STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS

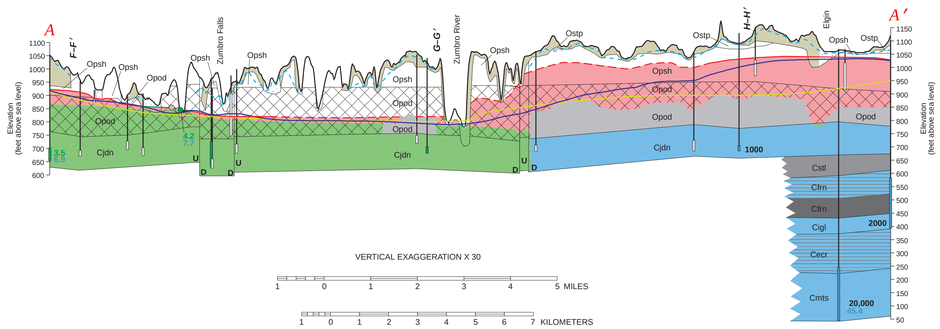
COUNTY ATLAS SERIES
ATLAS C-14, PART B, PLATE 9 OF 10
Hydrogeologic Cross Sections

HYDROGEOLOGIC CROSS SECTIONS

By

Todd A. Petersen

2005



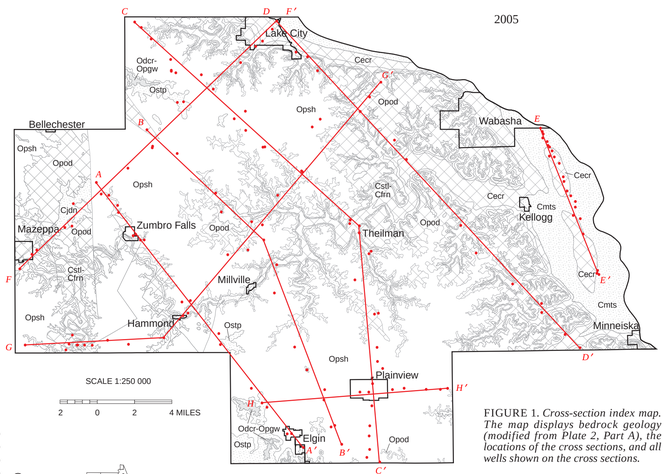


FIGURE 1. *Cross-section index map. The map displays bedrock geology (modified from Plate 2, Part A), the locations of the cross sections, and all wells shown on the cross sections.*

EXPLANATION

Tritium age

Vertical rectangle indicates well screen or open hole of well.

- Recent—Water entered the ground since about 1953 (10 or more tritium units).
- Mixed—Water is a mixture of recent and vintage waters (greater than 1 tritium unit to less than 10 tritium units).
- Vintage—Water entered the ground before 1953 (less than or equal to 1 tritium unit).
- Well not sampled for tritium.

Potentiometric surface

- Perched water table

Color indicates aquifer; dashed line indicates position is uncertain.

- Quaternary water table
- Prairie du Chien
- Jordan
- Combined St. Lawrence, Franconia, and Ironton-Galesville*

**Ironton-Galesville may be a separate aquifer, but the data are similar enough to combine these units to create a potentiometric surface for illustrating ground-water flow.*

Aquifer characteristics of lithologic units

Moderate to high conductivity under both shallow and deep bedrock conditions

- Sand and gravel deposits
- St. Peter Sandstone (Ostp)
- Shakopee Formation (Opsh)
- Jordan Sandstone (Cjdn)
- Mt. Simon Sandstone (Cmts)
- Fond du Lac Formation (Pmfl)

Moderate to high conductivity under shallow bedrock conditions. Low conductivity or confining under deep bedrock conditions. Crosshatch pattern denotes fractured or faulted condition, indicating enhanced hydraulic conductivity.

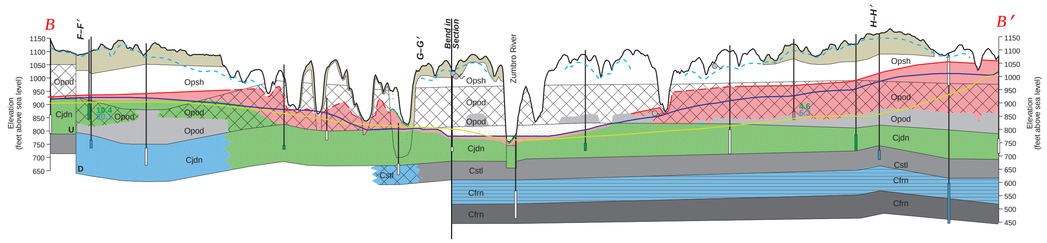
- Oneota Dolomite (Opod)
- St. Lawrence Formation (Cstl)
- Franconia Formation (Cfrn)
- Ironton-Galesville Sandstone (Cigl)
- Eau Claire Formation (Cecr)

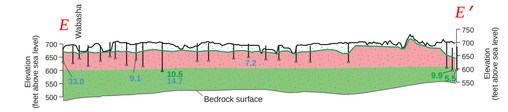
Confining units

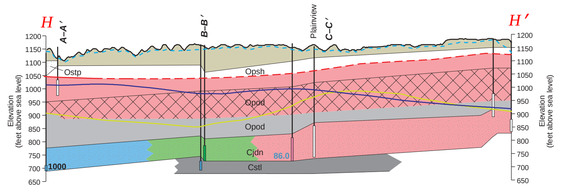
- Glacial till
- Franconia Formation - lower (Cfrn) (shown only on cross sections)

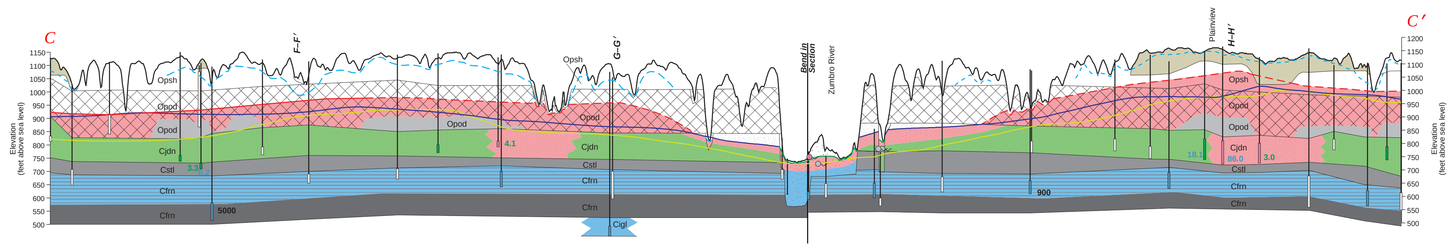
Cross-section symbols and labels

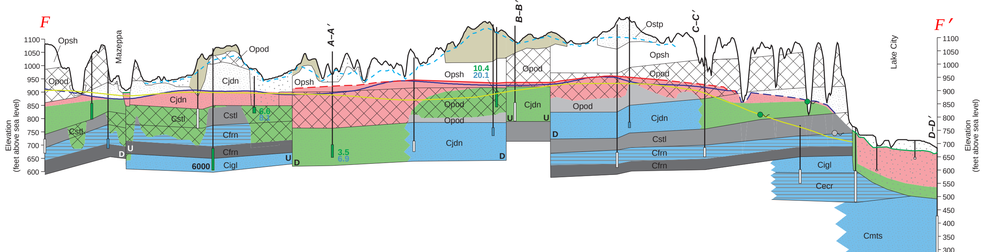
- **Spring; color indicates tritium age.**
- D — Fault—Approximately located; downthrown side.
- U — Fault—Approximately located; upthrown side.
- 5.5 — If shown, nitrate-nitrogen concentration equals or exceeds 3 parts per million.
- 9.1 — If shown, chloride concentration equals or exceeds 5 parts per million.
- 2000 — If shown, ground-water age in years, estimated by carbon-14 isotope analysis.

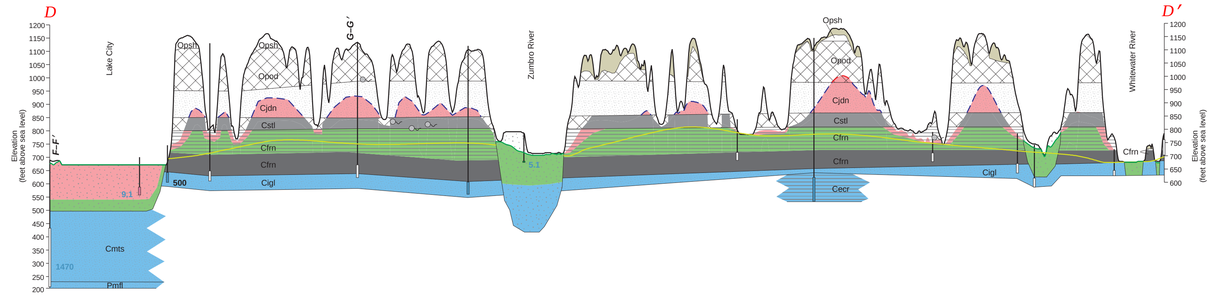


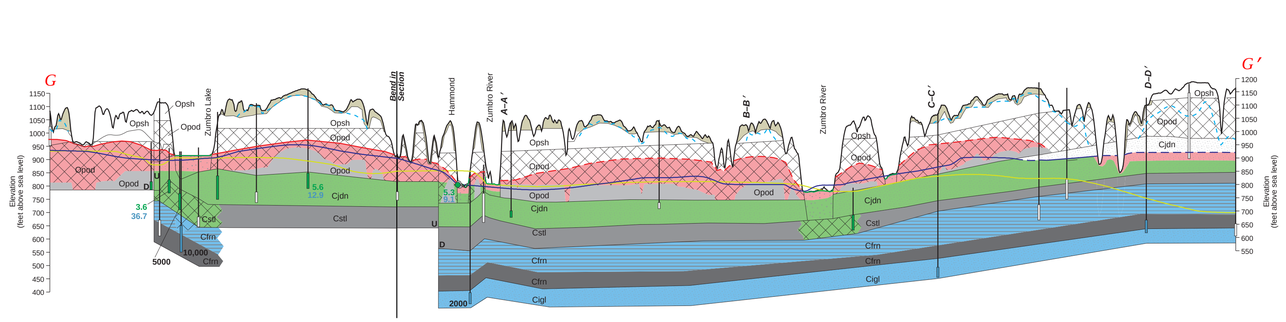












INTRODUCTION

The eight hydrogeologic cross sections shown on this plate illustrate the horizontal and vertical extent of hydrogeologic units (aquifers and confining units), ground-water residence time, and water-table and potentiometric surface profiles. The cross-section locations were selected to show the faulting in the western part of the county and the influence of the Zumbro River on the hydrogeologic system. These cross sections pass through as many sampled wells as possible to show the associated tritium and general chemistry data. The cross sections were constructed using a combination of well data from the County Well Index (CWI) and information from Bedrock Geology (Plate 2) and Surficial Geology (Plate 3) in Part A. Because of similar geology in Goodhue and Wabasha counties, the analysis and description on this plate are similar to the analysis and description on Plate 8, Part B of the Geologic Atlas of Goodhue County (Berg, 2003). The locations of wells and cross sections are shown in Figure 1. The well information for each cross section was projected onto the trace of the cross-section line from distances no greater than 1 mile.

Wabasha County has a very complex hydrogeology because of significant topographic relief, karst features, and faults. Most of the county is topographically high upland that is dissected by the deeply incised Zumbro and Mississippi River valleys. There is very little Quaternary cover over the bedrock aquifers resulting in rapid recharge and discharge of ground water in the shallow units. As shown by the potentiometric surface lines in the cross sections, ground water is recharged in the upland areas and discharged to the Zumbro and Mississippi River valleys. In the upland areas, much of the uppermost bedrock is unsaturated. The water table in the uppermost bedrock aquifer in the upland areas may be 100 feet or more below land surface.

RELATIVE HYDRAULIC CONDUCTIVITY

Runkel and others (2003) have found that weathering and fractures significantly increase hydraulic conductivity for some bedrock units in southeastern Minnesota when they are buried by less than 200 feet of overlying bedrock. Thus, they suggest that rock units within 200 feet of the bedrock surface are under shallow bedrock conditions and have higher permeability; those buried more deeply are under deep bedrock conditions where units generally have fewer fractures and much less secondary porosity.

The various aquifers and confining units shown on these cross sections are classified according to the regional average of hydraulic conductivity and whether they are under shallow or deep conditions (Runkel and others, 2003; Runkel, unpub. data, 2004). The Quaternary sand and gravel, Shakopee, Jordan, and Mt. Simon aquifers have moderate to high hydraulic conductivity everywhere. The Oneota, St. Lawrence, Franconia, Ironton-Galesville, and Eau Claire aquifers have moderate to high hydraulic conductivity only when under shallow conditions where weathering and fractures have increased the permeability. The lower St. Lawrence and upper Franconia Formations and the Ironton and Galesville Sandstones are aquifers under both shallow and deep conditions, but they are much more productive under shallow conditions because of increased secondary porosity.

The confining units include glacial till, the Oneota Dolomite (under deep conditions), the St. Lawrence Formation (under deep conditions), and the lower portion of the Franconia Formation. These units have low or very low vertical hydraulic conductivities. The tritium data suggest that the till may permit surface water to flow into the underlying aquifers in less than 50 years, so it should be classified as a leaky confining unit. Runkel and others (2003) suggest that deep occurrences of the St. Lawrence Formation are an aquifer in some locations and a confining unit in other locations. In Wabasha County, the St. Lawrence Formation is used as an aquifer primarily under shallow conditions. Very few wells are completed in the St. Lawrence Formation where it occurs under deep conditions. Under deep conditions, it protects the underlying Franconia Formation. Most water samples from the Franconia Formation below the St. Lawrence Formation (under deep conditions) were vintage age based on tritium data. The lower portion of the Franconia may be an effective confining unit under both shallow and deep conditions (Runkel, written commun.). Its low vertical conductivity can act as a protective barrier to downward vertical flow and a barrier to keep the underlying aquifers in a confined condition; however, fractures near bluff edges may allow water to move through this unit.

WATER TABLE AND POTENTIOMETRIC SURFACES

Several different water table and potentiometric surfaces are shown on the cross sections. The light blue dashed line identifies the perched water table in the upland areas. The perched water-table lines are elevation profiles derived from the water-table digital elevation model, which was used to create the modeled depth to ground water (Figure 4, Plate 8). The first bedrock aquifer (usually the Prairie du Chien) is mostly unconfined. The deeper aquifers are generally confined in the upland recharge areas, but sometimes become unconfined in the bluffs at the edges of the Mississippi and Zumbro River valleys .

GROUND-WATER RESIDENCE TIME

The pink, green, and blue areas shown in these cross sections represent the age of the ground water, also known as ground-water residence time. This is the approximate time that has elapsed from the moment the water infiltrated the land surface to the time it was pumped from the aquifer. Tritium is a naturally occurring isotope of hydrogen. Concentrations of this isotope were greatly increased between about 1953 and 1963 by above-ground nuclear tests (Alexander and Alexander, 1989). Nuclear power plants are a continuing source of low-level tritium today (Scott Alexander, written commun.). This isotope decays at a known rate (half-life of 12.43 years). Because of this, the proportion of recently recharged water (within about the last 50 years) can be estimated based on its tritium content. Water samples with tritium concentrations of 10 or more tritium units (TU) are considered to be recent water, entering the ground in about the last 50 years. Water samples with tritium concentrations of 1 TU or less are classified as vintage water, which entered the ground before about 1953. Water samples with tritium concentrations greater than 1 TU and less than 10 TU are considered mixed waters. They are a mixture of vintage and recent waters. When tritium data are not available, other geochemical indicators such as chloride concentration, nitrate concentration, or the chloride to bromide (Cl/Br) ratio can be used to estimate ground water age.

Ground-water age for the vintage samples can be better estimated by sampling for the carbon-14 (^{14}C) isotope. Carbon-14 is a naturally occurring isotope of carbon, with a half-life of 5730 years. Carbon-14 is used to estimate ground-water residence time between 100 years and 40,000 years. Of 12 wells sampled for carbon-14 in this study, the estimated ground-water ages ranged from 500 years to 20,000 years. Water samples from the Ironton-Galesville aquifer near the Mississippi River valley were the youngest of the samples age-dated by carbon-14 (500 years at Lake City and 800 years at Minneiska). The oldest samples were from the Mt. Simon aquifer (both 20,000 years). Water samples from the Franconia and Franconia-Ironton-Galesville aquifers ranged from 900 years to 10,000 years old. The one sample from the St. Lawrence aquifer is dated at 5000 years.

In samples from clusters or nests of wells, the shallower samples were younger than the deeper samples. The specific ages depended on the ground-water flow in each local area. On cross-section A–A′ near Elgin, water from the Jordan aquifer was dated at 1000 years, deeper water from the Franconia-Ironton-Galesville aquifer was dated at 2000 years, and water from the deep Mt. Simon aquifer was dated at 20,000 years. In the Zumbro Lake area on the west end of cross section G–G′, the water sample from the St. Lawrence aquifer was dated at 5000 years, and the deeper water sample from the Franconia-Ironton-Galesville aquifer was dated at 10,000 years. A third example of this occurred in Minneiska, where the water sample from the Ironton-Galesville aquifer was dated at 800 years, and the deeper water sample from the Mt. Simon was dated at 20,000 years (Plate 10). All three areas provide indications that the deepest water is moving slowly in a regional flow system.

The shallowest ground water, with more than 10 TU content, is less than about 50 years old. The next deepest layer of ground water is a zone with mixed tritium age; it is a mixture of recent and vintage age water. The deepest potable ground water (from the Mt. Simon aquifer) is up to 20,000 years old. The deepest water sample, from the Fond du Lac aquifer at the Lake City old number 3 well (cross-sections D–D′ and F–F′), was not analyzed for carbon-14. That sample has a chloride content of 1470 parts per million (ppm) compared with a few ppm in most other wells. The elevated chloride may result from mixing with deep saline water that is probably too old to date with the carbon-14 method.

UPLAND AREA

The upland areas (Figure 1, Plate 8) are predominantly ground-water recharge zones. Most water wells are completed in bedrock aquifers. The Prairie du Chien aquifer usually occurs under shallow bedrock conditions, and 81 percent of wells (17 of 21) completed in the Prairie du Chien (with static water-level information available) are unconfined. The overlying Quaternary sediments may contain a perched water table. The Shakopee Formation is a good aquifer where it is saturated. The Oneota Dolomite is more complex. The entire thickness of the Oneota Dolomite is in shallow bedrock conditions near the bluff edges and in some recharge zones like the one south of Plainview (cross-section C–C′). In areas where the bottom portion of the Oneota Dolomite is greater than 200 feet below the top of bedrock (deep conditions), it appears to act as a good confining unit. The Jordan aquifer beneath confining Oneota Dolomite usually has vintage water or pumping tests that indicate confined behavior. A pumping test by the Minnesota Department of Health (unpub. data, 2000) indicates that the Oneota Dolomite at Plainview well number 2 strongly confines the Jordan aquifer at that location. But tritium data from that well (Minnesota Department of Health, oral commun., 2004) and chemistry data from that well and surrounding wells indicate that recent water is reaching the well.

It is not entirely clear why the Jordan aquifer near Plainview has such recent water, yet behaves as a strongly confined aquifer when pumped. The Plainview area is a potentiometric high in all of the bedrock aquifers with a downward hydraulic gradient (cross-section C–C′). Just south of Plainview, the entire Oneota Formation is less than 200 feet below the top of the bedrock. The formation, therefore, is under shallow bedrock conditions (Runkel and others, 2003) and has enhanced permeability. Wells with open holes crossing both the Prairie du Chien and Jordan formations and ungrouted Jordan wells are in the area. High-capacity pumping from the Jordan aquifer could increase the downward hydraulic gradient. Some or all of these factors may explain the tritium, chloride, and nitrate anomalies near Plainview. Regardless of the precise mechanism, the Jordan aquifer near Plainview is highly susceptible to anthropogenic (human-influenced) contamination from the land surface and appears to be well connected to surface recharge.

Areas where much more than 200 feet of bedrock and intact Oneota Dolomite overlie the Jordan Sandstone usually have vintage water in the Jordan aquifer and below. For example, see the northern end of cross-section B–B′ or the southern end of cross-section A–A′. In these areas, the unweathered Oneota Dolomite is sufficiently thick above the Jordan aquifer to act as a confining unit and protect the aquifer from downward ground-water movement.

Zumbro Falls city well number 4 (completed in the Jordan Sandstone) on cross-section A–A′ is an example of Oneota Dolomite under shallow bedrock conditions. This area, which is also near a bluff edge and faults, has mostly mixed tritium age ground water from the Jordan aquifer because the overlying Oneota Dolomite provides little protection from ground-water infiltration from the surface.

The Franconia Formation exists under deep bedrock conditions throughout most of the county. On the western side of the county, the Franconia is under shallow bedrock conditions where faulting and erosion have brought this formation closer to the surface. This shallow condition, in concert with the faults, has allowed recent water to penetrate more deeply into the unit than it would without weathering.

RIVER VALLEY AREAS

The two major river valleys in the county (the Mississippi and Zumbro) are important ground-water discharge zones for the bedrock aquifers. The Quaternary sand and gravel aquifer that largely fills these valleys is an important source of drinking water in the Zumbro River valley, where bedrock aquifers are also used, and the primary source of drinking water in the Mississippi River valley.

Most wells in the western portion of the Zumbro River valley are completed in bedrock aquifers; a few wells in this area are completed in Quaternary sediment. Most wells completed in the Quaternary in the Zumbro River valley are between Theilman and Kellogg. Only two wells were tested for tritium in the Zumbro River valley, and both indicated mixed water (TU values of 9 and 9.9).

Most wells in the Mississippi River valley are completed in Quaternary sand and gravel. They were assumed to be readily recharged from precipitation and most were not tested for tritium. Of the two that were tested, one had 7.3 TU and the other had 11.1 TU (mixed and recent water, respectively). In the absence of tritium data, other geochemical indicators were used to determine the age of the ground water in these sand and gravel aquifers. Nitrate, chloride, and the Cl/Br ratio are all good indicators of anthropogenic contamination from the surface. Data gathered in the county indicate that nitrate concentrations greater than 3 parts per million (ppm) measured as nitrogen, chloride concentrations greater than or equal to 5 ppm, and Cl/Br ratios greater than about 400 correlate with recent or mixed tritium concentrations and indicate relatively recent recharge from the surface. A comparison of chloride versus tritium is presented in Figure 4, Plate 10. Data gathered elsewhere indicate that a Cl/Br ratio greater than about 500 implies relatively recent recharge from the land surface (S.A. Alexander, unpub. data, 2004). These geochemical indicators are not always present in recent water, but they are a good option for estimating recent recharge in ground water in the absence of tritium data. Of the 11 wells sampled for chemistry in the Mississippi River valley, 10 had chloride concentrations greater than 5 ppm, nine had Cl/Br ratios greater than 400, and three had nitrate concentrations greater than 3 ppm measured as nitrogen.

REFERENCES CITED

Alexander, S.C., and Alexander, E.C., Jr., 1989, Residence times of Minnesota groundwaters: Minnesota Academy of Sciences Journal, v. 55, no. 1, p. 48–52.

Berg, J.A., 2003, Hydrogeologic cross sections [Plate 8], *in* Geologic Atlas of Goodhue County, Minnesota: Minnesota Department of Natural Resources County Atlas Series C–12, Part B, Plate 1:150,000.

Runkel, A.C., Tipping, R.G., Alexander, E.C., Jr., Green, J.A., Mossler, J.H., Alexander, S.C., 2003, Hydrogeology of the Paleozoic bedrock in southeastern Minnesota: Minnesota Geological Survey, Report of Investigations 61, 105 p., 2 pls.

The DNR Information Center

Twin Cities: (651) 296-6157
Minnesota Toll Free: 1-888-646-6367
Telecommunication Device for the Hearing Impaired (TDD): (651) 296-5484
TDD Minnesota Toll Free: 1-800-657-3929
DNR Web Site: http://www.dnr.state.mn.us

This information is available in an alternative format on request.

This map was compiled and generated using geographic information systems (GIS) technology. Digital data products, including chemistry and geophysical data, are available from DNR Waters at http://www.dnr.state.mn.us/waters.
This map was prepared from publicly available information only. Every reasonable effort has been made to ensure the accuracy of the factual data on which this map interpretation is based. However, the Department of Natural Resources does not warrant the accuracy, completeness, or any implied uses of these data. Users may wish to verify critical information; sources include both the references here and information on file in the offices of the Minnesota Geological Survey and the Minnesota Department of Natural Resources. Every effort has been made to ensure the interpretation shown conforms to sound geologic and cartographic principles. This map should not be used to establish legal title, boundaries, or locations of improvements.
Digital base composite:
Roads and county boundaries - Minnesota Department of Transportation GIS Statewide Base Map (source scale 1:24,000)
Hydrologic features - U.S. Geological Survey Digital Line Graphs (source scale 1:100,000)
Digital base annotation - Minnesota Geological Survey
Project data compiled from 2003 to 2004 at a scale of 1:100,000. Universal Transverse Mercator projection, grid zone 15, 1983 North American datum. Vertical datum is mean sea level.
GIS and cartography by Todd Petersen and Greg Massaro. Edited by Nick Kroska.

GEOLOGIC ATLAS OF WABASHA COUNTY, MINNESOTA