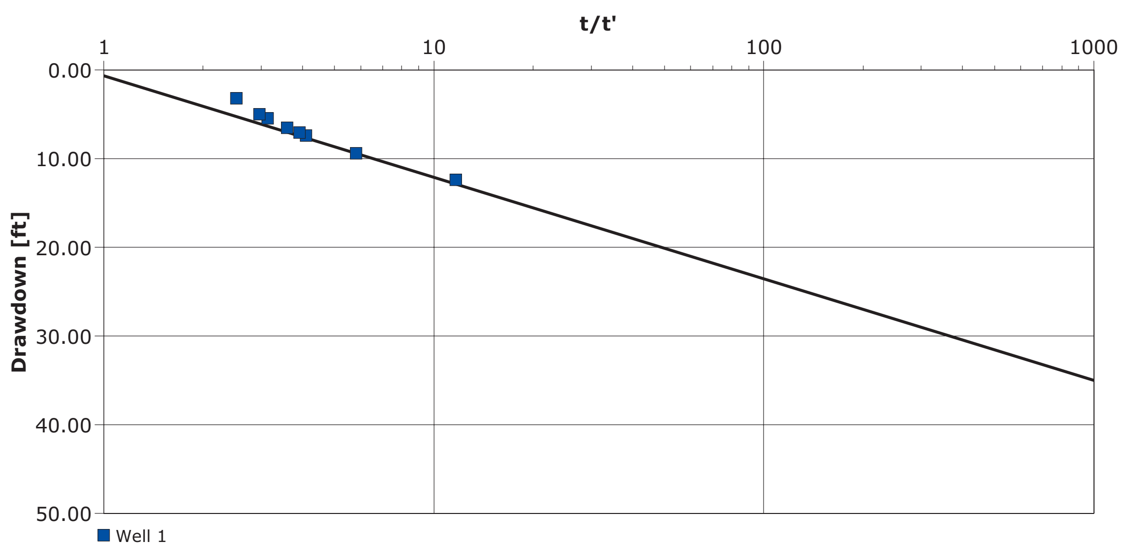
Pumping Test Analysis Report
Project: Farm Best
Number:
Client:

Location: Iowa Falls, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 8/29/2008
Analysis Performed by:	New analysis 1	Analysis Date: 8/29/2008
Aquifer Thickness: 533.00 ft	Discharge: variable, average rate 324.77 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	1.00×10^{3}	1.88×10^{0}	1.0

Iowa Department of Natural Resources
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Pumping Test - Water Level Data Page 1 of 1

Project: Fort Dodge Recovery Test		
Number:		
Client:		
Location:	Pumping Test: Well #17	Pumping Well: Well 17
Test Conducted by: Thorpe Well	Test Date: 9/3/1970	Discharge: variable, average rate 1049.9 [U.S. gal/min]
Observation Well: Well 17	Static Water Level [ft]: 160.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	8610	225.00	65.00
2	8760	201.00	41.00
3	8850	190.00	30.00
4	9570	181.00	21.00

Iowa Department of Natural Resources
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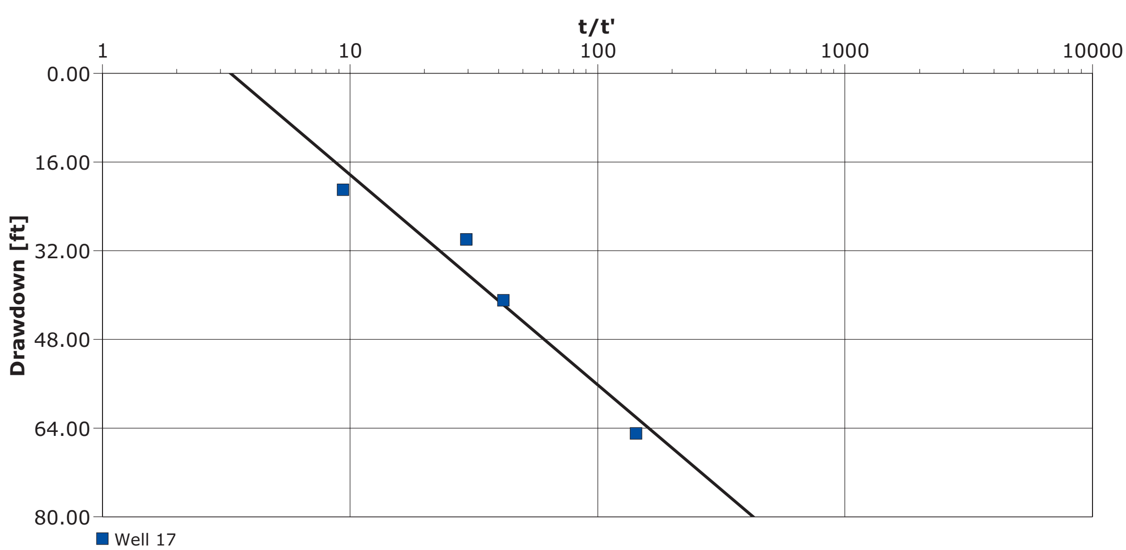
Pumping Test Analysis Report

Project: Fort Dodge Recovery Test		
Number:		
Client:		
Location:	Pumping Test: Well #17	Pumping Well: Well 17
Test Conducted by: Thorpe Well		Test Date: 9/3/1970
Analysis Performed by:	New analysis 1	Analysis Date: 9/25/2008
Aquifer Thickness: 480.00 ft	Discharge: variable, average rate 1049.9 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 17	9.76×10^{2}	2.03×10^{0}	1.0

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1 Project: Fort Dodge Recovery Test Number: Client:

Location: Fort Dodge, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 9/3/1970	Discharge: variable, average rate 2100 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 160.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	8700	225.00	65.00
2	8850	201.00	41.00
3	8940	190.00	30.00
4	9360	181.00	21.00

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

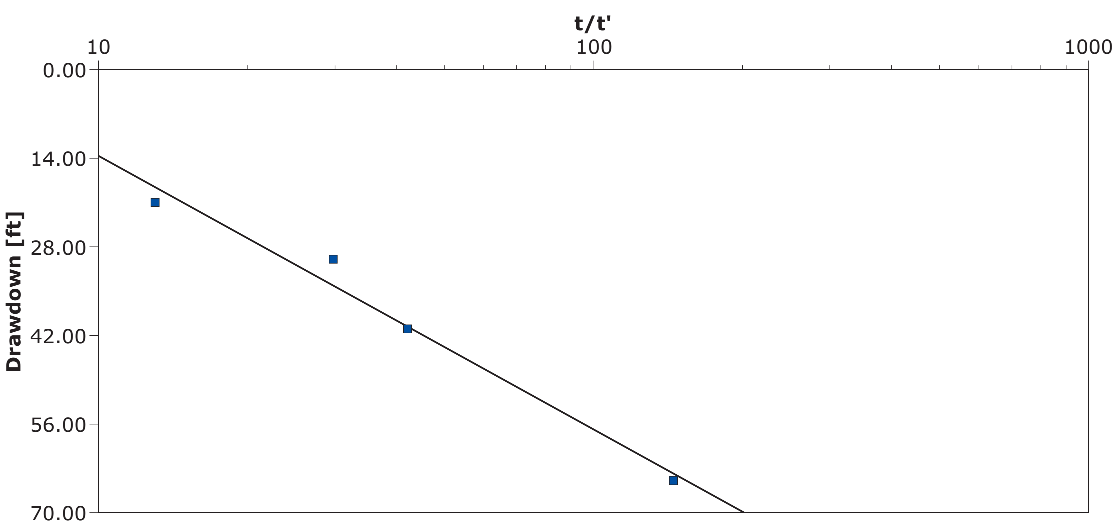
Pumping Test Analysis Report

Project: Fort Dodge Recovery Test

Number:

Client:

Location: Fort Dodge, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 9/3/1970
Analysis Performed by:	New analysis 3	Analysis Date: 11/3/2008
Aquifer Thickness: 435.00 ft	Discharge: variable, average rate 2100 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	1.71×10^3	3.94×10^0	0.5

Iowa Department of Natural Resources
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Iowa City, Iowa

Pumping Test - Water Level Data Page 1 of 1

Project: Mason City Golden Grains

Number:

Client:

Location:	Pumping Test: Golden Grains #2	Pumping Well: Golden #2
Test Conducted by:	Test Date: 4/26/2007	Discharge Rate: 600 [U.S. gal/min]
Observation Well: Golden #1	Static Water Level [ft]: 341.00	Radial Distance to PW [ft]: 800

	Time [min]	Water Level [ft]	Drawdown [ft]
1	0.1	342.00	1.00
2	120	350.00	9.00
3	240	351.00	10.00
4	390	353.00	12.00
5	720	353.00	12.00

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

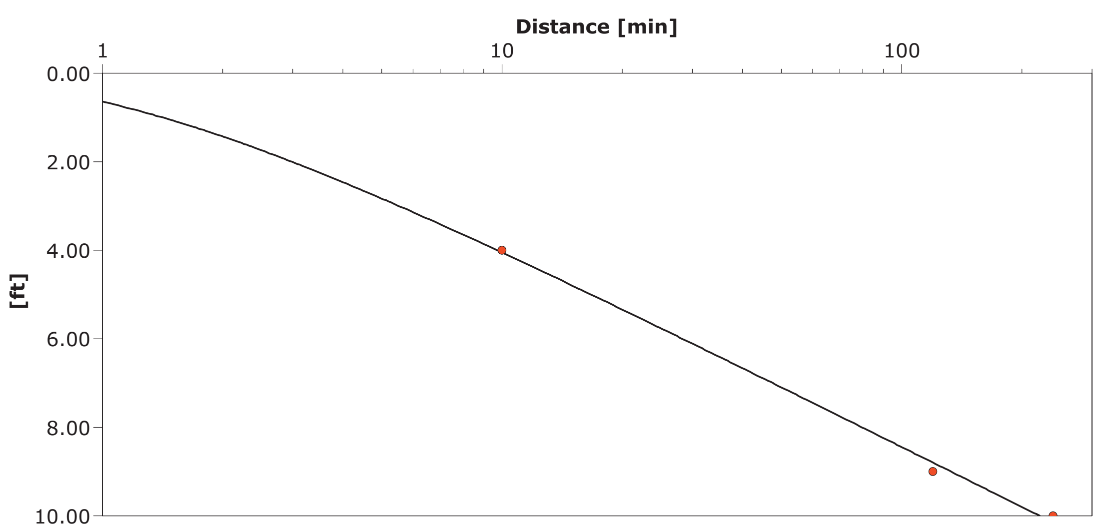
Pumping Test Analysis Report

Project: Mason City Golden Grains

Number:

Client:

Location:	Pumping Test: Golden Grains #2	Pumping Well: Golden #2
Test Conducted by:		Test Date: 4/26/2007
Analysis Performed by:	New analysis 15	Analysis Date: 5/19/2009
Aquifer Thickness: 700.00 ft	Discharge Rate: 600 [U.S. gal/min]	



Calculation after Theis

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Time [min]	Radial Distance to PW [ft]
Golden #1	4.68×10^{3}	6.68×10^{0}	1.57×10^{-5}	1.00×10^{-7}	800.0

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Pumping Test - Water Level Data Page 1 of 1

Project: Goose Lake Recovery Test		
Number:		
Client:		
Location: Goose Lake, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 6/17/2004	Discharge: variable, average rate 225 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 196.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	480	211.00	15.00
2	540	206.00	10.00
3	600	205.50	9.50

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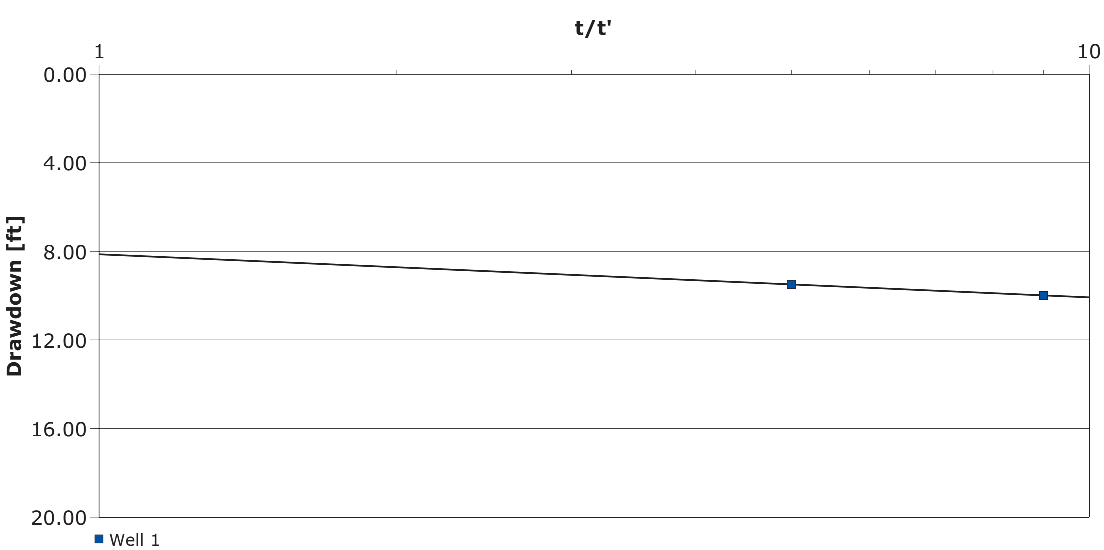
Pumping Test Analysis Report

Project: Goose Lake Recovery Test		
Number:		
Client:		
Location: Goose Lake, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 6/17/2004
Analysis Performed by:	New analysis 6	Analysis Date: 5/19/2009
Aquifer Thickness: 345.00 ft	Discharge: variable, average rate 225 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
Well 1	4.05×10^{3}	1.17×10^{1}	1.0	

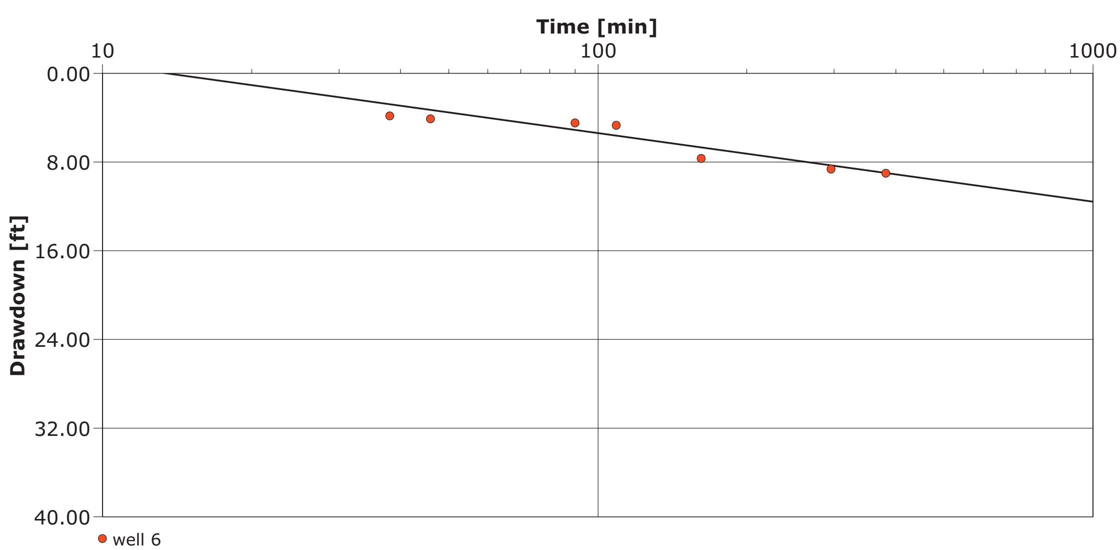
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
	Project: Grinnell Pump Test
	Number:
	Client:

Location: Grinnell, Iowa	Pumping Test: Well 5	Pumping Well: Well 5
Test Conducted by:	Test Date: 10/15/2008	Discharge: variable, average rate 357 [U.S. gal/min]
Observation Well: well 6	Static Water Level [ft]: 270.16	Radial Distance to PW [ft]: 42.5

	Time [min]	Water Level [ft]	Drawdown [ft]
1	0	270.16	0.00
2	38	274.02	3.86
3	46	274.25	4.09
4	90	274.63	4.47
5	109	274.88	4.72
6	162	277.85	7.69
7	296	278.79	8.63
8	382	279.16	9.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
	Project: Grinnell Pump Test
	Number:
	Client:

Location: Grinnell, Iowa	Pumping Test: Well 5	Pumping Well: Well 5
Test Conducted by:		Test Date: 10/15/2008
Analysis Performed by: Mike Gannon	New analysis 2	Analysis Date: 10/15/2008
Aquifer Thickness: 550.00 ft	Discharge: variable, average rate 357 [U.S. gal/min]	



Calculation after Cooper & Jacob

Observation Well	Transmissivity [ft^2/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]	
well 6	2.04×10^{3}	3.70×10^{0}	2.36×10^{-2}	42.5	

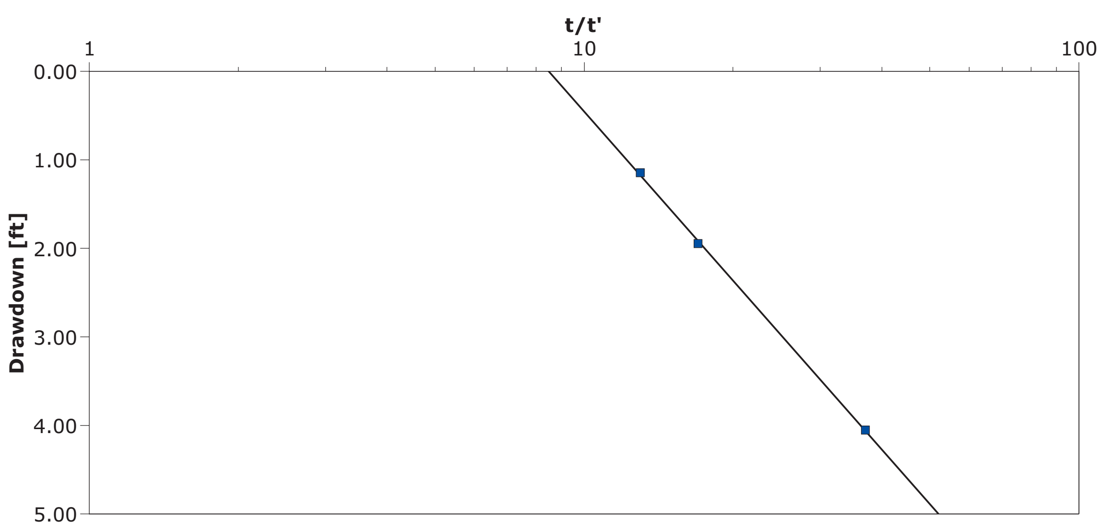
Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test - Water Level Data**	Page 1 of 1
	Project: Grinnell Well 7 Recovery Test	
	Number:	
	Client:	

Location:	Pumping Test: Well 7	Pumping Well: Well 7
Test Conducted by:	Test Date: 10/22/2008	Discharge: variable, average rate 800 [U.S. gal/min]
Observation Well: Well 7	Static Water Level [ft]: 304.75	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1480	308.80	4.05
2	1530	306.70	1.95
3	1560	305.90	1.15

Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test Analysis Report**	
	Project: Grinnell Well 7 Recovery Test	
	Number:	
	Client:	

Location:	Pumping Test: Well 7	Pumping Well: Well 7
Test Conducted by:		Test Date: 10/22/2008
Analysis Performed by:	New analysis 2	Analysis Date: 10/22/2008
Aquifer Thickness: 554.00 ft	Discharge: variable, average rate 800 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
Well 7	4.44×10^3	8.02×10^0	0.4	

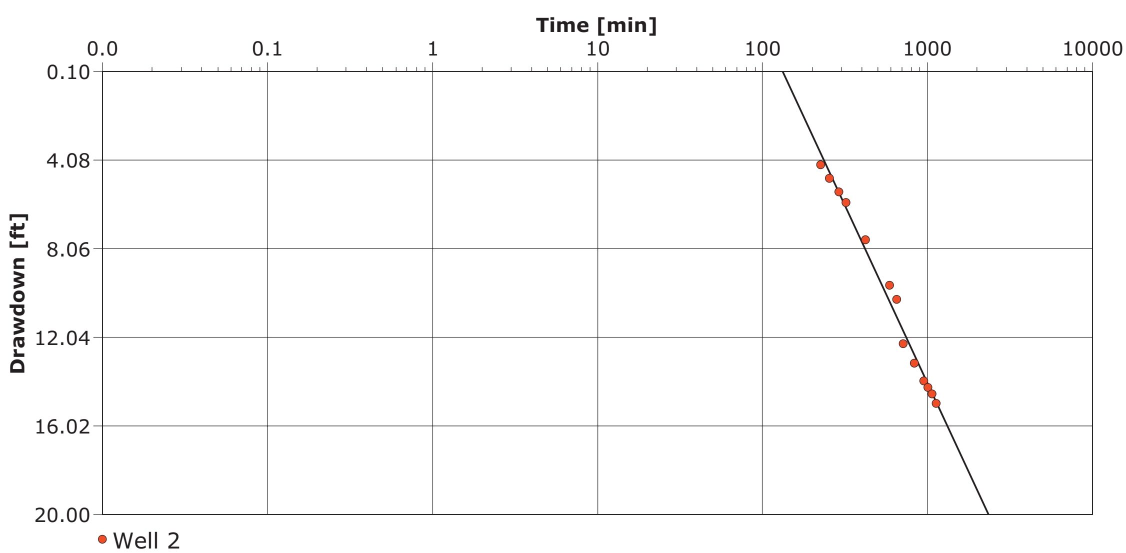
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1 Project: Homeland Ethanol Number: Client:

Location: Lawler, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by: Shawver	Test Date: 4/23/2008	Discharge: variable, average rate 1062.2 [U.S. gal/min]
Observation Well: Well 2	Static Water Level [ft]: 336.00	Radial Distance to PW [ft]: 205

	Time [min]	Water Level [ft]	Drawdown [ft]
1	0	336.00	0.00
2	225	340.30	4.30
3	255	340.90	4.90
4	290	341.50	5.50
5	322	342.00	6.00
6	420	343.65	7.65
7	590	345.70	9.70
8	650	346.33	10.33
9	710	348.33	12.33
10	830	349.20	13.20
11	950	350.00	14.00
12	1010	350.30	14.30
13	1070	350.60	14.60
14	1130	351.00	15.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report** Project: Homeland Ethanol Number: Client:

Location: Lawler, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by: Shawver		Test Date: 4/23/2008
Analysis Performed by:	New analysis 8	Analysis Date: 8/28/2008
Aquifer Thickness: 500.00 ft	Discharge: variable, average rate 1062.2 [U.S. gal/min]	



Calculation after Cooper & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]
Well 2	2.35×10^{3}	4.69×10^{0}	1.14×10^{-2}	205.0

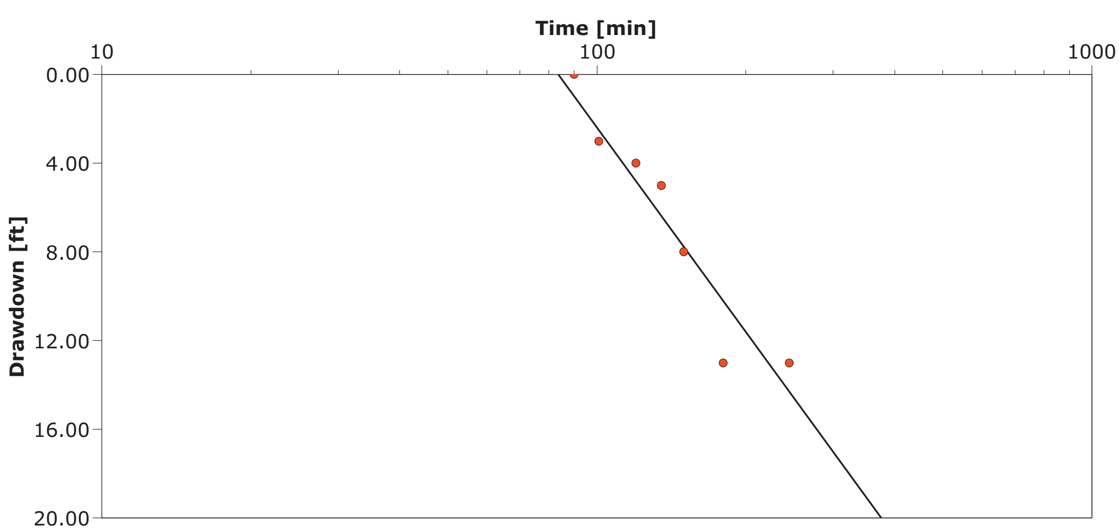
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
	Project: Indianola Pump Test
	Number:
	Client:

Location:	Pumping Test: Well 10	Pumping Well: Well 10
Test Conducted by:	Test Date: 10/20/2008	Discharge Rate: 650 [U.S. gal/min]
Observation Well: Well 9	Static Water Level [ft]: 122.00	Radial Distance to PW [ft]: 10000

	Time [min]	Water Level [ft]	Drawdown [ft]
1	90	122.00	0.00
2	101	125.00	3.00
3	120	126.00	4.00
4	135	127.00	5.00
5	150	130.00	8.00
6	180	135.00	13.00
7	245	135.00	13.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
	Project: Indianola Pump Test
	Number:
	Client:

Location:	Pumping Test: Well 10	Pumping Well: Well 10
Test Conducted by:		Test Date: 10/20/2008
Analysis Performed by:	New analysis 2	Analysis Date: 10/20/2008
Aquifer Thickness: 528.00 ft	Discharge Rate: 650 [U.S. gal/min]	



Calculation after Cooper & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Storage coefficient	Radial Distance to PW [ft]	
Well 9	7.47×10^{2}	1.42×10^{0}	9.76×10^{-7}	10000.0	

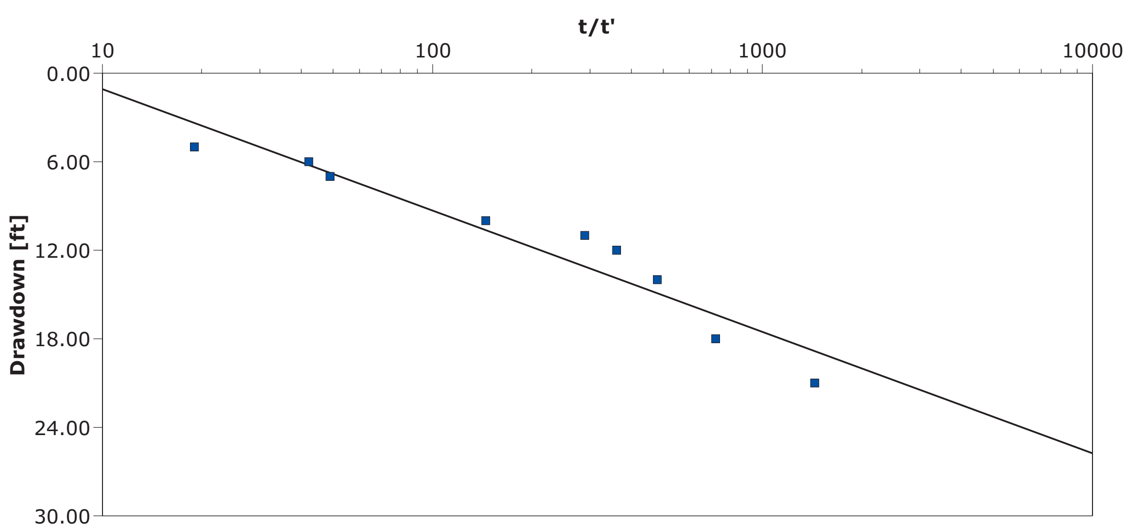
	Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
		Project: Indianola Recovery Test
		Number:
		Client:

Location: Indianola, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 6/18/1976	Discharge: variable, average rate 1850 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 188.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1441	209.00	21.00
2	1442	206.00	18.00
3	1443	202.00	14.00
4	1444	200.00	12.00
5	1445	199.00	11.00
6	1450	198.00	10.00
7	1470	195.00	7.00
8	1475	194.00	6.00
9	1520	193.00	5.00

	Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
		Project: Indianola Recovery Test
		Number:
		Client:

Location: Indianola, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 6/18/1976
Analysis Performed by:	New analysis 2	Analysis Date: 11/3/2008
Aquifer Thickness: 487.00 ft	Discharge: variable, average rate 1850 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
Well 1	7.92×10^{3}	1.63×10^{1}	0.6	

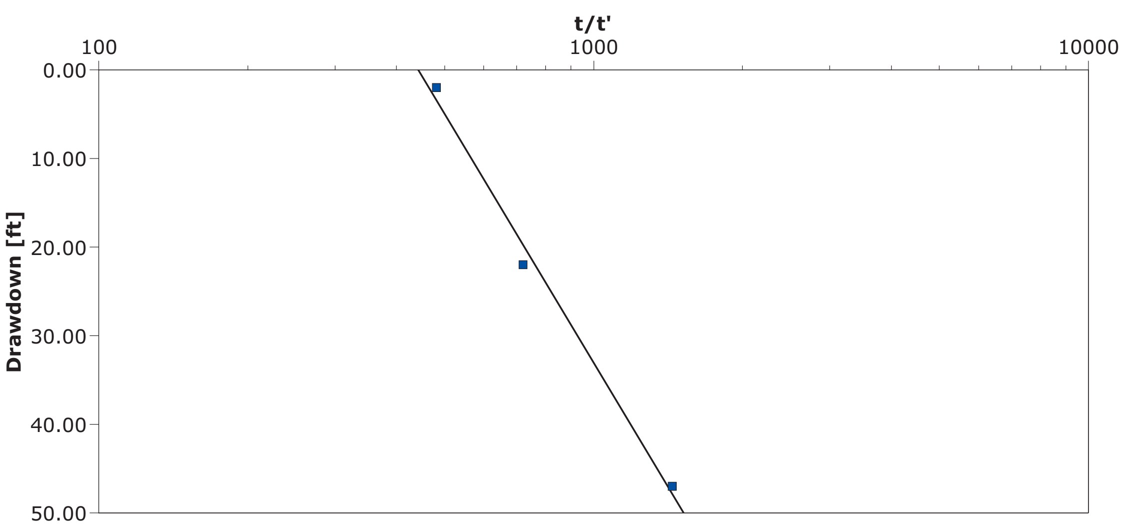
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
	Project: Indianola Recovery Test
	Number:
	Client:

Location: Indianola, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 8/23/1955	Discharge: variable, average rate 400 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 88.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1441	135.00	47.00
2	1442	110.00	22.00
3	1443	90.00	2.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
	Project: Indianola Recovery Test
	Number:
	Client:

Location: Indianola, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 8/23/1955
Analysis Performed by:	New analysis 2	Analysis Date: 11/4/2008
Aquifer Thickness: 490.00 ft	Discharge: variable, average rate 400 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	1.51×10^{2}	3.09×10^{-1}	0.33

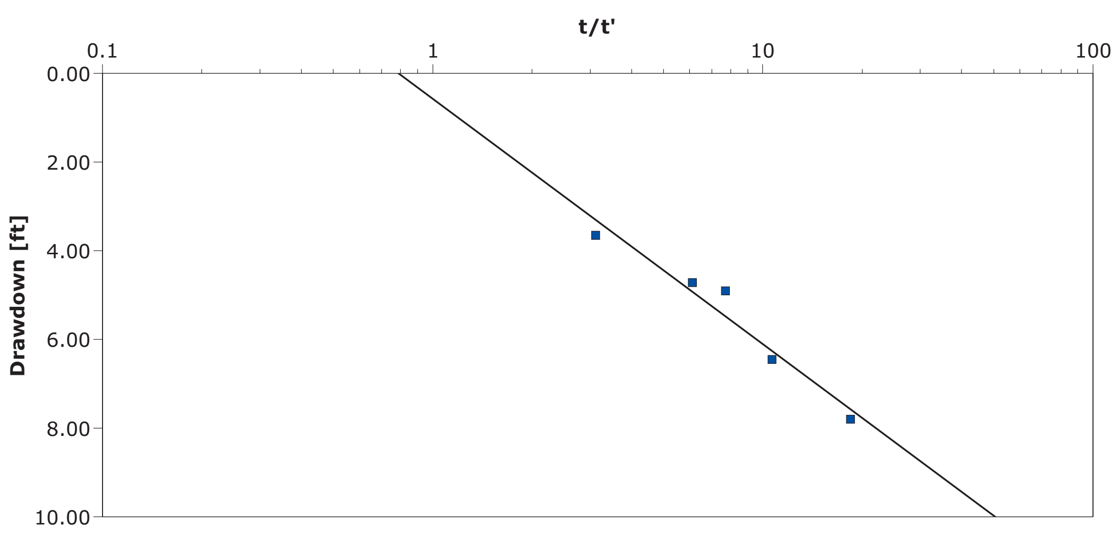
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	Pumping Test - Water Level Data	Page 1 of 1
	Project: Iowa City-Old Recovery Test	
	Number:	
	Client:	

Location:	Pumping Test: Pumping Test 1	Pumping Well: old well
Test Conducted by:	Test Date: 10/16/2008	Discharge: variable, average rate 1000 [U.S. gal/min]
Observation Well: old well	Static Water Level [ft]: 45.35	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	2760	53.15	7.80
2	2880	51.80	6.45
3	3000	50.26	4.91
4	3120	50.07	4.72
5	3840	49.00	3.65

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	Pumping Test Analysis Report
	Project: Iowa City-Old Recovery Test
	Number:
	Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: old well
Test Conducted by:		Test Date: 10/16/2008
Analysis Performed by:	New analysis 1	Analysis Date: 10/16/2008
Aquifer Thickness: 620.00 ft	Discharge: variable, average rate 1000 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
old well	6.37×10^3	1.03×10^1	0.33

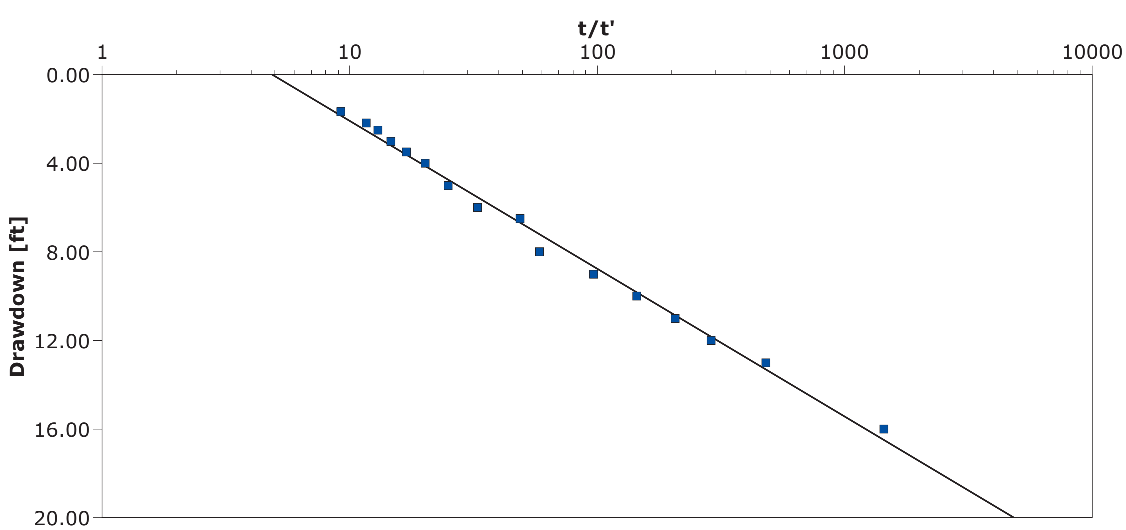
	Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
		Project: LeGrand Recovery Test
		Number:
		Client:

Location: LeGrand, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 12/29/1977	Discharge: variable, average rate 335 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 281.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1441	297.00	16.00
2	1443	294.00	13.00
3	1445	293.00	12.00
4	1447	292.00	11.00
5	1450	291.00	10.00
6	1455	290.00	9.00
7	1465	289.00	8.00
8	1470	287.50	6.50

	Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
		Project: LeGrand Recovery Test
		Number:
		Client:

Location: LeGrand, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 12/29/1977
Analysis Performed by:	New analysis 2	Analysis Date: 11/3/2008
Aquifer Thickness: 605.00 ft	Discharge: variable, average rate 335 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	1.77×10^{3}	2.92×10^{0}	0.41

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

Pumping Test - Water Level Data

Project: Lytton Recovery Test

Number:

Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 10/15/2008	Discharge: variable, average rate 110 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 74.40	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	251	84.10	9.70
2	253	83.53	9.13
3	258	82.55	8.15
4	262	82.04	7.64
5	274	80.95	6.55
6	292	79.90	5.50
7	301	79.50	5.10

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

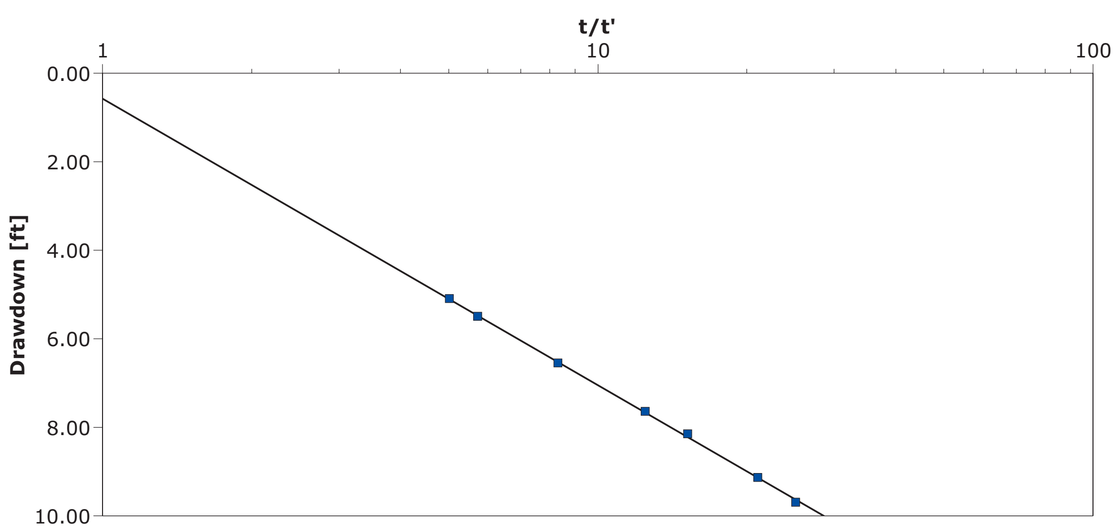
Pumping Test Analysis Report

Project: Lytton Recovery Test

Number:

Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 10/15/2008
Analysis Performed by:	New analysis 2	Analysis Date: 10/15/2008
Aquifer Thickness: 355.00 ft	Discharge: variable, average rate 110 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	5.98×10^2	1.69×10^0	1.0

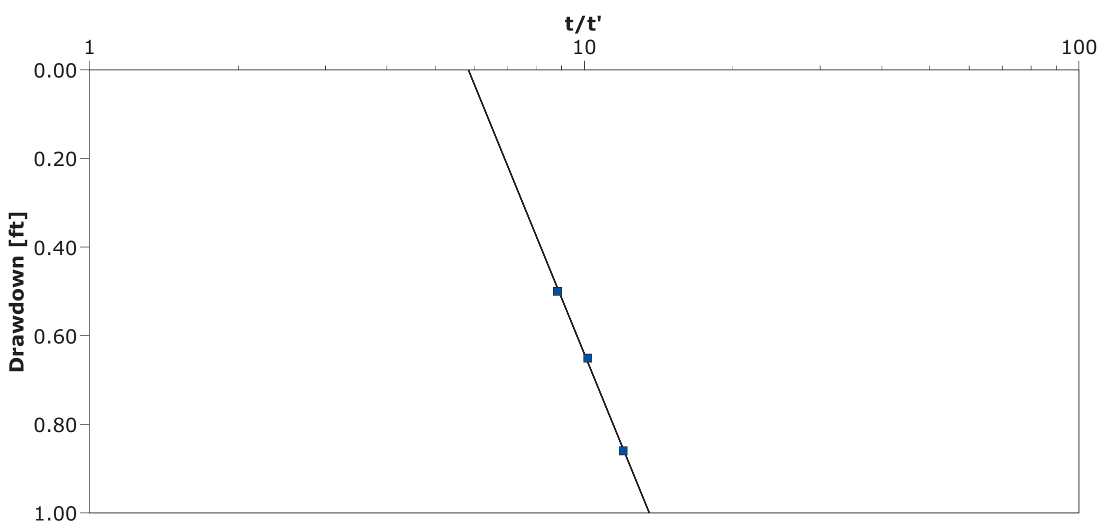
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa		**Pumping Test - Water Level Data**	Page 1 of 1
		Project: Mount Pleasant Recovery Test	
		Number:	
		Client:	

Location: Mount Pleasant, Iowa	Pumping Test: Well 3	Pumping Well: Well 3
Test Conducted by:	Test Date: 10/15/2008	Discharge: variable, average rate 293.93 [U.S. gal/min]
Observation Well: Well 3	Static Water Level [ft]: 91.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	120	91.86	0.86
2	122	91.65	0.65
3	124	91.50	0.50

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**	
	Project: Mount Pleasant Recovery Test	
	Number:	
	Client:	

Location: Mount Pleasant, Iowa	Pumping Test: Well 3	Pumping Well: Well 3
Test Conducted by:		Test Date: 10/15/2008
Analysis Performed by:	New analysis 3	Analysis Date: 10/15/2008
Aquifer Thickness: 695.00 ft	Discharge: variable, average rate 293.93 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 3	3.79×10^{3}	5.45×10^{0}	0.33

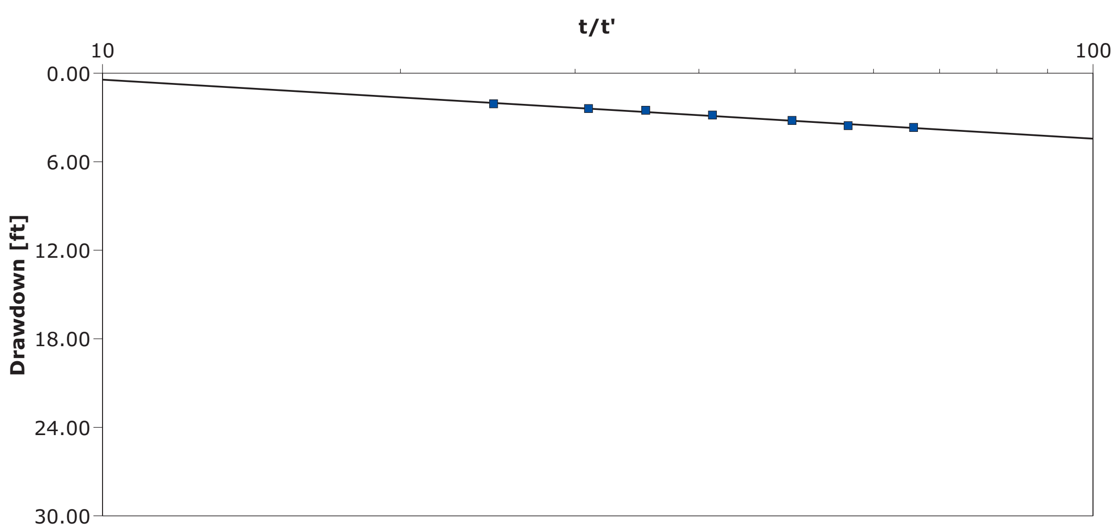
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data**	Page 1 of 1
	Project: North English Recovery Test	
	Number:	
	Client:	

Location:	Pumping Test: Pumping Test 1	Pumping Well: well 2
Test Conducted by:	Test Date: 10/15/2008	Discharge: variable, average rate 408.9 [U.S. gal/min]
Observation Well: well 2	Static Water Level [ft]: 129.30	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1168	149.58	20.28
2	1186	133.00	3.70
3	1189	132.85	3.55
4	1192	132.50	3.20
5	1197	132.16	2.86
6	1202	131.84	2.54
7	1207	131.70	2.40
8	1217	131.40	2.10

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
	Project: North English Recovery Test
	Number:
	Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: well 2
Test Conducted by:		Test Date: 10/15/2008
Analysis Performed by:	New analysis 2	Analysis Date: 10/15/2008
Aquifer Thickness: 570.00 ft	Discharge: variable, average rate 408.9 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
well 2	3.62×10^3	6.35×10^0	0.5

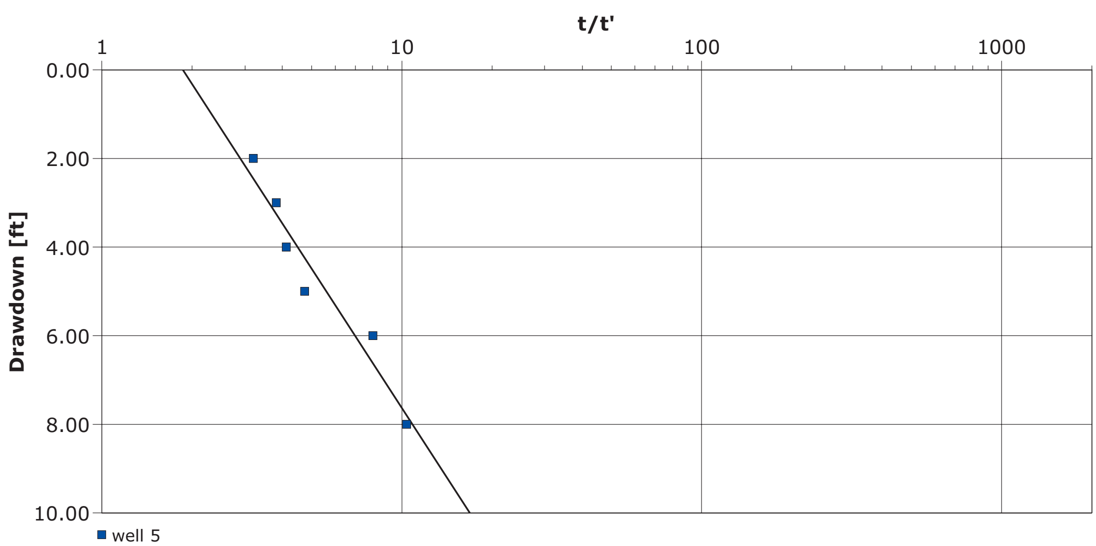
Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test - Water Level Data** Page 1 of 1 Project: North Liberty Recovery Test Number: Client:

Location: North Liberty, Iowa	Pumping Test: Well 5	Pumping Well: well 5
Test Conducted by: Winslow	Test Date: 10/31/1994	Discharge: variable, average rate 898.94 [U.S. gal/min]
Observation Well: well 5	Static Water Level [ft]: 250.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	935	258.00	8.00
2	965	256.00	6.00
3	1070	255.00	5.00
4	1115	254.00	4.00
5	1145	253.00	3.00
6	1230	252.00	2.00

Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test Analysis Report** Project: North Liberty Recovery Test Number: Client:

Location: North Liberty, Iowa	Pumping Test: Well 5	Pumping Well: well 5
Test Conducted by: Winslow		Test Date: 10/31/1994
Analysis Performed by:	New analysis 2	Analysis Date: 9/4/2008
Aquifer Thickness: 523.00 ft	Discharge: variable, average rate 898.94 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
well 5	3.03×10^3	5.79×10^0	1.0	

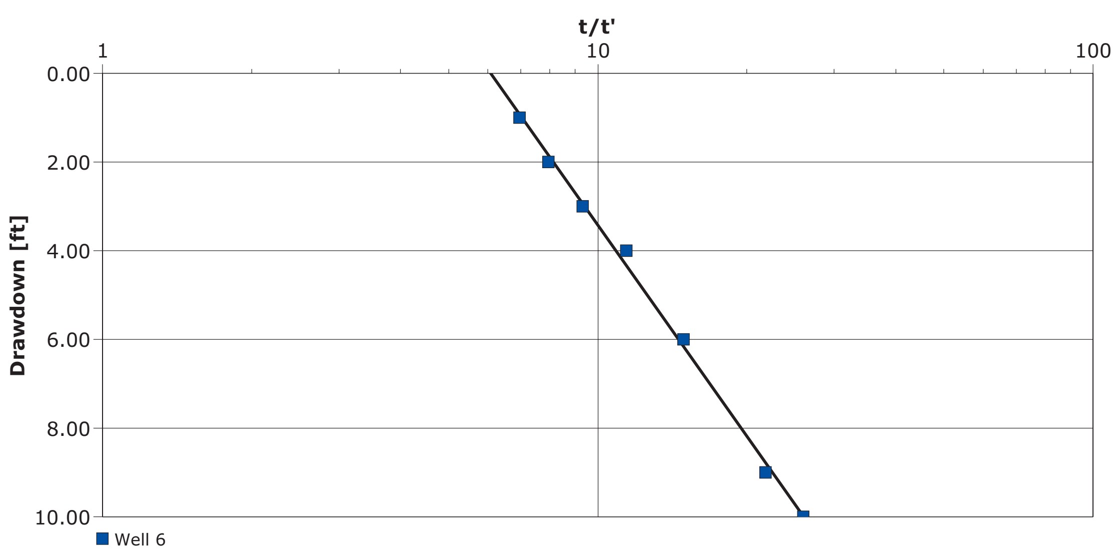
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
	Project: North Liberty Recovery Test
	Number:
	Client:

Location:	Pumping Test: Well 6	Pumping Well: Well 6
Test Conducted by:	Test Date: 9/4/2008	Discharge: variable, average rate 900 [U.S. gal/min]
Observation Well: Well 6	Static Water Level [ft]: 324.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	650	334.00	10.00
2	655	333.00	9.00
3	670	330.00	6.00
4	685	328.00	4.00
5	700	327.00	3.00
6	715	326.00	2.00
7	730	325.00	1.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
	Project: North Liberty Recovery Test
	Number:
	Client:

Location:	Pumping Test: Well 6	Pumping Well: Well 6
Test Conducted by:		Test Date: 9/4/2008
Analysis Performed by:	New analysis 1	Analysis Date: 9/4/2008
Aquifer Thickness: 528.00 ft	Discharge: variable, average rate 900 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 6	2.00×10^{3}	3.80×10^{0}	1.0

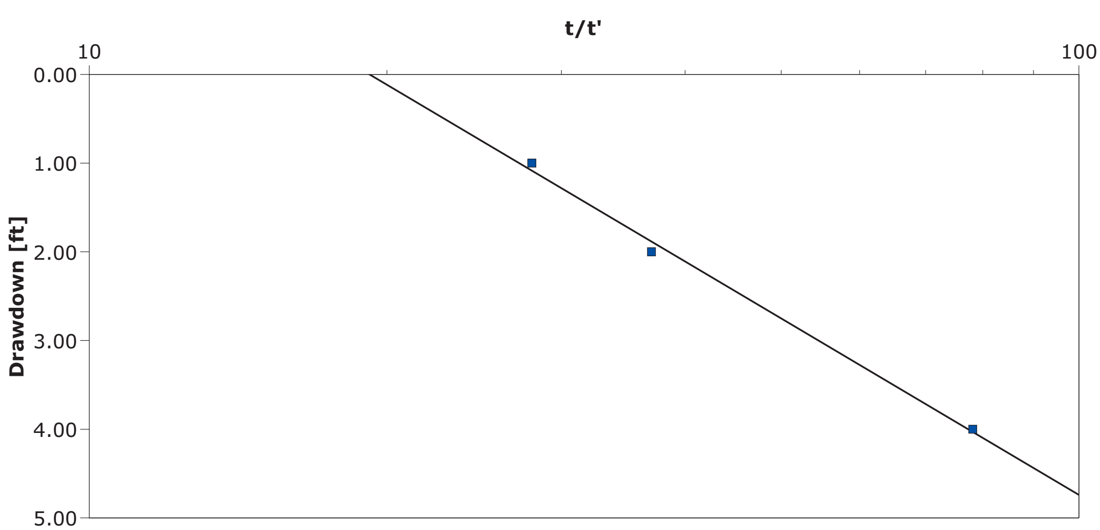
	Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	Pumping Test - Water Level Data	Page 1 of 1
		Project: Olds Recovery Test	
		Number:	
		Client:	

Location: Olds, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 4/8/1977	Discharge: variable, average rate 200.37 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 199.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	547	203.00	4.00
2	555	201.00	2.00
3	560	200.00	1.00

	Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	Pumping Test Analysis Report
		Project: Olds Recovery Test
		Number:
		Client:

Location: Olds, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 4/8/1977
Analysis Performed by:	New analysis 3	Analysis Date: 11/3/2008
Aquifer Thickness: 546.00 ft	Discharge: variable, average rate 200.37 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	1.07×10^{3}	1.96×10^{0}	0.33

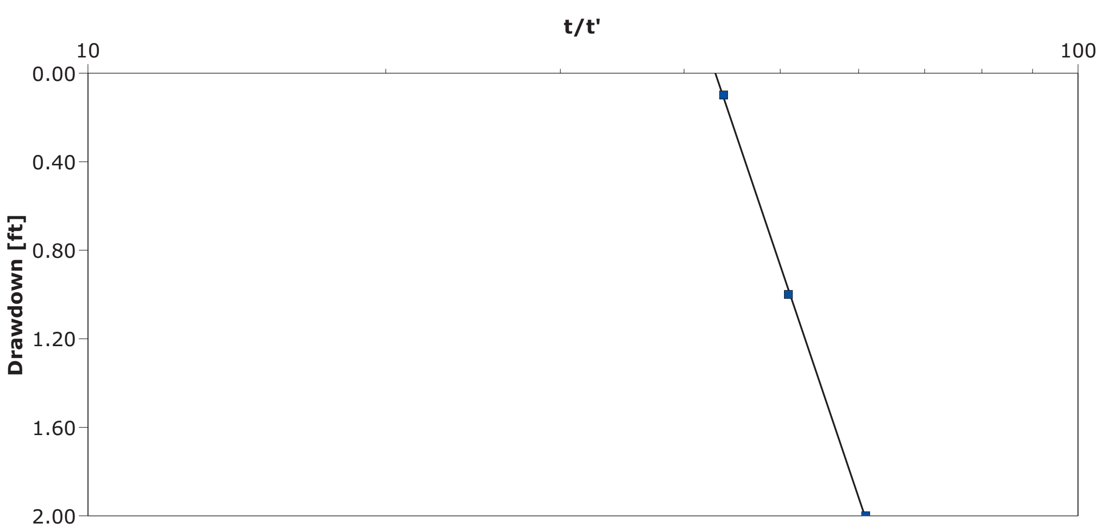
Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test - Water Level Data**	Page 1 of 1
	Project: Pella Recovery Test	
	Number:	
	Client:	

Location: Pella, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by: City of Pella	Test Date: 9/5/1989	Discharge: variable, average rate 2000 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 112.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	610	114.00	2.00
2	612	113.00	1.00
3	614	112.10	0.10

Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test Analysis Report**
	Project: Pella Recovery Test
	Number:
	Client:

Location: Pella, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by: City of Pella		Test Date: 9/5/1989
Analysis Performed by:	New analysis 2	Analysis Date: 11/3/2008
Aquifer Thickness: 530.00 ft	Discharge: variable, average rate 2000 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	5.32×10^3	1.00×10^1	0.5

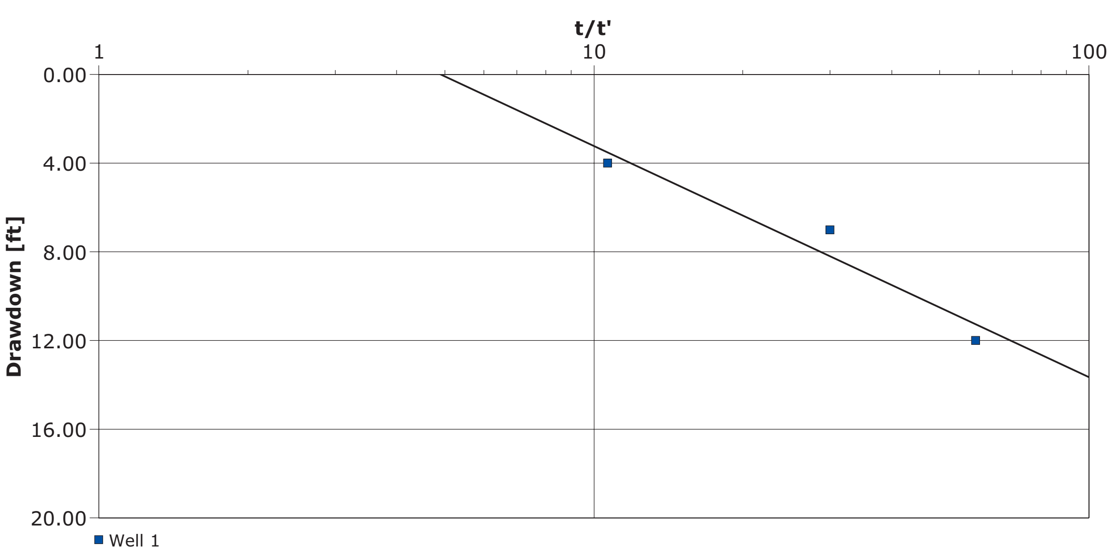
Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test - Water Level Data** Page 1 of 1 Project: Peosta Recovery Test Number: Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 10/31/2002	Discharge: variable, average rate 450 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 414.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	885	426.00	12.00
2	900	421.00	7.00
3	960	418.00	4.00

Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test Analysis Report** Project: Peosta Recovery Test Number: Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 10/31/2002
Analysis Performed by:	New analysis 4	Analysis Date: 9/10/2008
Aquifer Thickness: 445.00 ft	Discharge: variable, average rate 450 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
Well 1	1.52×10^3	3.42×10^0	1.0	

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

Pumping Test - Water Level Data Page 1 of 1

Project: Postville Recovery Test

Number:

Client:

Location: Postville, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 9/18/1975	Discharge: variable, average rate 402 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 425.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	604	455.00	30.00
2	606	453.00	28.00
3	610	451.00	26.00
4	615	449.00	24.00
5	620	447.00	22.00
6	625	446.00	21.00
7	640	445.00	20.00

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

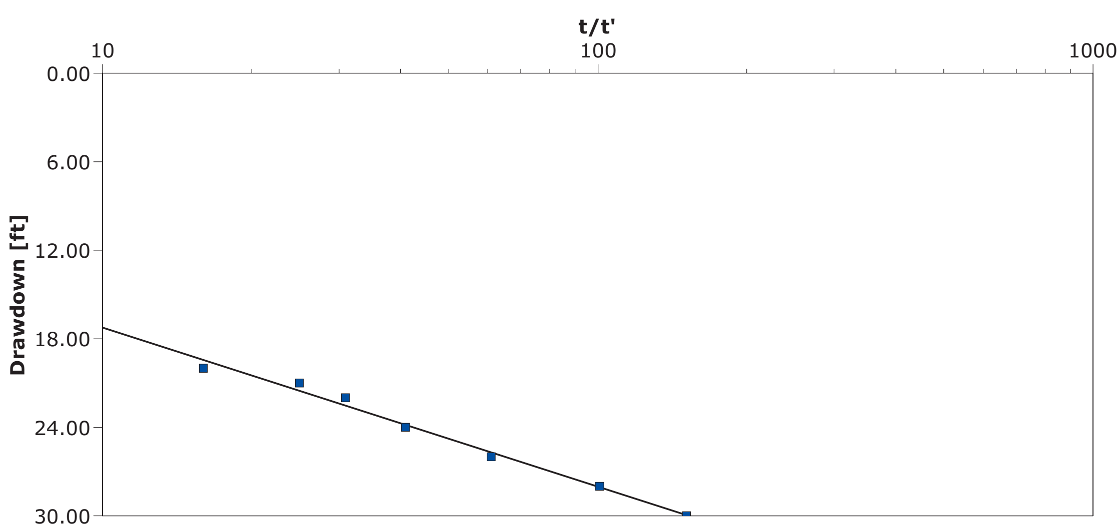
Pumping Test Analysis Report

Project: Postville Recovery Test

Number:

Client:

Location: Postville, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 9/18/1975
Analysis Performed by:	New analysis 2	Analysis Date: 11/3/2008
Aquifer Thickness: 451.00 ft	Discharge: variable, average rate 402 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
Well 1	1.31×10^{3}	2.91×10^{0}	0.6	

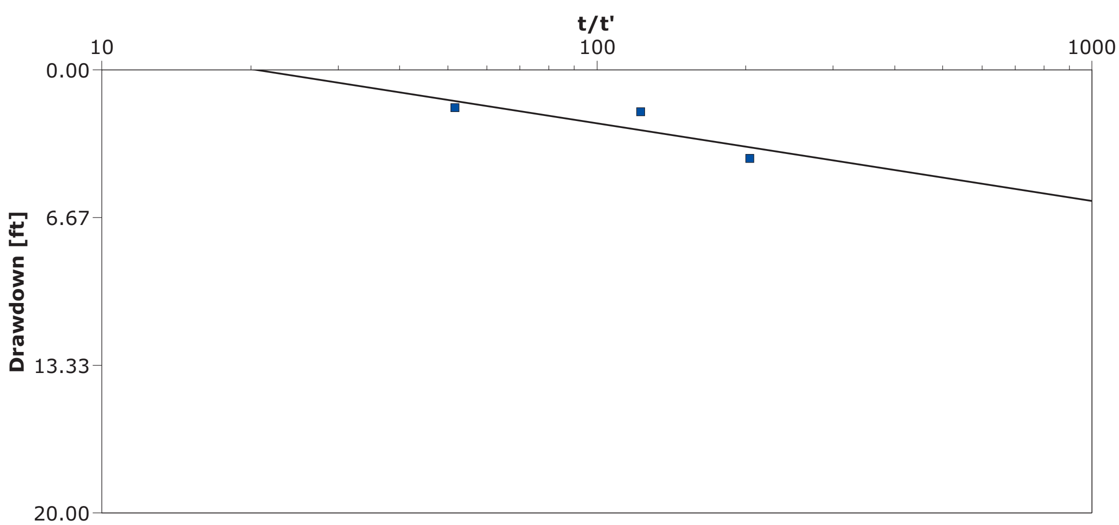
Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test - Water Level Data** Page 1 of 1 Project: Readlyn Recovery Test Number: Client:

Location: Readlyn	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 10/15/2008	Discharge: variable, average rate 130 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 34.10	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	305.5	38.10	4.00
2	306.5	36.00	1.90
3	310	35.80	1.70

Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test Analysis Report** Project: Readlyn Recovery Test Number: Client:

Location: Readlyn	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 10/15/2008
Analysis Performed by: Mike Gannon	New analysis 1	Analysis Date: 10/15/2008
Aquifer Thickness: 202.00 ft	Discharge: variable, average rate 130 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	1.31×10^3	6.47×10^0	0.25

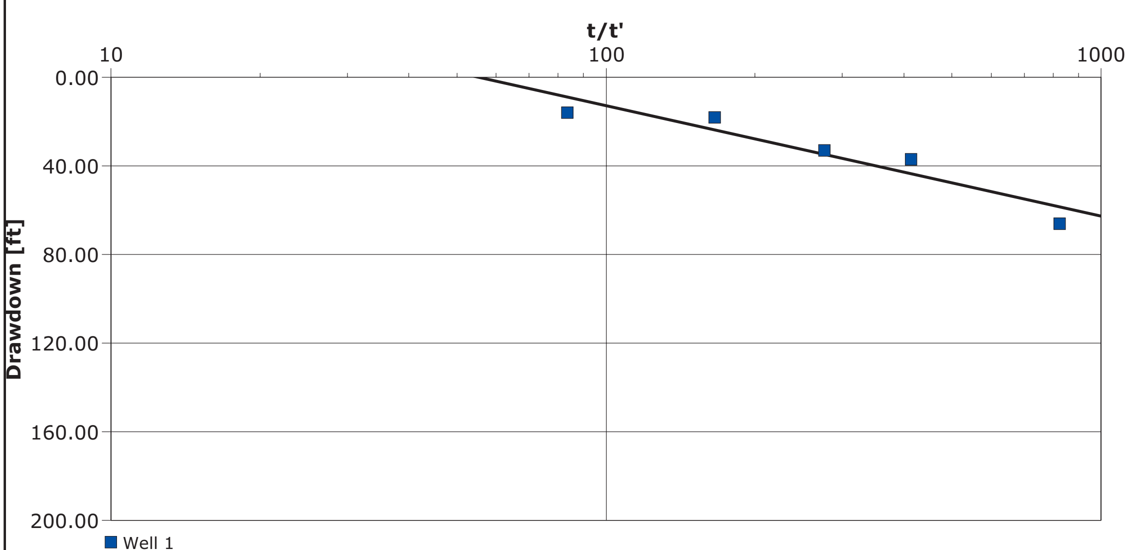
Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test - Water Level Data** Page 1 of 1 Project: Rockwell City Recovery Test Number: Client:

Location:	Pumping Test: Well 6	Pumping Well: Well 1
Test Conducted by:	Test Date: 8/26/2004	Discharge: variable, average rate 1750 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 208.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	825	323.00	115.00
2	826	274.00	66.00
3	827	245.00	37.00
4	828	241.00	33.00
5	830	226.00	18.00
6	835	224.00	16.00

Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test Analysis Report** Project: Rockwell City Recovery Test Number: Client:

Location:	Pumping Test: Well 6	Pumping Well: Well 1
Test Conducted by:		Test Date: 8/26/2004
Analysis Performed by:	New analysis 2	Analysis Date: 9/4/2008
Aquifer Thickness: 472.00 ft	Discharge: variable, average rate 1750 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	1.24×10^{3}	2.62×10^{0}	1.0

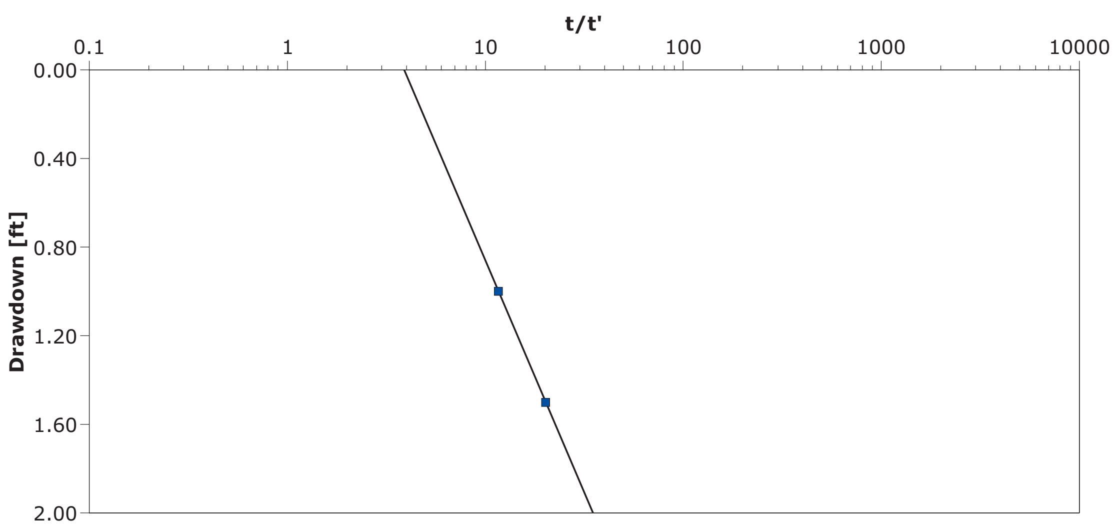
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1 Project: Sabula Recovery Test Number: Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 5/20/2004	Discharge: variable, average rate 299.38 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 89.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	505	90.50	1.50
2	525	90.00	1.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report** Project: Sabula Recovery Test Number: Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 5/20/2004
Analysis Performed by:	New analysis 1	Analysis Date: 9/10/2008
Aquifer Thickness: 425.00 ft	Discharge: variable, average rate 299.38 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
Well 1	5.03×10^{3}	1.18×10^{1}	1.0	

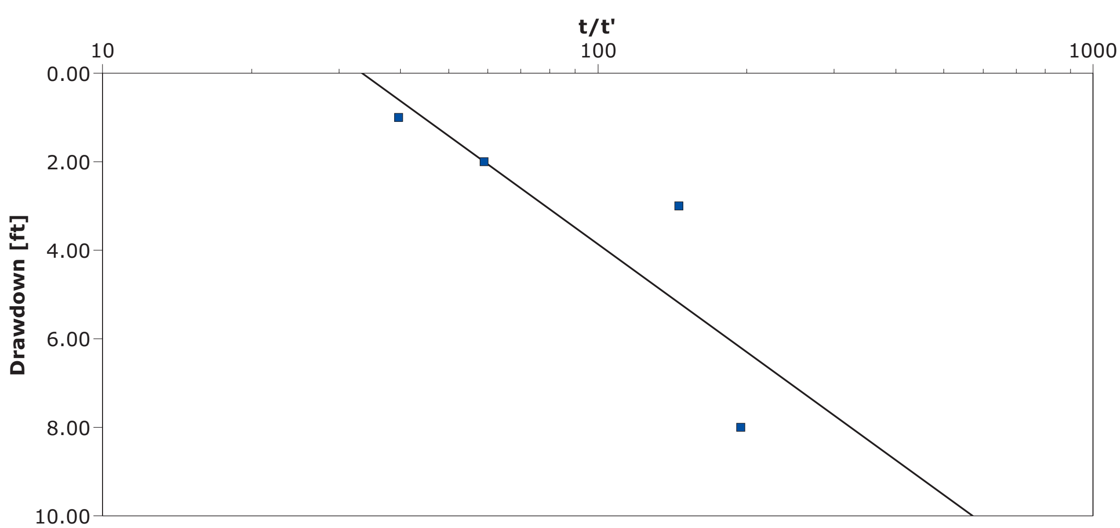
	Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data**	Page 1 of 1
		Project: Sully Recovery Test	
		Number:	
		Client:	

Location: Sully, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 12/21/1964	Discharge: variable, average rate 250.34 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 232.00	Radial Distance to PW [ft]: -

	Time [s]	Water Level [ft]	Drawdown [ft]
1	583	240.00	8.00
2	584	235.00	3.00
3	590	234.00	2.00
4	595	233.00	1.00

	Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**	
		Project: Sully Recovery Test	
		Number:	
		Client:	

Location: Sully, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 12/21/1964
Analysis Performed by:	New analysis 2	Analysis Date: 11/4/2008
Aquifer Thickness: 541.00 ft	Discharge: variable, average rate 250.34 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	1.09×10^3	2.01×10^0	0.33

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

Pumping Test - Water Level Data Page 1 of 1

Project: Toledo Well 2 Recovery Test

Number:

Client:

Location: Toledo, Iowa	Pumping Test: Pumping Test 1	Pumping Well: well 2
Test Conducted by:	Test Date: 7/26/1977	Discharge: variable, average rate 750 [U.S. gal/min]
Observation Well: well 2	Static Water Level [ft]: 232.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1445	277.00	45.00
2	1450	269.00	37.00
3	1455	262.00	30.00
4	1460	258.00	26.00
5	1465	254.00	22.00
6	1480	250.00	18.00
7	1630	248.00	16.00
8	3000	234.00	2.00

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

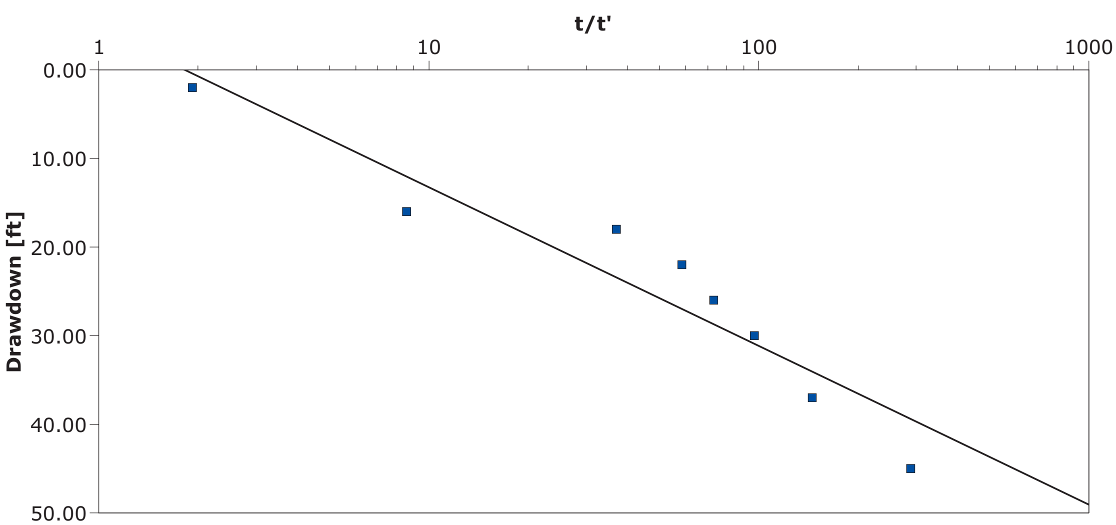
Pumping Test Analysis Report

Project: Toledo Well 2 Recovery Test

Number:

Client:

Location: Toledo, Iowa	Pumping Test: Pumping Test 1	Pumping Well: well 2
Test Conducted by:		Test Date: 7/26/1977
Analysis Performed by:	New analysis 2	Analysis Date: 10/23/2008
Aquifer Thickness: 545.00 ft	Discharge: variable, average rate 750 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
well 2	1.47×10^3	2.71×10^0	0.5	

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
	Project: Toledo Recovery Test
	Number:
	Client:

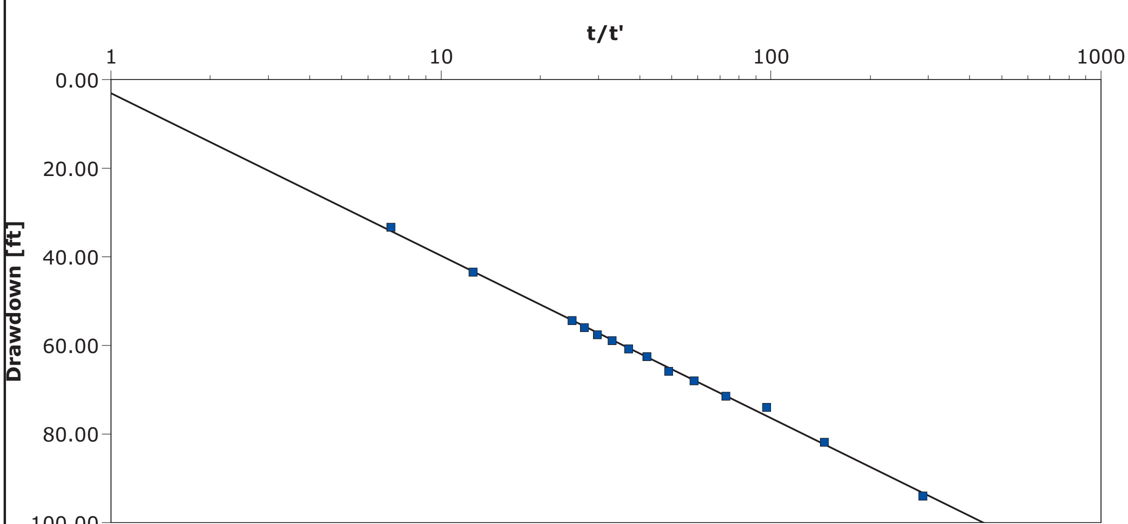
Location: Toledo, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 7/31/1961	Discharge: variable, average rate 1200 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 156.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1445	250.00	94.00
2	1450	237.92	81.92
3	1455	230.02	74.02
4	1460	227.40	71.40
5	1465	224.00	68.00
6	1470	221.85	65.85
7	1475	218.52	62.52
8	1480	216.85	60.85
9	1485	215.00	59.00
10	1490	213.59	57.59
11	1495	212.05	56.05
12	1500	210.42	54.42
13	1565	199.50	43.50
14	1678	189.35	33.35

Iowa Department of Natural Resources
Iowa Geological and Water Survey
Iowa City, Iowa

Pumping Test Analysis Report
Project: Toledo Recovery Test
Number:
Client:

Location: Toledo, Iowa	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 7/31/1961
Analysis Performed by:	New analysis 2	Analysis Date: 10/21/2008
Aquifer Thickness: 560.00 ft	Discharge: variable, average rate 1200 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	1.15×10^{3}	2.06×10^{0}	0.5

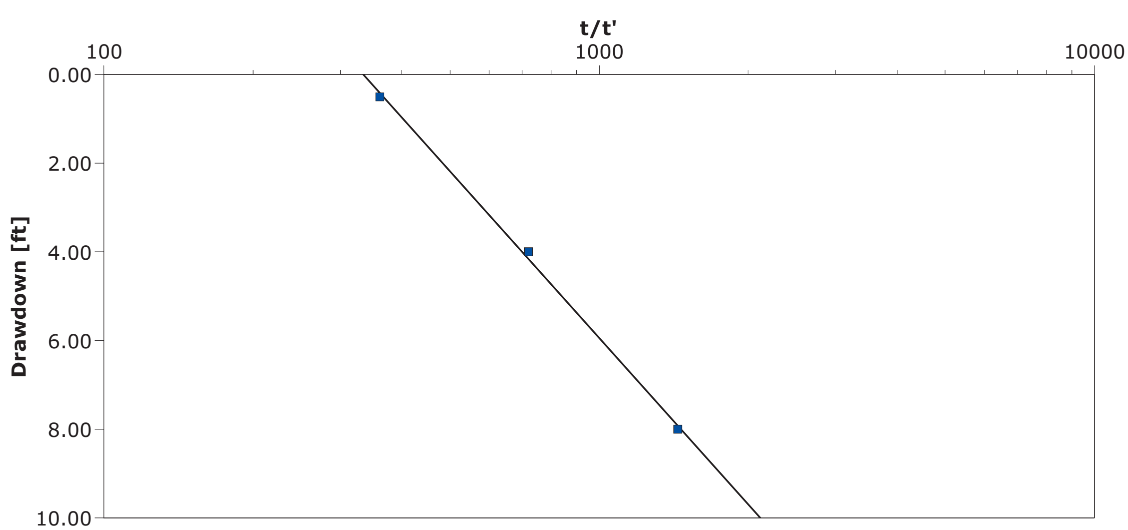
Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test - Water Level Data** Page 1 of 1 Project: Waukee Recovery Test Number: Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 2
Test Conducted by: Varner Well & Pump	Test Date: 11/20/1975	Discharge: variable, average rate 875 [U.S. gal/min]
Observation Well: Well 2	Static Water Level [ft]: 330.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	1441	338.00	8.00
2	1442	334.00	4.00
3	1444	330.50	0.50

Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test Analysis Report** Project: Waukee Recovery Test Number: Client:

Location:	Pumping Test: Pumping Test 1	Pumping Well: Well 2
Test Conducted by: Varner Well & Pump		Test Date: 11/20/1975
Analysis Performed by:	New analysis 2	Analysis Date: 10/21/2008
Aquifer Thickness: 470.00 ft	Discharge: variable, average rate 875 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
Well 2	2.47×10^{3}	5.26×10^{0}	0.33	

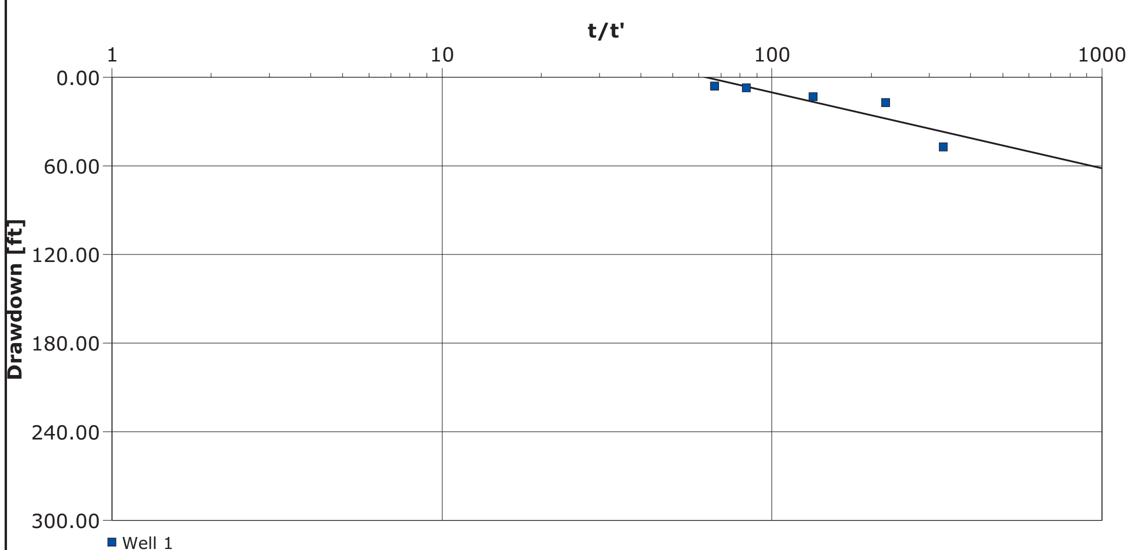
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	Pumping Test - Water Level Data	Page 1 of 1
	Project: Webster City Jordan	
	Number:	
	Client:	

Location:	Pumping Test: Recovery Test	Pumping Well: Well 1
Test Conducted by: Cahoy	Test Date: 12/4/1997	Discharge: variable, average rate 2137.8 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 115.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	660	321.00	206.00
2	662	162.00	47.00
3	663	132.00	17.00
4	665	128.00	13.00
5	668	122.00	7.00
6	670	121.00	6.00

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	Pumping Test Analysis Report
	Project: Webster City Jordan
	Number:
	Client:

Location:	Pumping Test: Recovery Test	Pumping Well: Well 1
Test Conducted by: Cahoy		Test Date: 12/4/1997
Analysis Performed by:	New analysis 9	Analysis Date: 5/19/2009
Aquifer Thickness: 463.00 ft	Discharge: variable, average rate 2137.8 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 1	1.47×10^3	3.17×10^0	1.0

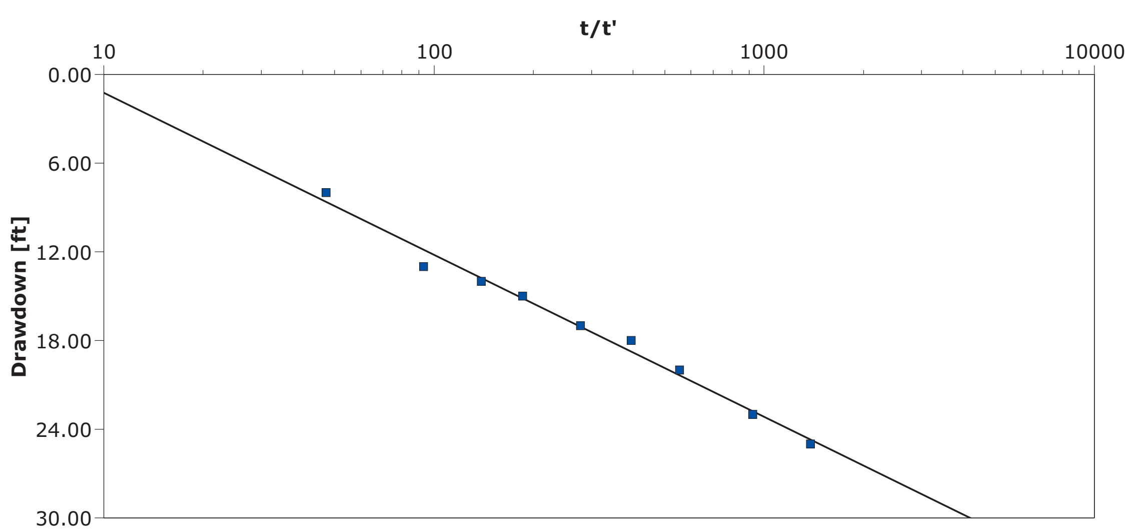
	Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data** Page 1 of 1
		Project: Wellsburg Recovery Test
		Number:
		Client:

Location: Grundy County	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:	Test Date: 1/15/1960	Discharge: variable, average rate 601.27 [U.S. gal/min]
Observation Well: Well 1	Static Water Level [ft]: 215.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	2767	240.00	25.00
2	2768	238.00	23.00
3	2770	235.00	20.00
4	2772	233.00	18.00
5	2775	232.00	17.00
6	2780	230.00	15.00
7	2785	229.00	14.00
8	2795	228.00	13.00
9	2825	223.00	8.00

	Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
		Project: Wellsburg Recovery Test
		Number:
		Client:

Location: Grundy County	Pumping Test: Pumping Test 1	Pumping Well: Well 1
Test Conducted by:		Test Date: 1/15/1960
Analysis Performed by:	New analysis 2	Analysis Date: 10/21/2008
Aquifer Thickness: 570.00 ft	Discharge: variable, average rate 601.27 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
Well 1	1.93×10^{3}	3.39×10^{0}	0.5	

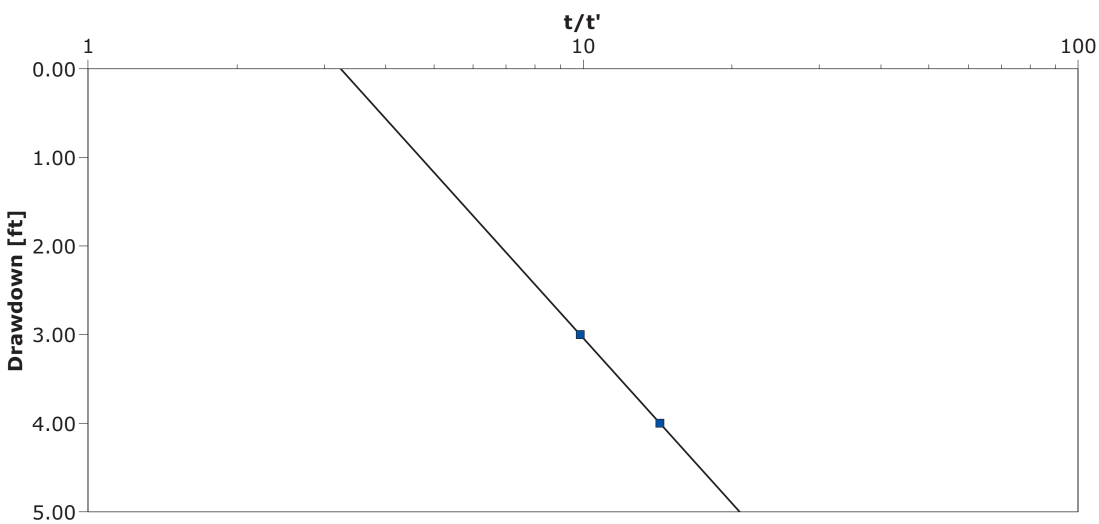
Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test - Water Level Data**	Page 1 of 1
	Project: West Liberty Well 2 Recovery Test	
	Number:	
	Client:	

Location:	Pumping Test: Well 2	Pumping Well: Well 2
Test Conducted by:	Test Date: 10/21/2008	Discharge: variable, average rate 550 [U.S. gal/min]
Observation Well: Well 2	Static Water Level [ft]: 92.00	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	286	96.00	4.00
2	296	95.00	3.00

Iowa Department of Natural Resources **Iowa Geological and Water Survey** **Iowa City, Iowa**	**Pumping Test Analysis Report**	
	Project: West Liberty Well 2 Recovery Test	
	Number:	
	Client:	

Location:	Pumping Test: Well 2	Pumping Well: Well 2
Test Conducted by:		Test Date: 10/21/2008
Analysis Performed by:	New analysis 4	Analysis Date: 10/21/2008
Aquifer Thickness: 560.00 ft	Discharge: variable, average rate 550 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]
Well 2	3.12×10^3	5.58×10^0	0.4

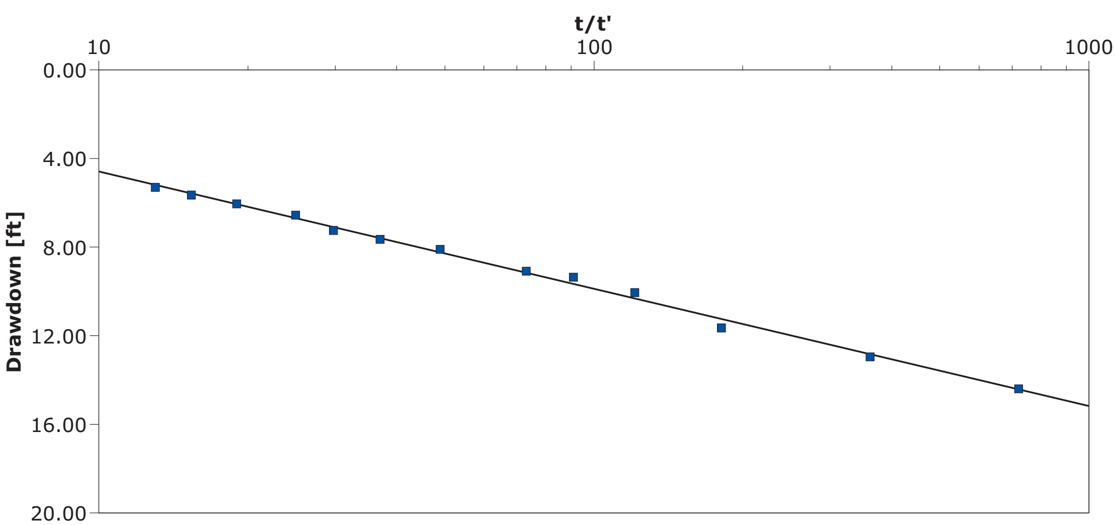
Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test - Water Level Data**	Page 1 of 1
	Project: West Liberty Recovery Test	
	Number:	
	Client:	

Location:	Pumping Test: Well 4	Pumping Well: Well 4
Test Conducted by:	Test Date: 10/20/2008	Discharge: variable, average rate 578 [U.S. gal/min]
Observation Well: Well 4	Static Water Level [ft]: 97.75	Radial Distance to PW [ft]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	721	112.15	14.40
2	722	110.70	12.95
3	724	109.40	11.65
4	726	107.80	10.05
5	728	107.10	9.35
6	730	106.85	9.10
7	735	105.85	8.10
8	740	105.40	7.65
9	745	105.00	7.25
10	750	104.30	6.55
11	760	103.80	6.05
12	770	103.40	5.65
13	780	103.05	5.30

Iowa Department of Natural Resources Iowa Geological and Water Survey Iowa City, Iowa	**Pumping Test Analysis Report**
	Project: West Liberty Recovery Test
	Number:
	Client:

Location:	Pumping Test: Well 4	Pumping Well: Well 4
Test Conducted by:		Test Date: 10/20/2008
Analysis Performed by:	New analysis 2	Analysis Date: 10/20/2008
Aquifer Thickness: 550.00 ft	Discharge: variable, average rate 578 [U.S. gal/min]	



Calculation after Theis & Jacob

Observation Well	Transmissivity [ft²/d]	Hydraulic Conductivity [ft/d]	Radial Distance to PW [ft]	
Well 4	3.84×10^{3}	6.99×10^{0}	0.6	

APPENDIX B.

WATER USE DATA
1901-1990

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Perry/Oscar Meyer	408846	4632474	60	0
Perry/Oscar Meyer	408846	4632474	70	-30000
Perry/Oscar Meyer	408846	4632474	80	-580000
Perry/Oscar Meyer	408846	4632474	90	-520000
Olds	622186	4554608	80	0
Olds	622186	4554608	90	-10000
Wayland	612287	4555979	70	0
Wayland	612287	4555979	80	-50000
Wayland	612287	4555979	90	-70000
Salem	616226	4523488	70	0
Salem	616226	4523488	80	-20000
Salem	616226	4523488	90	-30000
Mt. Pleasant	615658	4535990	10	0
Mt. Pleasant	615658	4535990	20	-210000
Mt. Pleasant	615658	4535990	30	-330000
Mt. Pleasant	615658	4535990	40	-460000
Mt. Pleasant	615658	4535990	50	-580000
Mt. Pleasant	615658	4535990	60	-700000
Mt. Pleasant	615658	4535990	70	-820000
Mt. Pleasant	615658	4535990	80	-960000
Mt. Pleasant	615658	4535990	90	-1000000
Iowa Falls	416544	4705766	60	0
Iowa Falls	416544	4705766	70	-240000
Iowa Falls	416544	4705766	80	-230000
Iowa Falls	416544	4705766	90	-150000
Indianola #9	451854	4576765	60	0
Indianola #9	451854	4576765	70	-420000
Indianola #9	451854	4576765	80	-160000
Indianola #9	451854	4576765	90	-70000
Hartford #4	466290	4589904	70	0
Hartford #4	466290	4589904	80	-20000
Hartford #4	466290	4589904	90	-30000
Norwalk/Lakewood	443472	4592409	60	0
Norwalk/Lakewood	443472	4592409	70	-20000
Norwalk/Lakewood	443472	4592409	80	-80000
Norwalk/Lakewood	443472	4592409	90	-100000
Indianola #10 & 11	454074	4579085	60	0
Indianola #10 & 11	454074	4579085	70	-180000
Indianola #10 & 11	454074	4579085	80	-700000
Indianola #10 & 11	454074	4579085	90	-890000
Fort Dodge	401474	4706362	10	0
Fort Dodge	401474	4706362	20	-740000
Fort Dodge	401474	4706362	30	-1010000
Fort Dodge	401474	4706362	40	-1170000
Fort Dodge	401474	4706362	50	0
Fort Dodge	401474	4706362	60	-1080000
Fort Dodge	401474	4706362	70	-2760000
Fort Dodge	401474	4706362	80	-3340000
Fort Dodge	401474	4706362	90	-3660000
Duncombe	418002	4702240	60	0
Duncombe	418002	4702240	70	-610000

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Duncombe	418002	4702240	80	-1220000
Duncombe	418002	4702240	90	-1130000
LeHigh (#4)	413469	4690116	50	0
LeHigh (#4)	413469	4690116	60	-20000
LeHigh (#4)	413469	4690116	70	-20000
LeHigh (#4)	413469	4690116	80	-20000
LeHigh (#4)	413469	4690116	90	-20000
Callender	393501	4690561	70	0
Callender	393501	4690561	80	-10000
Callender	393501	4690561	90	-20000
Nevada (#3)	462857	4653067	60	0
Nevada (#3)	462857	4653067	70	-400000
Nevada (#3)	462857	4653067	80	-480000
Nevada (#3)	462857	4653067	90	-510000
Dysart (#3)	557667	4668823	60	0
Dysart (#3)	557667	4668823	70	-90000
Dysart (#3)	557667	4668823	80	-120000
Dysart (#3)	557667	4668823	90	-130000
Traer (#3)	544291	4671305	60	0
Traer (#3)	544291	4671305	70	-80000
Traer (#3)	544291	4671305	80	-160000
Traer (#3)	544291	4671305	90	-180000
Tama-Toledo (Toledo #1)	534622	4649284	60	0
Tama-Toledo (Toledo #1)	534622	4649284	70	-1460000
Tama-Toledo (Toledo #1)	534622	4649284	80	-1910000
Tama-Toledo (Toledo #1)	534622	4649284	90	-2070000
Keosauqua (#3)	587286	4510313	60	0
Keosauqua (#3)	587286	4510313	70	-130000
Keosauqua (#3)	587286	4510313	80	-140000
Stockport	598137	4523390	70	0
Stockport	598137	4523390	80	-20000
Stockport	598137	4523390	90	-30000
Eldon	566274	4530198	60	0
Eldon	566274	4530198	70	-100000
Eldon	566274	4530198	80	-100000
Eldon	566274	4530198	90	-100000
Agency	558522	4539191	70	0
Agency	558522	4539191	80	-40000
Agency	558522	4539191	90	-30000
Ottumwa/Morrell (#4)	549043	4540851	40	0
Ottumwa/Morrell (#4)	549043	4540851	50	-4000000
Ottumwa/Morrell (#4)	549043	4540851	60	-6000000
Ottumwa/Morrell (#4)	549043	4540851	70	-6000000
Ottumwa/Morrell (#4)	549043	4540851	80	-2000000
Ottumwa/Morrell (#4)	549043	4540851	90	0
Milo	463165	4570791	80	0
Milo	463165	4570791	90	-60000
Crawfordsville (#3)	622361	4563784	50	0
Crawfordsville (#3)	622361	4563784	60	-10000
Crawfordsville (#3)	622361	4563784	70	-20000
Crawfordsville (#3)	622361	4563784	80	-20000

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Crawfordsville (#3)	622361	4563784	90	-20000
Brighton (#1)	598895	4558898	70	0
Brighton (#1)	598895	4558898	80	-60000
Brighton (#1)	598895	4558898	90	-60000
Ainsworth	620531	4572277	80	0
Ainsworth	620531	4572277	90	-10000
Washington (#3)	609792	4573272	10	0
Washington (#3)	609792	4573272	20	-230000
Washington (#3)	609792	4573272	30	-300000
Washington (#3)	609792	4573272	40	-380000
Washington (#3)	609792	4573272	50	-460000
Washington (#3)	609792	4573272	60	-530000
Washington (#3)	609792	4573272	70	-610000
Washington (#3)	609792	4573272	80	-870000
Washington (#3)	609792	4573272	90	-990000
Odebolt (#8)	314094	4686502	70	0
Odebolt (#8)	314094	4686502	80	-140000
Odebolt (#8)	314094	4686502	90	-150000
Collins	474891	4638820	70	0
Collins	474891	4638820	80	-10000
Collins	474891	4638820	90	-20000
Huxley	449946	4637919	70	0
Huxley	449946	4637919	80	-40000
Huxley	449946	4637919	90	-70000
Grinnell (#5)	522827	4621051	50	0
Grinnell (#5)	522827	4621051	60	-680000
Grinnell (#5)	522827	4621051	70	-980000
Grinnell (#5)	522827	4621051	80	-1180000
Grinnell (#5)	522827	4621051	90	-1200000
Ackley (#2)	495319	4711476	60	0
Ackley (#2)	495319	4711476	70	-260000
Ackley (#2)	495319	4711476	80	-280000
Ackley (#2)	495319	4711476	90	-310000
Brooklyn	545792	4619487	60	0
Brooklyn	545792	4619487	70	-80000
Brooklyn	545792	4619487	80	-120000
Brooklyn	545792	4619487	90	-130000
Webster City (#1)	432951	4702476	40	0
Webster City (#1)	432951	4702476	50	-620000
Webster City (#1)	432951	4702476	60	-880000
Webster City (#1)	432951	4702476	70	-1020000
Webster City (#1)	432951	4702476	80	-1180000
Webster City (#1)	432951	4702476	90	-1040000
Lake Panora	386042	4616341	70	0
Lake Panora	386042	4616341	80	-120000
Lake Panora	386042	4616341	90	-130000
Jefferson	386098	4652258	70	0
Jefferson	386098	4652258	80	-60000
Jefferson	386098	4652258	90	0
Wellsburg	506175	4698087	60	0
Wellsburg	506175	4698087	70	-50000

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Wellsburg	506175	4698087	80	-70000
Wellsburg	506175	4698087	90	-70000
Stuart (#1)	390742	4595068	60	0
Stuart (#1)	390742	4595068	70	-100000
Stuart (#1)	390742	4595068	80	-160000
Stuart (#1)	390742	4595068	90	-180000
Hampton (#3)	483850	4731900	30	0
Hampton (#3)	483850	4731900	40	-90000
Hampton (#3)	483850	4731900	50	-120000
Hampton (#3)	483850	4731900	60	-250000
Hampton (#3)	483850	4731900	70	-150000
Hampton (#3)	483850	4731900	80	0
Hampton (#3)	483850	4731900	90	0
Charles City	525728	4767965	20	0
Charles City	525728	4767965	30	-490000
Charles City	525728	4767965	40	-680000
Charles City	525728	4767965	50	-440000
Charles City	525728	4767965	60	-620000
Charles City	525728	4767965	70	-420000
Charles City	525728	4767965	80	-180000
Charles City	525728	4767965	90	0
Rudd	507978	4775225	60	0
Rudd	507978	4775225	70	-40000
Rudd	507978	4775225	80	-40000
Rudd	507978	4775225	90	-40000
Fayette (#2)	597153	4743920	60	0
Fayette (#2)	597153	4743920	70	-40000
Fayette (#2)	597153	4743920	80	-140000
Fayette (#2)	597153	4743920	90	-150000
Oelwein (#1)	589349	4726048	60	0
Oelwein (#1)	589349	4726048	70	-770000
Oelwein (#1)	589349	4726048	80	-830000
Oelwein (#1)	589349	4726048	90	-860000
Dyersville (#4)	653282	4705872	70	0
Dyersville (#4)	653282	4705872	80	-10000
Dyersville (#4)	653282	4705872	90	-20000
Farley (#2)	664109	4700975	70	0
Farley (#2)	664109	4700975	80	-52000
Farley (#2)	664109	4700975	90	-69000
Gypsum	652282	4538631	70	0
Gypsum	652282	4538631	80	-150000
Gypsum	652282	4538631	90	-290000
Middletown/Denmark (Denmark #1)	640121	4511447	70	0
Middletown/Denmark (Denmark #1)	640121	4511447	80	-20000
Middletown/Denmark (Denmark #1)	640121	4511447	90	-20000
Leon	436717	4510174	60	0
Leon	436717	4510174	70	-120000
Leon	436717	4510174	80	-160000
Leon	436717	4510174	90	-170000
Waukee (#1)	426092	4607060	60	0
Waukee (#1)	426092	4607060	70	-80000

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Waukee (#1)	426092	4607060	80	-350000
Waukee (#1)	426092	4607060	90	-410000
Pulaski	561287	4505254	60	0
Pulaski	561287	4505254	70	-10000
Pulaski	561287	4505254	80	-20000
Pulaski	561287	4505254	90	-20000
Wheatland	679463	4634069	60	0
Wheatland	679463	4634069	70	-40000
Wheatland	679463	4634069	80	-60000
Wheatland	679463	4634069	90	-70000
Monona (#1)	630995	4768105	70	0
Monona (#1)	630995	4768105	80	-90000
Monona (#1)	630995	4768105	90	-100000
Elkader (#6)	631284	4747577	60	0
Elkader (#6)	631284	4747577	70	-160000
Elkader (#6)	631284	4747577	80	-230000
Elkader (#6)	631284	4747577	90	-230000
Guttenberg (#1)	655139	4738273	70	0
Guttenberg (#1)	655139	4738273	80	-200000
Guttenberg (#1)	655139	4738273	90	-210000
New Hampton (#5)	555110	4768115	60	0
New Hampton (#5)	555110	4768115	70	-240000
New Hampton (#5)	555110	4768115	80	-50000
New Hampton (#5)	555110	4768115	90	0
Murray	420036	4543924	60	0
Murray	420036	4543924	70	-10000
Murray	420036	4543924	80	-30000
Murray	420036	4543924	90	-40000
Spencer	327111	4778994	60	0
Spencer	327111	4778994	70	-2270000
Spencer	327111	4778994	80	-1440000
Spencer	327111	4778994	90	-1440000
Storm Lake	317146	4723664	60	0
Storm Lake	317146	4723664	70	-100000
Storm Lake	317146	4723664	80	-150000
Storm Lake	317146	4723664	90	-90000
Sumner (#3)	573716	4744140	50	0
Sumner (#3)	573716	4744140	60	-150000
Sumner (#3)	573716	4744140	70	-150000
Sumner (#3)	573716	4744140	80	-200000
Sumner (#3)	573716	4744140	90	-200000
La Porte City	566534	4685126	70	0
La Porte City	566534	4685126	80	-200000
La Porte City	566534	4685126	90	-310000
Garrison (#2)	570834	4666350	50	0
Garrison (#2)	570834	4666350	60	-10000
Garrison (#2)	570834	4666350	70	-30000
Garrison (#2)	570834	4666350	80	-30000
Garrison (#2)	570834	4666350	90	-30000
Shellsburg (#3)	593578	4660864	70	0
Shellsburg (#3)	593578	4660864	80	-50000

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Shellsburg (#3)	593578	4660864	90	-50000
Moravia	515433	4526906	70	0
Moravia	515433	4526906	80	-30000
Moravia	515433	4526906	90	-20000
Cincinnati	506397	4497621	70	0
Cincinnati	506397	4497621	80	-20000
Cincinnati	506397	4497621	90	-20000
Waukon (#3)	623715	4792713	10	0
Waukon (#3)	623715	4792713	20	-50000
Waukon (#3)	623715	4792713	30	-120000
Waukon (#3)	623715	4792713	40	-180000
Waukon (#3)	623715	4792713	50	-250000
Waukon (#3)	623715	4792713	60	-330000
Waukon (#3)	623715	4792713	70	-560000
Waukon (#3)	623715	4792713	80	-890000
Waukon (#3)	623715	4792713	90	-960000
Hopkinton (#3)	644737	4689971	60	0
Hopkinton (#3)	644737	4689971	70	-40000
Hopkinton (#3)	644737	4689971	80	-110000
Hopkinton (#3)	644737	4689971	90	-140000
Cresco (#1)	571301	4802431	60	0
Cresco (#1)	571301	4802431	70	-280000
Cresco (#1)	571301	4802431	80	-330000
Cresco (#1)	571301	4802431	90	-350000
Ossian (#2)	600358	4777907	60	0
Ossian (#2)	600358	4777907	70	-50000
Ossian (#2)	600358	4777907	80	-60000
Ossian (#2)	600358	4777907	90	-60000
State Center	486344	4651708	70	0
State Center	486344	4651708	80	-190000
State Center	486344	4651708	90	-200000
LeGrand	518136	4650353	80	0
LeGrand	518136	4650353	90	-10000
Bussey (#3)	509560	4561487	70	0
Bussey (#3)	509560	4561487	80	-40000
Bussey (#3)	509560	4561487	90	-50000
Dallas-Melcher	479706	4564320	70	0
Dallas-Melcher	479706	4564320	80	-80000
Dallas-Melcher	479706	4564320	90	-130000
Pershing-Attica (Pershing #1)	497180	4567959	70	0
Pershing-Attica (Pershing #1)	497180	4567959	80	-30000
Pershing-Attica (Pershing #1)	497180	4567959	90	-40000
Knoxville (#1)	491543	4574742	60	0
Knoxville (#1)	491543	4574742	70	-180000
Knoxville (#1)	491543	4574742	80	-1020000
Knoxville (#1)	491543	4574742	90	-1120000
Leighton	517902	4576567	70	0
Leighton	517902	4576567	80	-10000
Leighton	517902	4576567	90	-10000
Earlham	406285	4593770	60	0
Earlham	406285	4593770	70	-40000

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Earlham	406285	4593770	80	-120000
Earlham	406285	4593770	90	-130000
Russell	483296	4536908	70	0
Russell	483296	4536908	80	-60000
Russell	483296	4536908	90	-60000
Rath (Columbus Jt)	637556	4572711	60	0
Rath (Columbus Jt)	637556	4572711	70	-450000
Rath (Columbus Jt)	637556	4572711	80	-370000
Rath (Columbus Jt)	637556	4572711	90	-290000
Morning Sun (#2)	646464	4550940	50	0
Morning Sun (#2)	646464	4550940	60	-60000
Morning Sun (#2)	646464	4550940	70	-50000
Morning Sun (#2)	646464	4550940	80	-90000
Morning Sun (#2)	646464	4550940	90	-80000
Cedar Rapids (#1)	610046	4647981	0	0
Cedar Rapids (#1)	610046	4647981	10	-600000
Cedar Rapids (#1)	610046	4647981	20	-1100000
Cedar Rapids (#1)	610046	4647981	30	-1150000
Cedar Rapids (#1)	610046	4647981	40	-1540000
Cedar Rapids (#1)	610046	4647981	50	-1360000
Cedar Rapids (#1)	610046	4647981	60	-160000
Cedar Rapids (#1)	610046	4647981	70	-2540000
Cedar Rapids (#1)	610046	4647981	80	-3630000
Cedar Rapids (#1)	610046	4647981	90	-4720000
Marion (#5)	617625	4655850	50	0
Marion (#5)	617625	4655850	60	-130000
Marion (#5)	617625	4655850	70	-620000
Marion (#5)	617625	4655850	80	-860000
Marion (#5)	617625	4655850	90	-840000
St. Paul	625169	4514067	70	0
St. Paul	625169	4514067	80	-10000
St. Paul	625169	4514067	90	-20000
West Point	630858	4508681	70	0
West Point	630858	4508681	80	-20000
West Point	630858	4508681	90	-40000
Donnellson	621493	4500457	60	0
Donnellson	621493	4500457	70	-10000
Donnellson	621493	4500457	80	-10000
Donnellson	621493	4500457	90	-110000
Keota	587655	4579302	70	0
Keota	587655	4579302	80	-100000
Keota	587655	4579302	90	-110000
What Cheer	554115	4583313	70	0
What Cheer	554115	4583313	80	-90000
What Cheer	554115	4583313	90	-90000
Anamosa (#4)	642101	4664522	70	0
Anamosa (#4)	642101	4664522	80	-330000
Anamosa (#4)	642101	4664522	90	-380000
Richland	584391	4559967	70	0
Richland	584391	4559967	80	-60000
Richland	584391	4559967	90	-60000

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Iowa City (JW#2)	621756	4613706	60	0
Iowa City (JW#2)	621756	4613706	70	-80000
Iowa City (JW#2)	621756	4613706	80	-100000
Iowa City (JW#2)	621756	4613706	90	-70000
Coralville (#10)	617851	4616976	60	0
Coralville (#10)	617851	4616976	70	-320000
Coralville (#10)	617851	4616976	80	-440000
Coralville (#10)	617851	4616976	90	-510000
Fairfield (#1)	587875	4541322	60	0
Fairfield (#1)	587875	4541322	70	-440000
Fairfield (#1)	587875	4541322	80	-460000
Fairfield (#1)	587875	4541322	90	-570000
Sully	512673	4602755	60	0
Sully	512673	4602755	70	-60000
Sully	512673	4602755	80	-60000
Sully	512673	4602755	90	-70000
Andrew (#2)	698966	4669611	80	0
Andrew (#2)	698966	4669611	90	-20000
North English (#1)	577044	4596131	70	0
North English (#1)	577044	4596131	80	-80000
North English (#1)	577044	4596131	90	-80000
Amana Holiday Inn	590566	4615272	70	0
Amana Holiday Inn	590566	4615272	80	-20000
Amana Holiday Inn	590566	4615272	90	-40000
Adair	362082	4595819	70	0
Adair	362082	4595819	80	-100000
Adair	362082	4595819	90	-110000
Garnavillo (#6)	644007	4747373	60	0
Garnavillo (#6)	644007	4747373	70	-20000
Garnavillo (#6)	644007	4747373	80	-30000
Garnavillo (#6)	644007	4747373	90	-40000
Underwood (DOT #4)	275793	4585061	70	0
Underwood (DOT #4)	275793	4585061	80	-10000
Underwood (DOT #4)	275793	4585061	90	-10000
American Beef Oakland	298738	4575516	60	0
American Beef Oakland	298738	4575516	70	-20000
American Beef Oakland	298738	4575516	80	-350000
American Beef Oakland	298738	4575516	90	-360000
Ankeny (#5)	449238	4620343	60	0
Ankeny (#5)	449238	4620343	70	-360000
Ankeny (#5)	449238	4620343	80	-1120000
Ankeny (#5)	449238	4620343	90	-1320000
Grimes	434096	4615455	60	0
Grimes	434096	4615455	70	-80000
Grimes	434096	4615455	80	-240000
Grimes	434096	4615455	90	-260000
Altoona (#1)	461243	4610951	60	0
Altoona (#1)	461243	4610951	70	-210000
Altoona (#1)	461243	4610951	80	-520000
Altoona (#1)	461243	4610951	90	-660000
Mitchellville (Training School #4)	473727	4615011	50	0

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Mitchellville (Training School #4)	473727	4615011	60	-40000
Mitchellville (Training School #4)	473727	4615011	70	-30000
Mitchellville (Training School #4)	473727	4615011	80	0
Mitchellville (Training School #4)	473727	4615011	90	0
West Des Moines (#1)	439604	4602323	60	0
West Des Moines (#1)	439604	4602323	70	-430000
West Des Moines (#1)	439604	4602323	80	-1590000
West Des Moines (#1)	439604	4602323	90	-1540000
Runnels	470107	4596071	60	0
Runnels	470107	4596071	70	-10000
Runnels	470107	4596071	80	-30000
Runnels	470107	4596071	90	-30000
West Liberty (#4)	644418	4603317	10	0
West Liberty (#4)	644418	4603317	20	-60000
West Liberty (#4)	644418	4603317	30	-80000
West Liberty (#4)	644418	4603317	40	-110000
West Liberty (#4)	644418	4603317	50	-140000
West Liberty (#4)	644418	4603317	60	-160000
West Liberty (#4)	644418	4603317	70	-190000
West Liberty (#4)	644418	4603317	80	-860000
West Liberty (#4)	644418	4603317	90	-910000
West Burlington (#5)	653141	4521035	60	0
West Burlington (#5)	653141	4521035	70	-110000
West Burlington (#5)	653141	4521035	80	-260000
West Burlington (#5)	653141	4521035	90	-290000
Lowden	672292	4636611	40	0
Lowden	672292	4636611	50	-42000
Lowden	672292	4636611	60	-42000
Lowden	672292	4636611	70	-60000
Lowden	672292	4636611	80	-42000
Lowden	672292	4636611	90	-40000
Tipton (East Well)	655380	4625863	10	0
Tipton (East Well)	655380	4625863	20	-60000
Tipton (East Well)	655380	4625863	30	-100000
Tipton (East Well)	655380	4625863	40	-130000
Tipton (East Well)	655380	4625863	50	-170000
Tipton (East Well)	655380	4625863	60	-80000
Tipton (East Well)	655380	4625863	70	0
Tipton (East Well)	655380	4625863	80	0
Tipton (East Well)	655380	4625863	90	0
Osage (#3)	515406	4791881	40	0
Osage (#3)	515406	4791881	50	-154000
Osage (#3)	515406	4791881	60	-189000
Osage (#3)	515406	4791881	70	-245000
Osage (#3)	515406	4791881	80	-294000
Osage (#3)	515406	4791881	90	-301000
Delmar (#2)	697993	4652590	80	0
Delmar (#2)	697993	4652590	90	-42000
Clinton Industry	733739	4636075	40	0
Clinton Industry	733739	4636075	50	-1050000
Clinton Industry	733739	4636075	60	-1130000

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Clinton Industry	733739	4636075	70	-1240000
Clinton Industry	733739	4636075	80	-1640000
Clinton Industry	733739	4636075	90	-1690000
Farmersburg	633518	4757611	60	0
Farmersburg	633518	4757611	70	-30000
Farmersburg	633518	4757611	80	-30000
Farmersburg	633518	4757611	90	-30000
Waverly (#2)	543628	4730605	60	0
Waverly (#2)	543628	4730605	70	-580000
Waverly (#2)	543628	4730605	80	-580000
Waverly (#2)	543628	4730605	90	-550000
Vinton	580794	4669048	70	0
Vinton	580794	4669048	80	-320000
Vinton	580794	4669048	90	-310000
Van Horne	575340	4651056	60	0
Van Horne	575340	4651056	70	-60000
Van Horne	575340	4651056	80	-70000
Van Horne	575340	4651056	90	-80000
Oscar Meyer Davenport (#6)	700632	4599362	40	0
Oscar Meyer Davenport (#6)	700632	4599362	50	-410000
Oscar Meyer Davenport (#6)	700632	4599362	60	-410000
Oscar Meyer Davenport (#6)	700632	4599362	70	-630000
Oscar Meyer Davenport (#6)	700632	4599362	80	-1020000
Oscar Meyer Davenport (#6)	700632	4599362	90	-1020000
Hedrick (#2)	557949	4558090	70	0
Hedrick (#2)	557949	4558090	80	-60000
Hedrick (#2)	557949	4558090	90	-60000
Winfield (#2)	631450	4554356	70	0
Winfield (#2)	631450	4554356	80	-70000
Winfield (#2)	631450	4554356	90	-80000
Walnut (#2)	314285	4593919	70	0
Walnut (#2)	314285	4593919	80	-90000
Walnut (#2)	314285	4593919	90	-90000
DeWitt	702735	4632620	70	0
DeWitt	702735	4632620	80	-210000
DeWitt	702735	4632620	90	-210000
Arlington (#4)	609190	4733796	60	0
Arlington (#4)	609190	4733796	70	20000
Arlington (#4)	609190	4733796	80	-20000
Arlington (#4)	609190	4733796	90	-20000
Fairbank	578277	4720893	60	0
Fairbank	578277	4720893	70	-30000
Fairbank	578277	4720893	80	-60000
Fairbank	578277	4720893	90	-70000
Walker	401450	4706700	90	0
Ft. Dodge (Land o Lakes)	401447	4706681	70	0
Ft. Dodge (Land o Lakes)	401447	4706681	80	-580000
Ft. Dodge (Land o Lakes)	401447	4706681	90	-680000
Klemme (#1)	450914	4761644	70	0
Klemme (#1)	450914	4761644	80	-50000
Klemme (#1)	450914	4761644	90	-50000

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Stanhope	434469	4682256	60	0
Stanhope	434469	4682256	70	-30000
Stanhope	434469	4682256	80	0
Stanhope	434469	4682256	90	0
Maynard (#3)	592293	4736566	70	0
Maynard (#3)	592293	4736566	80	-50000
Maynard (#3)	592293	4736566	90	-50000
Estherville (#4)	350498	4806868	60	0
Estherville (#4)	350498	4806868	70	-1970000
Estherville (#4)	350498	4806868	80	-2190000
Estherville (#4)	350498	4806868	90	-2190000
Ringsted	377501	4794774	70	0
Ringsted	377501	4794774	80	-50000
Ringsted	377501	4794774	90	-50000
St. Olaf	631280	4754174	60	0
St. Olaf	631280	4754174	70	-10000
St. Olaf	631280	4754174	80	-10000
St. Olaf	631280	4754174	90	-10000
Moulton	527333	4503740	60	0
Moulton	527333	4503740	70	-80000
Moulton	527333	4503740	80	-80000
Moulton	527333	4503740	90	-60000
Protovin	573849	4785463	80	0
Protovin	573849	4785463	90	-20000
Preston	715625	4658596	60	0
Preston	715625	4658596	70	-80000
Preston	715625	4658596	80	-1640000
Preston	715625	4658596	90	-1640000
Rockwell City (#4)	365644	4695078	60	0
Rockwell City (#4)	365644	4695078	70	-250000
Rockwell City (#4)	365644	4695078	80	-340000
Rockwell City (#4)	365644	4695078	90	-240000
New London (#1)	635229	4531710	60	0
New London (#1)	635229	4531710	70	-96000
New London (#1)	635229	4531710	80	-136000
New London (#1)	635229	4531710	90	-136000
John Deere Dubuque (#1)	689462	4715656	60	0
John Deere Dubuque (#1)	689462	4715656	70	-746000
John Deere Dubuque (#1)	689462	4715656	80	-904000
John Deere Dubuque (#1)	689462	4715656	90	-718000
Dubuque (#8)	693415	4711364	60	0
Dubuque (#8)	693415	4711364	70	-2880000
Dubuque (#8)	693415	4711364	80	-2880000
Dubuque (#8)	693415	4711364	90	-2880000
Clinton (#8)	734152	4639629	30	0
Clinton (#8)	734152	4639629	40	-1050000
Clinton (#8)	734152	4639629	50	-1130000
Clinton (#8)	734152	4639629	60	-1240000
Clinton (#8)	734152	4639629	70	-1640000
Clinton (#8)	734152	4639629	80	-1690000
Clinton (#8)	734152	4639629	90	-1700000

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Maquoketa (#6)	693307	4659311	60	0
Maquoketa (#6)	693307	4659311	70	-352000
Maquoketa (#6)	693307	4659311	80	-464000
Maquoketa (#6)	693307	4659311	90	-512000
Dupont Clinton (Dupont #5)	728854	4631910	0	0
Dupont Clinton (Dupont #5)	728854	4631910	10	-780000
Dupont Clinton (Dupont #5)	728854	4631910	20	-780000
Dupont Clinton (Dupont #5)	728854	4631910	30	-790000
Dupont Clinton (Dupont #5)	728854	4631910	40	-790000
Dupont Clinton (Dupont #5)	728854	4631910	50	-2230000
Dupont Clinton (Dupont #5)	728854	4631910	60	-3220000
Dupont Clinton (Dupont #5)	728854	4631910	70	-4940000
Dupont Clinton (Dupont #5)	728854	4631910	80	-3760000
Dupont Clinton (Dupont #5)	728854	4631910	90	-3690000
Bellevue (#2)	712254	4682494	60	0
Bellevue (#2)	712254	4682494	70	-220000
Bellevue (#2)	712254	4682494	80	-220000
Bellevue (#2)	712254	4682494	90	-220000
Gowrie (#6)	393752	4682150	50	0
Gowrie (#6)	393752	4682150	60	-70000
Gowrie (#6)	393752	4682150	70	-100000
Gowrie (#6)	393752	4682150	80	-150000
Gowrie (#6)	393752	4682150	90	-150000
Davenport Airport (#1)	700790	4608702	50	0
Davenport Airport (#1)	700790	4608702	60	-10000
Davenport Airport (#1)	700790	4608702	70	-10000
Davenport Airport (#1)	700790	4608702	80	-10000
Davenport Airport (#1)	700790	4608702	90	-10000
Fredericksburg (#1)	565246	4757178	60	0
Fredericksburg (#1)	565246	4757178	70	-240000
Fredericksburg (#1)	565246	4757178	80	-240000
Fredericksburg (#1)	565246	4757178	90	-240000
Lytton (#2)	347145	4698571	50	0
Lytton (#2)	347145	4698571	60	-30000
Lytton (#2)	347145	4698571	70	-60000
Lytton (#2)	347145	4698571	80	-60000
Lytton (#2)	347145	4698571	90	-40000
Denver	555145	4724344	70	0
Denver	555145	4724344	80	-40000
Denver	555145	4724344	90	-40000
Postville (#5)	616476	4772797	10	0
Postville (#5)	616476	4772797	20	-30000
Postville (#5)	616476	4772797	30	-50000
Postville (#5)	616476	4772797	40	-60000
Postville (#5)	616476	4772797	50	-80000
Postville (#5)	616476	4772797	60	-370000
Postville (#5)	616476	4772797	70	-430000
Postville (#5)	616476	4772797	80	-780000
Postville (#5)	616476	4772797	90	-980000
Ayrshire (#2)	350695	4766757	70	0
Ayrshire (#2)	350695	4766757	80	-30000

Well name	X UTM m	Y UTM m	stop time year	pumping rate gpd
Ayrshire (#2)	350695	4766757	90	-30000
Garnavillo (#2)	644007	4747373	60	0
Garnavillo (#2)	644007	4747373	70	-30000
Garnavillo (#2)	644007	4747373	80	-20000
Garnavillo (#2)	644007	4747373	90	-20000
Ft. Atkinson (#2)	586765	4777441	60	0
Ft. Atkinson (#2)	586765	4777441	70	-10000
Ft. Atkinson (#2)	586765	4777441	80	-20000
Ft. Atkinson (#2)	586765	4777441	90	-20000

APPENDIX C.

WATER USE DATA
1990-2007

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Kraft Foods	700915.82	4599288.10	8	-141	-297	-350388
Kraft Foods	700915.82	4599288.10	9	-141	-297	-746474
Kraft Foods	700915.82	4599288.10	10	-141	-297	-748516
Kraft Foods	700915.82	4599288.10	11	-141	-297	-725534
Kraft Foods	700915.82	4599288.10	13	-141	-297	-747663
Kraft Foods	700915.82	4599288.10	14	-141	-297	-667322
Kraft Foods	700915.82	4599288.10	15	-141	-297	-578247
Kraft Foods	700915.82	4599288.10	16	-141	-297	-663093
Kraft Foods	700915.82	4599288.10	17	-141	-297	-717808
Marion, City of	616749.00	4656432.00	5	-63	-227	-1931537
Marion, City of	616749.00	4656432.00	6	-63	-227	-1968691
Marion, City of	616749.00	4656432.00	8	-63	-227	-1730877
Marion, City of	616749.00	4656432.00	9	-63	-227	-1935337
Marion, City of	616749.00	4656432.00	10	-63	-227	-2067448
Marion, City of	616749.00	4656432.00	11	-63	-227	-2346038
Marion, City of	616749.00	4656432.00	12	-63	-227	-2170315
Marion, City of	616749.00	4656432.00	13	-63	-227	-2383427
Marion, City of	616749.00	4656432.00	15	-63	-227	-2766227
Marion, City of	616749.00	4656432.00	16	-63	-227	-2550359
Marion, City of	616749.00	4656432.00	17	-63	-227	-2691997
Tama Paperboard	535038.10	4645248.50	5	-162	-326	-1321000
Tama Paperboard	535038.10	4645248.50	6	-162	-326	-1321000
Tama Paperboard	535038.10	4645248.50	7	-162	-326	-1319140
Tama Paperboard	535038.10	4645248.50	8	-162	-326	-1319140
Tama Paperboard	535038.10	4645248.50	9	-162	-326	-1319140
Tama Paperboard	535038.10	4645248.50	11	-162	-326	-1321000
Tama Paperboard	535038.10	4645248.50	12	-162	-326	-1321000
Tama Paperboard	535038.10	4645248.50	13	-162	-326	-1321000
Tama Paperboard	535038.10	4645248.50	14	-162	-326	-1321000
Tama Paperboard	535038.10	4645248.50	15	-162	-326	-1321000
Tama Paperboard	535038.10	4645248.50	16	-162	-326	-1321000
Tama Paperboard	535038.10	4645248.50	17	-162	-326	-1321000
Toledo, City of	534336.65	4649183.21	4	-155	-312	-320468
Toledo, City of	534336.65	4649183.21	7	-155	-312	-425992
Toledo, City of	534336.65	4649183.21	8	-155	-312	-294115
Toledo, City of	534336.65	4649183.21	10	-155	-312	-270820
Toledo, City of	534336.65	4649183.21	11	-155	-312	-275973
Toledo, City of	534336.65	4649183.21	12	-155	-312	-275981
Toledo, City of	534336.65	4649183.21	13	-155	-312	-287016
Toledo, City of	534336.65	4649183.21	14	-155	-312	-254940
Toledo, City of	534336.65	4649183.21	16	-155	-312	-577019
Toledo, City of	534336.65	4649183.21	17	-155	-312	-262803
US Gypsum	652215.32	4538521.53	5	-105	-293	-457142
US Gypsum	652215.32	4538521.53	6	-105	-293	-404082
US Gypsum	652215.32	4538521.53	8	-105	-293	-399014
US Gypsum	652215.32	4538521.53	9	-105	-293	-366923
US Gypsum	652215.32	4538521.53	11	-105	-293	-438616
US Gypsum	652215.32	4538521.53	12	-105	-293	-402740
US Gypsum	652215.32	4538521.53	13	-105	-293	-422192
US Gypsum	652215.32	4538521.53	14	-105	-293	-386339
US Gypsum	652215.32	4538521.53	15	-105	-293	-455616

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
US Gypsum	652215.32	4538521.53	16	-105	-293	-478603
US Gypsum	652215.32	4538521.53	17	-105	-293	-448162
John Deere Dubuque	689063.14	4715304.59	5	159	42	-14948
John Deere Dubuque	689063.14	4715304.59	6	159	42	-13831
John Deere Dubuque	689063.14	4715304.59	8	159	42	-13274
John Deere Dubuque	689063.14	4715304.59	9	159	42	-4605
John Deere Dubuque	689063.14	4715304.59	10	159	42	-14153
John Deere Dubuque	689063.14	4715304.59	11	159	42	-6559
John Deere Dubuque	689063.14	4715304.59	12	159	42	-12107
John Deere Dubuque	689063.14	4715304.59	13	159	42	-5192
John Deere Dubuque	689063.14	4715304.59	14	159	42	-9448
John Deere Dubuque	689063.14	4715304.59	15	159	42	-7704
John Deere Dubuque	689063.14	4715304.59	16	159	42	-7173
John Deere Dubuque	689063.14	4715304.59	17	159	42	-3000
Wellsburg, City of	506174.63	4698087.28	4	-105	-262	-97066
Wellsburg, City of	506174.63	4698087.28	6	-105	-262	-86075
Wellsburg, City of	506174.63	4698087.28	8	-105	-262	-71319
Wellsburg, City of	506174.63	4698087.28	9	-105	-262	-80978
Wellsburg, City of	506174.63	4698087.28	10	-105	-262	-78433
Wellsburg, City of	506174.63	4698087.28	11	-105	-262	-83298
Wellsburg, City of	506174.63	4698087.28	12	-105	-262	-71831
Wellsburg, City of	506174.63	4698087.28	13	-105	-262	-75553
Wellsburg, City of	506174.63	4698087.28	14	-105	-262	-76951
Wellsburg, City of	506174.63	4698087.28	15	-105	-262	-75124
Wellsburg, City of	506174.63	4698087.28	17	-105	-262	0
Wheatland	679408.22	4634058.69	8	-24	-127	-13195
Wheatland	679408.22	4634058.69	9	-24	-127	-21964
Wheatland	679408.22	4634058.69	11	-24	-127	-33510
Wheatland	679408.22	4634058.69	12	-24	-127	-33173
Wheatland	679408.22	4634058.69	16	-24	-127	-34664
Wheatland	679408.22	4634058.69	17	-24	-127	-33264
Verde Water Co.	691236.61	4702800.90	7	157	-5	-14736
Verde Water Co.	691236.61	4702800.90	8	157	-5	-34690
Verde Water Co.	691236.61	4702800.90	9	157	-5	-16754
Verde Water Co.	691236.61	4702800.90	10	157	-5	-34379
Verde Water Co.	691236.61	4702800.90	11	157	-5	-36374
Verde Water Co.	691236.61	4702800.90	13	157	-5	-34664
Verde Water Co.	691236.61	4702800.90	15	157	-5	-32444
Verde Water Co.	691236.61	4702800.90	16	157	-5	-32193
Cargill, Inc.	530006.94	4554516.46	5	-216	-370	-1028310
Cargill, Inc.	530006.94	4554516.46	6	-216	-370	-981243
Cargill, Inc.	530006.94	4554516.46	7	-216	-370	-682359
Cargill, Inc.	530006.94	4554516.46	8	-216	-370	-591728
Cargill, Inc.	530006.94	4554516.46	9	-216	-370	-680758
Cargill, Inc.	530006.94	4554516.46	10	-216	-370	-565440
Cargill, Inc.	530006.94	4554516.46	11	-216	-370	-563150
Cargill, Inc.	530006.94	4554516.46	12	-216	-370	-849365
Cargill, Inc.	530006.94	4554516.46	13	-216	-370	-573356
Cargill, Inc.	530006.94	4554516.46	14	-216	-370	-607422
Cargill, Inc.	530006.94	4554516.46	15	-216	-370	-341143
Cargill, Inc.	530006.94	4554516.46	16	-216	-370	-339037

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Cargill, Inc.	530006.94	4554516.46	17	-216	-370	-438459
U of I	621522.08	4612901.48	5	-84	-262	-1947
Iowa City	620926.67	4615209.82	5	-84	-256	-852362
Iowa City	620926.67	4615209.82	6	-84	-256	-695410
Iowa City	620926.67	4615209.82	7	-84	-256	-423671
Iowa City	620926.67	4615209.82	8	-84	-256	-314301
Iowa City	620926.67	4615209.82	9	-84	-256	-509587
Iowa City	620926.67	4615209.82	11	-84	-256	-381219
Iowa City	620926.67	4615209.82	12	-84	-256	-278888
Iowa City	620926.67	4615209.82	13	-84	-256	-129300
Iowa City	620926.67	4615209.82	14	-84	-256	-240
Iowa City	620926.67	4615209.82	15	-84	-256	-2234
Iowa City	620926.67	4615209.82	16	-84	-256	-52894
Fort Dodge	400781.95	4706951.60	5	-109	-223	-1365847
Fort Dodge	400781.95	4706951.60	6	-109	-223	-1577948
Fort Dodge	400781.95	4706951.60	8	-109	-223	-2022142
Fort Dodge	400781.95	4706951.60	9	-109	-223	-2398000
Fort Dodge	400781.95	4706951.60	11	-109	-223	-1898142
Fort Dodge	400781.95	4706951.60	12	-109	-223	-1998825
Fort Dodge	400781.95	4706951.60	13	-109	-223	-1684318
Fort Dodge	400781.95	4706951.60	14	-109	-223	-1779068
Fort Dodge	400781.95	4706951.60	15	-109	-223	-2190414
Fort Dodge	400781.95	4706951.60	16	-109	-223	-2989151
Fort Dodge	400781.95	4706951.60	17	-109	-223	-2975592
Oelwein, City	588856.93	4725415.96	4	88	-73	-721427
Oelwein, City	588856.93	4725415.96	5	88	-73	-779803
Oelwein, City	588856.93	4725415.96	6	88	-73	-754740
Oelwein, City	588856.93	4725415.96	7	88	-73	-806274
Oelwein, City	588856.93	4725415.96	8	88	-73	-752216
Oelwein, City	588856.93	4725415.96	9	88	-73	-723436
Oelwein, City	588856.93	4725415.96	10	88	-73	-694380
Oelwein, City	588856.93	4725415.96	11	88	-73	-710677
Oelwein, City	588856.93	4725415.96	12	88	-73	-695079
Oelwein, City	588856.93	4725415.96	13	88	-73	-707841
Oelwein, City	588856.93	4725415.96	14	88	-73	-662672
Oelwein, City	588856.93	4725415.96	15	88	-73	-640241
Oelwein, City	588856.93	4725415.96	16	88	-73	-593159
Oelwein, City	588856.93	4725415.96	17	88	-73	-566838
General Mills	457953.65	4597270.38	5	-319	-460	-6370
General Mills	457953.65	4597270.38	6	-319	-460	-23467
General Mills	457953.65	4597270.38	8	-319	-460	-17317
General Mills	457953.65	4597270.38	9	-319	-460	-12659
General Mills	457953.65	4597270.38	10	-319	-460	-10245
General Mills	457953.65	4597270.38	11	-319	-460	-6482
General Mills	457953.65	4597270.38	12	-319	-460	-7407
General Mills	457953.65	4597270.38	13	-319	-460	-7586
General Mills	457953.65	4597270.38	15	-319	-460	-18837
General Mills	457953.65	4597270.38	16	-319	-460	-13521
General Mills	457953.65	4597270.38	17	-319	-460	-14268
Tyson meats	637886.54	4572288.42	4	-118	-279	-368468
Tyson meats	637886.54	4572288.42	5	-118	-279	-314277

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Tyson meats	637886.54	4572288.42	6	-118	-279	-320434
Tyson meats	637886.54	4572288.42	8	-118	-279	-298277
Tyson meats	637886.54	4572288.42	9	-118	-279	-335918
Tyson meats	637886.54	4572288.42	11	-118	-279	-245993
Tyson meats	637886.54	4572288.42	12	-118	-279	-365507
Tyson meats	637886.54	4572288.42	13	-118	-279	-334000
Tyson meats	637886.54	4572288.42	14	-118	-279	-91639
Tyson meats	637886.54	4572288.42	15	-118	-279	-228644
Tyson meats	637886.54	4572288.42	16	-118	-279	-150795
Tyson meats	637886.54	4572288.42	17	-118	-279	-138
Murray, City of	420043.40	4543908.40	5	-412	-537	-61857
Murray, City of	420043.40	4543908.40	8	-412	-537	-49
Murray, City of	420043.40	4543908.40	9	-412	-537	-103
Murray, City of	420043.40	4543908.40	10	-412	-537	-120
Murray, City of	420043.40	4543908.40	11	-412	-537	-109
Murray, City of	420043.40	4543908.40	12	-412	-537	-104
Murray, City of	420043.40	4543908.40	13	-412	-537	-63080
Murray, City of	420043.40	4543908.40	14	-412	-537	-71022
Murray, City of	420043.40	4543908.40	16	-412	-537	-7423
Murray, City of	420043.40	4543908.40	17	-412	-537	-72179
Ankeny, City of	449238.37	4620092.55	7	-300	-450	-2000000
Stuart, City of	395687.79	4599857.57	0	-346	-492	-99
Stuart, City of	395687.79	4599857.57	5	-346	-492	-5718
Stuart, City of	395687.79	4599857.57	11	-346	-492	-3290
Collis, Inc.	730131.37	4634140.35	5	-42	-176	-73563
Collis, Inc.	730131.37	4634140.35	6	-42	-176	-87814
Collis, Inc.	730131.37	4634140.35	8	-42	-176	-54419
Collis, Inc.	730131.37	4634140.35	9	-42	-176	-55499
Collis, Inc.	730131.37	4634140.35	10	-42	-176	-115552
Collis, Inc.	730131.37	4634140.35	11	-42	-176	-97210
Collis, Inc.	730131.37	4634140.35	12	-42	-176	-79788
Collis, Inc.	730131.37	4634140.35	13	-42	-176	-23716
Collis, Inc.	730131.37	4634140.35	14	-42	-176	-19942
Collis, Inc.	730131.37	4634140.35	15	-42	-176	-16778
Collis, Inc.	730131.37	4634140.35	16	-42	-176	-30791
Collis, Inc.	730131.37	4634140.35	17	-42	-176	-34586
Morning Sun	646520.84	4550976.55	5	-124	-312	-71936
Morning Sun	646520.84	4550976.55	6	-124	-312	-75191
Morning Sun	646520.84	4550976.55	7	-124	-312	-76251
Morning Sun	646520.84	4550976.55	8	-124	-312	-84404
Morning Sun	646520.84	4550976.55	9	-124	-312	-77678
Morning Sun	646520.84	4550976.55	10	-124	-312	-59301
Morning Sun	646520.84	4550976.55	11	-124	-312	-59157
Morning Sun	646520.84	4550976.55	12	-124	-312	-58775
Morning Sun	646520.84	4550976.55	13	-124	-312	-62858
Morning Sun	646520.84	4550976.55	14	-124	-312	-51052
Morning Sun	646520.84	4550976.55	15	-124	-312	-55647
Morning Sun	646520.84	4550976.55	16	-124	-312	-57340
Morning Sun	646520.84	4550976.55	17	-124	-312	-62175
IBP, Inc.	406560.51	4632768.63	4	-229	-330	-1253041
IBP, Inc.	406560.51	4632768.63	5	-229	-330	-854088

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
IBP, Inc.	406560.51	4632768.63	6	-229	-330	-994861
IBP, Inc.	406560.51	4632768.63	8	-229	-330	-950263
IBP, Inc.	406560.51	4632768.63	9	-229	-330	-1069663
IBP, Inc.	406560.51	4632768.63	11	-229	-330	-822597
IBP, Inc.	406560.51	4632768.63	12	-229	-330	-756378
IBP, Inc.	406560.51	4632768.63	13	-229	-330	-867644
IBP, Inc.	406560.51	4632768.63	14	-229	-330	-948087
IBP, Inc.	406560.51	4632768.63	15	-229	-330	-890567
IBP, Inc.	406560.51	4632768.63	16	-229	-330	-960608
Manchester	626787.25	4705442.75	0	60	-81	0
Donnellson	621474.75	4500268.85	5	-138	-325	-90854
Donnellson	621474.75	4500268.85	6	-138	-325	-89564
Donnellson	621474.75	4500268.85	7	-138	-325	-95017
Donnellson	621474.75	4500268.85	8	-138	-325	-97433
Donnellson	621474.75	4500268.85	9	-138	-325	-104182
Donnellson	621474.75	4500268.85	10	-138	-325	-102815
Donnellson	621474.75	4500268.85	11	-138	-325	-94067
Donnellson	621474.75	4500268.85	12	-138	-325	-98601
Donnellson	621474.75	4500268.85	13	-138	-325	-94778
Donnellson	621474.75	4500268.85	14	-138	-325	-72295
Donnellson	621474.75	4500268.85	15	-138	-325	-78025
Donnellson	621474.75	4500268.85	16	-138	-325	-77433
Donnellson	621474.75	4500268.85	17	-138	-325	-83959
Storm Lake	315862.05	4723517.28	5	22	-55	-240164
Storm Lake	315862.05	4723517.28	6	22	-55	-205279
Storm Lake	315862.05	4723517.28	8	22	-55	-153666
Storm Lake	315862.05	4723517.28	9	22	-55	-306838
Storm Lake	315862.05	4723517.28	10	22	-55	-312492
Storm Lake	315862.05	4723517.28	11	22	-55	-269951
Storm Lake	315862.05	4723517.28	12	22	-55	-273699
Storm Lake	315862.05	4723517.28	13	22	-55	-310882
Storm Lake	315862.05	4723517.28	14	22	-55	-185311
Storm Lake	315862.05	4723517.28	15	22	-55	-276460
Storm Lake	315862.05	4723517.28	16	22	-55	-276460
Storm Lake	315862.05	4723517.28	17	22	-55	-531123
Southeast Polk	463575.93	4605318.92	5	-304	-457	-469
Southeast Polk	463575.93	4605318.92	6	-304	-457	-6698
Southeast Polk	463575.93	4605318.92	8	-304	-457	-3981
Southeast Polk	463575.93	4605318.92	9	-304	-457	-769
Southeast Polk	463575.93	4605318.92	10	-304	-457	-1415
Southeast Polk	463575.93	4605318.92	12	-304	-457	-1283
Southeast Polk	463575.93	4605318.92	13	-304	-457	-1408
Southeast Polk	463575.93	4605318.92	14	-304	-457	-766
Southeast Polk	463575.93	4605318.92	15	-304	-457	-15599
Southeast Polk	463575.93	4605318.92	16	-304	-457	-4471
Southeast Polk	463575.93	4605318.92	17	-304	-457	-3601
New Hampton	555769.71	4767794.74	5	117	-35	-692759
New Hampton	555769.71	4767794.74	6	117	-35	-694525
New Hampton	555769.71	4767794.74	8	117	-35	-728400
New Hampton	555769.71	4767794.74	10	117	-35	-747574
New Hampton	555769.71	4767794.74	11	117	-35	-518014

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
New Hampton	555769.71	4767794.74	12	117	-35	-567184
New Hampton	555769.71	4767794.74	13	117	-35	-595356
New Hampton	555769.71	4767794.74	14	117	-35	-554861
New Hampton	555769.71	4767794.74	15	117	-35	-586562
New Hampton	555769.71	4767794.74	16	117	-35	-597359
New Hampton	555769.71	4767794.74	17	117	-35	-603797
Indianola	453328.99	4577795.96	5	-332	-476	-1434699
Indianola	453328.99	4577795.96	6	-332	-476	-1366153
Indianola	453328.99	4577795.96	8	-332	-476	-1210660
Indianola	453328.99	4577795.96	10	-332	-476	-1231404
Indianola	453328.99	4577795.96	11	-332	-476	-1350896
Indianola	453328.99	4577795.96	12	-332	-476	-1405370
Indianola	453328.99	4577795.96	13	-332	-476	-1321784
Indianola	453328.99	4577795.96	14	-332	-476	-1165022
Indianola	453328.99	4577795.96	15	-332	-476	-1300011
Indianola	453328.99	4577795.96	16	-332	-476	-1292688
Indianola	453328.99	4577795.96	17	-332	-476	-1206751
Koch Nitrogen	416730.67	4705675.68	4	-115	-246	-1252247
Koch Nitrogen	416730.67	4705675.68	5	-115	-246	-994356
Koch Nitrogen	416730.67	4705675.68	6	-115	-246	-1138251
Koch Nitrogen	416730.67	4705675.68	7	-115	-246	-1407836
Koch Nitrogen	416730.67	4705675.68	8	-115	-246	-2441233
Koch Nitrogen	416730.67	4705675.68	9	-115	-246	-2463753
Koch Nitrogen	416730.67	4705675.68	10	-115	-246	-2092240
Koch Nitrogen	416730.67	4705675.68	11	-115	-246	-917288
Koch Nitrogen	416730.67	4705675.68	12	-115	-246	-1263233
Koch Nitrogen	416730.67	4705675.68	13	-115	-246	-1528849
Koch Nitrogen	416730.67	4705675.68	14	-115	-246	-1715301
Koch Nitrogen	416730.67	4705675.68	15	-115	-246	-1012767
Koch Nitrogen	416730.67	4705675.68	16	-115	-246	-1010442
Koch Nitrogen	416730.67	4705675.68	17	-115	-246	-2133041
Sethness Products	731163.45	4633057.61	5	-46	-177	-111797
Sethness Products	731163.45	4633057.61	6	-46	-177	-130938
Sethness Products	731163.45	4633057.61	9	-46	-177	-130021
Sethness Products	731163.45	4633057.61	12	-46	-177	-128475
Sethness Products	731163.45	4633057.61	13	-46	-177	-77175
Sethness Products	731163.45	4633057.61	14	-46	-177	-82294
Sethness Products	731163.45	4633057.61	15	-46	-177	-84490
Sethness Products	731163.45	4633057.61	16	-46	-177	-72493
Sethness Products	731163.45	4633057.61	17	-46	-177	-106311
Fairfield, City	588675.03	4541663.57	5	-178	-359	-798011
Fairfield, City	588675.03	4541663.57	6	-178	-359	-1008893
Fairfield, City	588675.03	4541663.57	8	-178	-359	-790411
Fairfield, City	588675.03	4541663.57	9	-178	-359	-1612000
Fairfield, City	588675.03	4541663.57	10	-178	-359	-1787489
Fairfield, City	588675.03	4541663.57	11	-178	-359	-1556403
Fairfield, City	588675.03	4541663.57	12	-178	-359	-1393219
Fairfield, City	588675.03	4541663.57	13	-178	-359	-1556778
Fairfield, City	588675.03	4541663.57	14	-178	-359	-1480260
Fairfield, City	588675.03	4541663.57	15	-178	-359	-1616364
Fairfield, City	588675.03	4541663.57	16	-178	-359	-1511271

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
West Liberty Food	644741.00	4603719.00	5	-114	-275	-388635
West Liberty Food	644741.00	4603719.00	6	-114	-275	-327675
West Liberty Food	644741.00	4603719.00	7	-114	-275	-297803
West Liberty Food	644741.00	4603719.00	8	-114	-275	-360504
West Liberty Food	644741.00	4603719.00	9	-114	-275	-522241
West Liberty Food	644741.00	4603719.00	11	-114	-275	-503279
West Liberty Food	644741.00	4603719.00	12	-114	-275	-554704
West Liberty Food	644741.00	4603719.00	13	-114	-275	-599112
West Liberty Food	644741.00	4603719.00	14	-114	-275	-522664
West Liberty Food	644741.00	4603719.00	15	-114	-275	-628677
West Liberty Food	644741.00	4603719.00	16	-114	-275	-730940
West Liberty Food	644741.00	4603719.00	17	-114	-275	-740271
Cresco, City of	571304.51	4802995.91	4	212	73	-342740
Cresco, City of	571304.51	4802995.91	5	212	73	-348636
Cresco, City of	571304.51	4802995.91	6	212	73	-358000
Cresco, City of	571304.51	4802995.91	8	212	73	-422759
Cresco, City of	571304.51	4802995.91	9	212	73	-383240
Cresco, City of	571304.51	4802995.91	10	212	73	-367353
Cresco, City of	571304.51	4802995.91	11	212	73	-375336
Cresco, City of	571304.51	4802995.91	12	212	73	-408435
Cresco, City of	571304.51	4802995.91	13	212	73	-441270
Cresco, City of	571304.51	4802995.91	14	212	73	-361180
Cresco, City of	571304.51	4802995.91	15	212	73	-394844
Cresco, City of	571304.51	4802995.91	16	212	73	-357282
Cresco, City of	571304.51	4802995.91	17	212	73	-376074
Des Moines Golf	431894.95	4605221.22	17	-363	-496	-800000
Fayette, City	597765.85	4743785.15	17	109	-37	-114852
Olds, City of	622200.54	4554669.49	4	-160	-347	-44348
Olds, City of	622200.54	4554669.49	5	-160	-347	-39158
Olds, City of	622200.54	4554669.49	6	-160	-347	-44982
Olds, City of	622200.54	4554669.49	7	-160	-347	-43899
Olds, City of	622200.54	4554669.49	10	-160	-347	-42542
Olds, City of	622200.54	4554669.49	11	-160	-347	-42802
Olds, City of	622200.54	4554669.49	12	-160	-347	-38862
Olds, City of	622200.54	4554669.49	13	-160	-347	-41198
Olds, City of	622200.54	4554669.49	14	-160	-347	-40728
Olds, City of	622200.54	4554669.49	15	-160	-347	-41548
Olds, City of	622200.54	4554669.49	16	-160	-347	-41215
Olds, City of	622200.54	4554669.49	17	-160	-347	-27333
Oakdale	616225.20	4617980.19	1	-92	-263	-95852
Oakdale	616225.20	4617980.19	4	-92	-263	-95015
Oakdale	616225.20	4617980.19	5	-92	-263	-72324
Oakdale	616225.20	4617980.19	6	-92	-263	-45399
Oakdale	616225.20	4617980.19	8	-92	-263	-39509
Oakdale	616225.20	4617980.19	9	-92	-263	-26980
Oakdale	616225.20	4617980.19	11	-92	-263	-37746
Oakdale	616225.20	4617980.19	12	-92	-263	-48121
Oakdale	616225.20	4617980.19	13	-92	-263	-43059
Oakdale	616225.20	4617980.19	14	-92	-263	-45330
Oakdale	616225.20	4617980.19	15	-92	-263	-67443
Oakdale	616225.20	4617980.19	16	-92	-263	-55475

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Oakdale	616225.20	4617980.19	17	-92	-263	-45014
Washington, City	609490.03	4573398.06	4	-126	-313	-1016929
Washington, City	609490.03	4573398.06	5	-126	-313	-967321
Washington, City	609490.03	4573398.06	8	-126	-313	-915003
Washington, City	609490.03	4573398.06	9	-126	-313	-954038
Washington, City	609490.03	4573398.06	10	-126	-313	-914631
Washington, City	609490.03	4573398.06	11	-126	-313	-983222
Washington, City	609490.03	4573398.06	12	-126	-313	-918227
Washington, City	609490.03	4573398.06	13	-126	-313	-934770
Washington, City	609490.03	4573398.06	14	-126	-313	-919033
Washington, City	609490.03	4573398.06	15	-126	-313	-902140
Washington, City	609490.03	4573398.06	16	-126	-313	-906241
Washington, City	609490.03	4573398.06	17	-126	-313	-941099
Anamosa, City	642301.63	4664207.22	5	-38	-163	-339071
Anamosa, City	642301.63	4664207.22	7	-38	-163	-374562
Anamosa, City	642301.63	4664207.22	8	-38	-163	-229000
Anamosa, City	642301.63	4664207.22	9	-38	-163	-379496
Anamosa, City	642301.63	4664207.22	11	-38	-163	-400507
Anamosa, City	642301.63	4664207.22	13	-38	-163	-433496
Anamosa, City	642301.63	4664207.22	15	-38	-163	-417334
Anamosa, City	642301.63	4664207.22	17	-38	-163	-394121
Knoxville Water	491965.53	4576747.88	5	-253	-409	-1663082
Knoxville Water	491965.53	4576747.88	6	-253	-409	-1647104
Knoxville Water	491965.53	4576747.88	7	-253	-409	-1637066
Knoxville Water	491965.53	4576747.88	8	-253	-409	-1591181
Knoxville Water	491965.53	4576747.88	9	-253	-409	-1603455
Knoxville Water	491965.53	4576747.88	10	-253	-409	-1672831
Knoxville Water	491965.53	4576747.88	11	-253	-409	-1653318
Knoxville Water	491965.53	4576747.88	12	-253	-409	-1764792
Knoxville Water	491965.53	4576747.88	13	-253	-409	-1702175
Knoxville Water	491965.53	4576747.88	14	-253	-409	-1586658
Knoxville Water	491965.53	4576747.88	15	-253	-409	-1558288
Knoxville Water	491965.53	4576747.88	16	-253	-409	-1552567
Knoxville Water	491965.53	4576747.88	17	-253	-409	-1540099
Mount Pleasant	619542.62	4534794.70	5	-151	-360	-1049147
Mount Pleasant	619542.62	4534794.70	6	-151	-360	-1072697
Mount Pleasant	619542.62	4534794.70	8	-151	-360	-1155986
Mount Pleasant	619542.62	4534794.70	9	-151	-360	-1401664
Mount Pleasant	619542.62	4534794.70	10	-151	-360	-1524580
Mount Pleasant	619542.62	4534794.70	11	-151	-360	-1755234
Mount Pleasant	619542.62	4534794.70	12	-151	-360	-1874495
Mount Pleasant	619542.62	4534794.70	13	-151	-360	-1826908
Mount Pleasant	619542.62	4534794.70	14	-151	-360	-1748126
Mount Pleasant	619542.62	4534794.70	15	-151	-360	-1807344
Mount Pleasant	619542.62	4534794.70	16	-151	-360	-1680967
Mount Pleasant	619542.62	4534794.70	17	-151	-360	-1564679
Pershing Utilities	497180.43	4567959.32	5	-268	-408	-32326
Pershing Utilities	497180.43	4567959.32	6	-268	-408	-34828
Pershing Utilities	497180.43	4567959.32	8	-268	-408	-37622
Pershing Utilities	497180.43	4567959.32	9	-268	-408	-36712
Pershing Utilities	497180.43	4567959.32	10	-268	-408	-43560

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Pershing Utilities	497180.43	4567959.32	11	-268	-408	-41732
Pershing Utilities	497180.43	4567959.32	12	-268	-408	-45395
Pershing Utilities	497180.43	4567959.32	13	-268	-408	-50071
Pershing Utilities	497180.43	4567959.32	14	-268	-408	-46751
Pershing Utilities	497180.43	4567959.32	15	-268	-408	-46595
Pershing Utilities	497180.43	4567959.32	16	-268	-408	-48915
Pershing Utilities	497180.43	4567959.32	17	-268	-408	-44838
ADM Corn Sweet	608780.72	4642599.20	5	-76	-231	-1847446
Dyersville, City	654308.41	4704569.38	5	91	-43	-303258
Dyersville, City	654308.41	4704569.38	6	91	-43	-302683
Dyersville, City	654308.41	4704569.38	8	91	-43	-397553
Dyersville, City	654308.41	4704569.38	9	91	-43	-408422
Dyersville, City	654308.41	4704569.38	10	91	-43	-380478
Dyersville, City	654308.41	4704569.38	12	91	-43	-455066
Dyersville, City	654308.41	4704569.38	13	91	-43	-407326
Dyersville, City	654308.41	4704569.38	14	91	-43	-374257
Dyersville, City	654308.41	4704569.38	15	91	-43	-414504
Dyersville, City	654308.41	4704569.38	16	91	-43	-423690
Dyersville, City	654308.41	4704569.38	17	91	-43	-363411
Thunder Hills	679791.78	4702197.80	4	184	-1	-11368
Thunder Hills	679791.78	4702197.80	6	184	-1	-27185
Thunder Hills	679791.78	4702197.80	7	184	-1	-24926
Thunder Hills	679791.78	4702197.80	8	184	-1	-25124
Thunder Hills	679791.78	4702197.80	13	184	-1	-22448
Thunder Hills	679791.78	4702197.80	14	184	-1	-13173
Thunder Hills	679791.78	4702197.80	15	184	-1	-22504
Thunder Hills	679791.78	4702197.80	16	184	-1	-19177
Thunder Hills	679791.78	4702197.80	17	184	-1	-20573
Grinnell, City	523262.95	4620729.63	2	-216	-369	-1261836
Grinnell, City	523262.95	4620729.63	5	-216	-369	-1101471
Grinnell, City	523262.95	4620729.63	6	-216	-369	-1067735
Grinnell, City	523262.95	4620729.63	8	-216	-369	-1114534
Grinnell, City	523262.95	4620729.63	9	-216	-369	-1232764
Grinnell, City	523262.95	4620729.63	10	-216	-369	-1205566
Grinnell, City	523262.95	4620729.63	11	-216	-369	-1209058
Grinnell, City	523262.95	4620729.63	12	-216	-369	-1150682
Grinnell, City	523262.95	4620729.63	13	-216	-369	-1141921
Grinnell, City	523262.95	4620729.63	14	-216	-369	-1116227
Grinnell, City	523262.95	4620729.63	15	-216	-369	-1251984
Grinnell, City	523262.95	4620729.63	16	-216	-369	-1366041
Grinnell, City	523262.95	4620729.63	17	-216	-369	-1473197
City of Altoona	460272.77	4610810.77	5	-304	-450	-1121288
City of Altoona	460272.77	4610810.77	6	-304	-450	-1206393
City of Altoona	460272.77	4610810.77	7	-304	-450	-1360301
City of Altoona	460272.77	4610810.77	8	-304	-450	-1388164
City of Altoona	460272.77	4610810.77	9	-304	-450	-1438384
City of Altoona	460272.77	4610810.77	10	-304	-450	-1687861
City of Altoona	460272.77	4610810.77	11	-304	-450	-1757981
City of Altoona	460272.77	4610810.77	12	-304	-450	-1617918
City of Altoona	460272.77	4610810.77	13	-304	-450	-1577178
City of Altoona	460272.77	4610810.77	14	-304	-450	-1622650

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
City of Altoona	460272.77	4610810.77	15	-304	-450	-1817644
City of Altoona	460272.77	4610810.77	16	-304	-450	-1855132
City of Altoona	460272.77	4610810.77	17	-304	-450	-1914101
Iowa Quality Beef	537252.70	4645367.28	5	-156	-326	-480310
Iowa Quality Beef	537252.70	4645367.28	6	-156	-326	-573265
Iowa Quality Beef	537252.70	4645367.28	7	-156	-326	-506649
Iowa Quality Beef	537252.70	4645367.28	8	-156	-326	-526430
Iowa Quality Beef	537252.70	4645367.28	9	-156	-326	-548430
Iowa Quality Beef	537252.70	4645367.28	13	-156	-326	-208308
Salem, City of	616257.92	4523500.87	5	-152	-352	-54501
Salem, City of	616257.92	4523500.87	6	-152	-352	-56596
Salem, City of	616257.92	4523500.87	7	-152	-352	-46773
Salem, City of	616257.92	4523500.87	10	-152	-352	-47552
Salem, City of	616257.92	4523500.87	11	-152	-352	-33244
Salem, City of	616257.92	4523500.87	12	-152	-352	-38685
Salem, City of	616257.92	4523500.87	13	-152	-352	-39825
Salem, City of	616257.92	4523500.87	14	-152	-352	-39757
Salem, City of	616257.92	4523500.87	15	-152	-352	-38773
Salem, City of	616257.92	4523500.87	16	-152	-352	-43425
Webster City	433366.42	4702671.89	0	-120	-257	-1122386
Webster City	433366.42	4702671.89	4	-120	-257	-1198027
Webster City	433366.42	4702671.89	5	-120	-257	-1181693
Webster City	433366.42	4702671.89	6	-120	-257	-1281620
Webster City	433366.42	4702671.89	8	-120	-257	-1214611
Webster City	433366.42	4702671.89	10	-120	-257	-1295385
Webster City	433366.42	4702671.89	11	-120	-257	-1379525
Webster City	433366.42	4702671.89	12	-120	-257	-1265759
Webster City	433366.42	4702671.89	13	-120	-257	-1241534
Webster City	433366.42	4702671.89	14	-120	-257	-1205101
Webster City	433366.42	4702671.89	15	-120	-257	-1244261
Webster City	433366.42	4702671.89	17	-120	-257	-1233011
City of Ainsworth	620530.71	4572277.42	6	-125	-311	-51262
City of Ainsworth	620530.71	4572277.42	8	-125	-311	-50318
City of Ainsworth	620530.71	4572277.42	10	-125	-311	-46298
City of Ainsworth	620530.71	4572277.42	11	-125	-311	-41104
City of Ainsworth	620530.71	4572277.42	12	-125	-311	-46873
City of Ainsworth	620530.71	4572277.42	13	-125	-311	-42143
City of Ainsworth	620530.71	4572277.42	15	-125	-311	-39097
City of Ainsworth	620530.71	4572277.42	16	-125	-311	-40144
Center Point	600822.05	4671096.42	13	-63	-202	-1494
Center Point	600822.05	4671096.42	14	-63	-202	-1325
Center Point	600822.05	4671096.42	15	-63	-202	-30296
Center Point	600822.05	4671096.42	16	-63	-202	-42044
Center Point	600822.05	4671096.42	17	-63	-202	-50997
Peosta, City of	676027.10	4701612.74	4	170	-14	-6456
Peosta, City of	676027.10	4701612.74	5	170	-14	-9573
Peosta, City of	676027.10	4701612.74	8	170	-14	-57
Peosta, City of	676027.10	4701612.74	10	170	-14	-55
Peosta, City of	676027.10	4701612.74	12	170	-14	-140751
Peosta, City of	676027.10	4701612.74	17	170	-14	-129184
Hedrick, City	557948.69	4558088.74	5	-193	-354	-75940

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Hedrick, City	557948.69	4558088.74	7	-193	-354	-69978
Hedrick, City	557948.69	4558088.74	9	-193	-354	-69597
Hedrick, City	557948.69	4558088.74	10	-193	-354	-83975
Hedrick, City	557948.69	4558088.74	12	-193	-354	-99222
Hedrick, City	557948.69	4558088.74	13	-193	-354	-112425
Hedrick, City	557948.69	4558088.74	14	-193	-354	-105377
Hedrick, City	557948.69	4558088.74	15	-193	-354	-123975
Hedrick, City	557948.69	4558088.74	16	-193	-354	-75438
Hedrick, City	557948.69	4558088.74	17	-193	-354	-63025
Lehigh, City of	413472.40	4690076.99	3	-170	-287	-29436
Lehigh, City of	413472.40	4690076.99	4	-170	-287	-33425
Lehigh, City of	413472.40	4690076.99	5	-170	-287	-38773
Lehigh, City of	413472.40	4690076.99	7	-170	-287	-40173
Lehigh, City of	413472.40	4690076.99	9	-170	-287	-41734
Lehigh, City of	413472.40	4690076.99	10	-170	-287	-46421
Lehigh, City of	413472.40	4690076.99	11	-170	-287	-37323
Lehigh, City of	413472.40	4690076.99	12	-170	-287	-37537
Lehigh, City of	413472.40	4690076.99	13	-170	-287	-38030
Lehigh, City of	413472.40	4690076.99	14	-170	-287	-38959
Lehigh, City of	413472.40	4690076.99	15	-170	-287	-48468
Lehigh, City of	413472.40	4690076.99	16	-170	-287	-34241
Lehigh, City of	413472.40	4690076.99	17	-170	-287	-32400
Wayland, City	612265.44	4555969.98	5	-155	-339	-143170
Wayland, City	612265.44	4555969.98	6	-155	-339	-99617
Wayland, City	612265.44	4555969.98	8	-155	-339	-81600
Wayland, City	612265.44	4555969.98	9	-155	-339	-80545
Wayland, City	612265.44	4555969.98	10	-155	-339	-82803
Wayland, City	612265.44	4555969.98	11	-155	-339	-83767
Wayland, City	612265.44	4555969.98	12	-155	-339	-81148
Wayland, City	612265.44	4555969.98	13	-155	-339	-82282
Wayland, City	612265.44	4555969.98	14	-155	-339	-76669
Wayland, City	612265.44	4555969.98	15	-155	-339	-81458
Wayland, City	612265.44	4555969.98	16	-155	-339	-84123
Wayland, City	612265.44	4555969.98	17	-155	-339	-69024
City of Andrew	699106.86	4669731.57	8	-21	-100	-29193
City of Andrew	699106.86	4669731.57	9	-21	-100	-33626
City of Andrew	699106.86	4669731.57	10	-21	-100	-33277
City of Andrew	699106.86	4669731.57	11	-21	-100	-33717
City of Andrew	699106.86	4669731.57	12	-21	-100	-31144
City of Andrew	699106.86	4669731.57	13	-21	-100	-31025
City of Andrew	699106.86	4669731.57	14	-21	-100	-27675
City of Andrew	699106.86	4669731.57	15	-21	-100	-28253
City of Andrew	699106.86	4669731.57	16	-21	-100	-25298
City of Andrew	699106.86	4669731.57	17	-21	-100	-26830
Oakland, Am. Beef	298436.84	4577143.85	4	-437	-519	-29938
Oakland, Am. Beef	298436.84	4577143.85	6	-437	-519	-21283
Oakland, Am. Beef	298436.84	4577143.85	8	-437	-519	-86555
Oakland, Am. Beef	298436.84	4577143.85	13	-437	-519	-3000
Oakland, Am. Beef	298436.84	4577143.85	14	-437	-519	-300
Oakland, Am. Beef	298436.84	4577143.85	15	-437	-519	-300
Oakland, Am. Beef	298436.84	4577143.85	16	-437	-519	-300

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Oakland, Am. Beef	298436.84	4577143.85	17	-437	-519	-300
Worthington, City	654976.94	4695415.89	5	76	-58	-29912
Worthington, City	654976.94	4695415.89	6	76	-58	-28393
Worthington, City	654976.94	4695415.89	8	76	-58	-27919
Worthington, City	654976.94	4695415.89	9	76	-58	-28160
Worthington, City	654976.94	4695415.89	10	76	-58	-38519
Worthington, City	654976.94	4695415.89	12	76	-58	-30928
Worthington, City	654976.94	4695415.89	13	76	-58	-29755
Worthington, City	654976.94	4695415.89	14	76	-58	-42587
Worthington, City	654976.94	4695415.89	15	76	-58	-31114
Worthington, City	654976.94	4695415.89	16	76	-58	-27342
Worthington, City	654976.94	4695415.89	17	76	-58	-26227
Dubuque, City	688628.53	4711064.41	5	146	28	-2932932
Dubuque, City	688628.53	4711064.41	8	146	28	-3027534
Dubuque, City	688628.53	4711064.41	9	146	28	-2985616
Dubuque, City	688628.53	4711064.41	10	146	28	-2555464
Dubuque, City	688628.53	4711064.41	11	146	28	-2758164
Dubuque, City	688628.53	4711064.41	12	146	28	-3049479
Dubuque, City	688628.53	4711064.41	13	146	28	-2883792
Dubuque, City	688628.53	4711064.41	14	146	28	-2883795
Dubuque, City	688628.53	4711064.41	15	146	28	-2923534
Dubuque, City	688628.53	4711064.41	17	146	28	-2785068
Hendricks	637594.85	4484184.95	5	-114	-319	-1085
Hendricks	637594.85	4484184.95	6	-114	-319	-11475
Hendricks	637594.85	4484184.95	7	-114	-319	-7825
Hendricks	637594.85	4484184.95	8	-114	-319	-12362
Hendricks	637594.85	4484184.95	9	-114	-319	-33468
Hendricks	637594.85	4484184.95	10	-114	-319	-11574
Hendricks	637594.85	4484184.95	11	-114	-319	-7036
Hendricks	637594.85	4484184.95	12	-114	-319	-12263
Hendricks	637594.85	4484184.95	13	-114	-319	-8351
Hendricks	637594.85	4484184.95	14	-114	-319	-6721
Hendricks	637594.85	4484184.95	15	-114	-319	-9929
Hendricks	637594.85	4484184.95	16	-114	-319	-8877
Hendricks	637594.85	4484184.95	17	-114	-319	-5786
New Vienna	654886.05	4712185.26	5	111	-27	-45242
New Vienna	654886.05	4712185.26	6	111	-27	-29905
New Vienna	654886.05	4712185.26	8	111	-27	-33424
New Vienna	654886.05	4712185.26	9	111	-27	-25579
New Vienna	654886.05	4712185.26	10	111	-27	-25572
New Vienna	654886.05	4712185.26	11	111	-27	-28198
New Vienna	654886.05	4712185.26	12	111	-27	-28438
New Vienna	654886.05	4712185.26	13	111	-27	-33348
New Vienna	654886.05	4712185.26	14	111	-27	-28275
New Vienna	654886.05	4712185.26	15	111	-27	-27311
New Vienna	654886.05	4712185.26	16	111	-27	-25736
New Vienna	654886.05	4712185.26	17	111	-27	-26698
Newton Water	490332.84	4611001.54	11	-258	-409	-521772
Newton Water	490332.84	4611001.54	12	-258	-409	-755482
Newton Water	490332.84	4611001.54	13	-258	-409	-731786
Newton Water	490332.84	4611001.54	14	-258	-409	-420623

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Newton Water	490332.84	4611001.54	15	-258	-409	-774359
Newton Water	490332.84	4611001.54	16	-258	-409	-1246370
Newton Water	490332.84	4611001.54	17	-258	-409	-1342162
Hopkinton, City	644603.77	4689718.47	5	57	-78	-109260
Hopkinton, City	644603.77	4689718.47	6	57	-78	-104995
Hopkinton, City	644603.77	4689718.47	8	57	-78	-91666
Hopkinton, City	644603.77	4689718.47	9	57	-78	-92636
Hopkinton, City	644603.77	4689718.47	10	57	-78	-84552
Hopkinton, City	644603.77	4689718.47	11	57	-78	-86430
Hopkinton, City	644603.77	4689718.47	12	57	-78	-79871
Hopkinton, City	644603.77	4689718.47	13	57	-78	-80351
Hopkinton, City	644603.77	4689718.47	14	57	-78	-78194
Hopkinton, City	644603.77	4689718.47	15	57	-78	-83485
Hopkinton, City	644603.77	4689718.47	16	57	-78	-57893
Hopkinton, City	644603.77	4689718.47	17	57	-78	-63416
United Property	443574.66	4595204.53	15	-347	-487	-15926
United Property	443574.66	4595204.53	16	-347	-487	-17104
Goose Lake, City	717019.70	4649500.18	15	10	-117	-14896
Goose Lake, City	717019.70	4649500.18	16	10	-117	-20659
Goose Lake, City	717019.70	4649500.18	17	10	-117	-19572
Edgewood, City	631136.16	4722510.84	4	117	-13	-95033
Edgewood, City	631136.16	4722510.84	5	117	-13	-94299
Edgewood, City	631136.16	4722510.84	6	117	-13	-92145
Edgewood, City	631136.16	4722510.84	8	117	-13	-100408
Edgewood, City	631136.16	4722510.84	9	117	-13	-105219
Edgewood, City	631136.16	4722510.84	11	117	-13	-86014
Edgewood, City	631136.16	4722510.84	12	117	-13	-93584
Edgewood, City	631136.16	4722510.84	13	117	-13	-93510
Edgewood, City	631136.16	4722510.84	14	117	-13	-83549
Edgewood, City	631136.16	4722510.84	15	117	-13	-70921
Edgewood, City	631136.16	4722510.84	16	117	-13	-72639
Edgewood, City	631136.16	4722510.84	17	117	-13	-72532
Ajinomoto	529979.98	4555109.33	4	-220	-372	-173235
Ajinomoto	529979.98	4555109.33	5	-220	-372	-192911
Ajinomoto	529979.98	4555109.33	6	-220	-372	-190412
Ajinomoto	529979.98	4555109.33	7	-220	-372	-210027
Ajinomoto	529979.98	4555109.33	8	-220	-372	-203362
Ajinomoto	529979.98	4555109.33	9	-220	-372	-262147
Ajinomoto	529979.98	4555109.33	10	-220	-372	-305455
Ajinomoto	529979.98	4555109.33	11	-220	-372	-305455
Ajinomoto	529979.98	4555109.33	12	-220	-372	-374046
Ajinomoto	529979.98	4555109.33	13	-220	-372	-423807
Ajinomoto	529979.98	4555109.33	15	-220	-372	-709127
Ajinomoto	529979.98	4555109.33	16	-220	-372	-596209
Ajinomoto	529979.98	4555109.33	17	-220	-372	-675211
Lytton, City of	348469.52	4698467.25	6	-88	-187	-94988
Lytton, City of	348469.52	4698467.25	7	-88	-187	-61554
Lytton, City of	348469.52	4698467.25	8	-88	-187	-56811
Lytton, City of	348469.52	4698467.25	9	-88	-187	-64136
Lytton, City of	348469.52	4698467.25	11	-88	-187	-61956
Lytton, City of	348469.52	4698467.25	12	-88	-187	-41953

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Lytton, City of	348469.52	4698467.25	13	-88	-187	-40792
Lytton, City of	348469.52	4698467.25	14	-88	-187	-77238
Lytton, City of	348469.52	4698467.25	15	-88	-187	-57995
Lytton, City of	348469.52	4698467.25	16	-88	-187	-49795
Lytton, City of	348469.52	4698467.25	17	-88	-187	-69375
State Center	486189.05	4652428.15	5	-234	-395	-155585
State Center	486189.05	4652428.15	6	-234	-395	-169745
State Center	486189.05	4652428.15	7	-234	-395	-144409
State Center	486189.05	4652428.15	9	-234	-395	-146581
State Center	486189.05	4652428.15	10	-234	-395	-116807
State Center	486189.05	4652428.15	11	-234	-395	-120468
State Center	486189.05	4652428.15	12	-234	-395	-123337
State Center	486189.05	4652428.15	13	-234	-395	-124915
State Center	486189.05	4652428.15	14	-234	-395	-121153
State Center	486189.05	4652428.15	15	-234	-395	-116145
State Center	486189.05	4652428.15	16	-234	-395	-107799
State Center	486189.05	4652428.15	17	-234	-395	-120807
Vinton, City of	580236.55	4669125.00	4	-53	-206	-185732
Vinton, City of	580236.55	4669125.00	5	-53	-206	-191342
Vinton, City of	580236.55	4669125.00	6	-53	-206	-188743
Vinton, City of	580236.55	4669125.00	7	-53	-206	-191178
Sabula, City of	733861.20	4661049.35	5	0	-131	-12879
Sabula, City of	733861.20	4661049.35	6	0	-131	-18025
Sabula, City of	733861.20	4661049.35	7	0	-131	-24449
Sabula, City of	733861.20	4661049.35	8	0	-131	-10693
Sabula, City of	733861.20	4661049.35	9	0	-131	-11907
Sabula, City of	733861.20	4661049.35	10	0	-131	-8410
Sabula, City of	733861.20	4661049.35	11	0	-131	-16992
Sabula, City of	733861.20	4661049.35	12	0	-131	-5756
Sabula, City of	733861.20	4661049.35	13	0	-131	-6348
Sabula, City of	733861.20	4661049.35	14	0	-131	-6331
Sabula, City of	733861.20	4661049.35	15	0	-131	-1814
Sabula, City of	733861.20	4661049.35	16	0	-131	-113671
Sabula, City of	733861.20	4661049.35	17	0	-131	-111263
New London	635256.15	4531704.95	5	-130	-329	-171819
New London	635256.15	4531704.95	7	-130	-329	-176978
New London	635256.15	4531704.95	8	-130	-329	-176340
New London	635256.15	4531704.95	9	-130	-329	-236770
New London	635256.15	4531704.95	10	-130	-329	-189216
New London	635256.15	4531704.95	12	-130	-329	-186915
New London	635256.15	4531704.95	13	-130	-329	-164926
New London	635256.15	4531704.95	15	-130	-329	-163279
New London	635256.15	4531704.95	16	-130	-329	-113923
New London	635256.15	4531704.95	17	-130	-329	-181096
Shellsburg, City	593144.95	4660812.90	7	-79	-225	-106220
Shellsburg, City	593144.95	4660812.90	8	-79	-225	-103232
Shellsburg, City	593144.95	4660812.90	10	-79	-225	-111842
Shellsburg, City	593144.95	4660812.90	11	-79	-225	-112055
Shellsburg, City	593144.95	4660812.90	12	-79	-225	-106685
Shellsburg, City	593144.95	4660812.90	13	-79	-225	-103510
Shellsburg, City	593144.95	4660812.90	14	-79	-225	-107025

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Shellsburg, City	593144.95	4660812.90	15	-79	-225	-94688
Shellsburg, City	593144.95	4660812.90	16	-79	-225	-43795
Shellsburg, City	593144.95	4660812.90	17	-79	-225	-81868
Estherville, City	351319.25	4806703.70	5	249	170	-987984
Estherville, City	351319.25	4806703.70	6	249	170	-946074
Estherville, City	351319.25	4806703.70	8	249	170	-1175350
Estherville, City	351319.25	4806703.70	9	249	170	-1092685
Estherville, City	351319.25	4806703.70	10	249	170	-1075197
Estherville, City	351319.25	4806703.70	11	249	170	-1085198
Estherville, City	351319.25	4806703.70	12	249	170	-1047937
Estherville, City	351319.25	4806703.70	13	249	170	-1053208
Estherville, City	351319.25	4806703.70	14	249	170	-1154242
Estherville, City	351319.25	4806703.70	15	249	170	-1193938
Estherville, City	351319.25	4806703.70	16	249	170	-1186451
Estherville, City	351319.25	4806703.70	17	249	170	-1169469
Russell, City	483299.00	4536927.40	5	-281	-426	-71781
Russell, City	483299.00	4536927.40	7	-281	-426	-71863
Russell, City	483299.00	4536927.40	8	-281	-426	-71233
Russell, City	483299.00	4536927.40	10	-281	-426	-66940
Keota, City of	587640.30	4579298.45	4	-128	-313	-106732
Keota, City of	587640.30	4579298.45	5	-128	-313	-117663
Keota, City of	587640.30	4579298.45	6	-128	-313	-106779
Keota, City of	587640.30	4579298.45	8	-128	-313	-122082
Keota, City of	587640.30	4579298.45	9	-128	-313	-91644
Keota, City of	587640.30	4579298.45	10	-128	-313	-99134
Keota, City of	587640.30	4579298.45	11	-128	-313	-106896
Keota, City of	587640.30	4579298.45	12	-128	-313	-94589
Keota, City of	587640.30	4579298.45	13	-128	-313	-90438
Keota, City of	587640.30	4579298.45	14	-128	-313	-88036
Keota, City of	587640.30	4579298.45	15	-128	-313	-91814
Keota, City of	587640.30	4579298.45	16	-128	-313	-88603
Keota, City of	587640.30	4579298.45	17	-128	-313	-79241
Marcus, City of	271269.07	4745202.73	12	140	100	-2425
Marcus, City of	271269.07	4745202.73	13	140	100	-1356
Marcus, City of	271269.07	4745202.73	14	140	100	-199
Milo, City of	463165.00	4570790.80	4	-318	-459	-88219
De Witt, City	704712.20	4632848.50	5	-32	-169	-463786
De Witt, City	704712.20	4632848.50	6	-32	-169	-506566
De Witt, City	704712.20	4632848.50	8	-32	-169	-556156
De Witt, City	704712.20	4632848.50	9	-32	-169	-586496
De Witt, City	704712.20	4632848.50	10	-32	-169	-590497
De Witt, City	704712.20	4632848.50	11	-32	-169	-596471
De Witt, City	704712.20	4632848.50	12	-32	-169	-646345
De Witt, City	704712.20	4632848.50	13	-32	-169	-617970
De Witt, City	704712.20	4632848.50	15	-32	-169	-679600
De Witt, City	704712.20	4632848.50	16	-32	-169	-556175
De Witt, City	704712.20	4632848.50	17	-32	-169	-584321
Rockwell City	365532.70	4695128.50	5	-90	-174	-449334
Rockwell City	365532.70	4695128.50	8	-90	-174	-254696
Rockwell City	365532.70	4695128.50	9	-90	-174	-262510
Rockwell City	365532.70	4695128.50	10	-90	-174	-273306

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Rockwell City	365532.70	4695128.50	11	-90	-174	-282959
Rockwell City	365532.70	4695128.50	12	-90	-174	-253789
Rockwell City	365532.70	4695128.50	13	-90	-174	-239970
Rockwell City	365532.70	4695128.50	14	-90	-174	-250019
Rockwell City	365532.70	4695128.50	15	-90	-174	-235836
Rockwell City	365532.70	4695128.50	16	-90	-174	-267504
Rockwell City	365532.70	4695128.50	17	-90	-174	-266575
Sumner, City of	573351.65	4744132.40	5	102	-57	-174285
Sumner, City of	573351.65	4744132.40	6	102	-57	-183495
Sumner, City of	573351.65	4744132.40	7	102	-57	-182214
Sumner, City of	573351.65	4744132.40	8	102	-57	-176573
Sumner, City of	573351.65	4744132.40	9	102	-57	-185488
Sumner, City of	573351.65	4744132.40	11	102	-57	-165485
Sumner, City of	573351.65	4744132.40	12	102	-57	-176085
Sumner, City of	573351.65	4744132.40	14	102	-57	-177740
Sumner, City of	573351.65	4744132.40	15	102	-57	-198490
Sumner, City of	573351.65	4744132.40	16	102	-57	-183203
Sumner, City of	573351.65	4744132.40	17	102	-57	-183397
Keystone, City	566063.20	4650129.15	4	-117	-280	-31910
Keystone, City	566063.20	4650129.15	5	-117	-280	-34277
Keystone, City	566063.20	4650129.15	7	-117	-280	-9611
Keystone, City	566063.20	4650129.15	9	-117	-280	-34110
Ackley, City of	495330.85	4711281.05	5	-90	-243	-396712
Ackley, City of	495330.85	4711281.05	6	-90	-243	-421926
Ackley, City of	495330.85	4711281.05	7	-90	-243	-368778
Ackley, City of	495330.85	4711281.05	8	-90	-243	-435693
Ackley, City of	495330.85	4711281.05	9	-90	-243	-402907
Ackley, City of	495330.85	4711281.05	10	-90	-243	-416617
Ackley, City of	495330.85	4711281.05	11	-90	-243	-460551
Ackley, City of	495330.85	4711281.05	12	-90	-243	-344236
Ackley, City of	495330.85	4711281.05	13	-90	-243	-227312
Ackley, City of	495330.85	4711281.05	14	-90	-243	-239090
Ackley, City of	495330.85	4711281.05	15	-90	-243	-232797
Ackley, City of	495330.85	4711281.05	16	-90	-243	-239241
Ackley, City of	495330.85	4711281.05	17	-90	-243	-268277
Fairbank, City	577770.90	4720822.75	5	67	-85	-46041
Fairbank, City	577770.90	4720822.75	6	67	-85	-45926
Fairbank, City	577770.90	4720822.75	8	67	-85	-46784
Fairbank, City	577770.90	4720822.75	9	67	-85	-46866
Fairbank, City	577770.90	4720822.75	10	67	-85	-43445
Fairbank, City	577770.90	4720822.75	11	67	-85	-43403
Fairbank, City	577770.90	4720822.75	12	67	-85	-60107
Fairbank, City	577770.90	4720822.75	13	67	-85	-54795
Fairbank, City	577770.90	4720822.75	14	67	-85	-45128
Fairbank, City	577770.90	4720822.75	15	67	-85	-47685
Winfield, City	631400.45	4554346.05	5	-136	-331	-94011
Winfield, City	631400.45	4554346.05	6	-136	-331	-96680
Winfield, City	631400.45	4554346.05	7	-136	-331	-93367
Winfield, City	631400.45	4554346.05	10	-136	-331	-95197
Winfield, City	631400.45	4554346.05	11	-136	-331	-101937
Winfield, City	631400.45	4554346.05	12	-136	-331	-102236

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Winfield, City	631400.45	4554346.05	13	-136	-331	-102126
Winfield, City	631400.45	4554346.05	14	-136	-331	-98036
Winfield, City	631400.45	4554346.05	15	-136	-331	-119663
Winfield, City	631400.45	4554346.05	16	-136	-331	-121578
Richland, City	603442.51	4566098.00	17	-147	-326	-51770
Wellman, City	597220.95	4590829.25	10	-144	-304	-54893
Wellman, City	597220.95	4590829.25	11	-144	-304	-62912
Wellman, City	597220.95	4590829.25	12	-144	-304	-144655
Wellman, City	597220.95	4590829.25	13	-144	-304	-167611
Delmar, City of	698126.35	4652536.95	6	0	-111	-48114
Delmar, City of	698126.35	4652536.95	7	0	-111	-45353
Delmar, City of	698126.35	4652536.95	8	0	-111	-27496
Delmar, City of	698126.35	4652536.95	9	0	-111	-29163
Delmar, City of	698126.35	4652536.95	10	0	-111	-31300
Delmar, City of	698126.35	4652536.95	12	0	-111	-38224
Delmar, City of	698126.35	4652536.95	13	0	-111	-38721
Delmar, City of	698126.35	4652536.95	14	0	-111	-37495
Delmar, City of	698126.35	4652536.95	15	0	-111	-36740
Delmar, City of	698126.35	4652536.95	16	0	-111	-33732
Delmar, City of	698126.35	4652536.95	17	0	-111	-30375
Klemme, City of	450902.70	4761644.90	6	66	-69	-59809
Klemme, City of	450902.70	4761644.90	7	66	-69	-60839
Klemme, City of	450902.70	4761644.90	10	66	-69	-64302
Klemme, City of	450902.70	4761644.90	11	66	-69	-61333
Klemme, City of	450902.70	4761644.90	12	66	-69	-55947
Klemme, City of	450902.70	4761644.90	13	66	-69	-43041
Klemme, City of	450902.70	4761644.90	14	66	-69	-42478
Klemme, City of	450902.70	4761644.90	15	66	-69	-37889
Klemme, City of	450902.70	4761644.90	16	66	-69	-36675
Klemme, City of	450902.70	4761644.90	17	66	-69	-38512
North English	576944.85	4596106.25	4	-165	-320	-963014
North English	576944.85	4596106.25	6	-165	-320	-1288251
North English	576944.85	4596106.25	7	-165	-320	-1236301
North English	576944.85	4596106.25	10	-165	-320	-112601
North English	576944.85	4596106.25	11	-165	-320	-123855
North English	576944.85	4596106.25	12	-165	-320	-126508
North English	576944.85	4596106.25	13	-165	-320	-153336
North English	576944.85	4596106.25	14	-165	-320	-139115
North English	576944.85	4596106.25	15	-165	-320	-157334
North English	576944.85	4596106.25	16	-165	-320	-149425
North English	576944.85	4596106.25	17	-165	-320	-190003
Walker, City of	600500.05	4682333.90	5	-36	-186	-60254
Walker, City of	600500.05	4682333.90	6	-36	-186	-59693
Walker, City of	600500.05	4682333.90	8	-36	-186	-48197
Walker, City of	600500.05	4682333.90	9	-36	-186	-53244
Walker, City of	600500.05	4682333.90	10	-36	-186	-47610
Walker, City of	600500.05	4682333.90	11	-36	-186	-53329
Walker, City of	600500.05	4682333.90	12	-36	-186	-60403
Walker, City of	600500.05	4682333.90	13	-36	-186	-47370
Walker, City of	600500.05	4682333.90	14	-36	-186	-48270
Walker, City of	600500.05	4682333.90	15	-36	-186	-54052

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Walker, City of	600500.05	4682333.90	16	-36	-186	-50074
Walker, City of	600500.05	4682333.90	17	-36	-186	-52030
Quaker Oats Co	610177.00	4648565.50	4	-75	-227	-529723
Quaker Oats Co	610177.00	4648565.50	5	-75	-227	-570819
Quaker Oats Co	610177.00	4648565.50	6	-75	-227	-489653
Quaker Oats Co	610177.00	4648565.50	8	-75	-227	-467813
Quaker Oats Co	610177.00	4648565.50	9	-75	-227	-433815
Quaker Oats Co	610177.00	4648565.50	11	-75	-227	-424490
Quaker Oats Co	610177.00	4648565.50	12	-75	-227	-276413
Quaker Oats Co	610177.00	4648565.50	13	-75	-227	-297296
Quaker Oats Co	610177.00	4648565.50	14	-75	-227	-423228
Quaker Oats Co	610177.00	4648565.50	15	-75	-227	-293839
Quaker Oats Co	610177.00	4648565.50	16	-75	-227	-237551
Quaker Oats Co	610177.00	4648565.50	17	-75	-227	-236795
Calamus, City	692948.91	4651356.87	17	0	-100	-32274
Walnut, City of	314294.50	4593946.50	4	-359	-464	-101104
Walnut, City of	314294.50	4593946.50	5	-359	-464	-114603
Walnut, City of	314294.50	4593946.50	6	-359	-464	-143934
Walnut, City of	314294.50	4593946.50	7	-359	-464	-153307
Walnut, City of	314294.50	4593946.50	10	-359	-464	-191355
Walnut, City of	314294.50	4593946.50	11	-359	-464	-185510
Walnut, City of	314294.50	4593946.50	12	-359	-464	-142636
Walnut, City of	314294.50	4593946.50	13	-359	-464	-120405
Walnut, City of	314294.50	4593946.50	14	-359	-464	-105992
Walnut, City of	314294.50	4593946.50	16	-359	-464	-88523
Walnut, City of	314294.50	4593946.50	17	-359	-464	-89112
Dows, City of	458708.75	4722843.80	5	-39	-191	-94630
Dows, City of	458708.75	4722843.80	7	-39	-191	-113616
Dows, City of	458708.75	4722843.80	9	-39	-191	-54863
Dows, City of	458708.75	4722843.80	10	-39	-191	-71688
Dows, City of	458708.75	4722843.80	11	-39	-191	-64620
Dows, City of	458708.75	4722843.80	12	-39	-191	-69168
Dows, City of	458708.75	4722843.80	13	-39	-191	-81943
Dows, City of	458708.75	4722843.80	14	-39	-191	-59396
Dows, City of	458708.75	4722843.80	15	-39	-191	-59229
Dows, City of	458708.75	4722843.80	16	-39	-191	-53130
Dows, City of	458708.75	4722843.80	17	-39	-191	-47062
Pleasantville	477545.50	4581637.35	5	-272	-419	-192822
Pleasantville	477545.50	4581637.35	6	-272	-419	-205628
Pleasantville	477545.50	4581637.35	8	-272	-419	-183726
Pleasantville	477545.50	4581637.35	9	-272	-419	-162959
Pleasantville	477545.50	4581637.35	10	-272	-419	-176093
Pleasantville	477545.50	4581637.35	11	-272	-419	-212110
Pleasantville	477545.50	4581637.35	12	-272	-419	-198137
Pleasantville	477545.50	4581637.35	13	-272	-419	-167786
Pleasantville	477545.50	4581637.35	14	-272	-419	-147951
Pleasantville	477545.50	4581637.35	15	-272	-419	-162027
Pleasantville	477545.50	4581637.35	16	-272	-419	-222247
Pleasantville	477545.50	4581637.35	17	-272	-419	-207123
Lamont, City of	611472.20	4717236.80	5	96	-47	-38207
Lamont, City of	611472.20	4717236.80	6	96	-47	-40270

Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Lamont, City of	611472.20	4717236.80	8	96	-47	-35374
Lamont, City of	611472.20	4717236.80	11	96	-47	-32268
Lamont, City of	611472.20	4717236.80	12	96	-47	-34210
Lamont, City of	611472.20	4717236.80	13	96	-47	-32922
Lamont, City of	611472.20	4717236.80	14	96	-47	-29182
Lamont, City of	611472.20	4717236.80	15	96	-47	-31492
Lamont, City of	611472.20	4717236.80	16	96	-47	-29295
Lamont, City of	611472.20	4717236.80	17	96	-47	-30698
Odebolt, City	313353.00	4687108.50	5	-95	-180	-107504
Odebolt, City	313353.00	4687108.50	6	-95	-180	-131082
Odebolt, City	313353.00	4687108.50	8	-95	-180	-115227
Odebolt, City	313353.00	4687108.50	9	-95	-180	-111162
Odebolt, City	313353.00	4687108.50	11	-95	-180	-117216
Odebolt, City	313353.00	4687108.50	12	-95	-180	-115356
Odebolt, City	313353.00	4687108.50	13	-95	-180	-127701
Odebolt, City	313353.00	4687108.50	14	-95	-180	-132948
Odebolt, City	313353.00	4687108.50	15	-95	-180	-133663
Odebolt, City	313353.00	4687108.50	16	-95	-180	-156921
Odebolt, City	313353.00	4687108.50	17	-95	-180	-152016
Gazette Co.	610714.10	4648321.30	5	-77	-227	-65200
Gazette Co.	610714.10	4648321.30	6	-77	-227	-8872
Gazette Co.	610714.10	4648321.30	7	-77	-227	-16924
Gazette Co.	610714.10	4648321.30	8	-77	-227	-35621
Gazette Co.	610714.10	4648321.30	10	-77	-227	-32052
Gazette Co.	610714.10	4648321.30	12	-77	-227	-18419
Gazette Co.	610714.10	4648321.30	13	-77	-227	-20603
Gazette Co.	610714.10	4648321.30	14	-77	-227	-66667
Gazette Co.	610714.10	4648321.30	15	-77	-227	-33425
Gazette Co.	610714.10	4648321.30	16	-77	-227	-33425
Arlington, City	608879.50	4733643.50	5	109	-25	-39737
Arlington, City	608879.50	4733643.50	6	109	-25	-33959
Arlington, City	608879.50	4733643.50	9	109	-25	-38058
Arlington, City	608879.50	4733643.50	11	109	-25	-31742
Arlington, City	608879.50	4733643.50	12	109	-25	-31663
Arlington, City	608879.50	4733643.50	13	109	-25	-29674
Arlington, City	608879.50	4733643.50	14	109	-25	-28978
Arlington, City	608879.50	4733643.50	15	109	-25	-29381
Arlington, City	608879.50	4733643.50	16	109	-25	-29110
Arlington, City	608879.50	4733643.50	17	109	-25	-29997
Mason City, City	484434.50	4777435.50	1	103	-30	-2350000
Mason City, City	484434.50	4777435.50	2	103	-30	-2550000
Mason City, City	484434.50	4777435.50	3	103	-30	-2640000
Mason City, City	484434.50	4777435.50	4	103	-30	-2000000
Mason City, City	484434.50	4777435.50	5	103	-30	-2750000
Mason City, City	484434.50	4777435.50	6	103	-30	-2650000
Mason City, City	484434.50	4777435.50	7	103	-30	-2300000
Mason City, City	484434.50	4777435.50	8	103	-30	-2500000
Mason City, City	484434.50	4777435.50	9	103	-30	-2750000
Mason City, City	484434.50	4777435.50	10	103	-30	-2440000
Mason City, City	484434.50	4777435.50	11	103	-30	-2450000
Mason City, City	484434.50	4777435.50	12	103	-30	-2250000

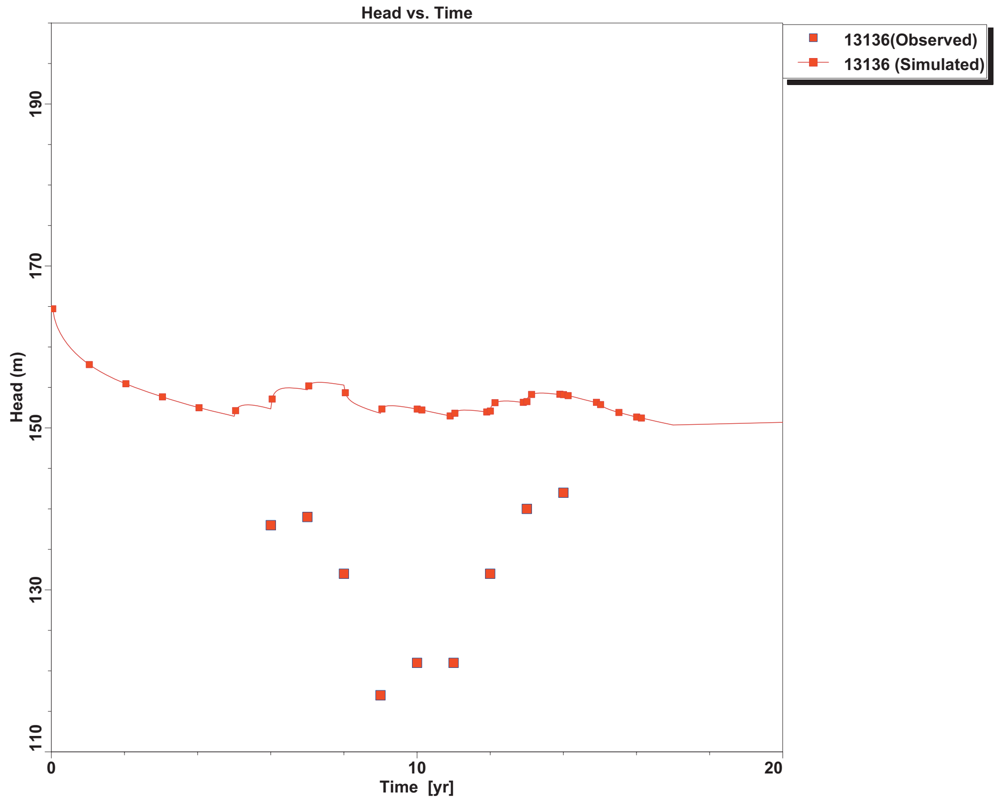
Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Mason City, City	484434.50	4777435.50	13	103	-30	-2500000
Mason City, City	484434.50	4777435.50	14	103	-30	-2950000
Mason City, City	484434.50	4777435.50	15	103	-30	-2800000
Mason City, City	484434.50	4777435.50	16	103	-30	-2950000
Mason City, City	484434.50	4777435.50	17	103	-30	-2800000
Callender, City	393389.50	4690662.50	5	-150	-258	-54622
Callender, City	393389.50	4690662.50	8	-150	-258	-44003
Callender, City	393389.50	4690662.50	9	-150	-258	-44047
Callender, City	393389.50	4690662.50	10	-150	-258	-41320
Callender, City	393389.50	4690662.50	11	-150	-258	-41789
Callender, City	393389.50	4690662.50	12	-150	-258	-40830
Callender, City	393389.50	4690662.50	13	-150	-258	-40975
Callender, City	393389.50	4690662.50	14	-150	-258	-42202
Callender, City	393389.50	4690662.50	15	-150	-258	-47318
Callender, City	393389.50	4690662.50	16	-150	-258	-40208
Callender, City	393389.50	4690662.50	17	-150	-258	-34515
La Porte City	566352.40	4685243.05	5	0	-173	-122581
La Porte City	566352.40	4685243.05	6	0	-173	-143226
La Porte City	566352.40	4685243.05	7	0	-173	-97823
La Porte City	566352.40	4685243.05	8	0	-173	-106698
La Porte City	566352.40	4685243.05	10	0	-173	-140022
La Porte City	566352.40	4685243.05	11	0	-173	-129003
La Porte City	566352.40	4685243.05	12	0	-173	-190557
La Porte City	566352.40	4685243.05	13	0	-173	-140764
La Porte City	566352.40	4685243.05	14	0	-173	-134531
La Porte City	566352.40	4685243.05	15	0	-173	-119810
La Porte City	566352.40	4685243.05	16	0	-173	-115591
La Porte City	566352.40	4685243.05	17	0	-173	-97158
Hazleton, City	589823.20	4719027.50	5	89	-60	-64932
Hazleton, City	589823.20	4719027.50	6	89	-100	-56284
Hazleton, City	589823.20	4719027.50	8	89	-100	-53151
Hazleton, City	589823.20	4719027.50	9	89	-100	-81096
Hazleton, City	589823.20	4719027.50	10	89	-100	-46721
Hazleton, City	589823.20	4719027.50	11	89	-100	-48767
Hazleton, City	589823.20	4719027.50	12	89	-100	-45205
Hazleton, City	589823.20	4719027.50	13	89	-100	-45753
Hazleton, City	589823.20	4719027.50	14	89	-100	-45902
Hazleton, City	589823.20	4719027.50	15	89	-100	-42005
Hazleton, City	589823.20	4719027.50	16	89	-100	-44614
Hazleton, City	589823.20	4719027.50	17	89	-100	-46482
Georgia-Pacific	405979.70	4702734.40	5	-133	-245	-120000
Georgia-Pacific	405979.70	4702734.40	6	-133	-245	-115000
Georgia-Pacific	405979.70	4702734.40	8	-133	-245	-212548
Georgia-Pacific	405979.70	4702734.40	10	-133	-245	-171366
Georgia-Pacific	405979.70	4702734.40	13	-133	-245	-155123
Georgia-Pacific	405979.70	4702734.40	14	-133	-245	-163634
Georgia-Pacific	405979.70	4702734.40	15	-133	-245	-180548
Georgia-Pacific	405979.70	4702734.40	16	-133	-245	-174301
Georgia-Pacific	405979.70	4702734.40	17	-133	-245	-163589
Mount Pleasant MH	623056.60	4534659.30	13	-145	-354	-115000
Mount Pleasant MH	623056.60	4534659.30	16	-145	-354	-115000

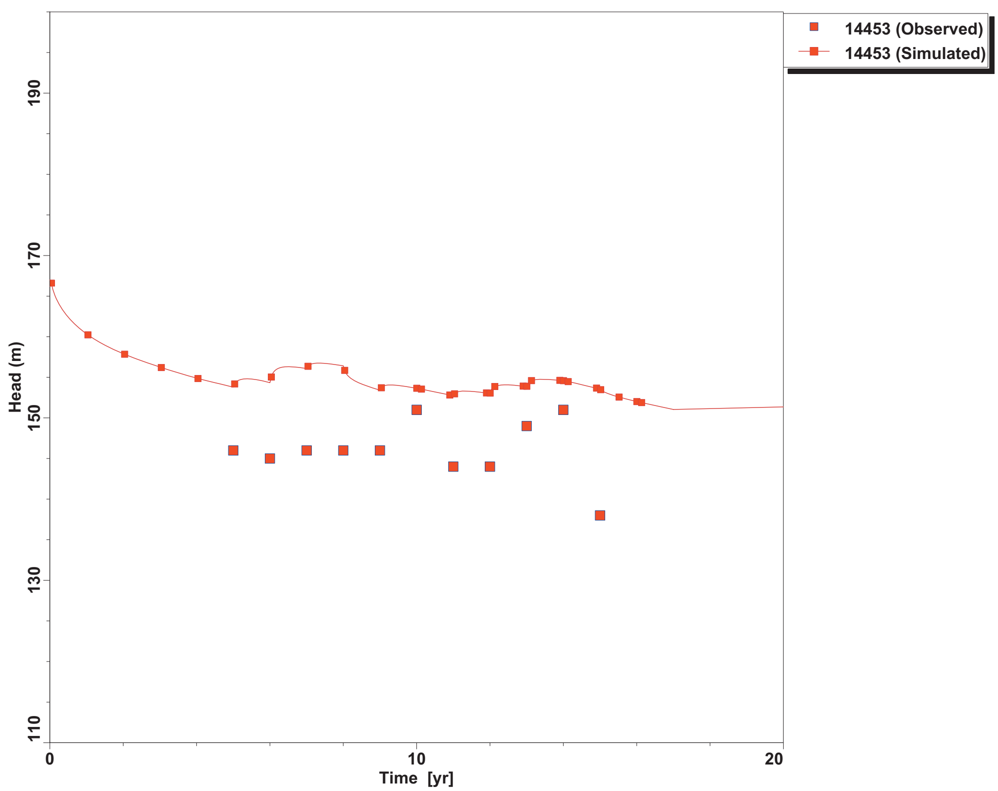
Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Mount Pleasant MH	623056.60	4534659.30	17	-145	-354	-115000
Bernard, City	678775.00	4686757.00	7	79	-57	-7781
Bernard, City	678775.00	4686757.00	8	79	-57	-9027
Bernard, City	678775.00	4686757.00	9	79	-57	-7649
Bernard, City	678775.00	4686757.00	10	79	-57	-7719
Bernard, City	678775.00	4686757.00	11	79	-57	-8145
Bernard, City	678775.00	4686757.00	12	79	-57	-7592
Bernard, City	678775.00	4686757.00	13	79	-57	-7540
Bernard, City	678775.00	4686757.00	14	79	-57	-7265
Bernard, City	678775.00	4686757.00	15	79	-57	-7175
Bernard, City	678775.00	4686757.00	16	79	-57	-7477
Bernard, City	678775.00	4686757.00	17	79	-57	-6422
Royal Oaks Sub	679578.68	4702707.21	12	181	2	-4855
Royal Oaks Sub	679578.68	4702707.21	13	181	2	-5227
Royal Oaks Sub	679578.68	4702707.21	15	181	2	-7515
Royal Oaks Sub	679578.68	4702707.21	16	181	2	-6853
Fremont Farms	535578.29	4620413.75	12	-192	-354	-20811
Fremont Farms	535578.29	4620413.75	13	-192	-354	-28849
Fremont Farms	535578.29	4620413.75	14	-192	-354	-29164
Fremont Farms	535578.29	4620413.75	15	-192	-354	-36986
Fremont Farms	535578.29	4620413.75	16	-192	-354	-35507
Fremont Farms	535578.29	4620413.75	17	-192	-354	-35704
Golden Oval Egg	441387.22	4807322.95	10	248	89	-23068
Golden Oval Egg	441387.22	4807322.95	11	248	89	-121134
Golden Oval Egg	441387.22	4807322.95	12	248	89	-204120
Golden Oval Egg	441387.22	4807322.95	13	248	89	-213714
Golden Oval Egg	441387.22	4807322.95	14	248	89	-235970
Golden Oval Egg	441387.22	4807322.95	15	248	89	-333365
Golden Oval Egg	441387.22	4807322.95	16	248	89	-382404
Golden Oval Egg	441387.22	4807322.95	17	248	89	-336893
Holcim (US)	483575.10	4779872.05	10	110	-25	-116964
Holcim (US)	483575.10	4779872.05	11	110	-25	-117666
Holcim (US)	483575.10	4779872.05	12	110	-25	-189896
Holcim (US)	483575.10	4779872.05	13	110	-25	-273600
Holcim (US)	483575.10	4779872.05	14	110	-25	-187148
Holcim (US)	483575.10	4779872.05	15	110	-25	-230614
Holcim (US)	483575.10	4779872.05	16	110	-25	-216427
Holcim (US)	483575.10	4779872.05	17	110	-25	-130586
Interstate Power	476168.44	4771365.17	13	95	-44	-483373
Interstate Power	476168.44	4771365.17	15	95	-44	-898189
Interstate Power	476168.44	4771365.17	16	95	-44	-808203
Interstate Power	476168.44	4771365.17	17	95	-44	-979882
Gantz, Jim	688179.30	4712511.52	14	151	34	-315
Gantz, Jim	688179.30	4712511.52	15	151	34	-3939
Gantz, Jim	688179.30	4712511.52	16	151	34	-2635
Gantz, Jim	688179.30	4712511.52	17	151	34	-4247
Vernon Water	681444.80	4700458.31	14	172	-10	-112
Vernon Water	681444.80	4700458.31	15	172	-10	-12381
Vernon Water	681444.80	4700458.31	16	172	-10	-13149
Luxemburg, City	658058.78	4718876.33	14	125	-5	-6411
Luxemburg, City	658058.78	4718876.33	15	125	-5	-13637

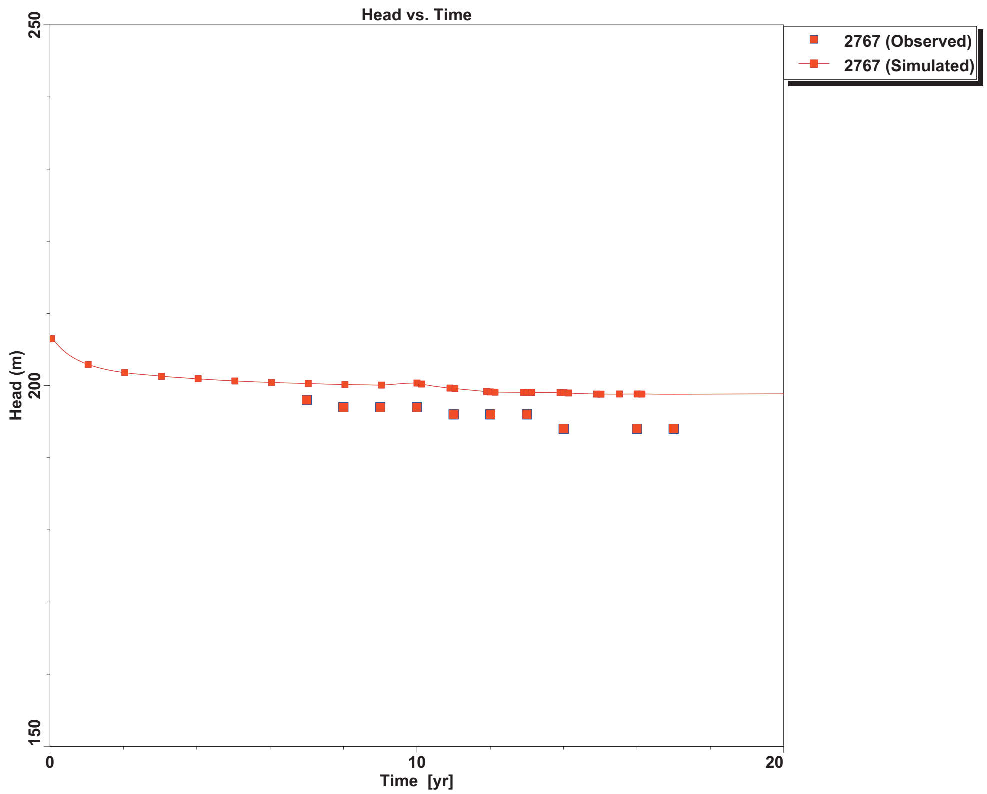
Well Location	UTM X (m)	UTM Y (m)	Stop Year	btm casing elev m	btm well elev m	Q gpd
Luxemburg, City	658058.78	4718876.33	16	125	-5	-12591
Luxemburg, Cit	658058.78	4718876.33	17	125	-5	-14408
Lehigh Portland	482556.59	4780682.87	13	112	-22	-764186
Lehigh Portland	482556.59	4780682.87	14	112	-22	-2441311
Lehigh Portland	482556.59	4780682.87	15	112	-22	-2448000
Lehigh Portland	482556.59	4780682.87	16	112	-22	-409316
Lehigh Portland	482556.59	4780682.87	17	112	-22	-352513
US Gypsum Co	406241.93	4704153.62	15	-129	-250	-16274
US Gypsum Co	406241.93	4704153.62	16	-129	-250	-66841
US Gypsum Co	406241.93	4704153.62	17	-129	-250	-67512
Hawkeye Renew	579118.74	4703172.29	16	38	-100	-789623
Hawkeye Renew	579118.74	4703172.29	17	38	-100	-977745
Xethanol Biofuel	576793.76	4638087.68	16	-129	-294	-106510
Xethanol Biofuel	576793.76	4638087.68	17	-129	-294	-76691
Penford Products	566032.05	4650854.10	17	-77	-226	-203621
Hawkeye Renewables	531336.59	4715069.60	16	-25	-185	-417126
Hawkeye Renewables	531336.59	4715069.60	17	-25	-185	-512721
Brighton	599393.00	4559390.00	17	-170	-322	-61500
Coralville	618225.00	467709.00	17	-90	-262	-500000
North Liberty	617351.00	4622322.00	17	-87	-258	-830000
Clinton	727134.00	4633919.00	17	-32	-162	-3000000
Preston	716345.00	4658706.00	17	27	-104	-100000
Maquoketa	694159.00	4659986.00	17	-10	-131	-537000
Bellevue	712348.00	4681918.00	17	74	-49	-212000
West Liberty	644223.00	4603655.00	17	-114	-275	-350000
Asbury	681840.00	4709073.00	17	154	16	-40000
Tiffin	609945.00	4618167.00	17	-103	-275	-75000
Waukee	427308.00	4607206.00	13	-362	-495	-600000
Waukee	427308.00	4607206.00	17	-362	-495	-700000
West Des Moines	435437.00	4601951.00	17	-344	-485	-2000000
Denmark	640765.00	4512002.00	17	-127	-331	-40000
Van Horne	577093.00	4648347.00	14	-111	-276	-65000
West Bend	381246.00	4760159.00	17	77	-50	-82000
Grimes	434496.00	4615690.00	8	-344	-481	-200000

APPENDIX D.

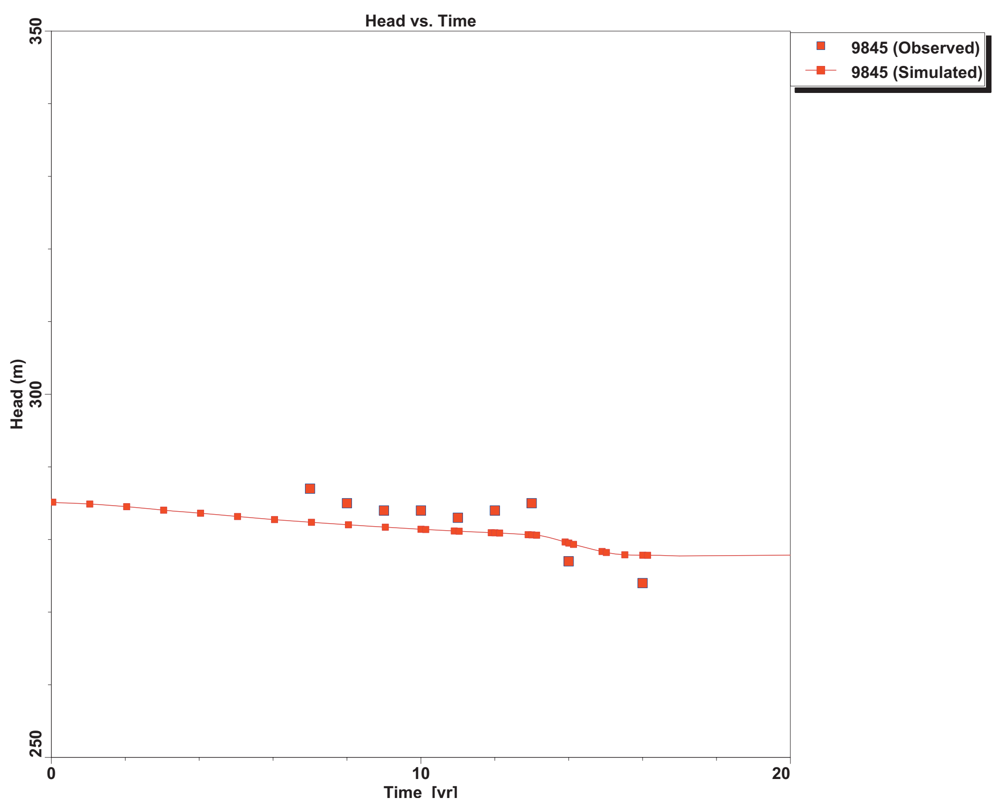
TIME SERIES WATER LEVEL DATA


Head vs. Time
13136(Observed)
13136 (Simulated)
Head (m)
110
130
150
170
190
0
10
20
Time [yr]

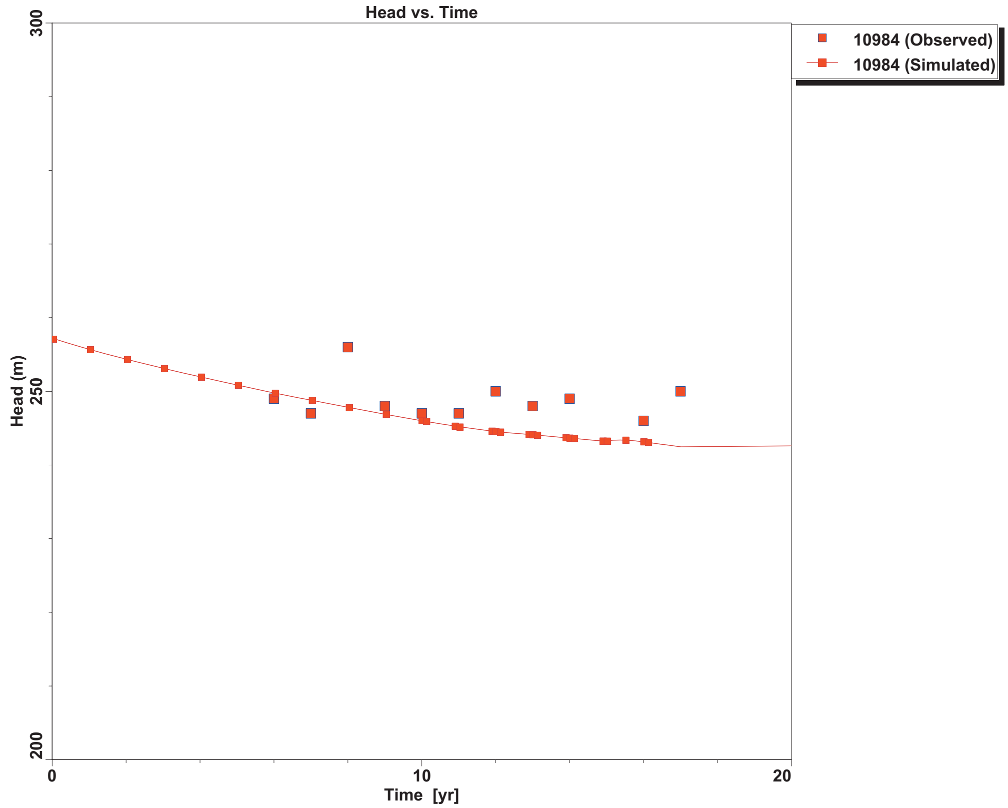

14453 (Observed)
14453 (Simulated)
Head (m)
110
130
150
170
190
0
10
20
Time [yr]



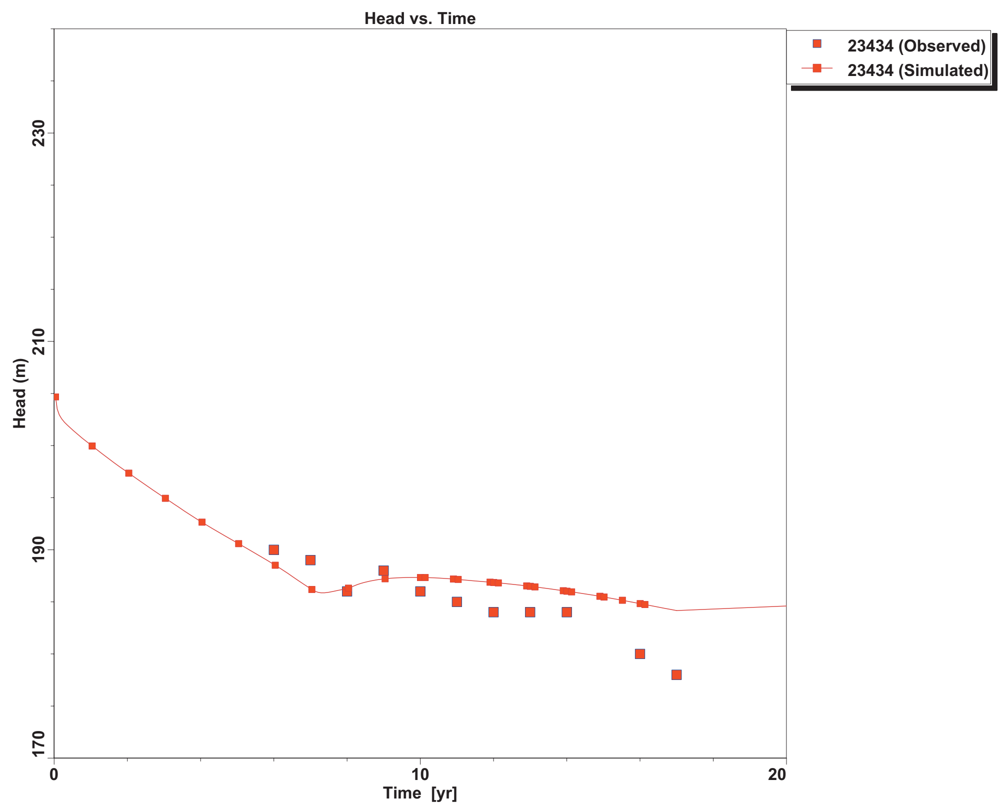
Head vs. Time
250
200
150
Head (m)
0
10
20
Time [yr]
2767 (Observed)
2767 (Simulated)



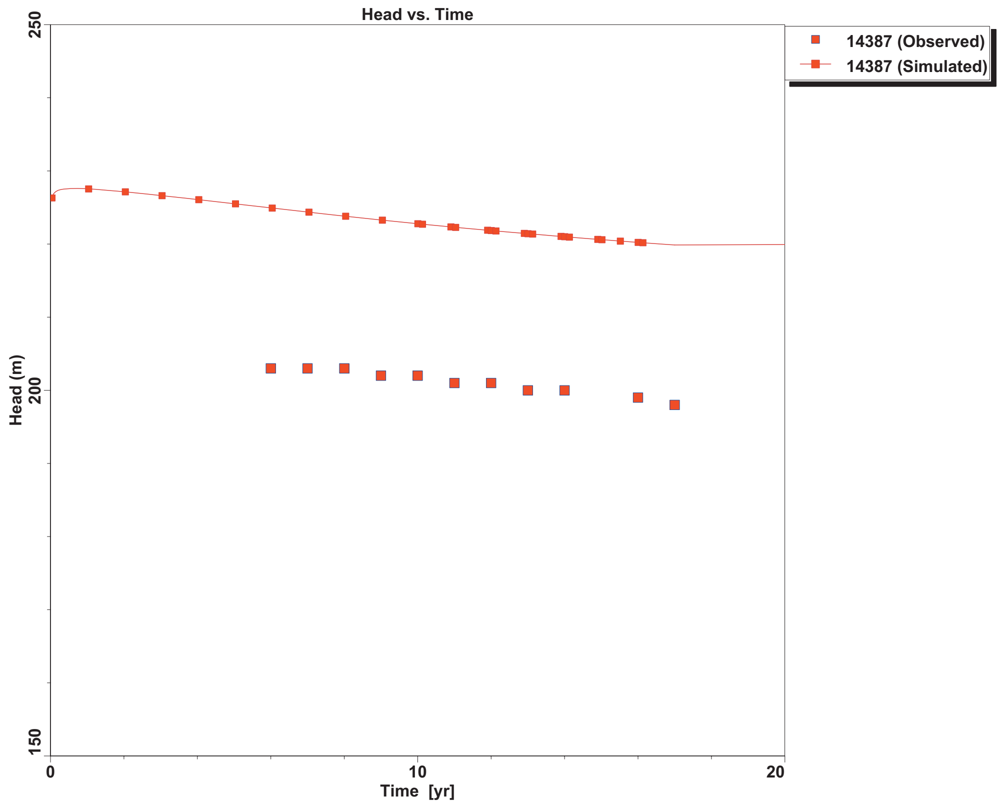
Head vs. Time
350
300
250
Head (m)
0
10
20
Time [yr]
9845 (Observed)
9845 (Simulated)

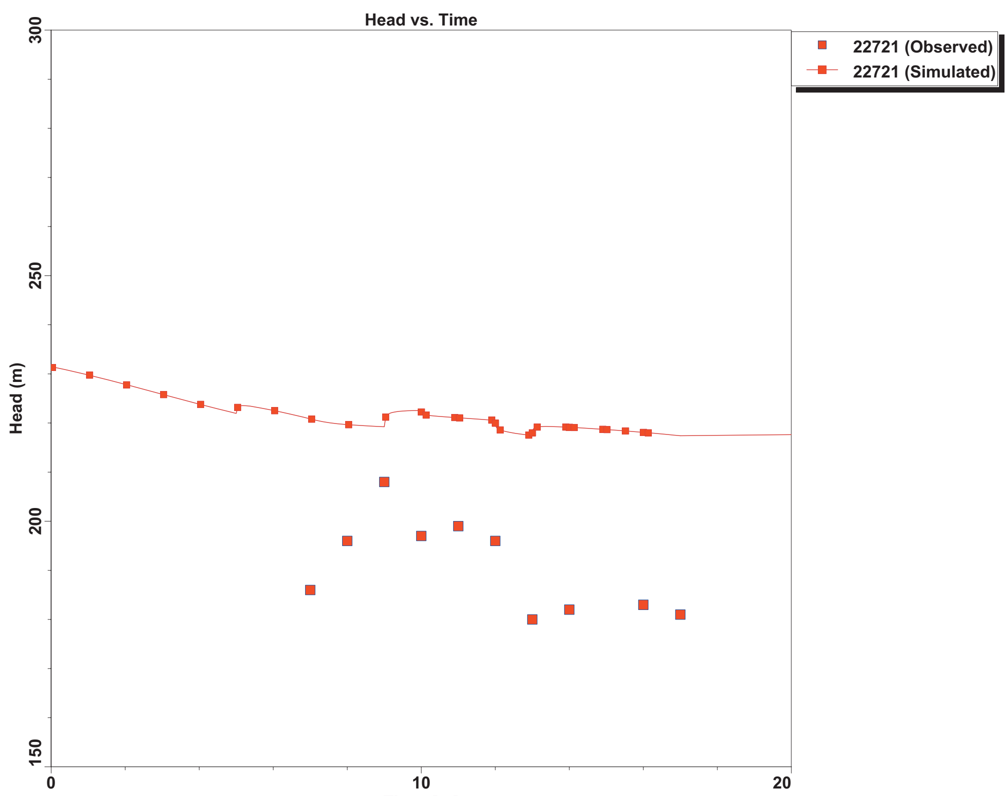


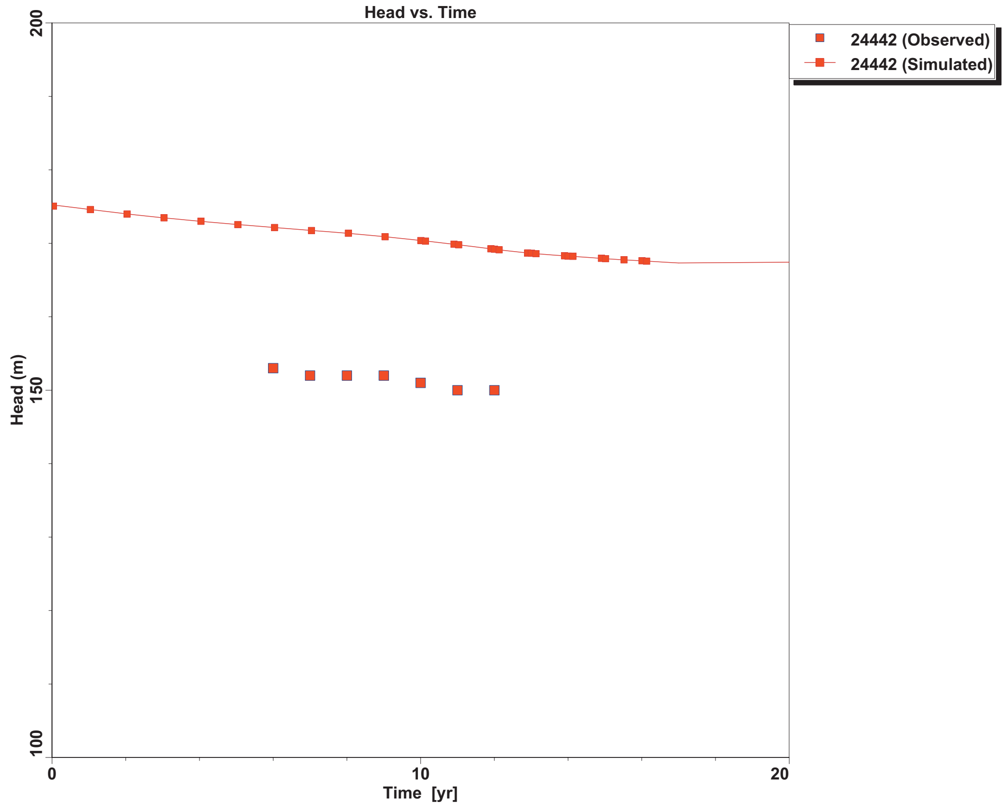
Head vs. Time
10984 (Observed)
10984 (Simulated)
Head (m)
300
250
200
0
10
20
Time [yr]

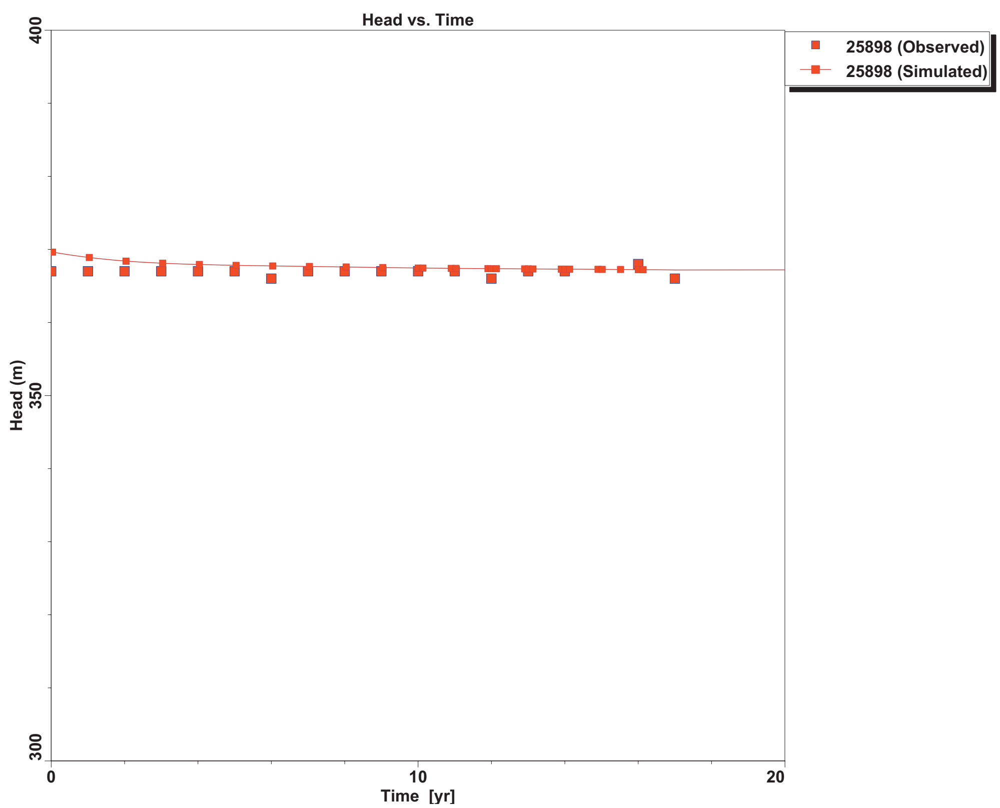


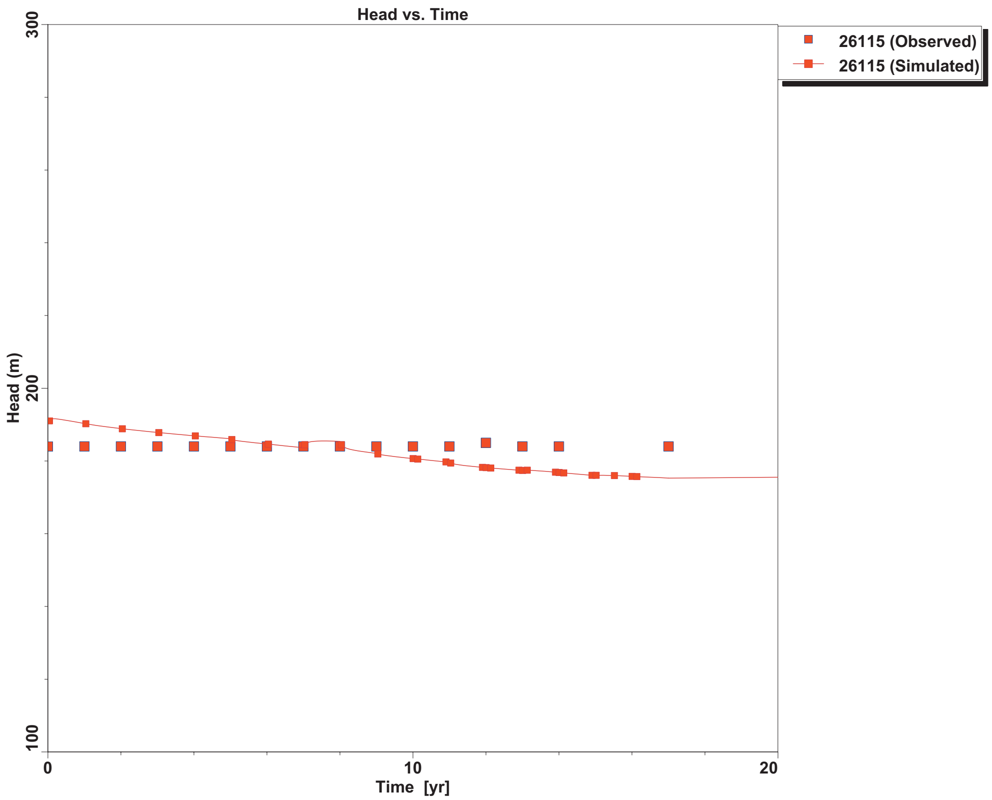
Head vs. Time
23434 (Observed)
23434 (Simulated)
Head (m)
230
210
190
170
0
10
20
Time [yr]


Head vs. Time
14387 (Observed)
14387 (Simulated)
Head (m)
250
200
150
0
10
20
Time [yr]

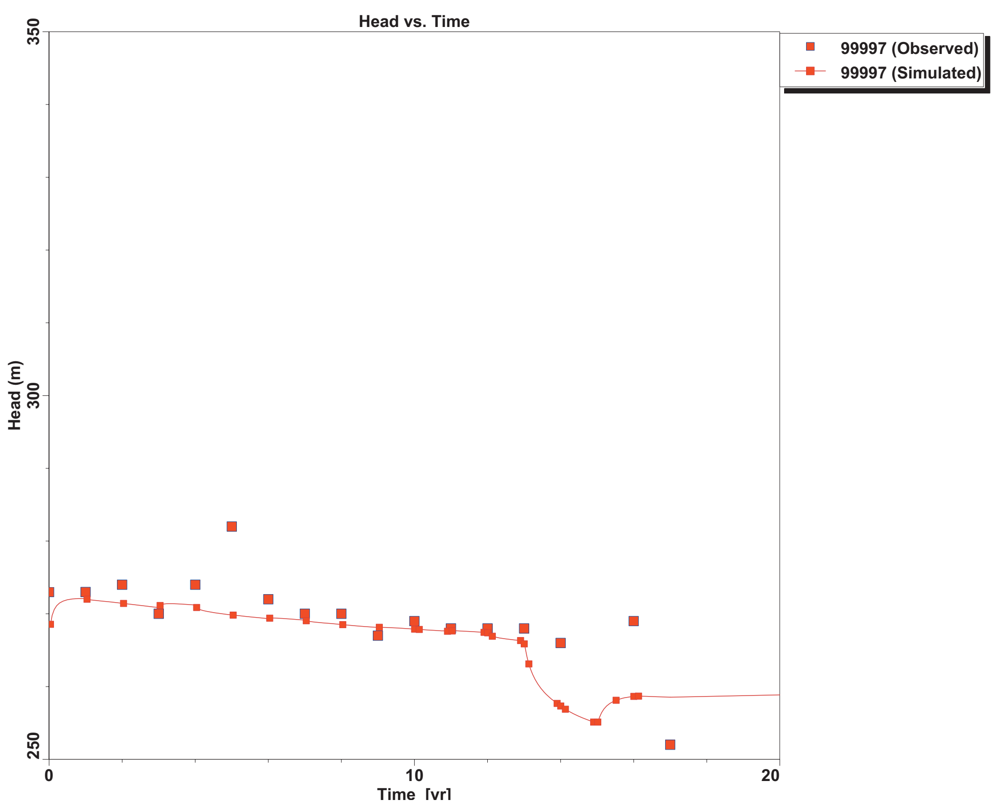

Head vs. Time
22721 (Observed)
22721 (Simulated)
Head (m)
300
250
200
150
0
10
20
Time [yr]


Head vs. Time
24442 (Observed)
24442 (Simulated)
Head (m)
200
150
100
0
10
20
Time [yr]


Head vs. Time
25898 (Observed)
25898 (Simulated)
Head (m)
400
350
300
0
10
20
Time [yr]



Head vs. Time
26115 (Observed)
26115 (Simulated)
Head (m)
300
200
100
0
10
20
Time [yr]



Head vs. Time
99997 (Observed)
99997 (Simulated)
Head (m)
350
300
250
0
10
20
Time [yr]

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