Groundwater Resource Evaluation of the Lower Dakota Aquifer in North-Central and Southwest Iowa

Water Resources Investigation Report 12

The University of Iowa

IOWA GEOLOGICAL SURVEY

IIHR Hydroscience & Engineering

Cover Photo: Stone State Park, Woodbury County, Iowa.

Groundwater Resource Evaluation of the Lower Dakota Aquifer in North-Central and Southwest Iowa

Prepared by

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and
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Iowa Geological Survey
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Table of Contents

List of Figures

List of Appendices

EXECTUIVE SUMMARY

The reoccurring drought in western Iowa starting in 2011 has forced many public water utilities to actively look for alternative sources of water. Based on this demand for additional water, many water utilities and private well owners in western Iowa are looking at the Lower Dakota aquifer as a primary or secondary water supply. Due to the increased interest in the Lower Dakota aquifer, the Iowa Department of Natural Resources (IDNR) contracted with the Iowa Geological Survey (IGS) to characterize a portion of the Lower Dakota aquifer in north-central and southwest Iowa. This current study is a continuation of a study conducted in 2008 (Gannon et al., 2008).

An isopach, or thickness, map of the Lower Dakota aquifer was generated for north-central and southwest Iowa. Most of the study area has a sandstone thickness of less than 50 feet, and is discontinuous in both lateral and vertical extents. The Fremont bedrock valley and its many smaller associated bedrock valleys cut though the southwestern portion of the study area. Numerous outliers exist in Adair, Cerro Gordo, Floyd, Franklin, Greene, Hancock, Mitchell, Page, Webster, Winnebago and Wright counties. Based on the isopach map, a sandstone thickness of greater than 100 feet exists southwest of Titonka in Kossuth County, east of Dakota City in Humboldt County, southeast of Scranton City in Greene County, northern and southern Guthrie County, and northeast and northwest of Red Oak in Montgomery and Cass counties.

Transmissivity values range from less than 100 to greater than 3,000 ft^2/day in the study area. The highest transmissivity values occur in portions of Carroll, Cass, Greene, Guthrie, Humboldt, Kossuth, and Montgomery counties.

Potential well yields range from less than 5 gallons per minute (gpm) to 500 gpm. The highest potential well yields occur in portions of Carroll, Cass, Greene, Guthrie, Humboldt, Kossuth, and Montgomery counties.

The results of the 16 county area studied in 2008 and the current study area were combined to produce an isopach map and well yield map of the Lower Dakota aquifer in Iowa.

Total water withdrawal by type of usage was estimated for the Lower Dakota aquifer. Public water supplies use the most water at 23.2 million gallons per day (mgd) or 56% of the total. This is followed by agriculture at 11.8 mgd (28%), industry at 4 mgd (10%), and domestic or private usage at 2.6 mgd (6%).

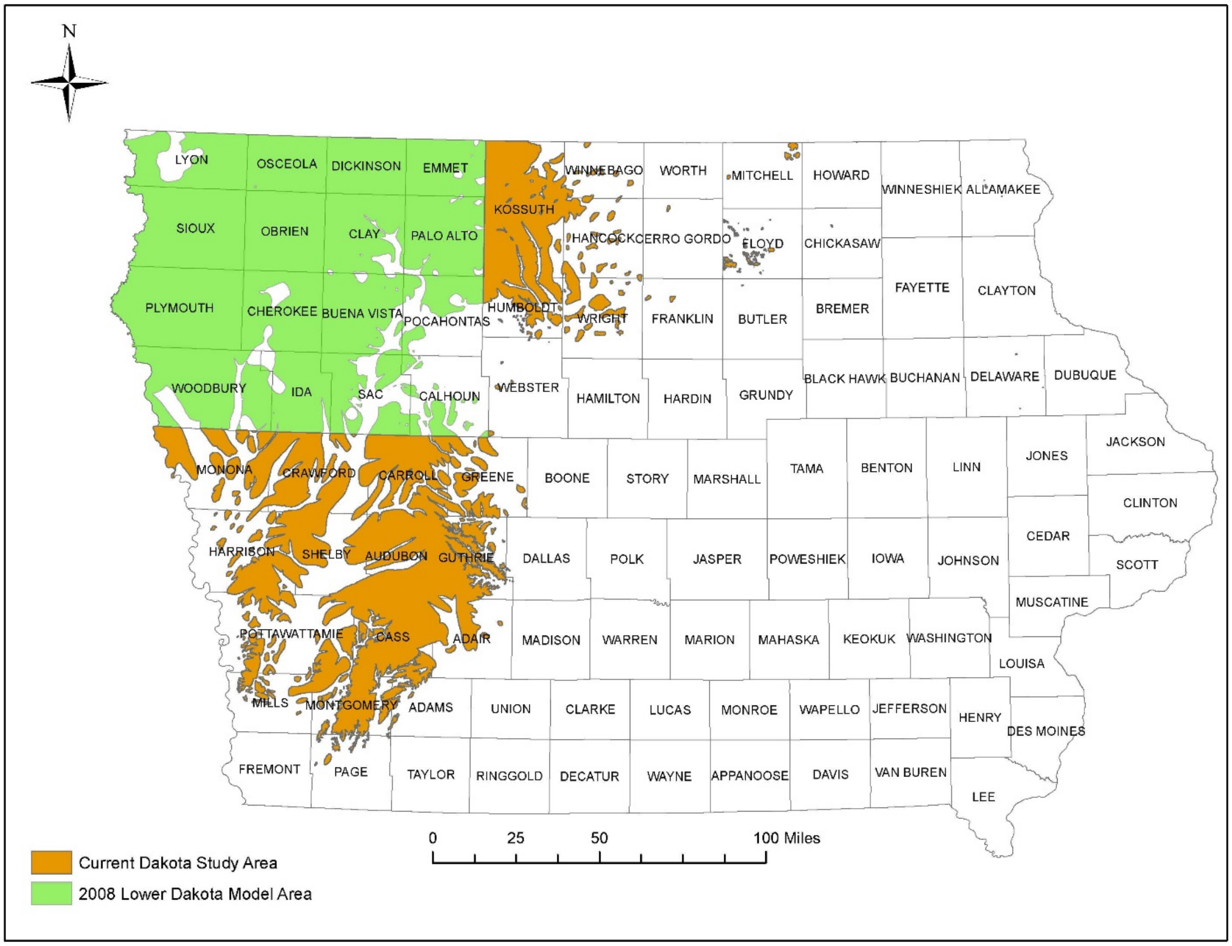

Figure 1. Total extent of the Lower Dakota aquifer in Iowa including the current study area.

INTRODUCTION

In 2008 the IGS conducted a hydrogeological investigation of the Cretaceous System in a 16 county area of northwest Iowa (Figure 1). This study also included a three-dimensional groundwater flow model to evaluate the sustainability of the Cretaceous System, and more specifically, the Lower Dakota aquifer (Gannon et al., 2008). The lateral extent of the Cretaceous system actually extends well beyond the original 16 county area but the discontinuous nature of the sandstone prevented the development of a three-dimensional model in this region. Figure 1 shows the area studied in 2008 alongside the current study region.

Despite the discontinuous nature outside the 16 county area, many private and public water users have production wells that are screened in this unit. The reoccurring drought in western Iowa starting in 2011 has forced many public water utilities to look for an additional source of water to supplement their shallow alluvial water source. Based on this demand for additional water, the IDNR has asked the IGS to characterize the Dakota aquifer outside the original 16 County area (Figure 1). The study included the following tasks:

- Collecting, compiling, and analyzing available geologic and hydrologic data.
- Constructing a grid or raster surface of the overall thickness of the Dakota sandstone.

- Constructing grid or raster surfaces for the estimated transmissivity, hydraulic conductivity, and estimated maximum well yield.
- Collecting, compiling, and estimating the location and amounts of groundwater withdrawals within the study area.

GEOLOGY

The geology of the study area is broken up into three primary stratigraphic groups. The first group is the unconsolidated Quaternary group, which overlies the Dakota Formation followed by isolated Pennsylvanian, Mississippian and Devonian systems. The second group is the shale and sandstone units of the Dakota Formation. The third group is loosely labeled as Sub-Cretaceous, or Sub-Dakota Formation. A more detailed discussion of the Quaternary group and Dakota Formation is included in the following sections. The sub-Cretaceous will not be discussed in this report. For additional information on the Sub-Cretaceous, please refer to Gannon et al. (2008).

Quaternary Geology

The unconsolidated materials that overlie Cretaceous rocks in the study area are grouped together as Quaternary materials. From youngest to oldest, this grouping includes: 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 (Figure 2). Although the hydrologic characteristics of these units vary greatly, limited well data introduces difficulties in mapping their distributions and thicknesses. For this investigation, the unconsolidated materials are treated as a single unit. The isopach map of the unconsolidated material is shown in Figure 3. Quaternary thickness varies from 1 to 640 feet.

Dakota Formation

The Dakota Formation is the most widespread Cretaceous stratigraphic unit in Iowa. The name is derived from exposures in the Missouri River Valley in Dakota County, Nebraska, across the river from Sioux City, Iowa. The Sioux City area comprises the classic type section of the formation (Ravn and Witzke, 1994). The Dakota Formation is characterized by a succession of poorly consolidated sandstone and mudstone (shaly strata), which typically dominates the upper portion. Its thickness is highly variable due to being truncated by numerous bedrock valleys. Where the Dakota Formation forms the bedrock surface in our study area, it ranges from less than 10 feet to about 300 feet in thickness.

The Dakota Formation is stratigraphically sub-divided into two lithologically distinct members across most of its extent in Iowa, a lower Nishnabotna Member and an upper Woodbury Member (see Munter et al., 1983; Raven and Witzke, 1994; see Figure 4). These member names are derived from lower Dakota exposures along the Nishnabotna River Valley in southwest Iowa and from upper Dakota exposures in Woodbury County, northwest Iowa, respectively.

The Nishnabotna Member is dominated by poorly consolidated sandstone and mudstone strata. However, quartz sandstones overwhelmingly dominate the member over most of the study area. The sandstones vary between very fine and very coarse-grained units, with some conglomerate units found near the base of the Nishnabotna Member in southwest Iowa.

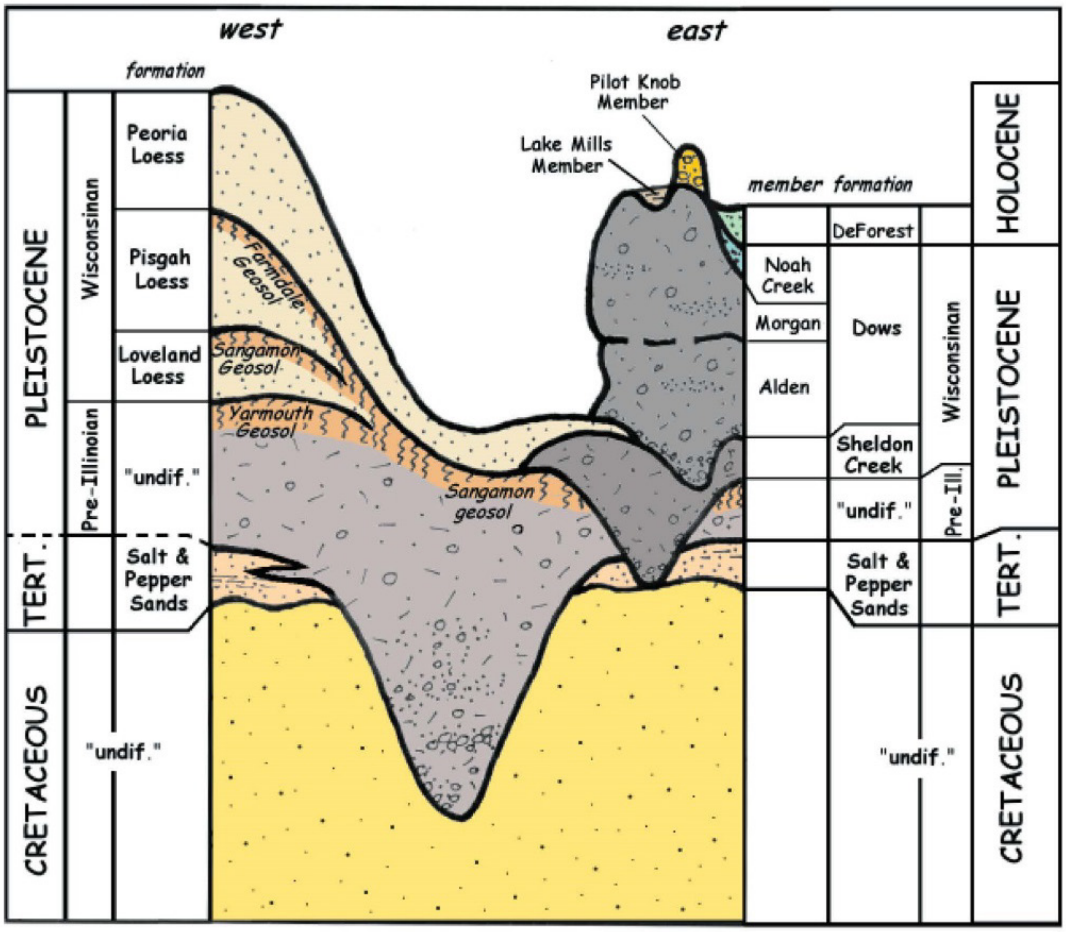

Figure 2. Stratigraphic representation of Quaternary materials within the study area (Gannon et al., 2008).

Definition of the Lower Dakota Aquifer

A study by the Iowa Geological Survey during the early 1980s was the first to recognize the stratigraphic complexity of the Dakota aquifer. As summarized by Munter et al., (1983, p. 19), that study was the first to recognize the relationship between the stratigraphy and water yields within the aquifer:

> "The term Dakota aquifer, as used in this report, refers to sandstone beds within the Dakota Formation that yield significant quantities of water to wells. Wells drilled only into the Woodbury Member are significantly less productive than wells completed in the Nishnabotna Member because of the limited vertical and lateral extent of the sandstone deposits within the Woodbury. Wells penetrating a significant thickness of the Nishnabotna Member, commonly have very high yields (800-1000 gpm) because of the thick and extensive nature of the sandstone units."

These observations significantly changed the earlier conception of a homogeneous Dakota aquifer. Stratigraphic position within the Dakota Formation proved to be vitally important in the development of high-capacity wells. The important results of the Munter study were used in the design of the current study, with our primary focus on defining the stratigraphic package that hosts the lower highly productive part of the aquifer. However, unlike the earlier

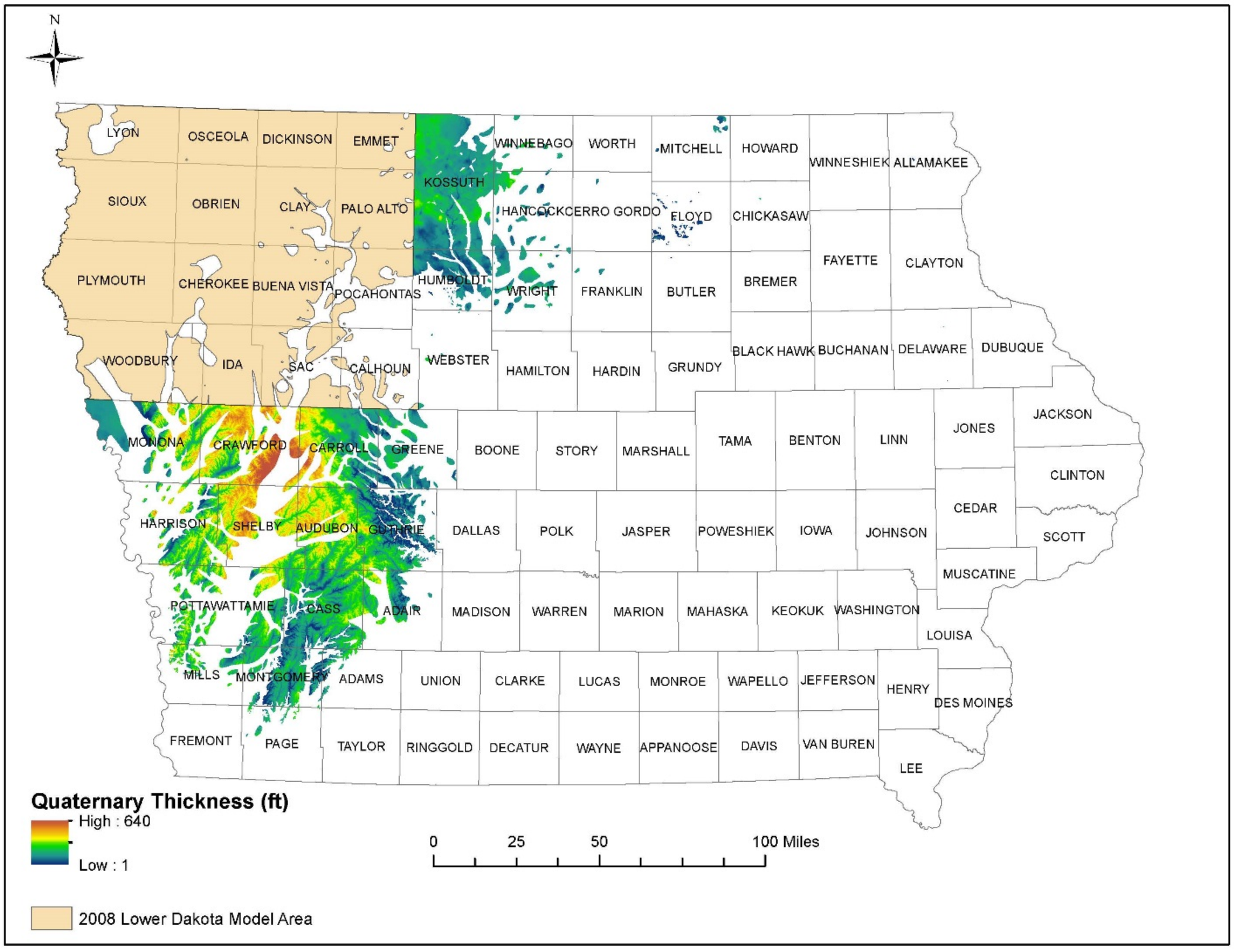

Figure 3. Quaternary isopach map of the study area.

study by Munter et al. (1983), the lower aquifer was not simply restricted to the Nishnabotna Member. Instead, the current study has recognized that the hydrologic container of the lower aquifer can also include contiguous sandstone bodies of the lower Woodbury Member. The Lower Dakota aquifer is now defined to include the body of contiguous sandstone that encompasses portions of the Nishnabotna and lower Woodbury members.

Lateral and Vertical Extents of the Lower Dakota Aquifer in the Study Area

The lateral and vertical extents of the Lower Dakota aquifer were evaluated using well data found in the IGS GeoSam database (GeoSam, 2015) and the IDNR Private Well Tracking System database (PWTS, 2015). A total of 795 striplogs and drilling logs were found in the study area. The highest concentration of logs were found in Guthrie and Greene counties, and are associated with the natural gas storage structures in the area. A total of 5 new striplogs were produced in locations shown on Figure 5. Four of the new striplogs were in Kossuth County, and one was in Carroll County. These five new striplogs are shown in Appendix A.

An isopach, or thickness, map of the Lower Dakota aquifer was generated following analysis of the geologic log data (Figure 5). Most of the study area has a sandstone thickness of less than 50 feet, and is discontinuous in both lateral and vertical extents. The Fremont bedrock valley and its many smaller associated bedrock valleys cut

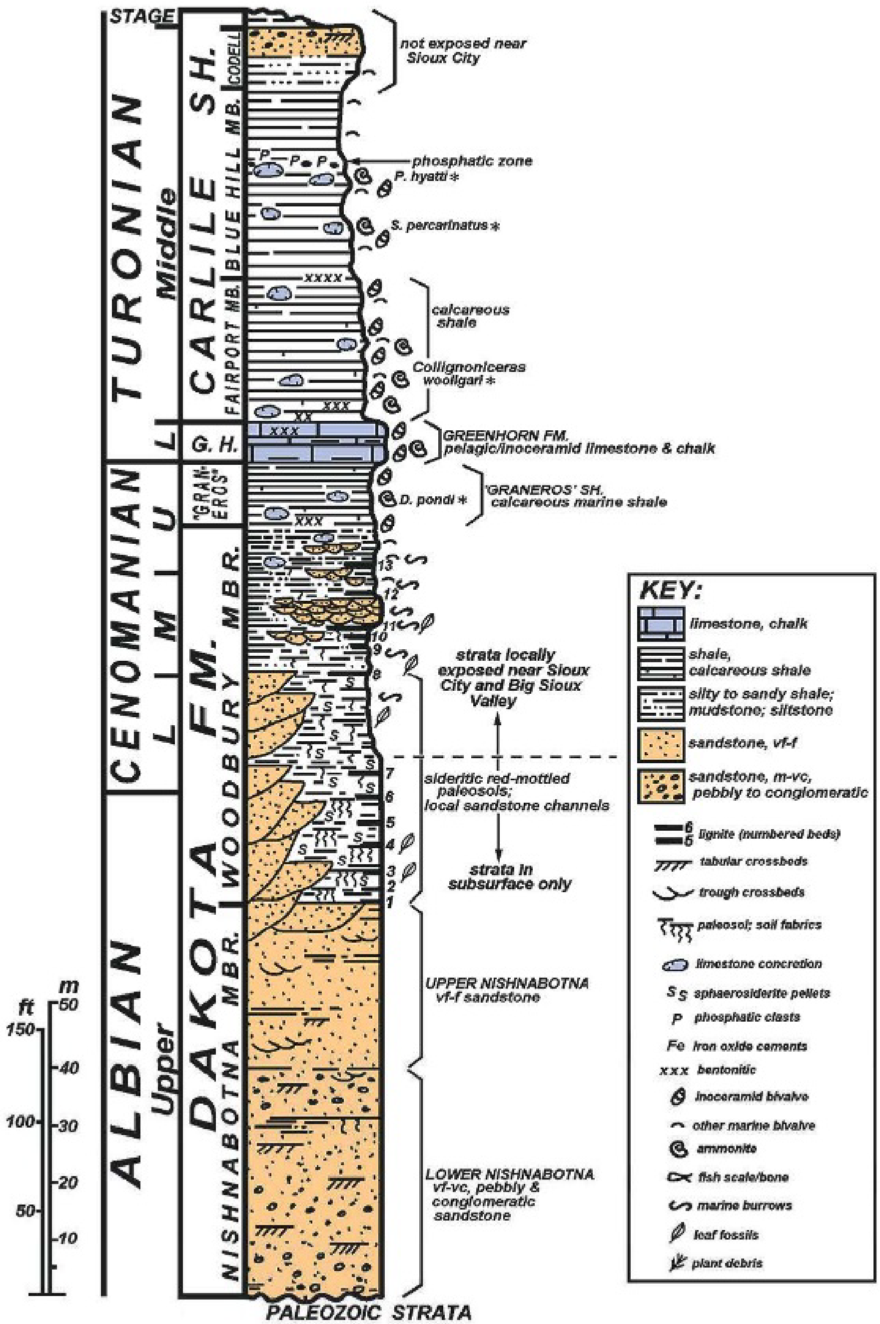

Figure 4. Stratigraphic representation of the Dakota Formation in Iowa (Gannon et al., 2008).

though the southwestern portion of the Lower Dakota aquifer. Numerous outliers exist in Adair, Cerro Gordo, Floyd, Franklin, Greene, Hancock, Mitchell, Page, Webster, Winnebago and Wright counties. Based on the isopach map, sandstone thickness of greater than 100 feet exists southwest of Titonka in Kossuth County, east of Dakota City in Humboldt County, southeast of Scranton City in Greene County, northern and southern Guthrie County, and northeast and northwest of Red Oak in Montgomery and Cass counties.

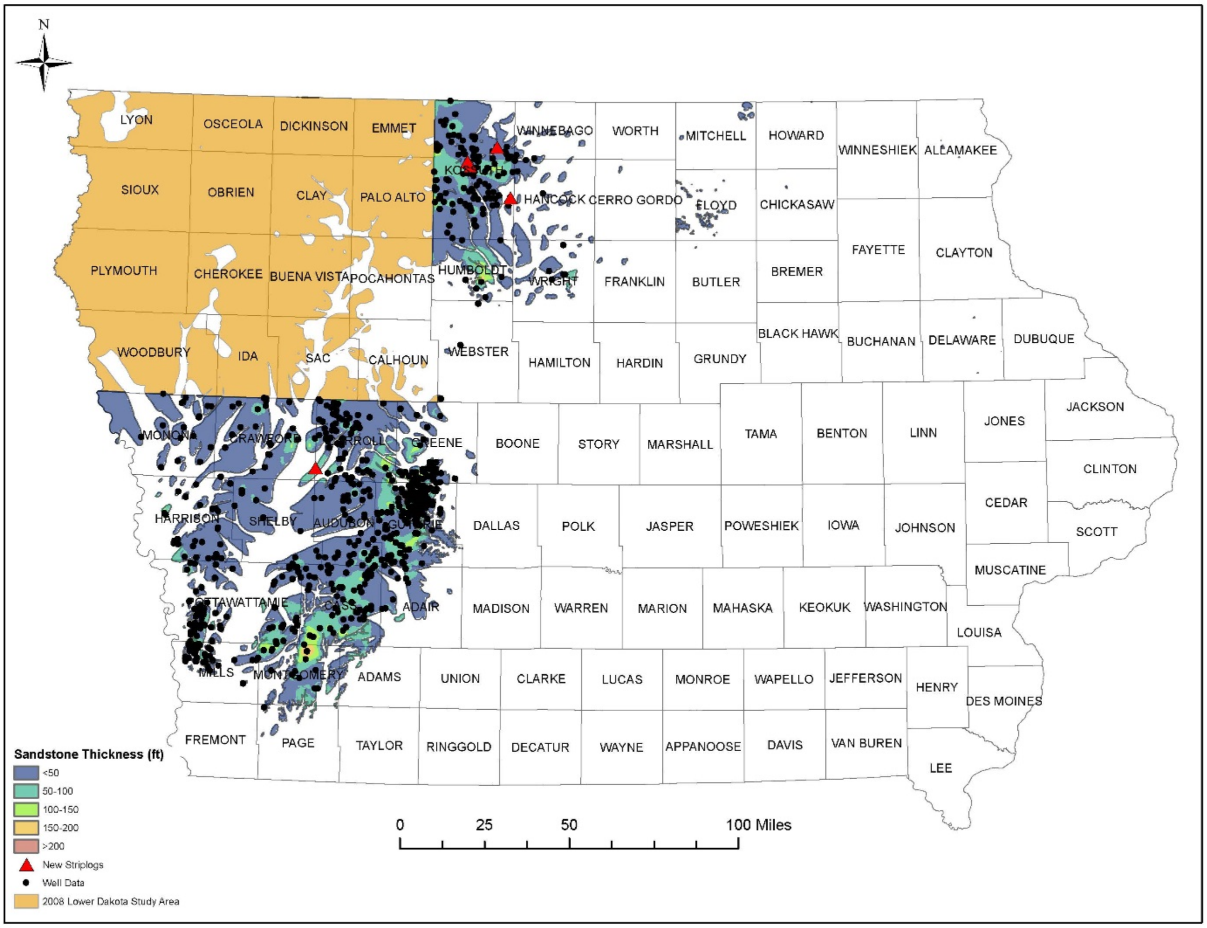

Figure 5. Lower Dakota aquifer isopach map for the study area.

Transmissivity of the Lower Dakota Aquifer in the Study Area

The Lower Dakota aquifer is defined as the contiguous body of sandstone that lies at the base of the Dakota Formation. The hydraulic properties of the Lower Dakota aquifer vary both laterally and vertically. The aquifer consists of fine to coarse sandstone, as well as isolated conglomerate units. Most of the sandstone and conglomerate is poorly cemented, and wells installed in the Lower Dakota aquifer require well screens. Exceptions to this occur in parts of southwest Iowa, especially in Guthrie County, where the sandstone and conglomerate units are well cemented. A total of 167 specific capacity tests were conducted in the Lower Dakota aquifer in the study area by various consultants, well drillers, and communities. The distribution of these tests is shown in Figure 6. Appendix B lists each specific capacity test estimated transmissivity values, aquifer thicknesses, and hydraulic conductivity values. Estimates of the transmissivity values were calculated using the Illinois Water Survey method (Walton and Csallany, 1963).

Figure 7 incorporates both the 167 specific capacity values in Figure 6 and Appendix B , and the transmissivity estimate based on the average hydraulic conductivity of 48 feet/day (Munter and others, 1983), multiplied by the sandstone thickness (Figure 5). Based on Figure 7, the highest transmissivity values occur in portions of Carroll, Cass, Greene, Guthrie, Humboldt, Kossuth, and Montgomery counties.

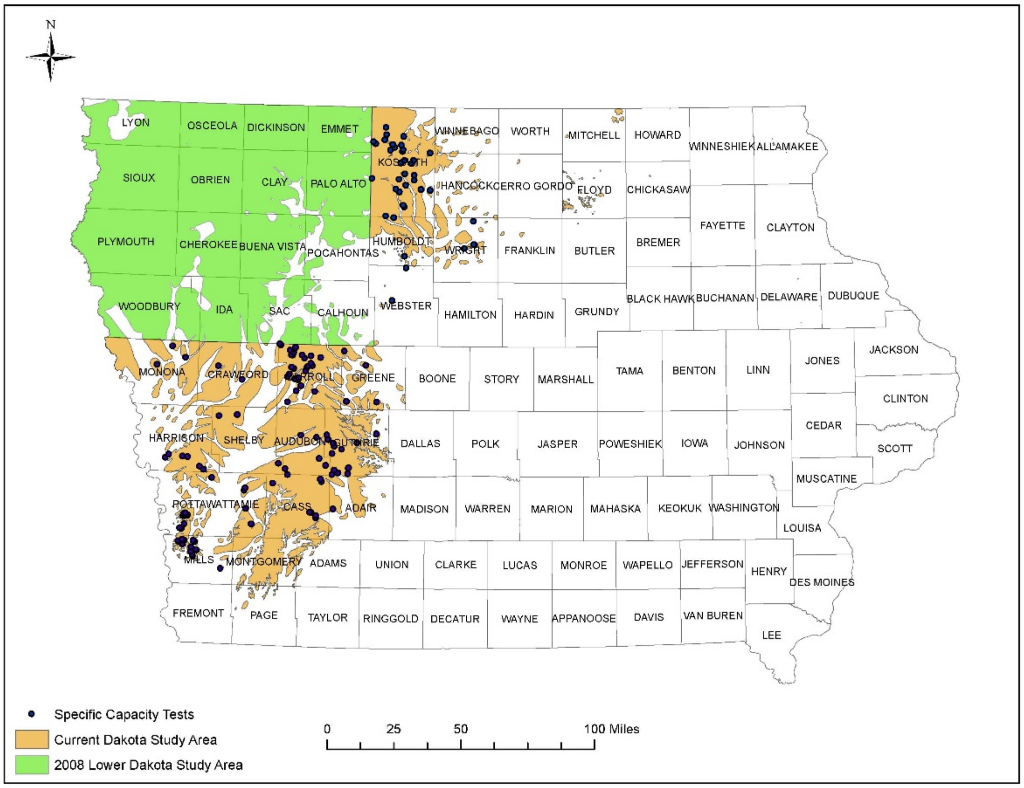

Figure 6. Specific capacity test distribution within the study area.

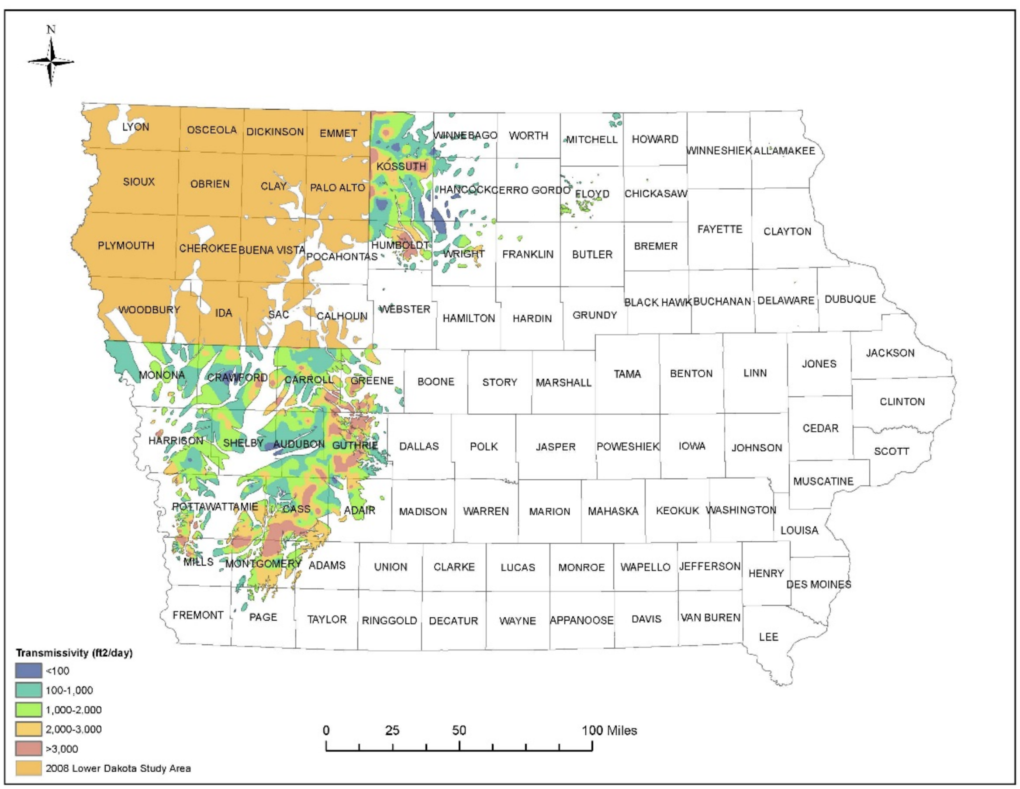

Figure 7. Transmissivity distribution within the study area.

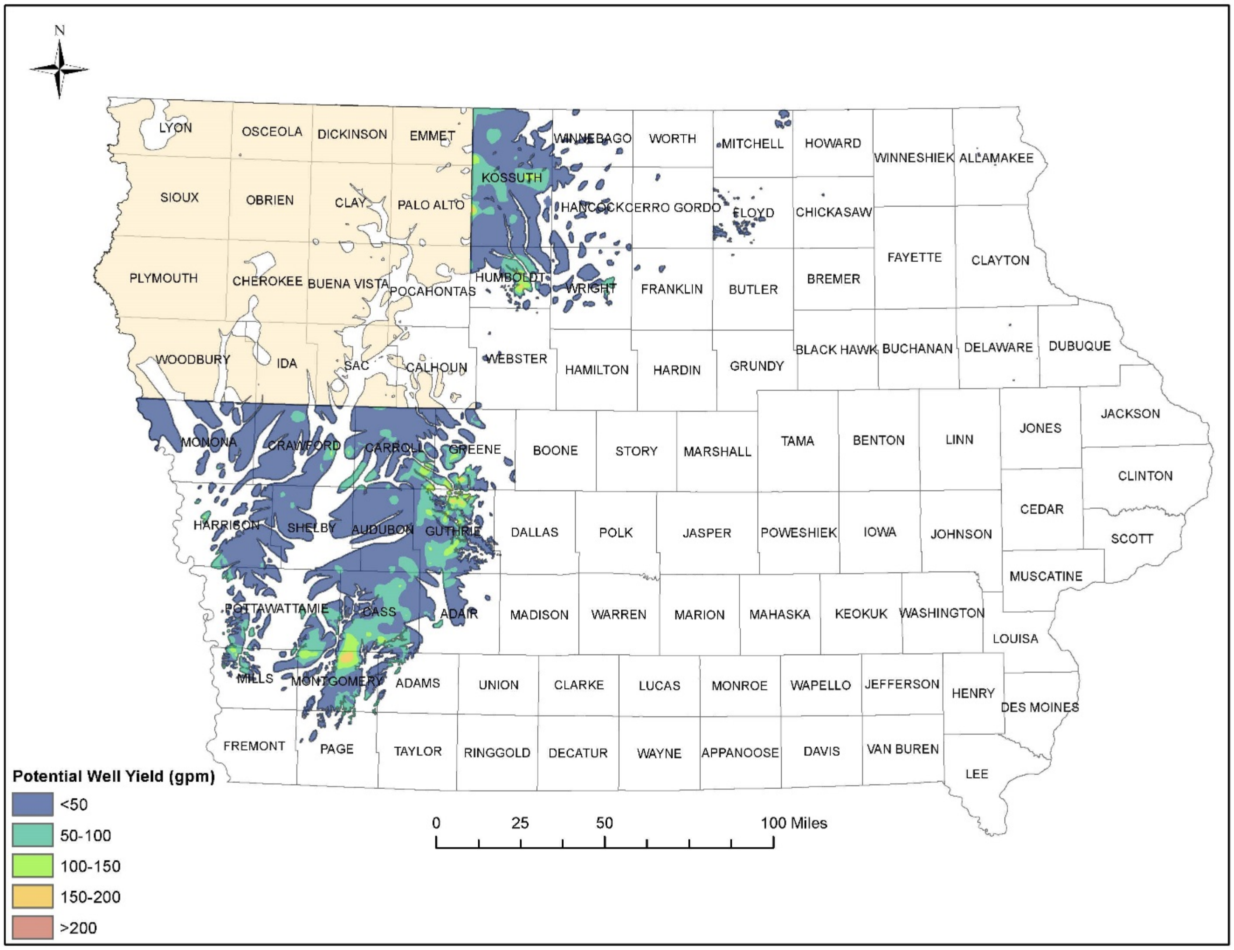

Figure 8. Estimated potential well yields in the Lower Dakota aquifer within the study area based on transmissivity, specific capacity data, and available drawdown.

Estimated Potential Well Yields of the Lower Dakota Aquifer in the Study Area

The potential well yields in the study area were estimated by converting the transmissivity to specific capacity and multiplying by half of the available drawdown. The available drawdown was assumed to be one-half the distance between the static water level and the top of the aquifer. Available drawdown varied considerably by location, and ranged from 7 feet in Mills County to 145 feet in Greene County.

The estimated potential well yields are shown in Figure 8. Based on Figure 8, the highest potential well yields occur in portions of Carroll, Cass, Greene, Guthrie, Humboldt, Kossuth, and Montgomery counties.

Combining Results from 2008 and 2015

The results of the 16 county area studied in 2008 and the current study area (Figure 1) were combined to produce isopach and potential well yield maps of the Lower Dakota aquifer in Iowa. Figure 9 shows the isopach map of the Lower Dakota aquifer for the state of Iowa. Data from the edges of the two study regions were correlated when possible. As part of the correlation process, some of the point data from the 2008 study were revaluated along the southern edge of Woodbury, Ida, Sac, and Calhoun counties. Following reevaluation, sandstone thickness was reduced in

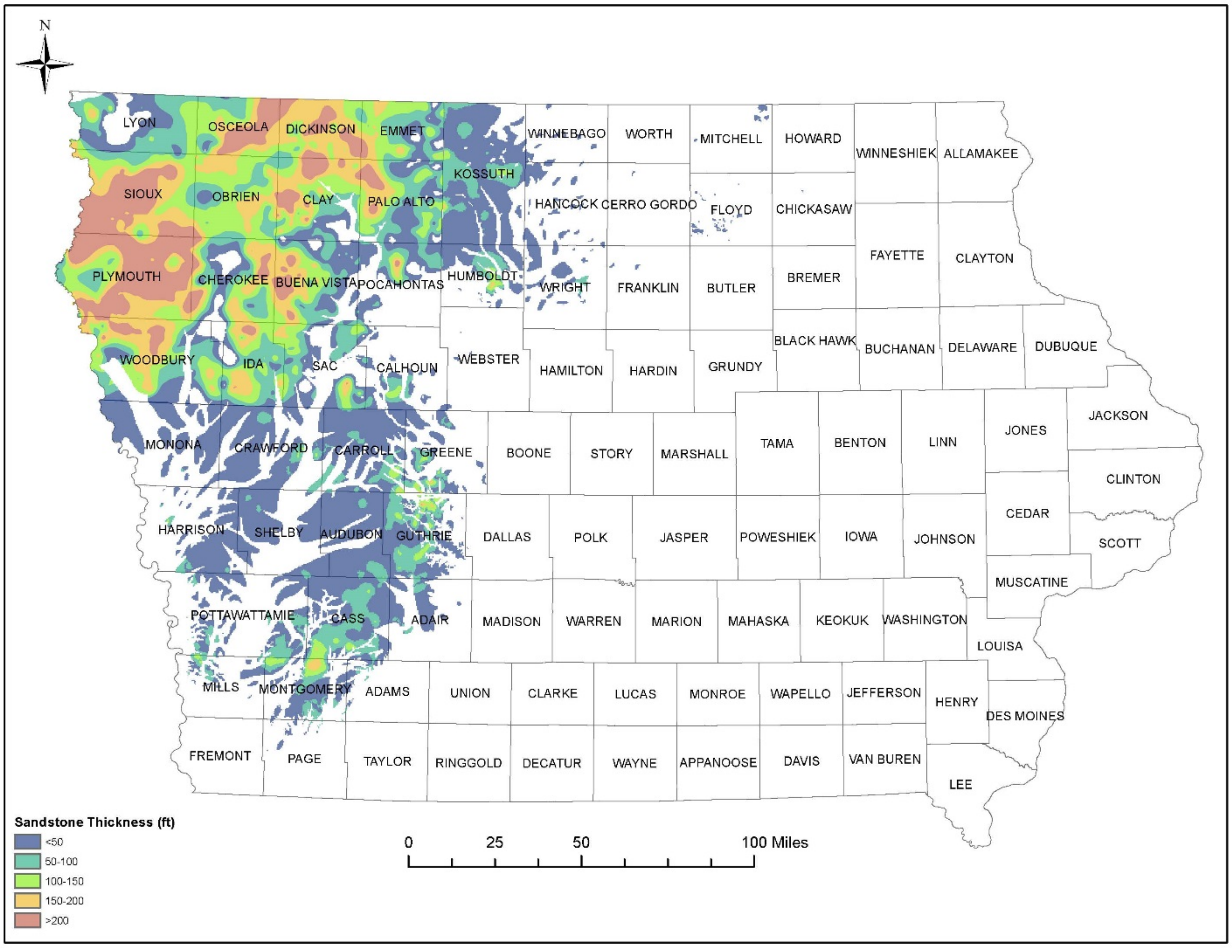

Figure 9. Lower Dakota aquifer isopach map in Iowa generated by combining Figure 5 with work completed by Gannon et al. (2008).

many cases, especially in Woodbury County. Many of the interpretations in 2008 used the entire thickness of the Dakota Formation to create the isopach map, which included nearly 100 feet of Woodbury shale. The reevaluation of the data to include only the sandstone thickness allowed for more accurate correlation between the map products. Based on the results in Figure 9, the Lower Dakota sandstone is much thicker and more laterally extensive in the following counties: Buena Vista, Cherokee, Clay, Dickinson, Emmet, Ida, O'Brien, Osceola, Palo Alto, Plymouth, Sac, Sioux, and Woodbury counties.

Figure 10 shows the estimated potential well yields for the Lower Dakota aquifer in Iowa. Well yields were found to be much higher within the 16 county area studied in 2008 and more variable outside the 16 county area. The discontinuous nature of the aquifer and the variable sandstone thickness most likely account for the variability in potential well yields.

Water Usage in the Lower Dakota Aquifer

Known water use wells found in the Lower Dakota aquifer are shown in Figure 11. Permits indicate water use from public water supplies, industrial usage, and agricultural usage. Estimated total water withdrawal by type of usage is shown in Figure 12, and was obtained primarily from IDNR source water data

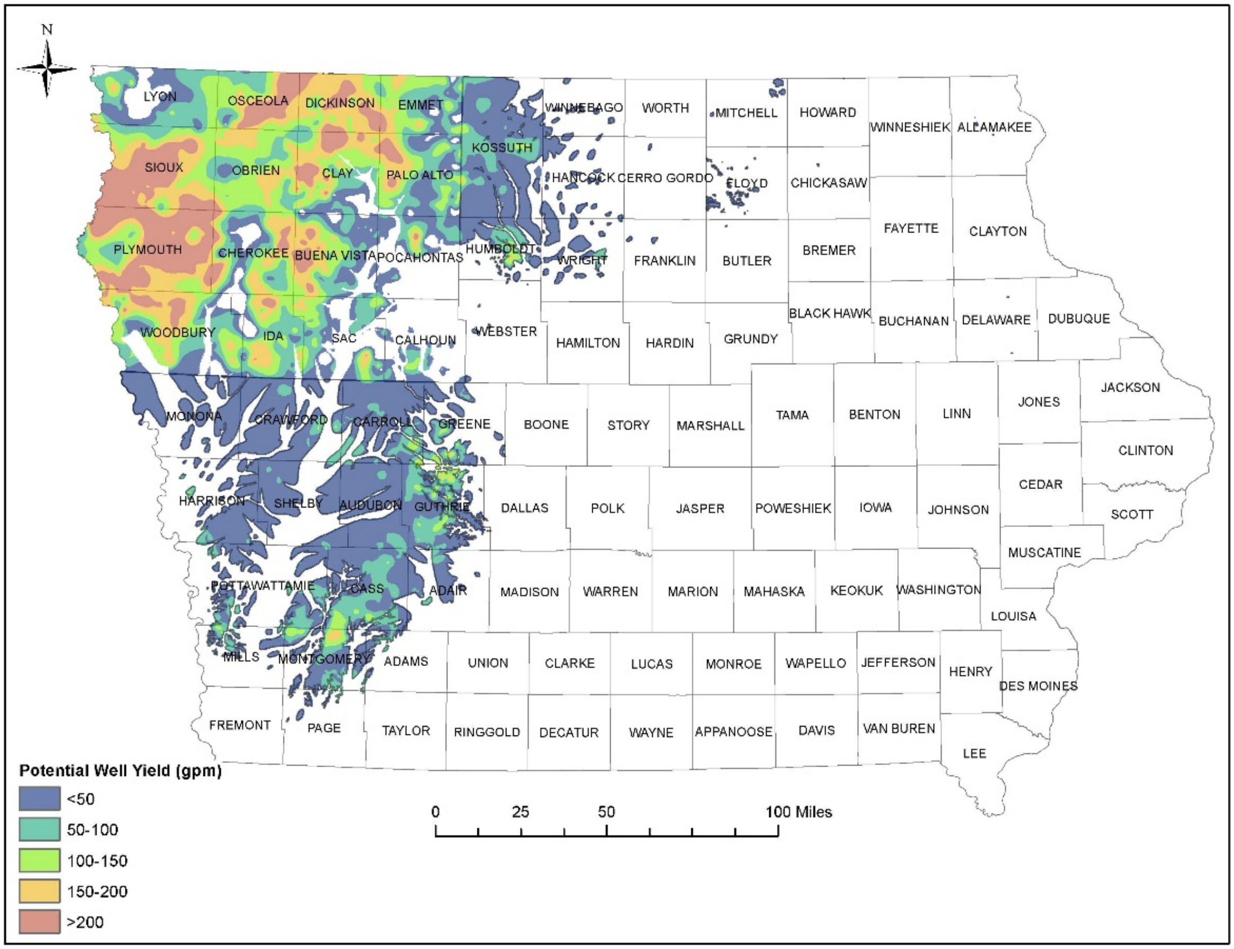

Figure 10. Estimated potential well yields in the Lower Dakota aquifer in Iowa.

(IDNR Source Water Database, 2015), and the IDNR water use database (IDNR Water Use Database, 2015). Domestic supplies were estimated based on 1,000 gallons per day per known private well. Public water supplies use the most water at 23.2 million gallons per day (mgd) or 56% of the total. This is followed by agriculture at 11.8 mgd (28%), industry at 4 mgd (10%), and domestic at 2.6 mgd (6%).

CONCLUSIONS

The reoccurring drought in western Iowa starting in 2011 has forced many public water utilities to actively look for alternative sources of water. Based on this demand for additional water, many water utilities and private well owners in western Iowa are looking at the Lower Dakota aquifer as a primary or secondary water supply. Due to the increased interest in the Lower Dakota aquifer, the IDNR contracted with the IGS to characterize a portion of the Lower Dakota aquifer in north-central and southwest Iowa. This current study is a continuation of a study conducted in 2008 (Gannon et al., 2008).

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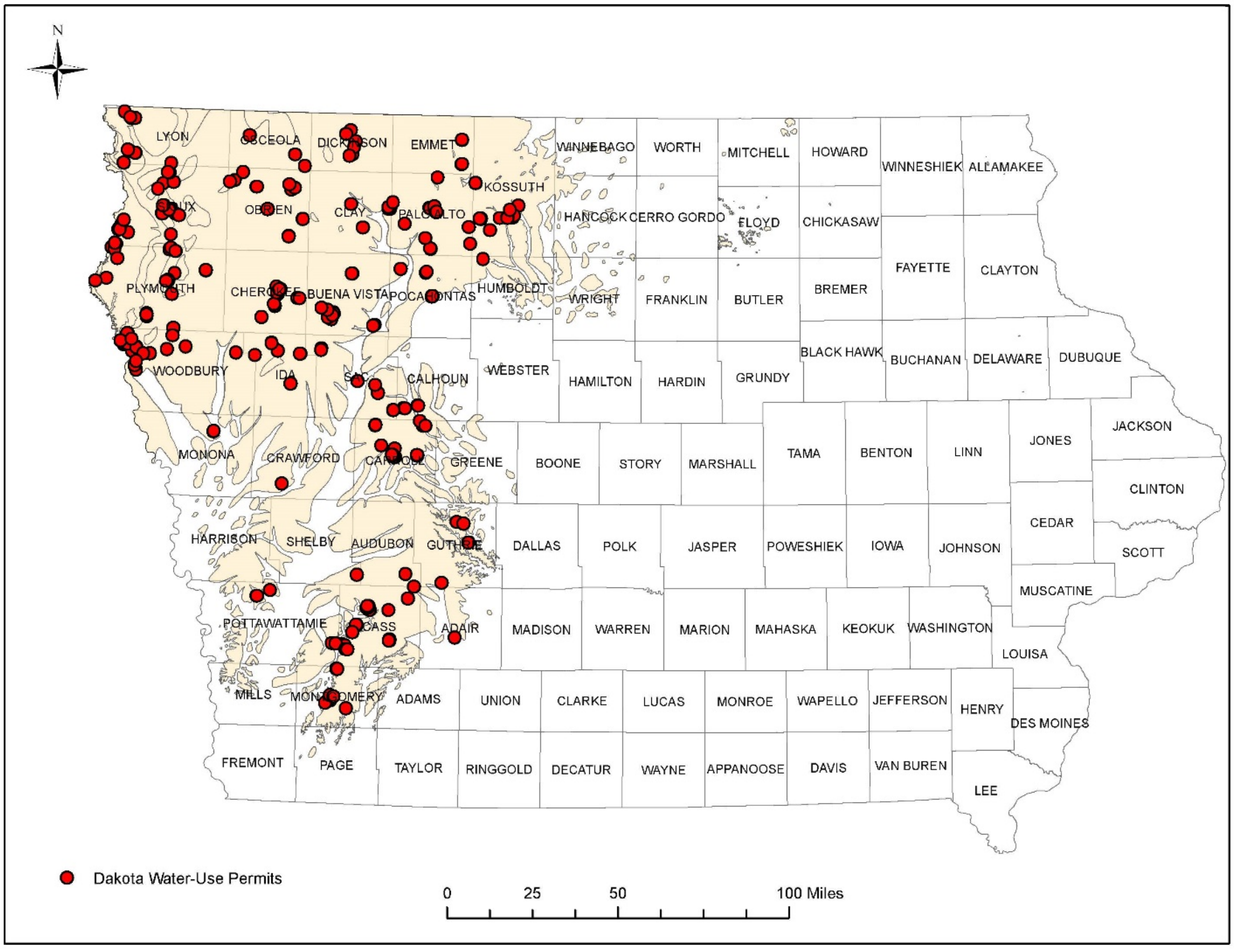

Figure 11. Known water use permitted wells screened in the Lower Dakota aquifer in Iowa.

Mitchell, Page, Webster, Winnebago and Wright counties. Based on the isopach map, sandstone thickness of greater than 100 feet exists southwest of Titonka in Kossuth County, east of Dakota City in Humboldt County, southeast of Scranton City in Greene County, northern and southern Guthrie County, and northeast and northwest of Red Oak in Montgomery and Cass counties.

Transmissivity values range from less than 100 to greater than 3,000 ft^2/day. The highest transmissivity values occur in portions of Carroll, Cass, Greene, Guthrie, Humboldt, Kossuth, and Montgomery counties.

Potential well yields range from less than 5 gpm to 500 gpm. The highest potential well yields occur in portions of Carroll, Cass, Greene, Guthrie, Humboldt, Kossuth, and Montgomery counties.

The results of the 16 county area studied in 2008 and the current study area were combined to produce a isopach and well yield maps of the Lower Dakota aquifer in Iowa.

Total water withdrawal by type of usage was estimated for the Lower Dakota aquifer. Public water supplies use the most water at 23.2 mgd or 56% of the total. This is followed by agriculture at 11.8 mgd (28%), industry at 4 mgd (10%), and domestic or private usage at 2.6 mgd (6%).

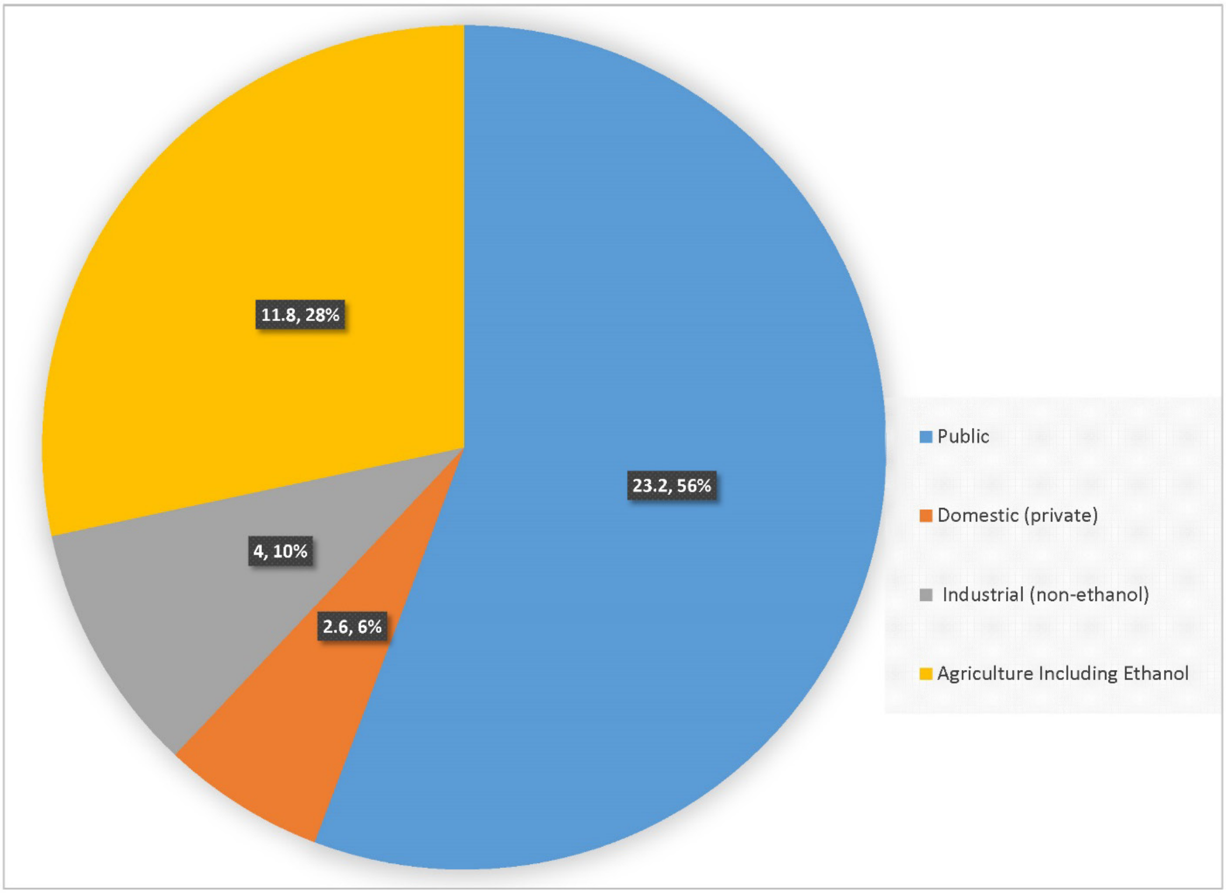

Figure 12. Water usage in the Lower Dakota aquifer in Iowa (millions of gallons per day).

ACKNOWLEDGEMENTS

The authors would like to acknowledge the contributions of the individuals who assisted in the production of this report. Funding for this project was provided by the Iowa Department of Natural Resources. Much of the knowledge of the Dakota Formation was produced by retired IGS geologists Bill Bunker, Brian Witzke, Ray Anderson, and Greg Ludvigson. Ryan Clark performed the geologic logging and new striplog generation.

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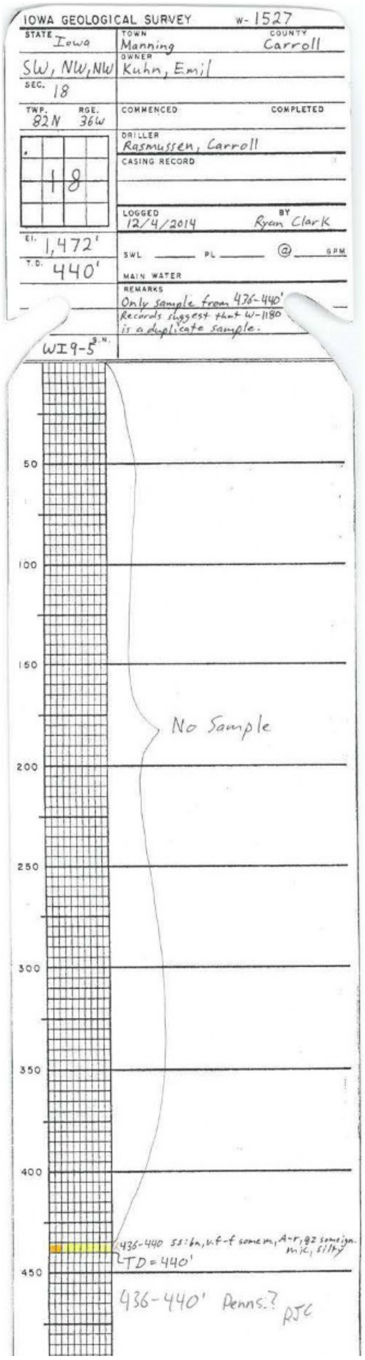
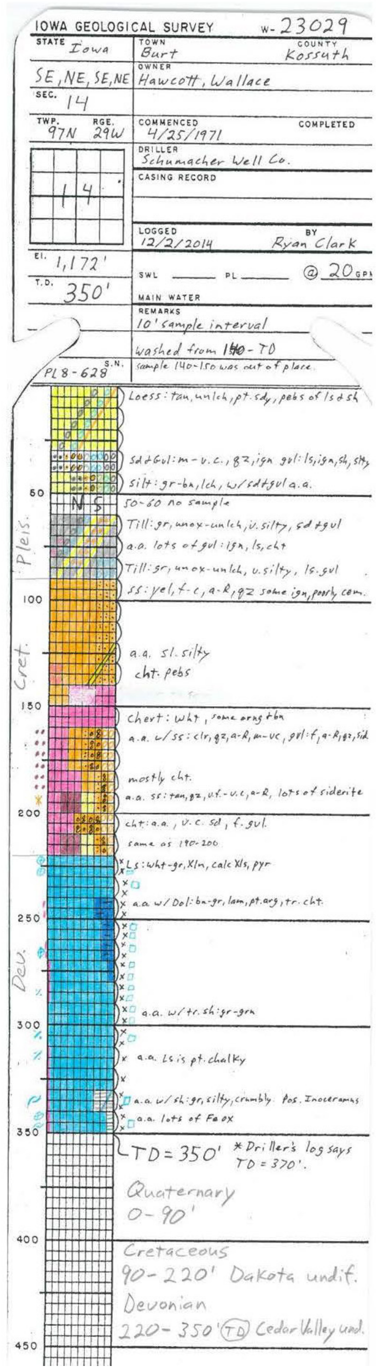
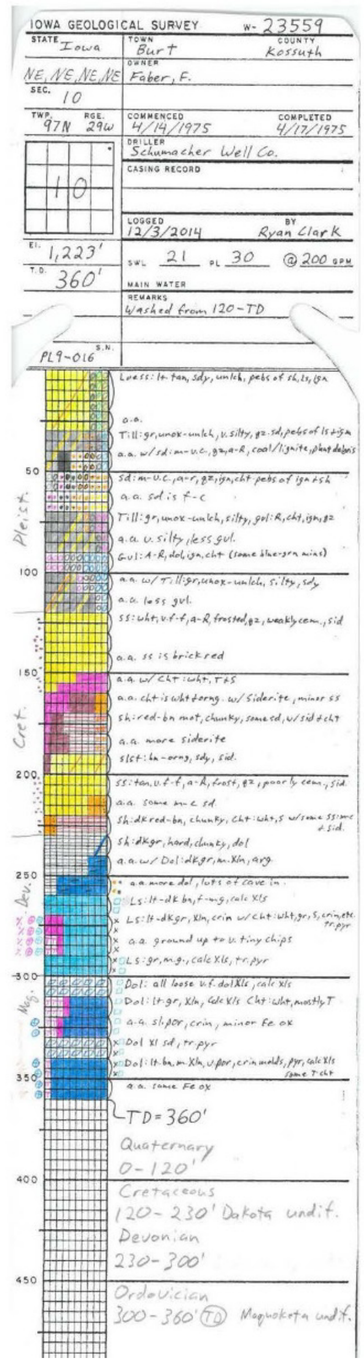
APPENDIX A


IOWA GEOLOGICAL SURVEY
W-1527
STATE Iowa
TOWN Manning
COUNTY Carroll
SW, NW, NW
OWNER Kuhn, Emil
SEC. 18
TWP. 82N
RGE. 36W
COMMENCED
COMPLETED
DRILLER Rasmussen, Carroll
CASING RECORD
LOGGED 12/4/2014
BY Ryan Clark
El. 1,472'
T.D. 440'
SWL
PL
GPM
MAIN WATER
REMARKS
Only sample from 436-440'
Records suggest that W-1180 is a duplicate sample.
S.N. WI9-5
No Sample
TD = 440'
436-440' Penns.? RJC
50
100
150
200
250
300
350
400
450


IOWA GEOLOGICAL SURVEY
W-23029
STATE Iowa
TOWN Burt
COUNTY Kossuth
SE, NE, SE, NE
OWNER Hawcott, Wallace
SEC. 14
TWP. 97N
RGE. 29W
COMMENCED 4/25/1971
COMPLETED
DRILLER Schumacher Well Co.
CASING RECORD
LOGGED 12/2/2014
BY Ryan Clark
El. 1,172'
T.D. 350'
SWL
PL
@ 20 GPM
MAIN WATER
REMARKS
10' sample interval
washed from 140-TD
sample 140-150 was out of place.
S.N. PL8-628
Loess: tan, unlch, pt. sdy, pebs of ls & sh
Sd & Gvl: m-v.c., qz, ign gvl: ls, ign, sh, slts
Silt: gr-bn, lch, w/ sd & gvl a.a.
50-60 no sample
NS
Till: gr, unox-unlch, v. silty, sd & gvl
a.a. lots of gvl: ign, ls, cht
Till: gr, unox-unlch, v. silty, ls. gvl
ss: yel, f-c, a-R, qz some ign, poorly cem.
a.a. sl. silty
cht. pebs
Chert: wht, some orng & bn
mostly cht.
cht: a.a., v.c. sd, f. gvl.
same as 190-200
LS: wht-gr, Xln, calc Xls, pyr
a.a. w/ Dol: bn-gr, lam, pt. arg, tr. cht.
a.a. w/ tr. sh: gr-grn
a.a. Ls is pt. chalky
a.a. lots of Fe ox
Pleis.
Cret.
Dev.
TD = 350'
* Driller's log says TD = 370'.
Quaternary
0-90'
Cretaceous
90-220' Dakota undif.
Devonian
220-350' TD Cedar Valley und.
50
100
150
200
250
300
350
400
450


IOWA GEOLOGICAL SURVEY
W-23559
STATE Iowa
TOWN Burt
COUNTY Kossuth
NE, NE, NE, NE
OWNER Faber, F.
SEC. 10
TWP. 97N
RGE. 29W
COMMENCED 4/14/1975
COMPLETED 4/17/1975
DRILLER Schumacher Well Co.
CASING RECORD
LOGGED 12/3/2014
BY Ryan Clark
El. 1,223'
T.D. 360'
SWL 21
PL 30
@ 200 GPM
MAIN WATER
REMARKS
Washed from 120-TD
S.N. PL9-016
a.a.
a.a. sd is f-c
a.a. v. silty, less gvl.
a.a. less gvl.
a.a. ss is brick red
a.a. more siderite
a.a. some m-c sd
a.a. ground up to v. tiny chips
a.a. some Fe ox
Pleist.
Cret.
Dev.
TD = 360'
Quaternary
0-120'
Cretaceous
120-230' Dakota undif.
Devonian
230-300'
Ordovician
300-360' TD Maquoketa undif.
50
100
150
200
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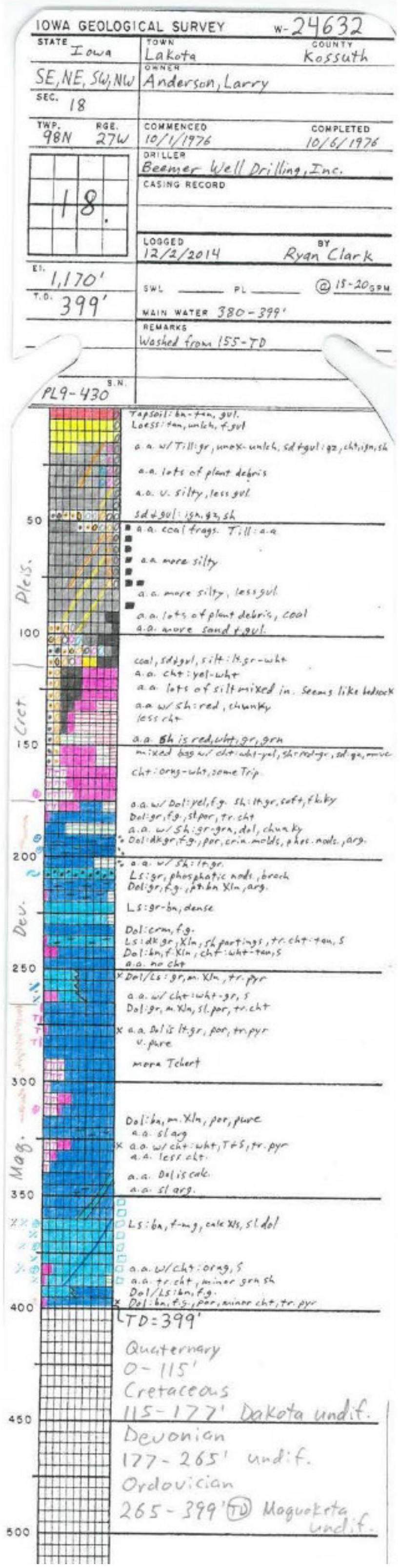
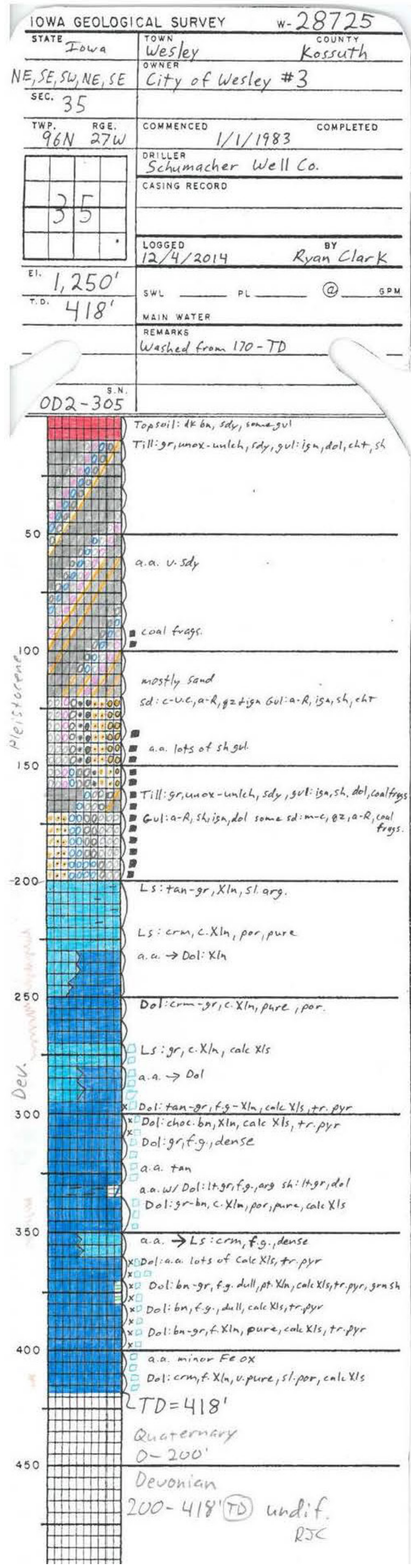
350
400
450


IOWA GEOLOGICAL SURVEY W-24632
STATE Iowa
TOWN Lakota
COUNTY Kossuth
SE, NE, SW, NW
OWNER Anderson, Larry
SEC. 18
TWP. 98N RGE. 27W
COMMENCED 10/1/1976
COMPLETED 10/6/1976
DRILLER Beemer Well Drilling, Inc.
CASING RECORD
18
LOGGED 12/2/2014 BY Ryan Clark
El. 1,170'
T.D. 399'
SWL PL @ 15-20 GPM
MAIN WATER 380-399'
REMARKS Washed from 155-TD
S.N. PL9-430
Topsoil: bn-tan, gvl.
Loess: tan, unlch, f.gvl
a.a. w/ Till: gr, unox-unlch, sd+gvl: qz, cht, ign, sh
a.a. lots of plant debris
a.a. v. silty, less gvl
sd+gvl: ign, qz, sh
a.a. coal frags. Till: a.a
a.a. more silty
a.a. more silty, less gvl
a.a. lots of plant debris, coal
a.a. more sand + gvl.
coal, sd+gvl, silt: lt.gr-wht
a.a. cht: yel-wht
a.a. lots of silt mixed in. Seems like bedrock
a.a. w/ sh: red, chunky
less cht
a.a. Sh is red, wht, gr, grn
cht: orng-wht, some Trip.
a.a. w/ Dol: yel, f.g. Sh: lt.gr, soft, flaky
Dol: gr, f.g., sl.por, tr.cht
a.a. w/ Sh: gr-grn, dol, chunky
Dol: dk.gr, f.g., por, crin. molds, phos. nods., arg.
a.a. w/ Sh: lt.gr.
Ls: gr, phosphatic nods, brech
Dol: gr, f.g., pt.bn Xln, arg.
Ls: gr-bn, dense
Dol: crm, f.g.
Ls: dk.gr, Xln, sh partings, tr.cht: tan, S
Dol: bn, f.Xln, cht: wht-tan, S
a.a. no cht
Dol/Ls: gr, m.Xln, tr.pyr
a.a. w/ cht: wht-gr, S
Dol: gr, m.Xln, sl.por, tr.cht
a.a. Dol is lt.gr, por, tr.pyr
v.pure
more Tchert
Dol: bn, m.Xln, por, pure
a.a. sl arg
a.a. w/ cht: wht, T+S, tr.pyr
a.a. less cht
a.a. Dol is calc.
a.a. sl arg.
Ls: bn, f-m.g, calc Xls, sl.dol
a.a. w/ cht: orng, S
a.a. tr.cht, minor grn sh
Dol/Ls: bn, f.g.
Dol: bn, f.g., por, minor cht, tr.pyr
Pleis.
Cret.
Dev.
Mag.
50
100
150
200
250
300
350
400
450
500
TD=399'
Quaternary
0-115'
Cretaceous
115-177' Dakota undif.
Devonian
177-265' undif.
Ordovician
265-399' (TD) Maquoketa undif.


IOWA GEOLOGICAL SURVEY W-28725
STATE Iowa
TOWN Wesley
COUNTY Kossuth
NE, SE, SW, NE, SE
OWNER City of Wesley #3
SEC. 35
TWP. 96N RGE. 27W
COMMENCED 1/1/1983
COMPLETED
DRILLER Schumacher Well Co.
CASING RECORD
35
LOGGED 12/4/2014 BY Ryan Clark
El. 1,250'
T.D. 418'
SWL PL @ GPM
MAIN WATER
REMARKS Washed from 170-TD
S.N. OD2-305
Topsoil: dk bn, sdy, some gvl
Till: gr, unox-unlch, sdy, gvl: ign, dol, cht, sh
a.a. v. sdy
coal frags.
mostly sand
sd: c-v.c, a-R, qz+ign Gvl: a-R, ign, sh, cht
a.a. lots of sh gvl
Till: gr, unox-unlch, sdy, gvl: ign, sh, dol, coal frags
Gvl: a-R, sh, ign, dol some sd: m-c, qz, a-R, coal frags.
Ls: tan-gr, Xln, sl. arg.
Ls: crm, c.Xln, por, pure
a.a. → Dol: Xln
Dol: crm-gr, c.Xln, pure, por.
Ls: gr, c.Xln, calc Xls
a.a. → Dol
Dol: tan-gr, f.g-Xln, calc Xls, tr.pyr
Dol: choc. bn, Xln, calc Xls, tr.pyr
Dol: gr, f.g., dense
a.a. tan
a.a. w/ Dol: lt.gr, f.g., arg sh: lt.gr, dol
Dol: gr-bn, c.Xln, por, pure, calc Xls
a.a. → Ls: crm, f.g., dense
Dol: a.a. lots of calc Xls, tr.pyr
Dol: bn-gr, f.g. dull, pt.Xln, calc Xls, tr.pyr, grn sh
Dol: bn, f.g., dull, calc Xls, tr.pyr
Dol: bn-gr, f.Xln, pure, calc Xls, tr.pyr
a.a. minor Fe ox
Dol: crm, f.Xln, v.pure, sl.por, calc Xls
Pleistocene
Dev.
50
100
150
200
250
300
350
400
450
TD=418'
Quaternary
0-200'
Devonian
200-418' (TD) undif.
RJC

APPENDIX B

W#	Name Owner	County	SWL (ft)	PWL (ft)	YIELD (gpm)	Thickness (ft)	SPC	Trans.
43267	Hayward, Michael	Mills	138	140	8	9	4.00	1080
52571	Mark Hughes Const.	Mills	200	207	8	40	1.14	308
52572	Mark Hughes Const	Mills	197	203	8	38	1.33	359
52641	Zito, Richard & Donna	Mills	221	231	8	51	0.80	216
48514	Fellowitch, John	Mills	285	324	8	87	0.21	57
47234	Pestel, Jon	Mills	251	258	8	24	1.14	308
43994	Bales, Tony	Mills	259	273	8	19	0.57	154
40438	Leggit, Elizabeth	Mills	235	252	20	60	1.18	319
53635	Hughes, Allan	Mills	219	221	8	54	4.00	1080
45484	Golschall, Richard	Mills	217	223	8	11	1.33	359
49930	Mark Hughes Const.	Mills	280	284	8	26	2.00	540
43997	Glenwood Contracting	Mills	301	312	8	25	0.73	197
44288	Clenwood Contracting	Mills	277	282	8	30	1.60	432
44287	Hughes, Mark	Mills	285	291	8	23	1.33	359
53818	Mnikolaicik, Greg	Mills	297	314	8	18	0.47	127
53634	Hughes, Mark	Mills	231	235	8	108	2.00	540
44290	Vannausdale, Harry	Mills	212	232	8	102	0.40	108
42967	West, Monte	Mills	263	266	8	68	2.67	721
53386	Mark Hughes Const.	Mills	312	348	8	109	0.22	59
44285	Landmark Enterprises	Pottawattamie	172	191	8	87	0.42	113
40441	Slotts, Frank	Pottawattamie	119	123	16	142	4.00	1080
60736	Canoyer, Craig	Pottawattamie	199	209	20	57	2.00	540
49699	Anderson, Ronald	Pottawattamie	233	238	8	45	1.60	432
25643	Mehlmann, Leroy	Cass	150	215	15	50	0.23	62
48654	Bluff Development	Pottawattamie	196	200	8	34	2.00	540
53790	Rich, Gary	Cass	233	263	12	31	0.40	108
49982	Neil Bach Colo-Neil	Pottawattamie	210	230	8	57	0.40	108
45901	Eby, Robert	Pottawattamie	204	208	8	43	2.00	540
45903	Paradise Homes	Pottawattamie	232	235	8	43	2.67	721
47151	Vacanti, Mark	Pottawattamie	240	255	8	43	0.53	143
47152	Paradise Homes	Pottawattamie	214	224	8	43	0.80	216
47960	Corey Goss Const	Pottawattamie	218	260	8	43	0.19	51
54002	Bach, Neil	Pottawattamie	240	244	8	47	2.00	540
45327	Clark, Tony & Jana	Pottawattamie	250	260	8	62	0.80	216
47122	Waters, Rick	Pottawattamie	233	238	8	81	1.60	432
39644	Sorensen, Merlin	Pottawattamie	226	244	16	46	0.89	240
50068	Bach, Neil	Pottawattamie	225	255	8	43	0.27	73
44967	James, Jason	Pottawattamie	251	263	8	52	0.67	181
45905	Sleper, Sherm	Pottawattamie	215	239	7	12	0.29	78
50261	Bach, Neil	Pottawattamie	230	252	8	8	0.36	97
45482	East Homes	Pottawattamie	242	247	8	18	1.60	432
40442	East Homes	Pottawattamie	250	260	25	37	2.50	675
39414	Mccarthy Construction	Pottawattamie	250	252	25	40	12.50	3375
39630	East Homes	Pottawattamie	240	246	16	40	2.67	721
39645	East Homes	Pottawattamie	240	246	16	40	2.67	721
39413	Coats Jr., Bill	Pottawattamie	213	235	15	44	0.68	184
34582	Campbell, Bill	Pottawattamie	215	260	155	64	3.44	929
21098	Brahms, Don	Cass	200	250	10	31	0.20	54
19317	Weber, Harley	Cass	150	160	20	50	2.00	540
53792	Raash, Don	Adair	120	250	12	55	0.09	24
1072	Nngc	Pottawattamie	25	75	25	160	0.50	135
1821	Nngc	Pottawattamie	335	462	53	10	0.42	113
60693	Kardell, Jimmy	Pottawattamie	205	220	10	6	0.67	181
74502	Schultz, Roy	Pottawattamie	198	227	13	51	0.45	122
75843	Book, Richard	Cass	150	173	8	8	0.35	95
53056	Carr, Clifford	Cass	196	209	8	68	0.62	167
19447	Barber, Paul	Cass	40	45	11	20	2.20	594
46658	Fischer, Jim	Pottawattamie	268	272	8	18	2.00	540
23939	Wilburn, Scott	Cass	120	180	17	25	0.28	76
53754	Carney, Charles	Guthrie	241	301	3	6	0.05	14
53796	Williams, Mark	Guthrie	192	290	3	57	0.03	8

W#	Name Owner	County	SWL (ft)	PWL (ft)	YIELD (gpm)	Thickness (ft)	SPC	Trans.
17805	Adair Feed Co.	Guthrie	253	283	12	15	0.40	108
75860	Sheeder, Virgil	Guthrie	260	269	5	30	0.53	143
53025	Corey Goss Const.	Harrison	290	320	8	60	0.27	73
40435	Nelson, Jay	Audubon	187	193	16	41	2.67	721
40261	Reed, Joan	Guthrie	204	284	5	96	0.06	16
43312	Williams, Donald	Guthrie	205	211	10	51	1.67	451
74479	Redinbaugh, Mike	Harrison	194	204	12	5	1.20	324
20552	Kammes, Lavern	Audubon	260	280	10	32	0.50	135
55421	Andersen, Brian	Shelby	213	225	12	11	1.00	270
60728	Schlater, Boyd	Audubon	219	234	15	18	1.00	270
52488	Mark Hughes Const	Harrison	246	250	8	47	2.00	540
52490	Mark Hughes Const.	Harrison	267	270	8	48	2.67	721
52491	Richardson, Kirk	Harrison	235	238	8	37	2.67	721
44738	Cosaert, Richard	Harrison	268	298	4	4	0.13	35
45696	Voss, Harold	Harrison	278	323	10	45	0.22	59
49532	Longmeyer, Dave	Harrison	282	340	5	4	0.09	24
64996	Rigler, Marie	Guthrie	254	272	10	10	0.56	151
60882	Crawley, Tom And Alita	Guthrie	175	180	20	35	4.00	1080
74467	Nelson, Tom	Guthrie	236	239	10	34	2.86	772
61794	Van Meter, Charlie	Guthrie	238	240	15	27	7.50	2025
75607	Helena Chemical	Guthrie	224	240	8	36	0.50	135
51558	Vanmeter, Charles	Guthrie	264	268	8	15	2.00	540
49698	Vanmeter, Charlie	Guthrie	259	270	8	57	0.73	197
54782	Sunberg, Terry	Audubon	134	141	8	12	1.14	308
40255	Jensen, Jerry	Audubon	239	249	10	8	1.00	270
53059	Fett, Marcel	Guthrie	277	289	8	65	0.67	181
72679	Roberts, Scott	Guthrie	343	400	15	20	0.26	70
55605	Frisby, Charles	Shelby	320	330	8	52	0.80	216
51560	Gross, Fr & Ija	Shelby	286	295	8	9	0.89	240
75909	Larson, Mitch	Greene	135	180	15	30	0.33	89
55410	Hinners, Richard	Carroll	177	280	8	96	0.08	22
75939	Prestage Farms	Greene	60	200	30	37	0.21	57
59665	Wendl , Dave	Carroll	188	273	10	22	0.12	32
54453	Reiman, Daryl	Carroll	169	170	12	22	12.00	3240
52207	Rupirer, Neal	Carroll	204	207	10	18	3.33	899
54187	Eisgheid, Alan	Carroll	158	160	15	12	7.50	2025
34	Denison, City Of	Crawford	88	170	200	10	2.44	659
22467	Eischeid, W.	Carroll	144	151	18	32	2.57	694
11726	Provost, Mrs. B.	Carroll	202	208	10	4	1.67	451
22175	Vounahme, Wilbert	Carroll	282	284	20	23	10.00	2700
52627	Tomka, Vic	Carroll	256	258	12	16	6.00	1620
76080	Carroll, City Of	Carroll	119	186	202	57	3.01	813
23137	Schroer, Elmer	Carroll	204	205	11	21	11.00	2970
39043	Frank, Harry	Carroll	151	202	10	50	0.20	54
40346	Eischeid, Tim	Carroll	184	220	30	26	0.83	224
21881	Poland, Phil	Carroll	141	166	17	12	0.68	184
21883	Andrews, Chuck	Carroll	175	185	18	15	1.80	486
20587	Thomsen, Bernie	Crawford	215	230	12	12	0.80	216
75900	Prestage Farms	Greene	160	360	20	20	0.10	27
39431	Healy, Roger	Monona	230	240	15	45	1.50	405
23405	Finch, Bob	Carroll	175	190	10	10	0.67	181
12308	Baumhover, Mrs. Emma	Carroll	172	173	20	17	20.00	5400
23462	Onken, Robert	Carroll	80	108	20	3	0.71	192
24657	Zediker	Monona	220	223	12	20	4.00	1080
45956	Wiederin, Craig	Carroll	105	107	12	30	6.00	1620
19307	Nieland, Leo	Carroll	210	220	13	20	1.30	351
46015	Vonnahme, Bill	Carroll	226	228	12	14	6.00	1620
14813	Kanne, Earl	Carroll	183	186	12	8	4.00	1080
44567	Elite Pork Partnership	Carroll	213	225	20	28	1.67	451
12638	Scheffers, Conrad	Carroll	180	183	5	10	1.67	451
75907	Billmeier, Heidi	Greene	190	300	25	29	0.23	62

W#	Name Owner	County	SWL (ft)	PWL (ft)	YIELD (gpm)	Thickness (ft)	SPC	Trans.
20600	Tiefenthaler, Alfred	Carroll	228	231	14	31	4.67	1261
53501	Breda, City Of	Carroll	204	278	206	37	2.78	751
22440	Schettler, Ray	Carroll	206	212	18	8	3.00	810
45724	Namanny, Dennis	Monona	240	310	5	2	0.07	19
63918	Prestage Farms	Carroll	210	300	30	32	0.33	89
22604	Keis, Ray	Carroll	187	194	18	12	2.57	694
22056	Vitamin Feed Co.	Webster	165	175	15	1052	10	2
8936	Sullivan, Francis	Webster	125	187	10	1016	20	0
58539	Kirchhoff, Leonard	Humboldt	96	140	20	1032	12	0
13127	Miller, Morris	Wright	35	36	20	986	25	20
36235	Smith, Dale	Wright	45	108	40	962	73	1
16227	Iowa Conservation Com.	Wright	60	105	900	1064	30	20
49822	Price, Jim	Wright	46	120	20	967	55	0
42857	Nelson, David	Wright	75	120	50	1058	20	1
56250	Reding, Jeff	Humboldt	31	85	30	1040	36	1
54069	Frederes, Howard	Kossuth	27	65	40	1031	12	1
43898	Reding, Mike	Kossuth	50	80	30	1029	23	1
73811	Bormann, Mike	Kossuth	48	80	20	1011	58	1
76398	Condoleon, Harry	Kossuth	80	120	40	1029	29	1
46424	Dornbier, Derwin	Kossuth	71	120	30	1059	3	1
76890	Wiebelhaus, Bill	Kossuth	102	140	20	964	12	1
56262	Woodlyn Hills	Kossuth	77	131	175	995	50	3
74995	Ag Processing Inc	Kossuth	76	85	800	997	11	89
9437	Mcenroe, Jim	Kossuth	65	70	25	1065	5	5
22962	Gulf Central Pipeline	Kossuth	75	240	429	1017	60	3
30310	Oswald, Bill	Kossuth	150	185	35	1013	20	1
65260	Christensen, Clark	Kossuth	41	80	30	1008	8	1
74015	Broesder, Paul	Kossuth	38	80	25	1044	26	1
4024	Carlson, Alex	Kossuth	0	50	12	944	85	0
616	Burt, City Of	Kossuth	25	76	177	1034	15	3
3009	Miller, L.L.	Kossuth	3	53	10	926	115	0
45608	Vaske, Kent	Kossuth	43	80	40	1063	23	1
12166	Franzen, Herman	Kossuth	35	42	15	959	50	2
11560	Laird	Kossuth	-1	80	6	1022	30	0
3277	Vaske, Marvin	Kossuth	6	15	35	1016	35	4
59701	Vaske, Roger	Kossuth	18	60	30	1043	4	1
65665	Mcnurtney, Charles	Kossuth	9	40	15	1010	5	0
67443	Bancroft, City Of	Kossuth	16	138	600	1033	5	5
2066	Lappe, Leonard	Kossuth	6	7	21	1060	5	21
3015	Murray Farms Co.	Kossuth	60	75	20	1004	50	1
52971	Laue, Leonard	Kossuth	66	100	30	995	12	1
8928	Garrison, H.	Kossuth	33	40	25	1022	10	4
59281	Goche, Wayne	Kossuth	18	60	15	1049	2	0
6345	Pupenfuhs	Kossuth	0	30	12	950	70	0
2705	Johnson & Cummings	Kossuth	48	80	15	926	90	0
SPC = Specific Capacity (gpm/foot Drawdown)								
Trans. = Transmissivity (ft^2/day)								

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