MINNESOTA DEPARTMENT OF NATURAL RESOURCES

Technical Appendix to Part B

GEOLOGIC ATLAS OF MOWER COUNTY, MINNESOTA

COUNTY ATLAS SERIES C–11

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(*Published separately by the Minnesota Geological Survey*)

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POTENTIOMETRIC SURFACES OF THE UPPERMOST BEDROCK AQUIFERS

by
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INTRODUCTION

The uppermost bedrock aquifers lie immediately beneath the Quaternary sediments in Mower County and are shown on Plate 7. These four aquifers were deposited during the Devonian and upper Ordovician periods and will be considered separately here. The areal extent, distribution of static water level data, potentiometric surface, and flow directions will be described for each aquifer. From youngest to oldest on the stratigraphic column, they are the Upper Cedar Valley aquifer, the Lower Cedar Valley aquifer, the Spillville-Maquoketa aquifer, and the Galena Group aquifer. The map on Plate 7 shows two shale units that separate bedrock aquifers. The Chickasaw Shale separates the Upper Cedar Valley aquifer from the Lower Cedar Valley aquifer, and the Dubuque Formation separates the Spillville-Maquoketa aquifer from the Galena Group aquifer. The Pinicon Ridge Formation separates the Lower Cedar Valley aquifer from the Spillville-Maquoketa aquifer in some places, but is not shown on Plate 7 because the density of wells is insufficient.

A gamma log (Figure 1) from a well in Lake Louise State Park, located in southeastern Mower County, shows the lithologic differences between aquifer and shale units. This log was selected because there are few places in the county where all of these aquifers exist, and few other wells have been drilled through all aquifers. A gamma log shows the concentration of radioactive potassium with depth. The peaks on the diagram indicate high values (long spikes to the right) if the concentration of radioactive potassium is high. Radioactive potassium is a naturally occurring isotope and is present in small amounts in all minerals containing potassium. Clay minerals are rich in potassium, and geologic units with high amounts of clay, like shales and till, will register long spikes to the right on a gamma log. Conversely, carbonate bedrock has relatively small amounts of potassium, and these rocks will register a smoother line along the left side of the gamma log. This gamma log shows clear evidence of shale units between these aquifers.

DESCRIPTIONS OF UPPERMOST AQUIFERS

Upper Cedar Valley Aquifer

The Upper Cedar Valley aquifer (Figure 2) occurs in southern Mower County beneath glacial deposits. The underlying Chickasaw Shale is exposed in patches in the middle of the subcrop and around the edges of the aquifer. Most wells completed in this aquifer are in the southeastern part of the county. There are few wells completed in this aquifer in the western part of the county. Potentiometric contour elevations range from 1320 feet to 1200 feet above mean sea level. Ground water in this aquifer flows from the east-central part of the county to the south and west.

Lower Cedar Valley Aquifer

The Lower Cedar Valley aquifer (Figure 3) occurs as the uppermost bedrock (subcrop) in an east-west band in central Mower County beneath the Chickasaw Shale and where the shale is absent. Patches of this aquifer occur to the north, but few wells are completed in them. Most wells completed in this aquifer are in the western part of the county, with the highest density in the Austin area. Few wells have been drilled through the edges of the Upper Cedar Valley aquifer or the Chickasaw Shale. These are scattered in the western and extreme southeastern parts of the county. Potentiometric contour elevations range from 1340 feet to 1160 feet above mean sea level. Like the flow direction in the Upper Cedar Valley aquifer, ground water in this aquifer flows from the east-central part of the county to the south and west.

Spillville-Maquoketa Aquifer

The Spillville-Maquoketa aquifer (Figure 4) occurs in an east-west band in northern Mower County beneath the Lower Cedar Valley aquifer and north of the Lower Cedar Valley aquifer where it is absent. Wells completed in this aquifer are most abundant in the western part of the county and less numerous in the east central and southeast. Many wells are drilled through the Lower Cedar Valley aquifer into the Spillville-Maquoketa aquifer in western Mower County, and there are a few wells in the central and eastern parts of the county. Potentiometric contour elevations range from 1320 feet to 1180 feet above mean sea level. In the northeast, ground water in this aquifer flows mainly north. In the northwest, the ground water flows in troughs toward the Cedar River (see Plate 7 and Plate 8, "Ground-Water Flow in Multiple-Porosity Carbonate Aquifers"). These troughs indicate significantly higher porosity and permeability at this location in the aquifer than the surrounding area. This type of feature occurs in aquifers with porosity enhanced by solution processes like that in triple-porosity aquifers. In the southwest, potentiometric contours are parallel to the Cedar River, and ground water flows toward the river.

Galena Group Aquifer

The Galena Group aquifer (Figure 5) occurs underneath the whole county but is the uppermost bedrock in northeastern Mower County. Few wells are completed in this aquifer and are widely scattered throughout the county. Because of limited data, the location of potentiometric contours is uncertain. In the eastern part of the county, contour elevations range approximately from 1280 feet to 1260 feet above mean sea level. Ground water in this aquifer flows north in northeastern Mower County. In western Mower County, the contour elevations range approximately from 1220 feet to 1180 feet above mean sea level. Here, ground water flows west.

DISCUSSION

The potentiometric surfaces of these aquifers have many similarities. The Upper Cedar Valley and the Lower Cedar Valley aquifers are similarly shaped, and ground water in the aquifers flows south and west from a potentiometric high in east-central Mower County. In southeastern Mower County, the potentiometric surfaces of the Upper Cedar Valley and Lower Cedar Valley aquifers are similar near the Little Iowa River. The Lower Cedar Valley and the Spillville-Maquoketa aquifers also have similar potentiometric elevations in southwestern Mower County near the Cedar River. Ground water in the Spillville-Maquoketa and Galena Group aquifers flows north in the northeast from a potentiometric high in east-central Mower County.

Differences occur in the middle of the county. Where locations of potentiometric surfaces of the Upper Cedar Valley, the Lower Cedar Valley, and the Spillville-Maquoketa aquifers overlap, the water level of each aquifer is lower than that of the aquifer above it, except near discharge points. This progression demonstrates a downward gradient. There is also evidence of a downward gradient between the Spillville-Maquoketa and Galena Group aquifers in northwestern Mower County. In northeastern Mower County, the data are too sparse to compare the Spillville-Maquoketa aquifer to the underlying Galena Group aquifer. The Spillville-Maquoketa aquifer is the only aquifer in Mower County in which trough-like features in the potentiometric surface have been identified. See Plate 7 for more information.

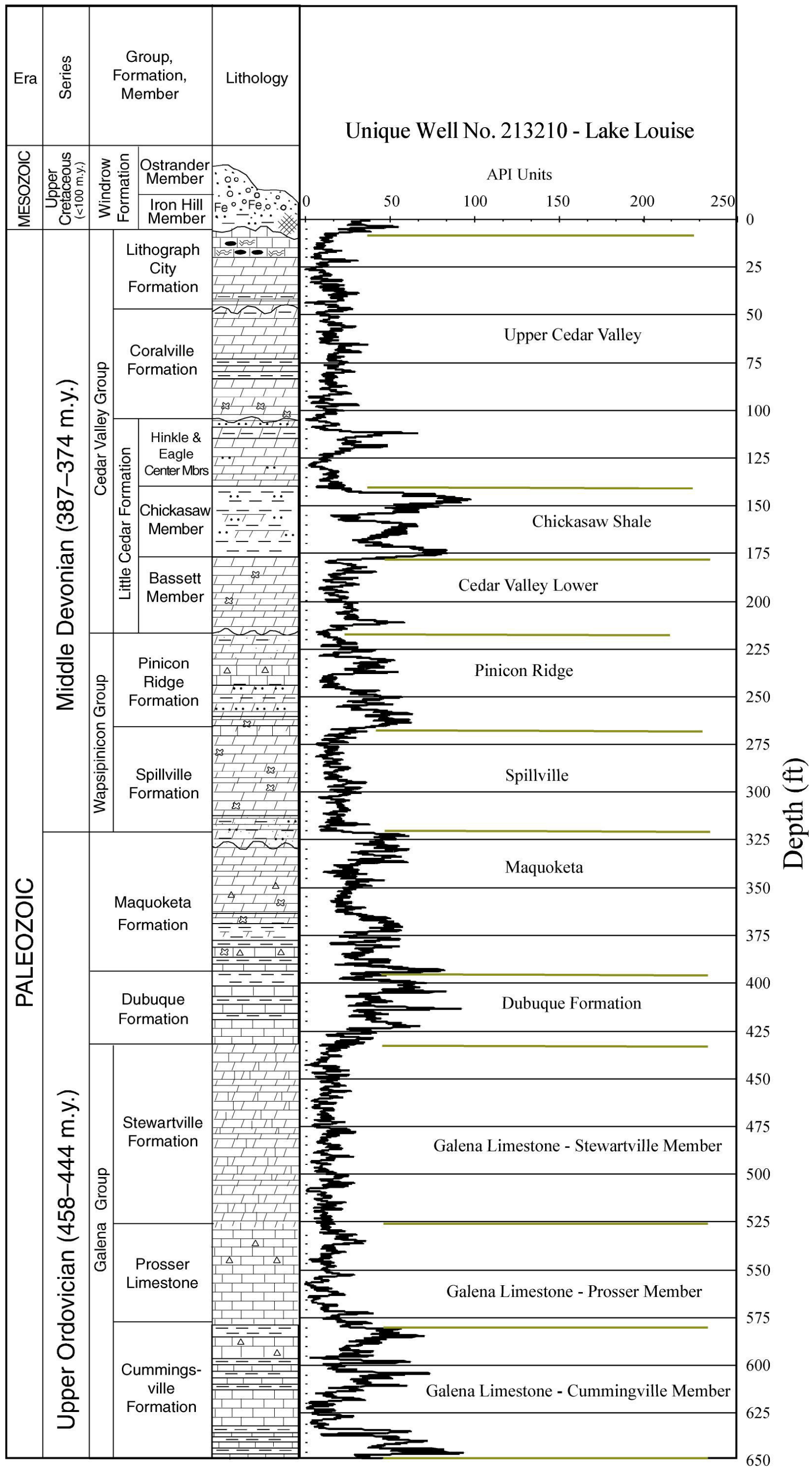

FIGURE 1. Stratigraphic column of Mower County adapted from Plate 2, Part A. Gamma log prepared by Scott C. Alexander, University of Minnesota, Department of Geology and Geophysics.

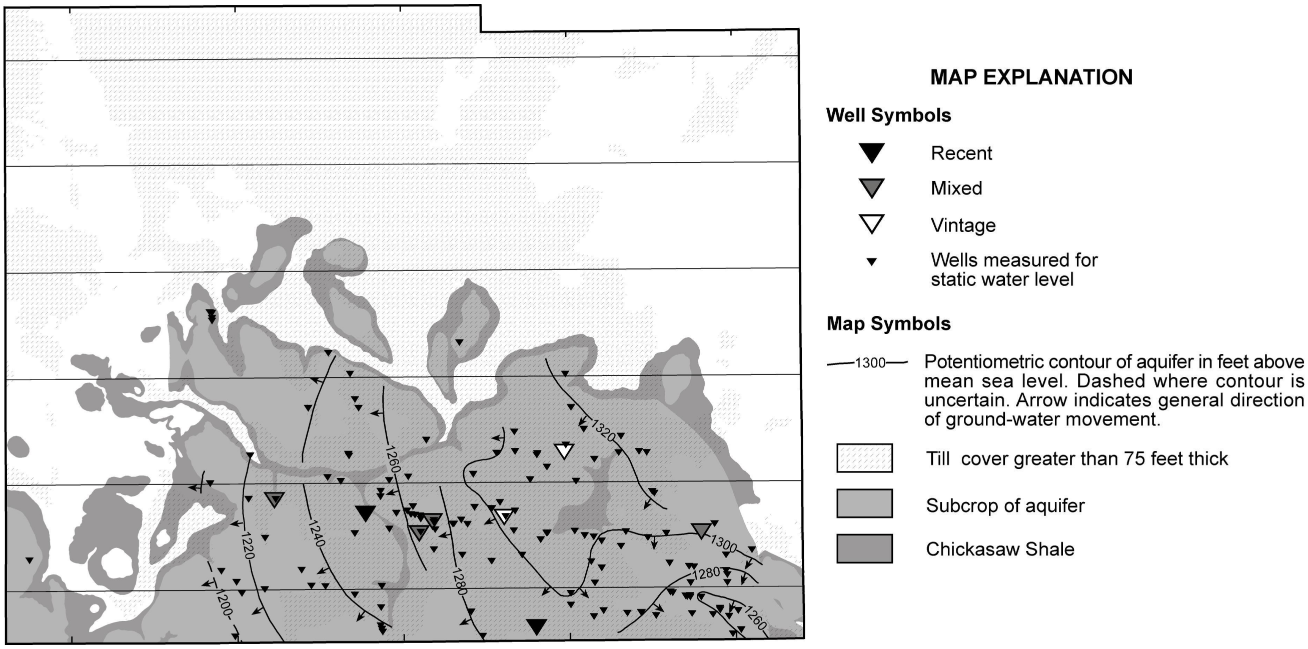

FIGURE 2. Upper Cedar Valley aquifer, southern Mower County.

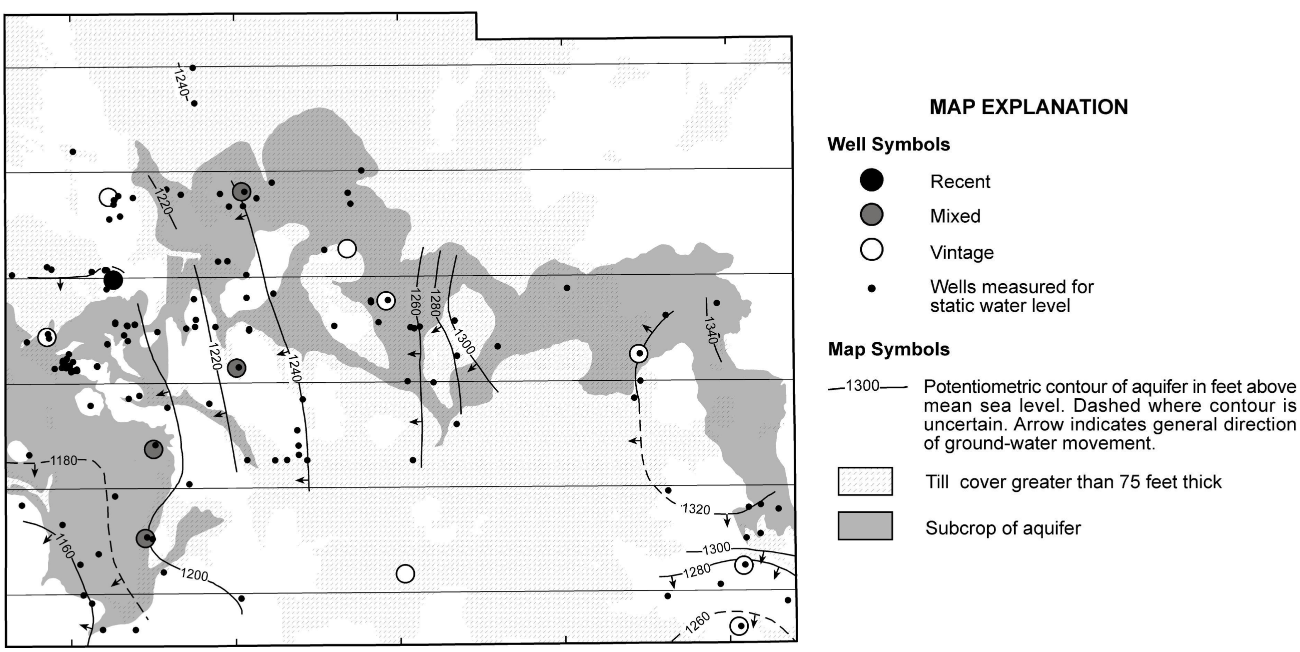

FIGURE 3. Lower Cedar Valley aquifer, central Mower County.

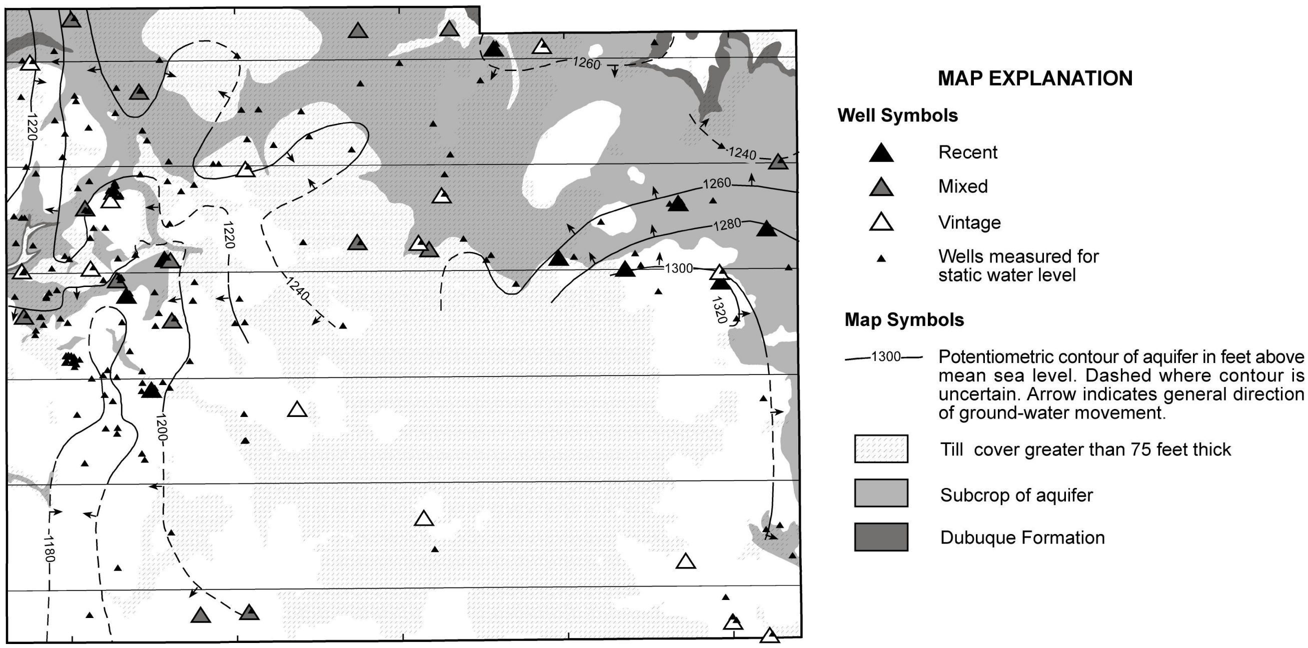

FIGURE 4. Spillville-Maquoketa aquifer, northern Mower County.

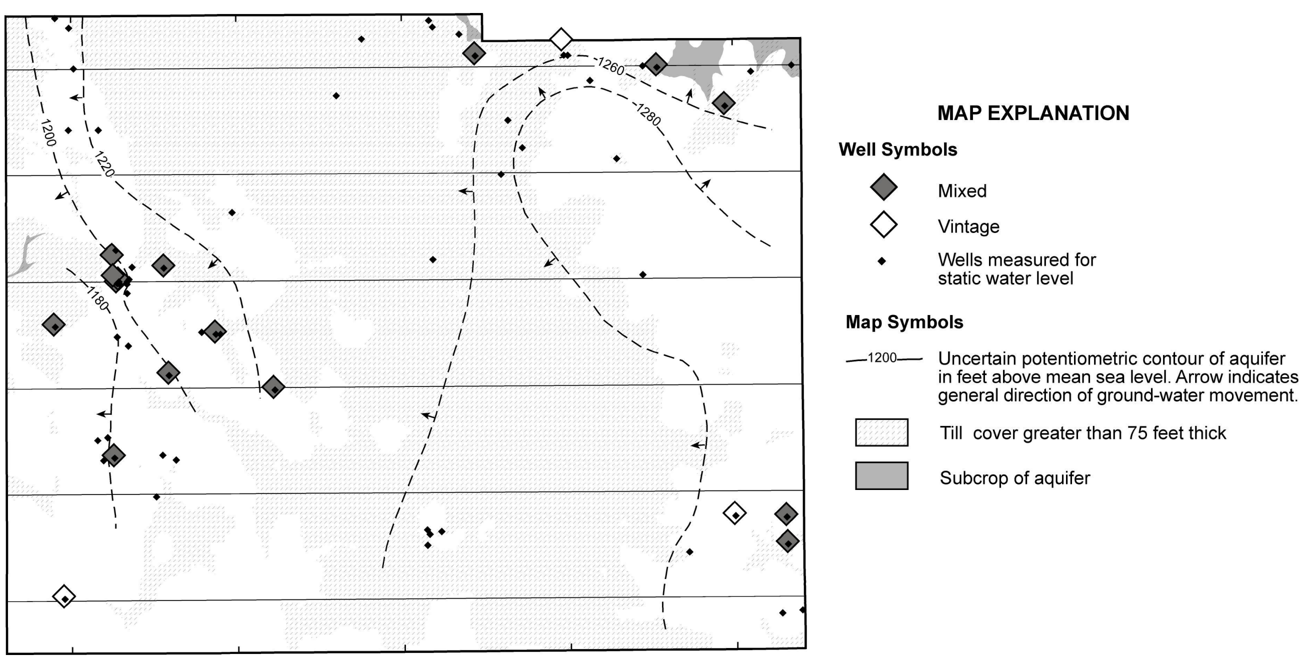

FIGURE 5. Galena Group aquifer, northern Mower County.

GLOSSARY

age dating—Expressing the age of water in years by measuring radioactive elements (e.g., tritium and carbon-14) and their decay products.

alluvium—Material deposited by streams and rivers in channels and on floodplains. It consists of particles of gravel, sand, silt, or clay.

aquifer—Geologic material capable of yielding a usable quantity of water to a well.

buried aquifer—A confined or unconfined aquifer covered by at least 10 feet of low-permeability sediments in a Quaternary setting.

carbon-14—A radioactive isotope of carbon (^{14}C) with a half-life of 5,730 years; used for age-dating.

carbonate rock—Rock containing the carbonate anion and consisting chiefly of carbonate minerals such as calcite and dolomite.

conduit—Rather large void in a bedrock aquifer created by solution process.

contamination—Degradation of natural water quality as a result of human activity.

cover—Low-permeability material such as till or shale over an aquifer.

CWI—County Well Index, a database of Minnesota wells maintained by the Minnesota Geological Survey.

discharge—The volume of water flowing through a given cross section in a given time period.

discharge area—Area near the surface in which there is an upward component to the direction of ground-water flow in an aquifer. Ground water may flow to the surface in a discharge area and escape as a spring, a seep, baseflow, or evaporation and transpiration.

fault—A fracture in rock along which the adjacent rock surfaces are differentially displaced.

flow lines or **arrows**—Lines or arrows on maps indicating the direction of ground-water flow.

focused recharge—Recharge occurring at rates greater than surrounding areas because of higher porosity and permeability conditions between the land surface and the aquifer or because the aquifer is at or near the surface.

fracture—A crack, joint, or fault in a rock due to mechanical failure by stress.

fracture flow—The flow of water through a fracture.

geologic (pollution) sensitivity—The potential for contamination, based on the properties of geologic materials along a flow path, that is proportional to the time needed for a contaminant to move from a source at the land surface to an aquifer or other target.

geologic (pollution) sensitivity target—Ground-water resource evaluated in geologic sensitivity assessment.

geologic sensitivity rating or **class**—Overlapping ratings of very high, high, moderate, low, or very low sensitivity based on time of travel.

gradient—See *hydraulic gradient.*

ground water—Water in saturated geologic material.

hydraulic gradient—The rate of change in total head per unit of flow distance in a direction; for example, the slope of a water-table surface.

hydrogeologic—Factors that deal with subsurface water and related geologic aspects of surface waters.

infiltration—The movement of water downward from the land surface into the soil profile.

isotope—One of two or more forms of a single element; the atoms of each isotope have the same number of protons but different numbers of neutrons.

karst—A topography formed over limestone, dolostone, or gypsum by solution and characterized by sinkholes, caves, and underground drainage.

lateral flow—Movement of ground water mostly in a horizontal plane driven by hydraulic gradient.

limestone—A sedimentary rock consisting chiefly of calcium carbonate, primarily in the form of the mineral calcite.

permeability—A measure of the ability of a geologic unit to transmit fluids.

porosity—The percentage of empty or void space in geologic material.

potentiometric surface—A representative surface of the level to which the water in a well in an aquifer would rise by hydrostatic pressure. The water table is a potentiometric surface where hydrostatic pressure and atmospheric pressure are equal.

primary porosity—All the pore space initially present in a rock.

radioactive isotope—Isotope of an element that decays at a known rate. Carbon-14 (^{14}C) and tritium (^{3}H) are examples of radioactive isotopes that can be used to measure the time water has been removed from the atmosphere.

recharge (ground water) area—Area at or near the land surface through which water moves to replenish an aquifer or other ground-water resource.

(ground-water) residence time—The time water has been underground; the time elapsed from when water left the atmosphere until it is discharged from the ground-water system.

sandstone—A sedimentary rock composed of abundant sand-sized grains set in a finer grained matrix and united by a cementing material.

secondary porosity—The pore spaces that appear in a rock after it has formed because of solution or stress effects such as fracturing.

sediment—Transported rock or mineral fragments or precipitated materials that accumulate, typically in loose layers, such as sand or mud.

shale—A fine-grained sedimentary rock formed by the consolidation of clay, silt, or mud. It is characterized by a finely laminated structure.

sinkhole—Closed depression found on land surface in karst landscape, usually formed by solution or collapse.

solution—Process of dissolving minerals into component ions, often intensified by weak acids found in the soil zone.

solution enhanced—Portions of an aquifer that have been modified by solution process along planar and linear elements resulting in greatly increased porosity and permeability.

static water level—The level to which water will rise in an unpumped well that is open to a single aquifer.

subcrop—The surface of a geological formation that occurs at depth. Subcrop refers here to surface of the bedrock that unconformably underlies unconsolidated glacial and postglacial sediments.

till—Predominantly unsorted and unstratified drift; generally unconsolidated sediments deposited directly by a glacier and consisting of a heterogeneous mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.

tracer—Matter or energy carried by ground water that will give information about the water’s direction, velocity, or both and potential contaminants that might be transported by the water.

travel time—The time required for water or a contaminant to move from a source at the land surface to an aquifer or other target.

water table—The surface separating the unsaturated and saturated zones.

weathering—The physical disintegration and chemical decomposition of rock materials at or near the land surface.