Prepared for:
Research and Special Programs Administration
Office of Pipeline Safety
Department of Transportation
Washington, DC 20590

UNUSUALLY SENSITIVE AREAS FOR

DRINKING WATER RESOURCES

REPORT FOR IOWA

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RPI/R/98-5 May 1998

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UNUSUALLY SENSITIVE AREAS FOR DRINKING WATER RESOURCES REPORT FOR IOWA

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INTRODUCTION

The Research and Special Programs Administration (RSPA) of the Department of Transportation is required to identify areas unusually sensitive to environmental damage in the event of a hazardous liquid pipeline accident, in accordance with pipeline safety laws (49 U.S.C. Section 60109). Accordingly, workshops were held with regulatory agencies, pipeline operators, and the public during which a process was developed to identify "unusually sensitive areas" (USAs) for drinking water resources. This process, which has been adopted by RSPA, consists of first identifying environmentally sensitive drinking water resources and other primary concerns, and then applying the following five filtering criteria to determine which of the drinking water source locations (i.e., surface water intakes, ground water wells) should be USAs:

Filter Criteria #1

If the public water system is a Transient Noncommunity Water System (TNCWS), the water intakes shall not be designated as USAs.

Filter Criteria #2

For Community Water Systems (CWS) and Nontransient Noncommunity Water Systems (NTNCWS) that obtain their water supply primarily from surface water sources, and do not have an adequate alternative source of water, the water intakes shall be designated as USAs.

Filter Criteria #3

For CWS and NTNCWS that obtain their water primarily from ground water sources, where the source aquifer is identified as a Class I or Class IIa, as defined in Pettyjohn et al. (1991), and do not have an adequate alternative source of water, these wells shall be designated as USAs. The wellhead protection area for each well will be used to define the area of the USA.

Filter Criteria #4

For CWS and NTNCWS that obtain their water primarily from ground water sources, where the source aquifer is identified as a Class IIb, IIc, III, or U, as defined in Pettyjohn et al. (1991), these wells shall not be designated as USAs.

Filter Criteria #5

For CWS and NTNCWS that obtain their water primarily from ground water sources, where the source aquifer is identified as a Class I or Class IIa, as defined in Pettyjohn et al. (1991), and the aquifer is designated as a sole source aquifer, these wells are also USAs, an area twice the wellhead protection area shall be designated as a USA,

All CWS and NTNCWS that obtain their water from surface water sources are automatically designated as USAs because information on which to evaluate whether they have an adequate alternative water supply is not available. Designation of ground water sources is much more complicated, thus the rest of this discussion describes the process that has been developed and implemented to classify ground water wells that supply the CWS and NTNCWS in the state of Iowa. Iowa was chosen for processing because the necessary data were available in digital format and the data quality was good. The status of data collection and evaluation for all states can be reviewed in the USA Data Catalog, which is available from RSPA.

A key to implementing the process for identifying USAs for ground water wells is distinguishing those wells that obtain their water from Class I or Class IIa aquifers (filter criteria 3 and 5), from those that do not (filter criteria 4). Another major criteria is the thickness of overlying, impermeable materials. For example, if Class I and IIa aquifers are overlain by more than 50 feet of impermeable glacial till then wells in that area would be Class III and, therefore, not USAs. Also, wells that tap an aquifer below an overlying confining unit, such as a layer of impermeable shale, would be classified as Class IIIv, and thus not be a USA regardless of the aquifer type. In both of these situations, the overlying impermeable layer would prevent a pipeline release from reaching the aquifer.

THE PETTYJOHN CLASSIFICATION SCHEME

The aquifer classification scheme developed in a report "Regional Assessment of the Aquifer Vulnerability and Sensitivity in the Conterminous United States" for the U.S. Environmental Protection Agency (USEPA/600/2-91/043) by Pettyjohn et al. is used to determine those parts of aquifers at risk to contamination from pipeline releases of a hazardous liquid. The Pettyjohn classification, based on an assessment of the potential contamination of ground water throughout the United States by the subsurface emplacement of fluids through injection wells, is outlined below:

Class I (Surficial or shallow permeable units; highly vulnerable to contamination)

Class Ia: Unconsolidated Aquifers. Consist of surficial, unconsolidated, and permeable alluvial, terrace, outwash, beach, dune and other similar deposits.

Class Ib: Soluble and Fractured Bedrock Aquifers. Consist of limestone, dolomite, and, locally, evaporitic units that contain documented karst features or solution channels, regardless of size. Also includes sedimentary strata and metamorphic and igneous rocks that are significantly faulted, fractured, or jointed.

Class Ic: Semiconsolidated Aquifers. Consist of semiconsolidated systems that contain poorly to moderately indurated sand and gravel that are interbedded with clay and silt.

Class Id: Covered Aquifers. Consists of any Class I aquifer that is overlain by less than 50 feet of low permeability, unconsolidated material, such as glacial till, lacustrian, and loess deposits.

Class II (Consolidated bedrock aquifers; moderately vulnerable to contamination)

Class IIa: Higher Yield Bedrock Aquifers. Consist of fairly coarse sandstone or conglomerate that contain lesser amounts of interbedded fine-grained clastics and occasionally carbonate units. In general, well yields must exceed 50 gallons per minute (gpm) to be included in this class.

Class IIb: Lower Yield Bedrock Aquifers. Consist of the same clastic rock types present in the higher yield systems. Well yields are commonly less than 50 gpm.

Class IIc: Covered Bedrock Aquifers. Consist of Class IIa and IIb aquifers that are overlain by less than 50 feet of unconsolidated material of low permeability.

Class III (Covered consolidated or unconsolidated aquifers)

This class includes those aquifers that are overlain by more than 50 feet of low permeability material.

Class U (Undifferentiated aquifers)

This classification is used where several lithologic and hydrologic conditions are present within a mapable area. This class is intended to convey a wider range of vulnerability than is usually contained in any other single class.

Subclass v (Variably covered aquifers)

The modifier "v" is used to describe areas where an undetermined or highly variable thickness of low permeability sediments overlies the major water-bearing zone. In practice, we have used this modifier where the geologic description of the aquifer indicates that there is a confining unit above the water producing zone.

IDENTIFYING USAs FOR DRINKING WATER RESOURCES IN IOWA

Data Sources

The Iowa Department of Natural Resources, Environmental Protection Division maintains a database of surface and groundwater wells for public water systems. The Iowa Department of Natural Resources, Geological Survey Bureau has Arc/INFO coverages for surficial geology, alluvial aquifers, and glacial till thickness. Iowa does not have an approved wellhead protection program. No sole source aquifers have been designated in Iowa. There currently is no readily available data source for identifying TNCWS or for determining if there is an adequate alternative source of water. Therefore, filtering criteria 1 cannot be implemented at this time. Also, in applying filtering criteria 2 and 3, we have assumed that all wells do not have an adequate alternative source of water. Based on our current understanding, determining if there is an adequate alternative source of water will require contacting the owner/operator of each system, which is not feasible at this time.

The Geology and Pettyjohn Classification of Aquifers in Iowa

As shown in Table 1, there are seven major aquifers in Iowa (summarized from the 1992 U.S. Geological Survey publication "Groundwater Atlas of the United States, Segment 9"). Most of the published geologic maps show the bedrock types present under a cover of glacial deposits. Much of the state is covered by glacial till deposits of variable thickness and sediment types, and only a small area in northeastern Iowa, called the driftless area, lacks a cover of glacial till or drift. The availability of a digital statewide database for the thickness of the glacial till was critical to the differentiation between Class I and Class III wells in Iowa.

TABLE 1. Iowa's aquifers and their classification according to the Pettyjohn classification scheme.

Aquifer Name	Aquifer Description	Pettyjohn Classification
Alluvial Aquifer	Sand and gravel deposits along modern-day stream valleys; it is Iowa's largest producer of groundwater	Class Ia because it is surficial, unconsolidated, and consists of permeable alluvial deposits
Pleistocene Aquifer	Glacial deposits of sand and gravel buried below either glacial till or modern-day valley deposits	Class Ia where it is overlain by the Alluvial Aquifer, which is permeable; Class III where it is overlain by >50 feet of impermeable till
Cretaceous Aquifer	Sandstone layer overlain by a shale or glacial deposits	Class IIIv because the water producing zone is overlain by a confining unit
Pennsylvanian Aquifer	Mostly shale confining beds, but some locally used sandstones and limestone aquifers	Class IIIv because of the overlying shale confining unit
Mississippian Aquifer	Dolomitic limestone	Class Id in the outcrop belt where the glacial till is thin because it is a soluble and fractured bedrock aquifer, and covered by less than 50 feet of low permeability material; Class III where the bedrock is covered by a thick glacial till
Devonian/ Silurian Aquifer	Dolomite and limestone	Class Id in the outcrop belt where the glacial till is thin because it is a soluble and fractured bedrock aquifer, and covered by less than 50 feet of low permeability material; Class III where the bedrock is covered by a thick glacial till; Class IIIv elsewhere because of overlying confining units
Ordovician/ Cambrian Aquifer	Sandstone	Class IIa where it crops out on the surface in the driftless area, because it contains higher yield sandstone with no impermeable surface cover; Class IIIv elsewhere because of the top confining unit (Maquoketa Formation)

Processing Steps

Every public water system well in Iowa was classified according to the Pettyjohn scheme. The results are presented by aquifer in order, from the youngest to the oldest, as listed in Table 1. The well data contain attributes for water source(s) and well depth. A well can have multiple sources, but the shallowest source was used in the processing steps because it is the one most likely to be impacted by pollutants moving downward from the surface. Other spatial data instrumental in classifying the Pettyjohn sensitivity of the wells were: glacial till thickness (where it is less than 50 feet thick), surficial geology, and alluvial valleys.

Determining the Pettyjohn classification is the primary objective; however, a system was implemented for tracking the spatial and attribute accuracy of the data in order to maintain a record of the decisions made and to allow checking of the resulting USAs. A "quality" variable was added to the data, as defined below:

Quality Rank	Description of the Data Quality
1	source information is available and the well is located within the boundary of the associated data layer (either alluvial valley, glacial till, or geologic formation)
2	source information is available and the well is located within the spatial tolerance of the associated data layer
3	source information is available and the well is located beyond the spatial tolerance of the associated data layer
4	source information is not available, but other attributes were used to classify the well

The sequential GIS processing began with the intersection of the groundwater wells with the polygons delineating the boundaries of the alluvial valleys, the glacial till (< 50 feet thick), and the surficial geology. Two attributes were added for identifying if the wells were located within or outside the alluvial valleys and the glacial till polygons. All wells that are outside these areas were processed to determine if they are within the spatial accuracy of the respective coverages. The following distances (from the metadata reports) were used in determining the spatial accuracies for each data layer:

groundwater wells: +/- 1,100 meters

alluvial valleys: +/- 300 meters

glacial till < 50 feet thick: +/- 500 meters

surficial geology: +/- 1,100 meters

To analyze the data, while compensating for spatial accuracy, the wells outside or beyond the boundaries of the associated data layer were tested for distance to the nearest boundary. For each well, if the location was within 1,400 meters of an alluvial valley, then the processing proceeded as if it was located inside the polygon and the Quality was assigned the value of 2. If the location was within 1,600 meters of the glacial till (< 50 feet thick) polygons then the Quality was also assigned the value of 2, and the well was processed as if it was located inside the glacial till polygon. When a well was located beyond the spatial accuracy limit, then the Quality was assigned a value of 3. If a well has no source information, then the Quality attribute was 4.

There are 2,256 public water supply groundwater wells in Iowa, of which 1,208 (54 percent) are located within alluvial valleys, 695 (31 percent) are within 1,400 meters of alluvial valleys, and 353 (15 percent) are not located within alluvial valleys. As stated earlier, glacial till covers almost all of Iowa which is a critical factor in determining groundwater vulnerability. Therefore, the spatial extent of thin (less than 50 feet) glacial till is a very important data layer for identifying USAs. Of the 2,256 wells, 535 are located within the thin till areas, 382 are located within 1,600 meters of the thin till areas, and 1,339 are not within the spatial limits of the thin till areas. There are 29 wells that do not have any source information. As each aquifer was analyzed, these non-sourced wells were examined with the associated data layers and well depths to identify the most appropriate category. All of these wells (Quality = 4) need to be checked.

The following sections describe the process methodology and are grouped by major aquifer (Table 1). The water sources for each well and the locations are described in descending geologic time (from youngest to oldest) (Fig. 1). A simple, yet critical, distinction is made between the geologic unit (aquifer) in which the well is screened and the surficial geology. For example, the well may obtain water from the Mississippian aquifer, but the well is located in the outcrop of the Pennsylvanian

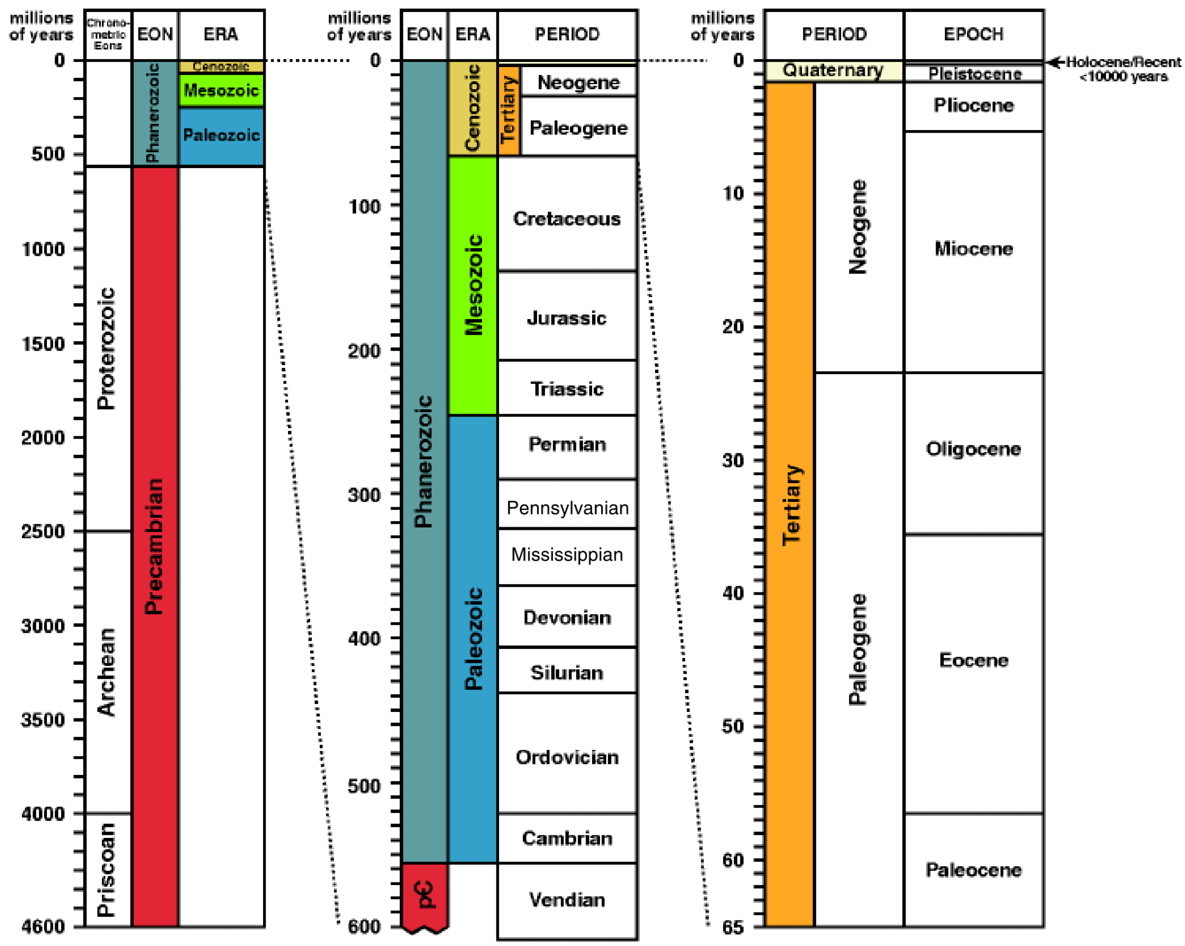

Figure 1. Geologic time scale.

geologic formation which overlies the Mississippian aquifer. Because the Pennsylvanian Outcrop Belt is an aquiclude, this well is classified as a Pettyjohn Class IIIv well. The classification of Pettyjohn vulnerability for the bedrock aquifers relies on the spatial analysis of where a well is located and which aquifer it obtains water from because this determines the presence or absence of overlying confining units which are barriers to pollution transmission.

The following sections outline the processing steps for each aquifer.

Alluvial Aquifers

There are 789 wells that obtain water from alluvial aquifers and are therefore Class Ia. Wells that obtain water from an alluvial aquifer and are located within the alluvial valleys are identified as Quality = 1 (727 wells). The alluvial-sourced wells that are located outside of the boundaries of the alluvial valleys were checked for accuracy distance. Those wells located within 1,400 meters of the alluvial valleys (the combined tolerance of the wells and the alluvial valleys) are identified as Quality = 2 (50 wells). Wells located further than 1,400 meters but with data attributes indicating that they obtain water from the alluvial valleys are still classified as Ia, but the Quality is ranked as 3 and they need to be checked (12 wells). There are 2 wells that have no aquifer source data, but are within alluvial valleys, and are shallow (less than 100 feet deep). These 2 wells are classified as Class Ia and Quality = 4. There are a total of 791 Class Ia Alluvial Aquifer wells which accounts for 35 percent of the groundwater wells in Iowa (Fig. 2).

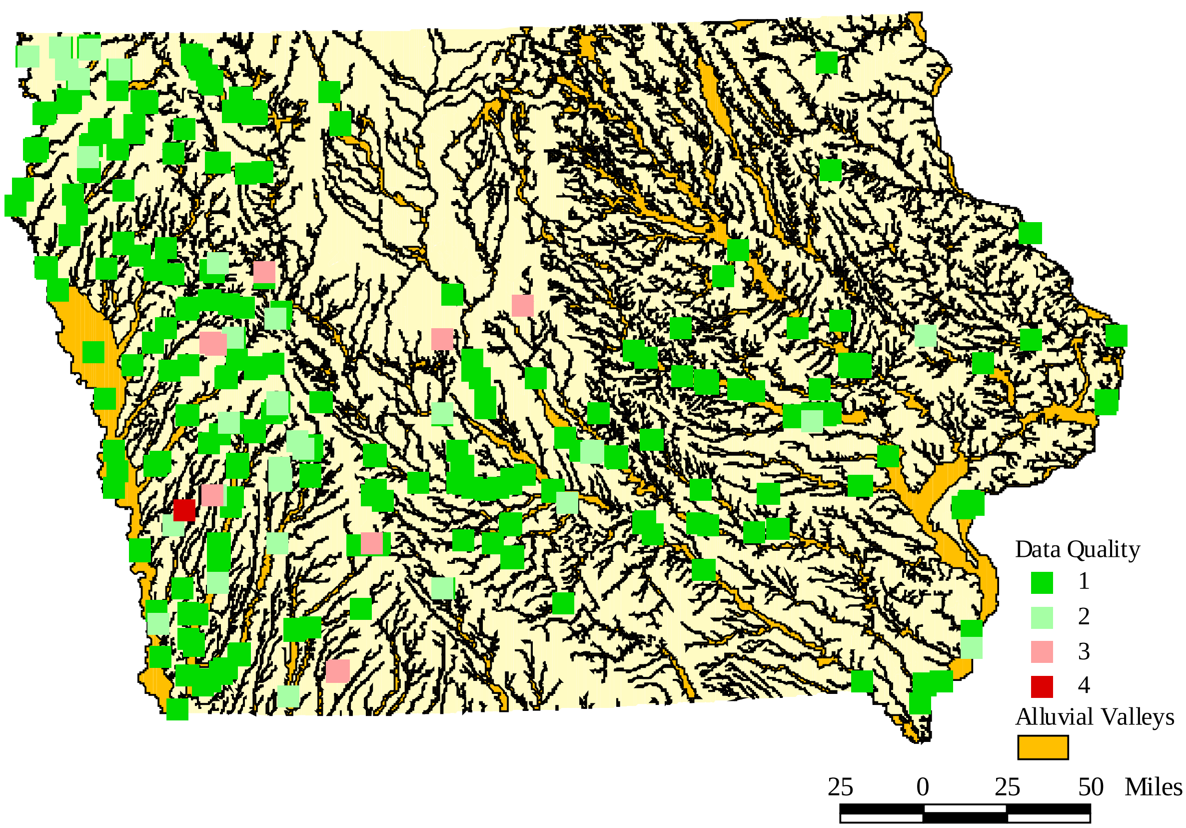

Figure 2. Groundwater wells, classified by data quality, that obtain water from alluvial aquifers. All of these wells are Pettyjohn Class Ia.

Pleistocene Aquifer

Wells that obtain water from the Pleistocene aquifer and are located in glacial till areas less than 50 feet thick are Class Id. There are a total of 334 wells that obtain water from the Pleistocene Aquifer, of which 27 wells are within the thin glacial till (Class = Ia and Quality = 1). There are 31 wells that are within 1,600 meters of thin glacial till which classifies them as Class Id and Quality = 2. Lastly, there are 276 wells that are not located within thin glacial till which identifies these as Class III because there is more than 50 feet of overlying impermeable material (Quality = 1). Wells that obtain water from the Pleistocene aquifer account for 15 percent of Iowa's groundwater wells and 58 wells (2 percent) are Class Id USAs (Fig. 3).

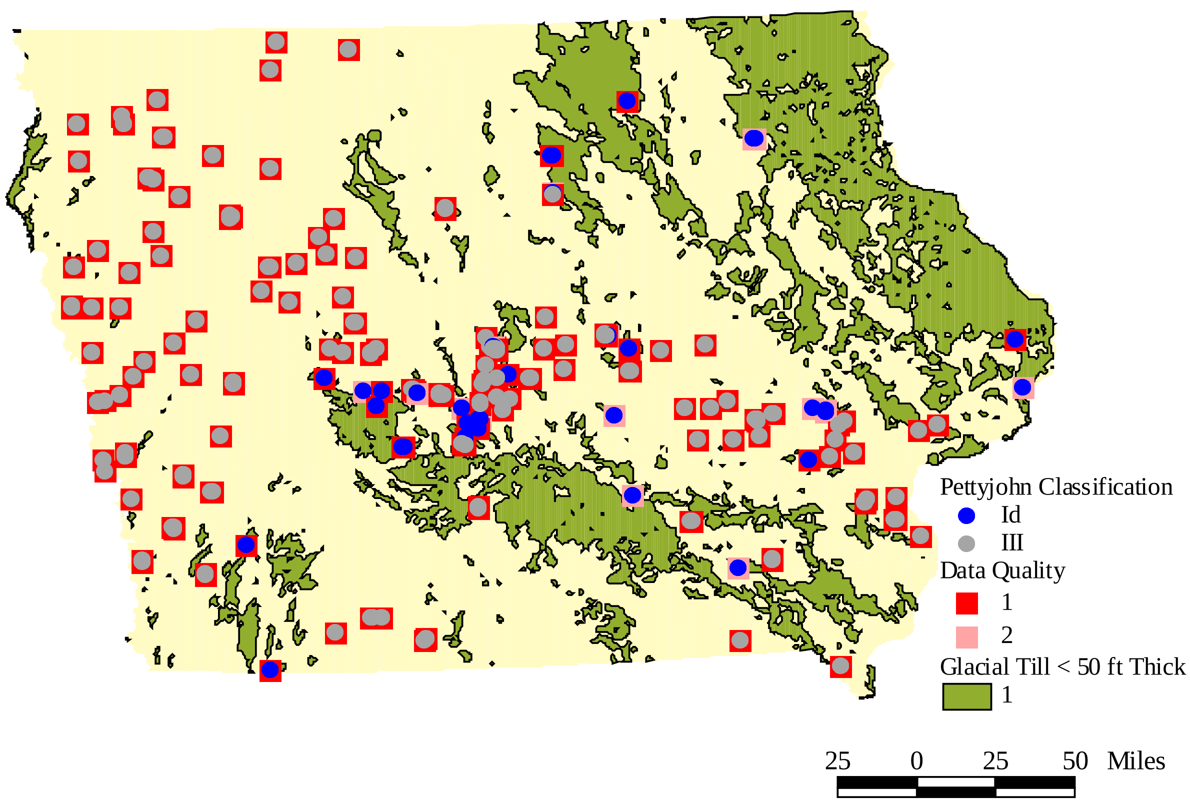

Figure 3. Groundwater wells, by Pettyjohn (1991) vulnerability classification and data quality, that obtain water from the Pleistocene aquifer.

Cretaceous Aquifer

All wells that obtain water from the Cretaceous aquifer (193 wells) are Class IIIv because the aquifer is confined by overlying impermeable limestone, shale, or till (Fig. 4). (Note: In a rare instance in an alluvial valley, the overlying impermeable material may have been eroded away, but the data do not allow this distinction, so all are designated as Class III.)

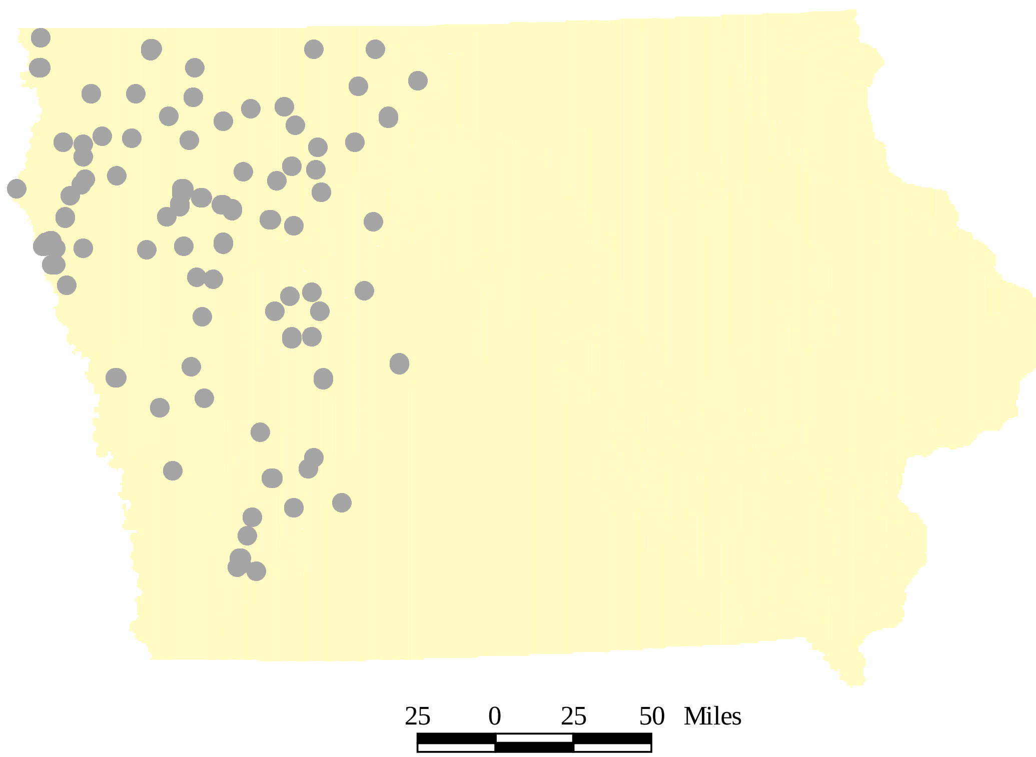

Figure 4. Groundwater wells that obtain water from the Cretaceous aquifer and are classified as Pettyjohn IIIv.

Pennsylvanian Aquifer

There are 22 wells that obtain water from the Pennsylvanian aquifer (Fig. 5). Of these, 19 wells are located in the Pennsylvanian Outcrop Belt and are Class IIIv because the aquifer is covered by the Pennsylvanian Aquiclude. Three wells are located in other

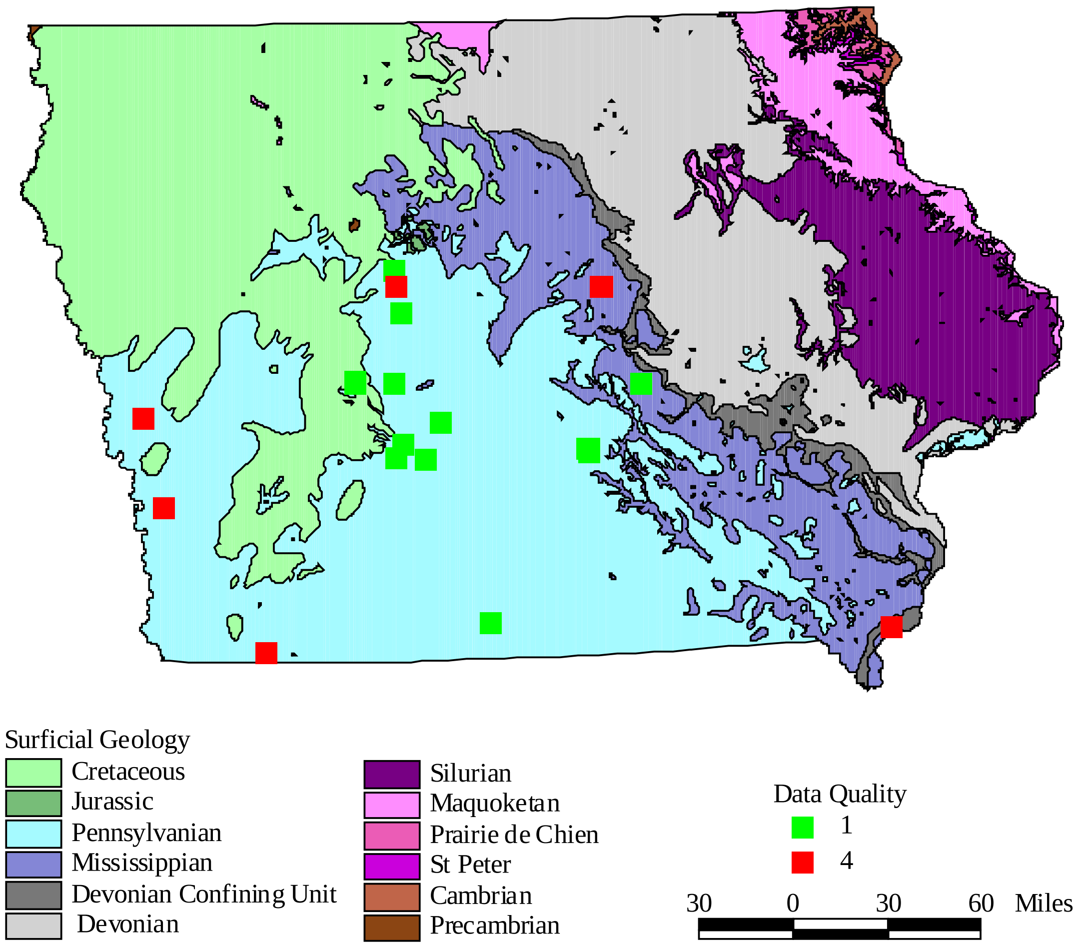

Figure 5. Groundwater wells, by data quality, that obtain water from the Pennsylvanian aquifer. All of these wells are Class IIIv.

formations (Cretaceous and Mississippian). The 2 wells located in the Cretaceous outcrop belt are Class IIIv because they are overlain by a confining unit and the 1 well located in the Mississippian outcrop belt is Class IIIv because the source aquifer is covered by the Pennsylvanian Aquiclude. There are 6 wells that do not have source information, they are within the Pennsylvanian outcrop belt, they are not located within or near alluvial valleys, and the well depths are similar to the other Pennsylvanian-sources wells. Therefore, these wells are Class IIIv and Quality = 4, thus they need to be checked.

Mississippian Aquifer

There are 158 wells that obtain water from the Mississippian aquifer (Fig. 6). Of these, 48 wells are located in the Pennsylvanian Outcrop Belt and are therefore Class IIIv because the aquifer is overlain by the Pennsylvanian Aquiclude. Of the remaining 110 wells, 90 are located in the Mississippian Outcrop Belt where 36 of these are located in the thin till areas and are Class Id. The remaining 54 wells are Class III. An exception would be where a well is drilled in a third order alluvial valley, which these data cannot identify. There are 16 wells located in the Cretaceous belt and are Class IIIv because they are overlain by a confining unit. Lastly, there are 4 wells for which the attribute data indicate they obtain water from the Mississippian Aquifer, but they are located in the boundary of the Devonian belt, indicating an error in one of the datasets (Quality = 3), thus these wells need to be checked. There are 3 wells that have no source information, but have similar depths as wells obtaining water from the Mississippian aquifer and are overlain by more than 50 feet of till making them Class III wells and Quality = 4.

Devonian and Silurian Aquifers

There are 436 wells (19 percent of the public groundwater wells) that obtain water from the Devonian or Silurian aquifers (Fig. 7). Of these, 365 wells are located in the Devonian/Silurian Outcrop Belt. In this area the till is generally thin, thus 247 wells are within thin till areas and are Class Id (Quality = 1). The remaining 118 wells are Class III because they are overlain by thick glacial till. Wells located in the Devonian Confining Unit outcrop belt are Class IIIv (20 wells) because they are overlain by the aquiclude. Wells located in the Cretaceous outcrop belt that obtain their water from older Devonian or Silurian aquifers are also Class IIIv (15 wells) because they are overlain by a confining unit. There are 12 wells that obtain water from the Devonian or Silurian aquifers and are located in the Mississippian outcrop belt that are also Class IIIv because they are overlain by the Devonian Aquiclude. There are 22 wells that obtain water from the Devonian or Silurian aquifers that are located in the Pennsylvanian outcrop belt and are Class IIIv because the Devonian and Silurian aquifers are covered by the Pennsylvanian Aquiclude. Lastly, there are 2 wells that obtain water from the Devonian aquifer and are located in the Maquoketa Aquiclude

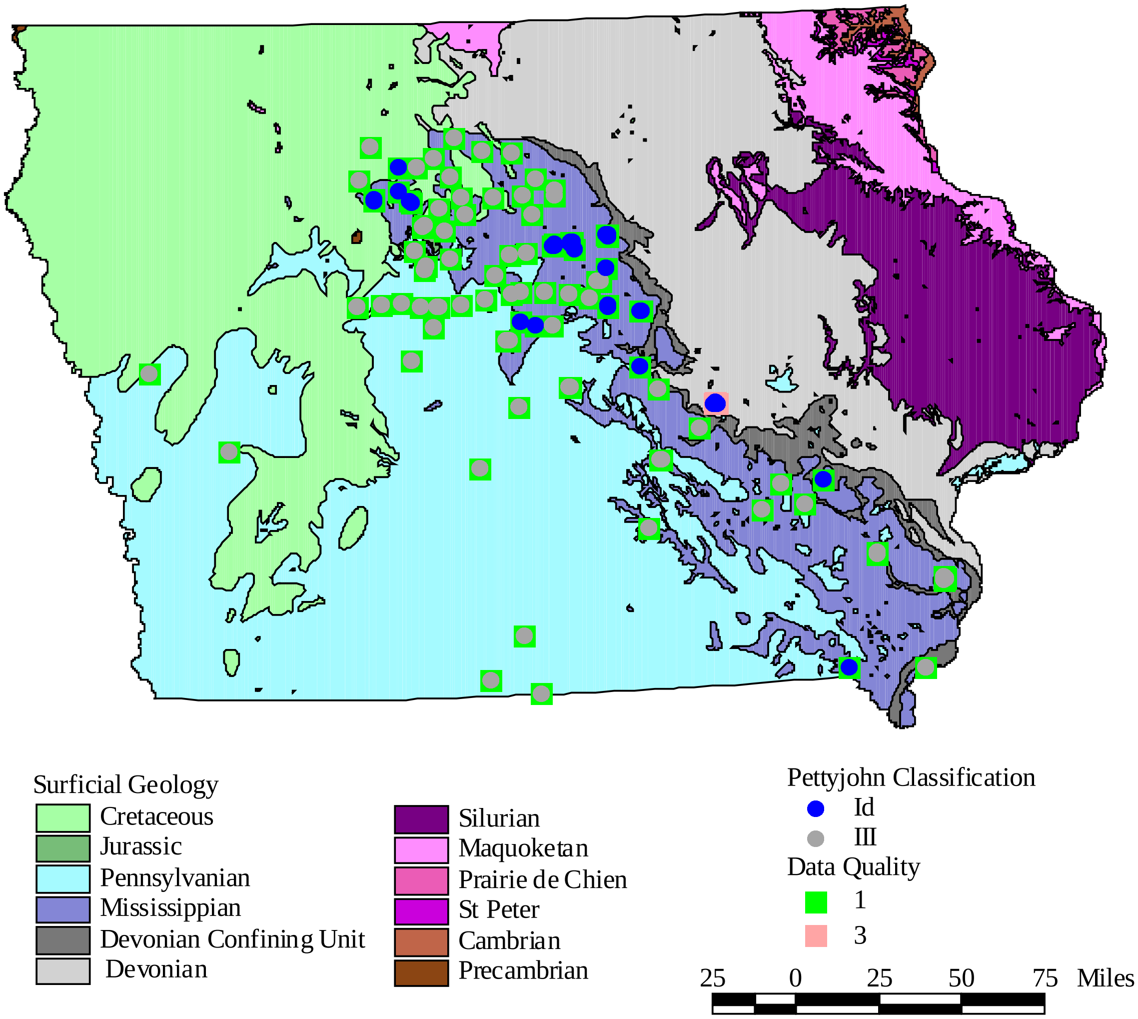

Figure 6. Groundwater wells, by Pettyjohn classification and data quality, that obtain water from the Mississippian aquifer.

and are Class IIIv because they may be deep enough to be confined by the Aquiclude or they may actually be located in the nearby Cretaceous region which is also overlain by a confining unit and is Class IIIv. Therefore, these 2 wells have Quality = 3 and need to be checked.

There are 11 wells that have no source information and are located within the Silurian and Devonian outcrop belts. Of these, 8 wells are also located in thin till areas and are Class Id (Quality = 4). Three of these wells are Class III because they are overlain by thick glacial till (Quality = 4). There is 1 well that has no source information (Quality =

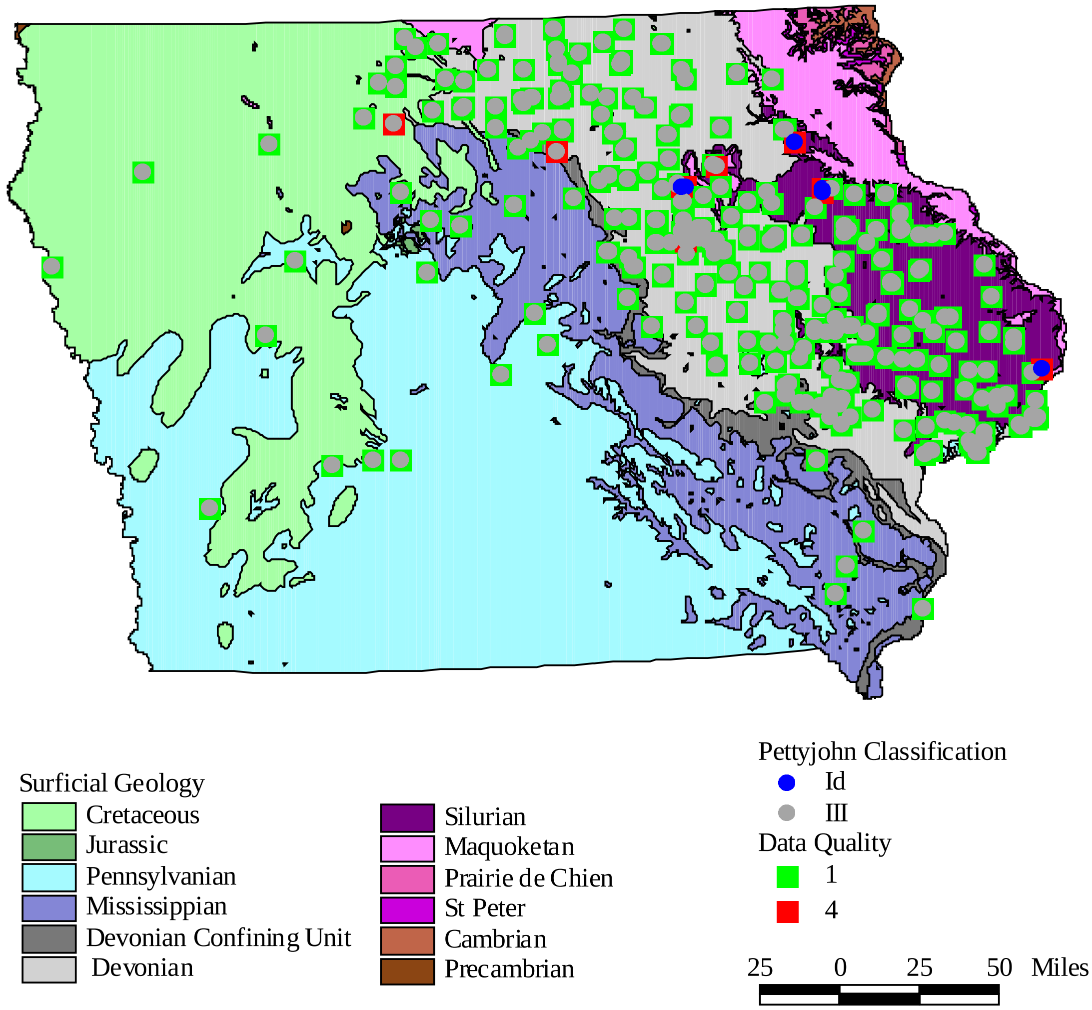

Figure 7. Groundwater wells, by Pettyjohn classification and data quality, that obtain water from the Devonian and Silurian aquifers.

4), but is within the Devonian Confining Unit and has a similar depth to the other wells located in this belt that obtain water from the Silurian/Devonian aquifer, so it is Class IIIv (Quality = 4). Additionally, there is 1 well that has no source information and is located in the Cretaceous outcrop belt, so it is also Class IIIv (Quality = 4) because it has a similar well depth as adjacent wells that obtain water from the Devonian aquifer.

Ordovician/Cambrian Aquifer

There are 293 wells that obtain water from the Ordovician/Cambrian aquifer (Fig. 8). Wells located in the St. Peter (4), Prairie de Chien (1), and Cambrian (6) aquifer outcrop belts are Class IIa because they are in the driftless area and they are high-yield sandstones. Wells located in the Devonian (56) or Silurian (46) outcrop belts are Class III because they are confined by the Maquoketa Aquiclude. Wells located in the Cretaceous outcrop belt (22) are Class IIIv because they are overlain by a confining unit. Wells located in the Maquoketa formation (59) are Class IIIv because the Maquoketa interval is an aquiclude of impermeable material. Wells located in the Mississippian outcrop belt (48) are Class III because the Ordovician and Cambrian aquifers are overlain by the Devonian Aquiclude. Wells located in the Pennsylvanian outcrop belt (51) are also Class III because the aquifers are overlain by the Pennsylvanian Aquiclude. There are 2 wells that obtain water from the Precambrian formation; however, the deepness of these wells is very similar to the Cambrian-sourced wells and they are also located in the Cretaceous outcrop belt. Therefore, these two wells are Class III and Quality = 4 and need to be checked. There are 5 wells that have no source information, are located in the Maquoketa formation, have similar well depths as adjacent wells that obtain water from the Ordovician aquifer. Therefore, these wells are Class IIIv, Quality = 4, and need to be checked.

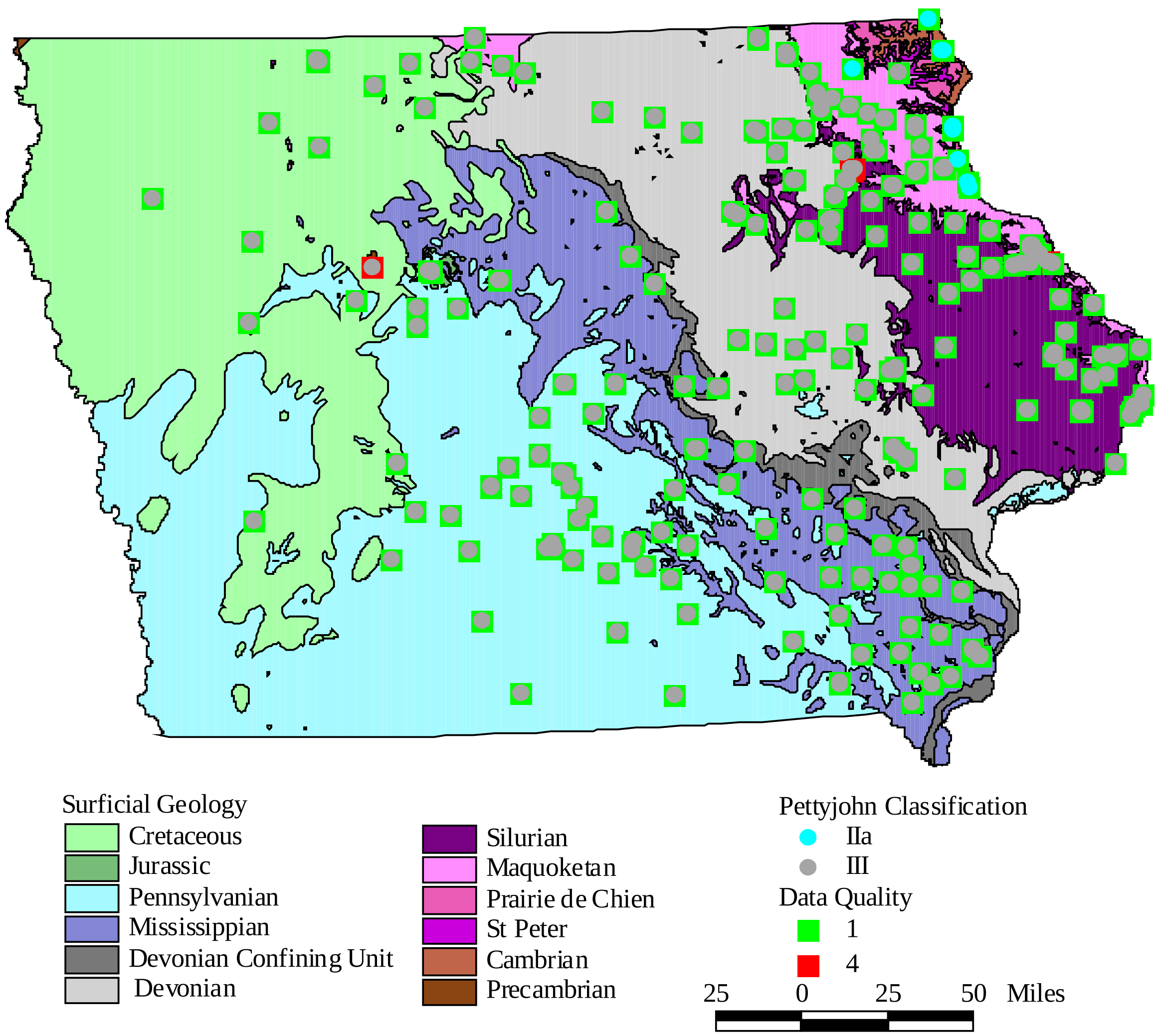

Figure 8. Groundwater wells, by Pettyjohn classification and data quality, that obtain water from the Ordovician and Cambrian aquifers.

Iowa drinking water USAs

The final USAs are derived by selecting all of the Pettyjohn Class Ia, Id, and IIa wells (908) and buffering them by 609.6 meters (which equals 2,000 feet) to create the default Wellhead Protection Areas (Iowa does not have an approved Wellhead Protection Program) (Fig. 9).

In the GIS database, the USAs have "region" topology which means that wells that are closer than 2,000 feet of each other have overlapping polygons and are still identified by each well and all of the associated attributes of each well (Fig. 10). Of the 2,256 public water system groundwater wells in Iowa, 805 were classified as Ia; 103 were classified as Id; and 11 were classified as IIa. Therefore, 40 percent of the public groundwater wells in Iowa were identified as USAs. This high proportion is a result of the importance of the surficial alluvial aquifers and the ability to distinguish the thickness of the glacial till. Additionally, all 84 surface water intakes were classified as USAs.

Data quality is always a concern when performing spatial analysis among various data layers. When identifying the location of wells within alluvial valleys and thin glacial till (1,574) the application of spatial tolerances identified 1,474 wells within the polygons (Quality = 1), 81 were identified within the spatial tolerance (Quality = 2), and 12 were not able to be accurately identified because they were beyond the spatial tolerance (Quality = 3). The most important variable in assessing the Pettyjohn vulnerability classification is the source of the water. There were 29 wells (1.3 percent) that did not have sources and, although these wells need to be checked, they were still classified using the ancillary data layers.

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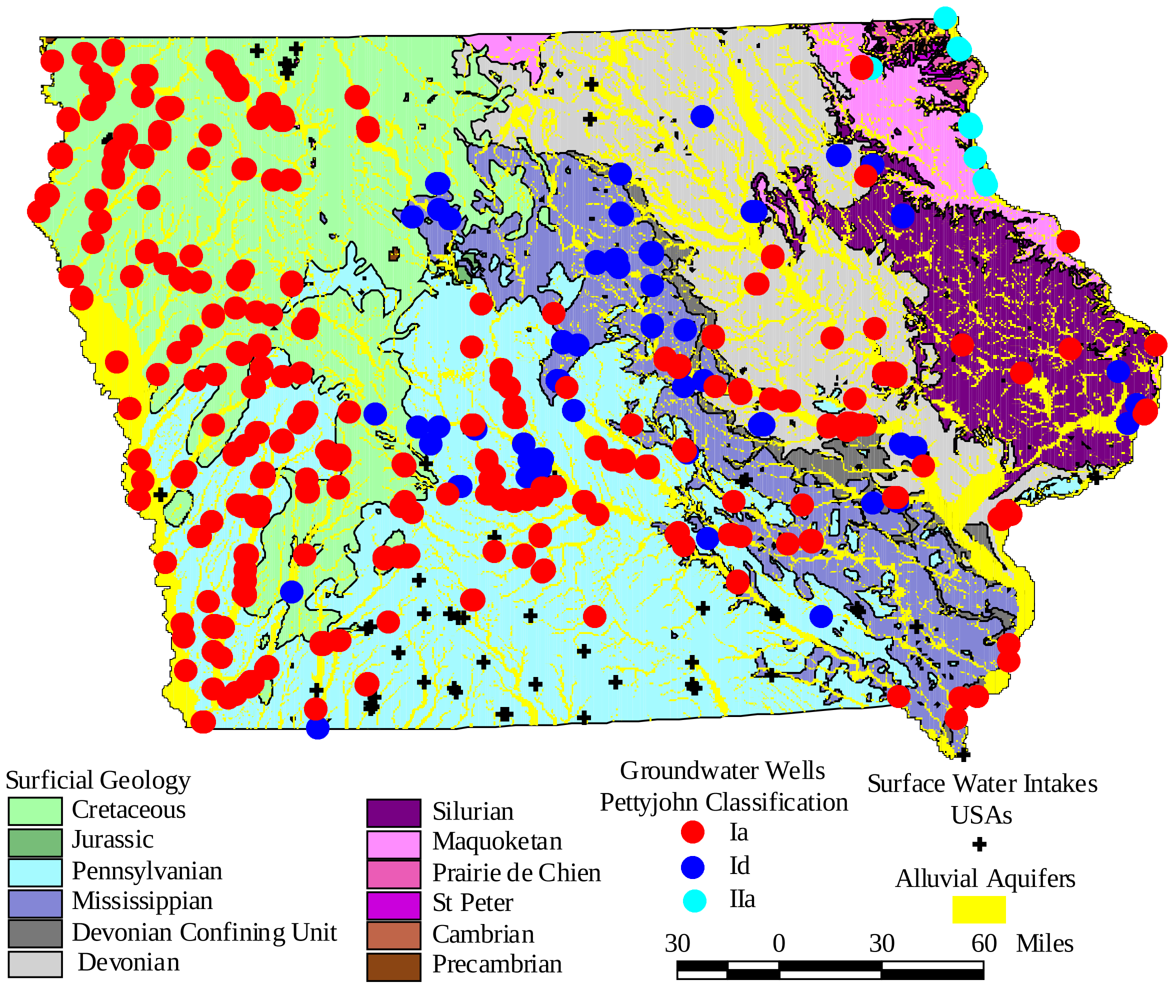

Figure 9. Drinking water surface water intakes and groundwater well USAs, by Pettyjohn classification and geologic formation.

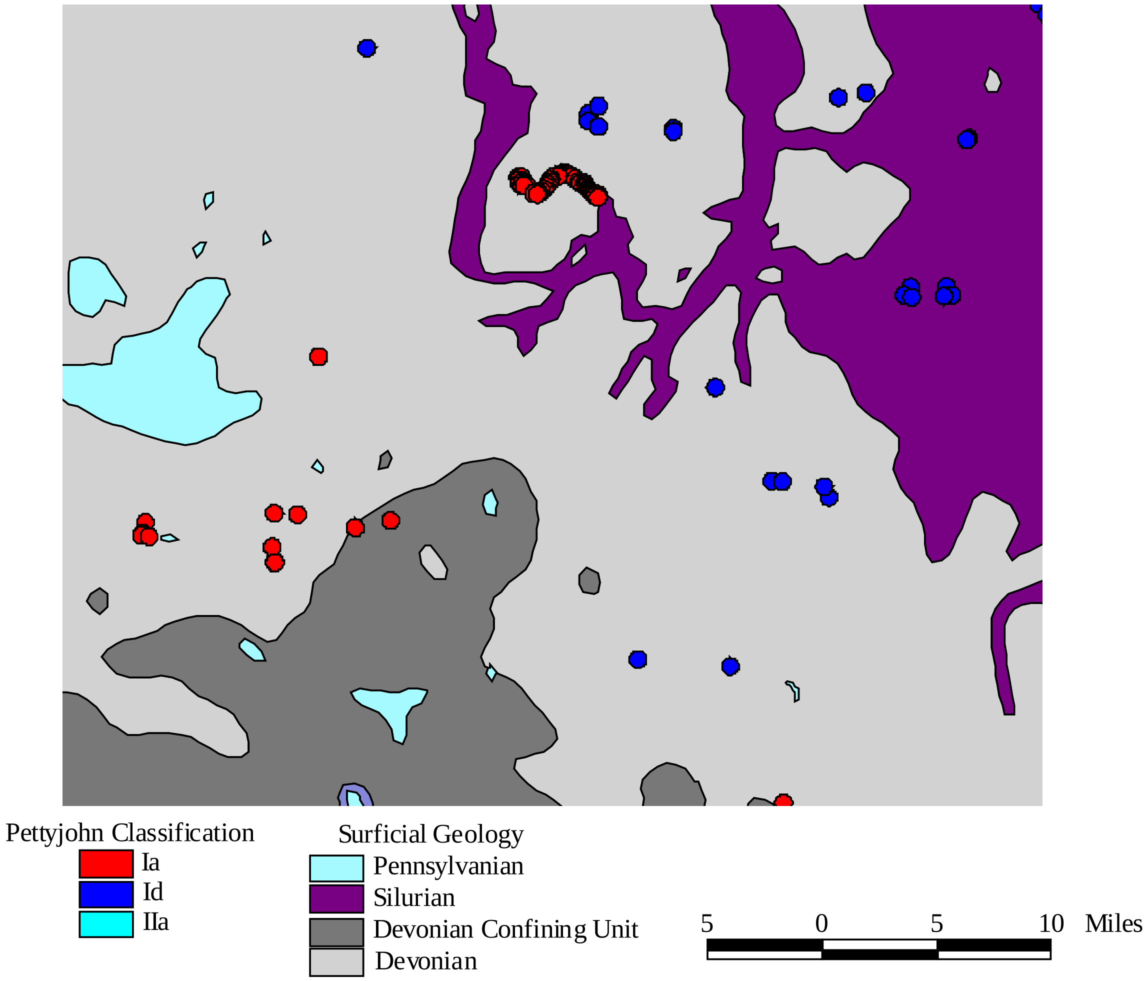

Figure 10. A closer view of the "region" GIS topology illustrating the overlapping groundwater USAs. Note the cluster of wells located in the Silurian outcrop.