STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS

BEDROCK HYDROGEOLOGY

By

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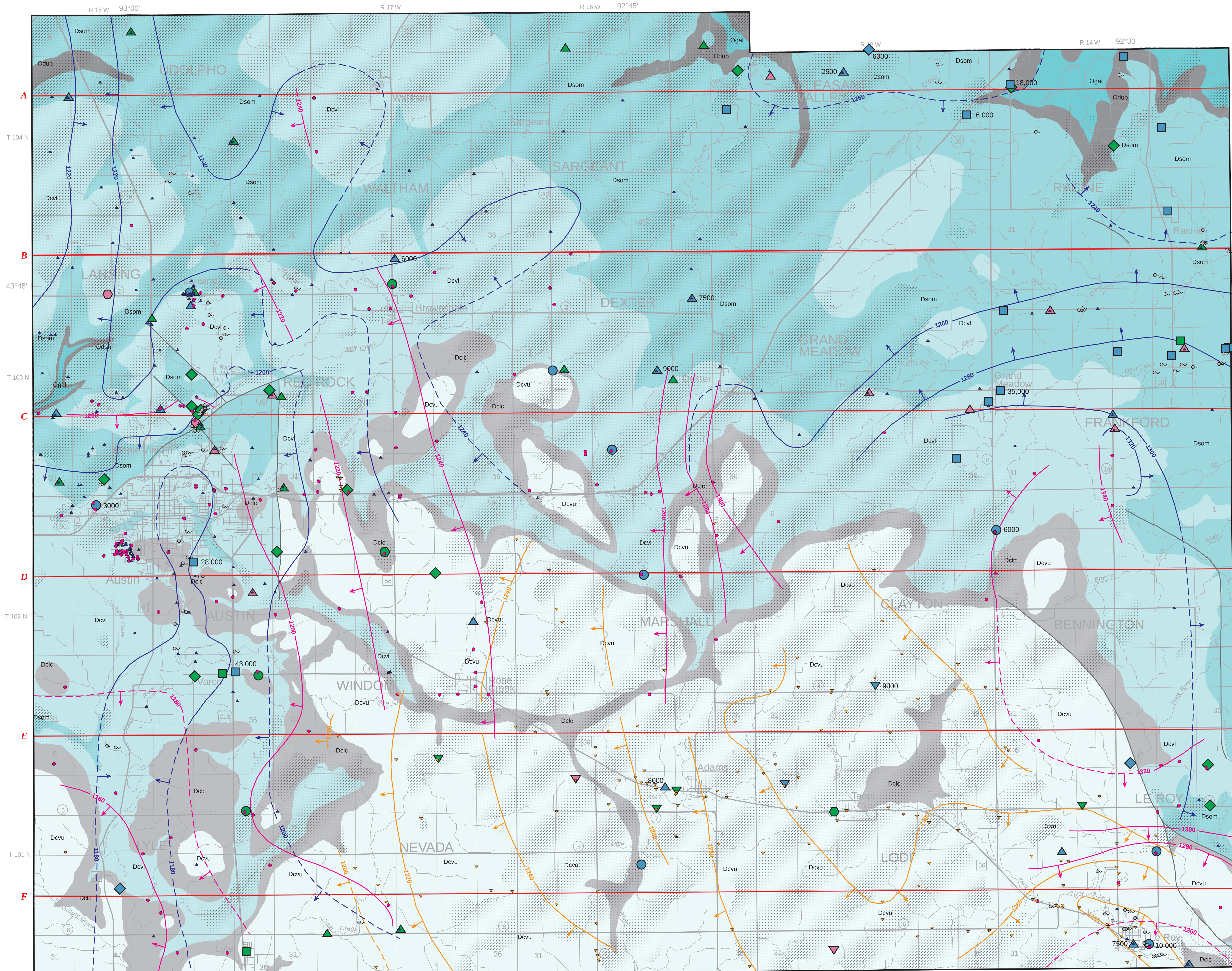


Digital base map composite:
Roads and county boundaries—Minnesota Department of Transportation GIS Statewide Base Map (source scale 1:24,000)
Hydrologic features—U.S. Geological Survey Digital Line Graphs (source scale 1:100,000)
Digital base map annotation—Minnesota Geological Survey.

Project data compiled from 1997 to 2001 at the scale of 1:100,000. Universal Transverse Mercator projection, grid zone 15, 1983 North American datum. Vertical datum is mean sea level.

GIS data and metadata available through the DNR Waters website: http://www.dnr.state.mn.us/waters

SCALE 1:100 000

1 0 1 2 3 4 5 MILES

1 0 1 2 3 4 5 6 7 8 KILOMETERS

MAP EXPLANATION

Well Symbols

Shape indicates aquifer type

- Quaternary
- Upper Cedar Valley
- Lower Cedar Valley
- Spillville-Maquoketa
- Galena Group
- St. Peter-Prairie du Chien-Jordan

Color indicates tritium age

- Recent—Waters with tritium concentrations of 10 tritium units (TU) or more entered the ground water since 1953.
- Mixed—Waters with 0.8 to 10 TU are a mixture of recent and vintage.
- Vintage—Waters with less than 0.8 TU entered the ground water before 1953.

Well Label

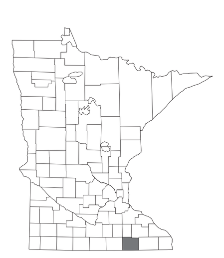
30,000 If shown, ground-water age in years, estimated by carbon-14

Map Symbols

- Fault line
- Spring

Uppermost Bedrock Aquifers and Confining Units

Aquifer or confining unit	Symbol
Greater than 75 feet of till cover	
Upper Cedar Valley aquifer	Dcvu
Chickasaw shale	Dclc
Lower Cedar Valley aquifer	Dcvl
Spillville-Maquoketa aquifer	Dsom
Dubuque Formation	Odub
Galena Group aquifer	Ogal



LOCATION DIAGRAM

Potentiometric Contour

1200 *Upper Cedar Valley*
1200 *Lower Cedar Valley*
1200 *Spillville-Maquoketa*

Potentiometric contour of aquifers in feet above mean sea level—Contour interval is 20 feet. Dashed where contour is uncertain. Arrow indicates general direction of ground-water movement.

Upper Cedar Valley
Lower Cedar Valley
Spillville-Maquoketa

Wells measured for static water level

MULTIAQUIFER SYSTEM IN DEVONIAN AND UPPER ORDOVICIAN BEDROCK IN MOWER COUNTY

Most of the previous hydrogeologic studies in Mower County describe a single, thick bedrock aquifer underlying the county. This study presents the Devonian and upper Ordovician bedrock as a sequence of carbonate aquifers separated by shale units. Hydrogeologists in Iowa (Libra and Hallberg, 1985) first classified the rocks as regionally extensive carbonate and shale units that compose a regional system of aquifers and confining units. John Mossler used this approach to classify the stratigraphy of these carbonates and shales on Plate 2, Part A. Green and others (1997) also described these rock units as aquifers and confining units similar to those in Iowa. Pump test data and residence time information in this study supported this approach to characterizing the carbonate and shale units. This approach also has practical benefits. With approval from the Minnesota Department of Health, wells may be completed in some shallow carbonate units beneath regional shale units. This change would reduce required depths of well completion by 300 feet to 500 feet and reduce construction costs by several thousand dollars per well.

The information below includes the rock unit name, aquifer symbol (where applicable, boldface in parentheses), bedrock symbol (in parentheses), and details about the rock units. A geologic column and more information about these aquifers are in the Technical Appendix.

Upper Cedar Valley Aquifer (Dcvu) (Dcuu and Dcum)**.** The Lithograph City Formation, the Coralville Formation, and the Hinkle and Eagle Center Members of the Little Cedar Formation form a shallow bedrock aquifer. The Lithograph City unit contains many joints, fractures, and bedding planes enlarged by solution resulting in a well-developed conduit network and high permeability (Green and others, 1997). The Coralville unit contains shale beds that may be several feet thick but are discontinuous (Libra and Hallberg, 1985). Most permeability in this aquifer is fracture related, with water moving through joints or bedding planes. The lower part of the aquifer has less solution-related permeability than the Lithograph City. This aquifer is up to 110 feet thick.

Chickasaw Shale (Dclc)**.** This silty shale has low permeability and hydrologically separates the Upper Cedar Valley above from the Lower Cedar Valley underneath. It has been mapped on Plate 2, Part A, and is clearly shown on the gamma log in the Technical Appendix. In western Mower County, buried stream valleys dissect it. This unit is 36 feet to 43 feet thick in southeastern Mower County and 15 feet to 20 feet thick in western Mower County.

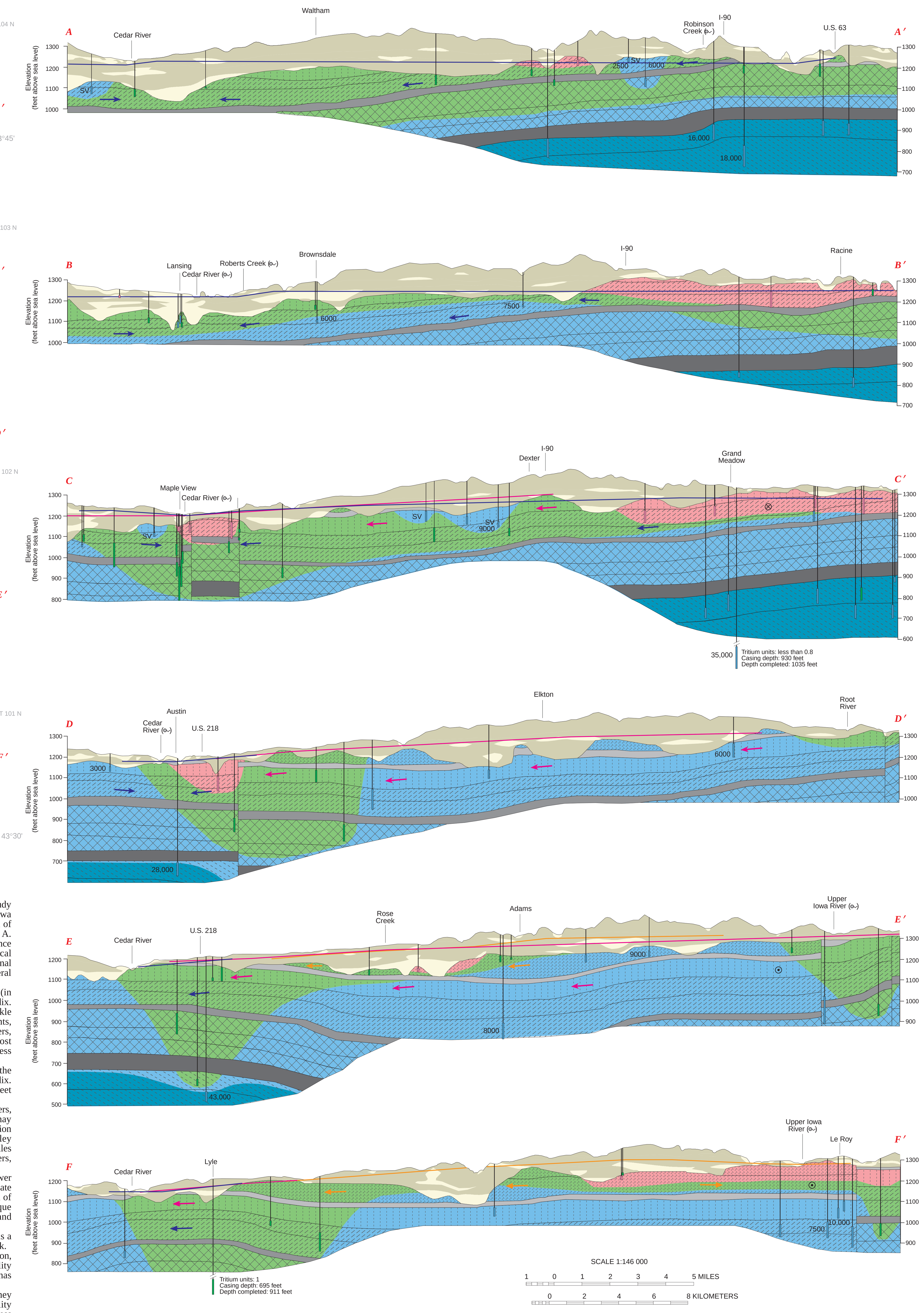
Lower Cedar Valley Aquifer (Dcvl) (Dclp)**.** The Bassett Member of the Little Cedar Formation forms a thin aquifer (Green and others, 1997) and is 40 feet to 70 feet thick. The upper and lower parts of the Pinicon Ridge Formation contain shale and shaly dolostone that may act as confining units. The Pinicon Ridge Formation is 20 feet to 47 feet thick. These shaly units were not mapped in Part A, and the distribution of data for this study is inconclusive regarding the ability of the Pinicon Ridge shales to hydrologically separate the Lower Cedar Valley aquifer from the underlying Spillville-Maquoketa aquifer. However, results from a pump test in Le Roy provide local evidence that the shales from the Pinicon Ridge do separate the Lower Cedar Valley aquifer from the underlying Spillville-Maquoketa aquifer (Green and others, 1997).

Spillville-Maquoketa Aquifer (Dsom) (Dspl and Omaq)**.** The Spillville and Maquoketa formations form a single aquifer unit in Mower County. The porosity and permeability in the upper part of the Spillville is due to fractures and in the lower part is due to fossil features (Plate 2, Part A). The upper part of the Maquoketa has extensive fracturing possibly because of exposure at the surface before the deposition of the overlying Spillville Formation. The lower part of the Maquoketa has many thin shale units and grades into the underlying Dubuque Formation, which together hydrologically separate the Spillville-Maquoketa aquifer from the Galena Group aquifer. The Spillville and Maquoketa formations together are up to 170 feet thick.

Dubuque Formation (Odub)**.** This formation consist of limestone interbedded with thin to medium beds of calcareous shale. It is a confining unit that separates the overlying Spillville-Maquoketa aquifer from the underlying Galena aquifer and is 23 feet to 35 feet thick.

Galena Group Aquifer (Ogal) (Ogal)**.** The Galena Group, which is an important regional aquifer, comprises the Stewartville Formation, Prosser Limestone, and Cummingsville Formation. The Stewartville and Prosser both have more well-developed porosity and permeability than the Cummingsville and form an aquifer. The greatest permeability of the group occurs where the aquifer is near the surface and has well-developed karst features. Total thickness of this group is 200 feet to 205 feet.

Decorah Shale–Platteville Formation–Glenwood Formation (Odpg)**.** These three formations are treated collectively because they are found between two extensive regional aquifers. Only the Decorah Shale and Glenwood Formation have predictable low-permeability characteristics. They effectively separate the Galena Group aquifer from the underlying St. Peter Sandstone and have a combined thickness of 45 feet to 50 feet. The Platteville Formation is a thin limestone aquifer (30 feet thick) between the Decorah Shale and the Glenwood Formation. Although it is not heavily used for water supply, the Glenwood Formation can transport large quantities of water.



CROSS-SECTION EXPLANATION

- Recent—Water entered the ground since 1953 (10 or more tritium units). Well screen color shows recent water.
- Mixed—Water is a mixture of recent and vintage waters (0.8 to less than 10 tritium units). Well screen color shows mixed water.
- Vintage—Water entered the ground before 1953 (less than 0.8 tritium units). Well screen color shows vintage water.
- Very old—Water with carbon-14 age greater than 10,000 years before present. Well screen color shows vintage water.

Potentiometric Contour

In feet above mean sea level. Contour interval is 20 feet. Arrow indicates general direction of ground-water movement

- Upper Cedar Valley
- Lower Cedar Valley
- Spillville-Maquoketa

Cross-Section Symbols

18,000	If shown, ground-water age in years, estimated by carbon-14
SV	Vintage water shallower than mixed water
	Spring associated with stream
	Ground-water flow into the cross section
	Ground-water flow out of the cross section

Geologic Units and Aquifers

- Sand and gravel deposits
- Undifferentiated till
- Upper Cedar Valley aquifer
- Chickasaw shale
- Lower Cedar Valley aquifer
- Spillville-Maquoketa aquifer
- Dubuque Formation
- Galena Group aquifer
- Decorah-Platteville-Glenwood map unit*
- St. Peter-Prairie du Chien-Jordan aquifer

*The Decorah Shale and Glenwood Formation both act as confining units, but the intervening Platteville Formation is a thin aquifer. Combined, these units are treated as a confining unit.

Characterization of Bedrock Hydrogeology

This plate displays the Mower County aquifer system in map and cross-section views. This presentation provides practical information about the hydrogeology in the county, which is crucial to understanding ground-water supply and management issues. The information also was essential to the development of the pollution sensitivity map on Plate 9. Concepts that require more detailed explanation are discussed on Plate 8 and in the Technical Appendix.

The interpretation of the bedrock hydrogeology was modified from a historical one-aquifer system to a sequence of several aquifers and confining units. This approach has been used by hydrogeologists in Iowa and Minnesota (see Plate 2, Part A). The presence of regional shale confining units provides protection from surface contamination in areas with limited, low-permeability glacial cover. Mapping the shallow confining units at a countywide scale provides an opportunity to avoid drilling unnecessarily deep wells for drinking water supply. Regulators who know the location of the regional shale units can target aquifers that may be hydrologically protected from surface contamination. This can reduce drilling costs for municipalities and residents who depend on ground water for drinking water, irrigation, and industry.

The bedrock aquifers, confining units, and major mapped faults in the county are shown on the map, and a pattern overlies the area where till thickness is greater than 75 feet. Cretaceous deposits are thin and discontinuous; they are not shown on the map or cross sections. The potentiometric surfaces for the three uppermost aquifers are shown with 20-foot contours of different colors, as well as the locations of wells used to develop the potentiometric contours. The locations of wells sampled for geochemistry and for residence time information from tritium and carbon-14 age dating are also displayed. The cross sections show the arrangement of aquifers and confining units at depth and colored residence time interpretations based on the age-dating results from the sampled wells. All sampled wells have been projected onto the closest cross section. No well is more than 2 miles from a cross section. See Plate 8 for a description of radiometric dating of ground water.

The map shows potentiometric contours of the Upper Cedar Valley, Lower Cedar Valley, and Spillville-Maquoketa aquifers. The small data points showing the well locations used to develop these surfaces are displayed in colors corresponding to the contours. There are few locations where wells from shallower and deeper aquifers are close enough to one another to be used as nests for a point-by-point comparison of water-level information from different aquifers. Enough data points exist, however, to show that the potentiometric surface of each aquifer is different. The potentiometric differences between the Upper Cedar Valley and the Lower Cedar Valley aquifers are subtle in the southeastern part of the county. Greater differences appear in the center of cross-section E–E′. The difference between the potentiometric surfaces of the Lower Cedar Valley and the Spillville-Maquoketa is most obvious in the center of the map and in the center of cross-section C–C′. Generally, ground water flows from east-central Mower County to the south and west in the Upper and Lower Cedar Valley aquifers. In the northeast, ground water in the Spillville-Maquoketa aquifer flows from the center of the county to the north. In the northwest, ground water in the Spillville-Maquoketa aquifer flows south through potentiometric troughs toward the Cedar River discharge area. Generally, potentiometric differences are smallest at the Cedar and Little Iowa rivers, which are regional discharge areas.

Recent ground water was found in samples from 12 wells based on tritium dating. Nine of the wells with samples of recent water have till cover less than 75 feet thick. For most of the central and northeastern parts of the county, ground water gets progressively older with depth. This is a typical way for water to infiltrate from the land surface into the bedrock aquifers. However, there are areas shown on cross-sections A–A′ and C–C′ where samples of vintage waters were found shallower than the samples of mixed waters in deeper nearby wells. In southwest and southeast Mower County, the distribution of recent, mixed, and vintage samples on the cross sections is different from the rest of the county. Recent and mixed waters are found at great depths. Recent and mixed waters found at depth indicate focused recharge. Faulting and sinkholes are also found in the western portion of C–C′ and D–D′ and the eastern portion of E–E′ and F–F′. The presence of faulting and karst features may be a factor in focused recharge. These residence time patterns are discussed in more detail on Plate 8.

Mower County has an abundant supply of high-quality drinking water in the bedrock aquifers found throughout the county. Ground water in the two uppermost bedrock aquifers flows from the east-central part of the county to the south and west. In the northeast, ground water in the Spillville-Maquoketa aquifer flows from the center of the county generally to the north. Results of age dating show that till thicker than 75 feet can restrict infiltration from the land surface to the bedrock aquifers. The faults and karst features in the west and southeast may contribute to the focused recharge of the bedrock aquifers from the land surface.

REFERENCES CITED

Green, J. A., Mossler, J. H., Alexander, S. C., and Alexander, E. C., Jr., 1997, Karst hydrogeology of Le Roy Township, Mower County, Minnesota: Minnesota Geological Survey Open-File Report 97-2, 2 pls., scale 1:24,000.

Libra, R. D., and Hallberg, G. R., 1985, Hydrogeologic observations from multiple core holes and piezometers in the Devonian carbonate aquifers in Floyd and Mitchell counties, Iowa: Iowa Geological Survey Open File Report 85-2, Part 1, p. 1–19.

GEOLOGIC ATLAS OF MOWER COUNTY, MINNESOTA