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MAJOR GROUND-WATER UNITS OF WISCONSIN

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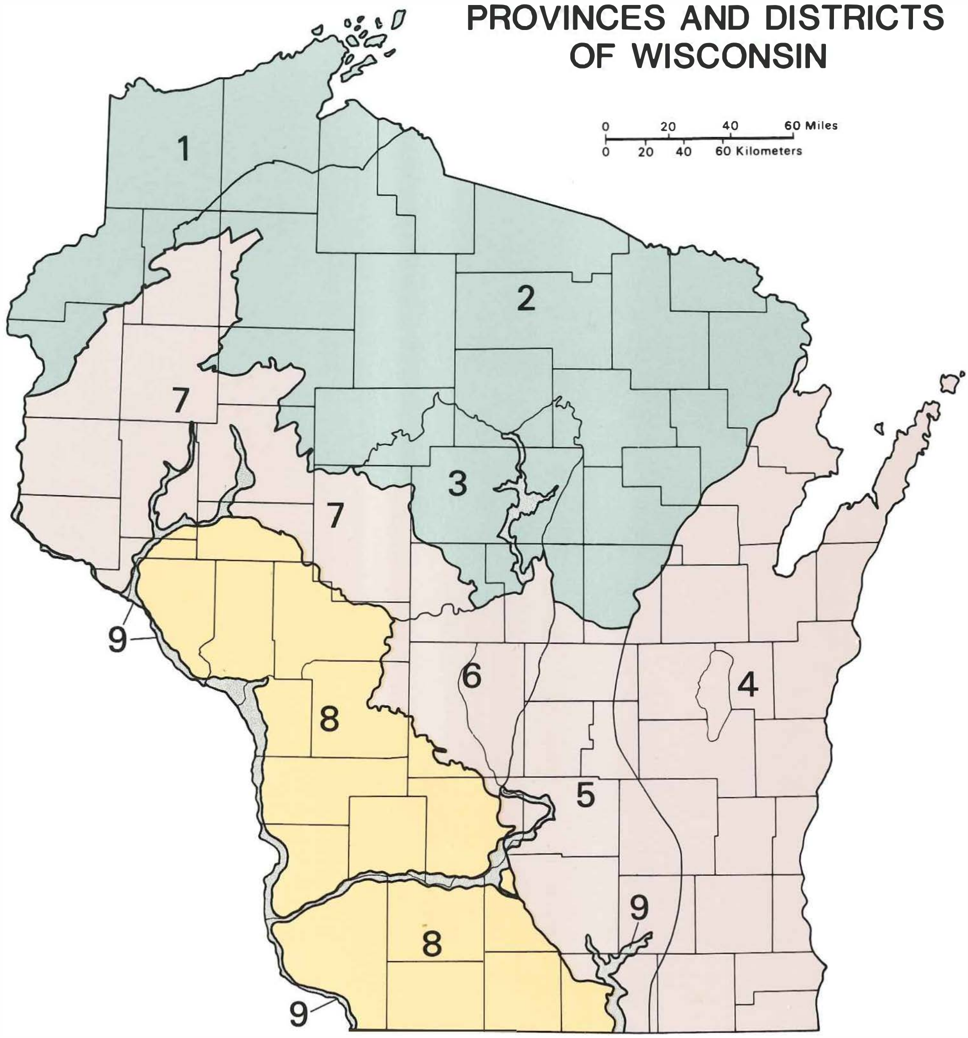
1985

HYDROGEOLOGIC PROVINCES AND DISTRICTS OF WISCONSIN



SUPERIOR UPLANDS
1. Lake Superior District
2. Northern Drift–Precambrian District
3. Central Precambrian District

GLACIATED PALEOZOIC
4. Eastern Drift–Paleozoic District
5. South Central Drift–Paleozoic District
6. Central Sand Plain District
7. West Central Drift–Paleozoic District

UNGLACIATED PALEOZOIC
8. Southwestern Paleozoic District

ALLUVIAL VALLEYS
9. Alluvial Valleys District

Cover: Map of the United States showing ground-water provinces (Meinzer, O.E., 1923); from U.S.G.S. Water Supply Paper 489, Plate XXXI.

ERRATA: Substitute for paragraph 4, page 1.

The properties and distribution of these rocks that serve as the principal source of ground water are the primary criteria used in this classification. For practical purposes, the Precambrian igneous and metamorphic rocks may be considered impermeable and form the lower limit of ground-water movement. The varying character and thickness of the Paleozoic bedrock and its unconsolidated cover enable subdivision of the state into nine hydrogeologic districts shown on the map on front end paper (1 to 9). Ground-water conditions in each of the nine districts are discussed in terms of major aquifers. There are three principal aquifers in Wisconsin: sand-and-gravel aquifer, eastern dolomite aquifer, and sandstone aquifer (see cross section on back end paper). The sand-and-gravel aquifer consists of discontinuous layers and lenses of sand or sand and gravel deposited above, within, or beneath less permeable, primarily Pleistocene unconsolidated deposits. Therefore, it is not a continuous unit. The eastern dolomite aquifer includes dolomite of Silurian and Devonian age underlying all or part of 15 counties along Lake Michigan. It is underlain by the sandstone aquifer comprised of Cambrian and Ordovician sandstones, siltstones, and dolomites, which can be subdivided into upper and lower aquifers. In eastern Wisconsin, the eastern dolomite aquifer and the sandstone aquifer are separated by the Maquoketa shale, which is the major impermeable rock unit (confining bed) in Wisconsin. Locally, the shale and Precambrian rocks are minor aquifers that are used where other aquifers are absent or yield poor-quality water.

MAJOR GROUND-WATER UNITS OF WISCONSIN

By Alexander Zaporozec and Dale Cotter

This report describes a division of the state, geographically, into nine major ground-water units–hydrogeologic districts; the concept being that within each district, ground-water occurrence is somewhat uniform. A division of the state into these hydrogeologic districts will define areas with natural hydrogeologic boundaries as potential management units and will provide a basis for the transfer of hydrogeologic knowledge within these units. It will also help to enhance the public's understanding of ground water in Wisconsin. This division by district represents one level of detail. The districts can be grouped into larger, more general units (provinces) or subdivided into smaller, more detailed units (subdistricts or zones), as needed for research, planning, or management purposes (Zaporozec, 1972). They are named districts to differentiate them from the nationwide hydrogeologic provinces.

The continental area of the United States was subdivided by Meinzer (1923) into 21 hydrogeologic provinces (see cover). The state of Wisconsin was included in three provinces shown on the cover map as F, G, and H. Meinzer's provinces were consolidated into 10 regions by Thomas (1952), and more recently into 12 regions by Heath (1982), who introduced a new region including only alluvial valleys. The first subdivision of Wisconsin into hydrogeologic units was attempted by Drescher (1956). His work was revised by Holt and others (1964). Our report subdivides the state's provinces into nine hydrogeologic districts. The subdivision takes into account all of these classifications, but it follows most closely that of Heath.

The rocks underlying Wisconsin form the framework within which ground water occurs and moves. The characteristics of these rocks ultimately determine the amount and natural quality of water available for use. These rocks include a basement complex of igneous, metamorphic, and sedimentary rocks of Precambrian age overlain by nearly horizontal layers of sedimentary rocks–remains of deposits built up in Paleozoic seas on the submerged Precambrian surface. These bedrock units are, in turn, overlain by unconsolidated sediments, mostly glacial and fluvial deposits of Pleistocene age (see cross section on back end paper).

The properties and distribution of these rocks that serve as the principal source of ground water are the primary criteria used in this classification. For practical purposes, the Precambrian igneous and metamorphic rocks may be considered impermeable and form the lower limit of ground-water movement. The varying character and thickness of the Paleozoic bedrock and its unconsolidated cover enable subdivision of the state into nine hydrogeologic districts shown on the map on front end paper (1 to 9). Ground-water conditions in each of the nine districts are discussed in terms of Pleistocene unconsolidated deposits. Therefore, it is not a continuous unit. The eastern dolomite aquifer includes dolomite of Silurian and Devonian age underlying all or part of 15 counties along Lake Michigan. It is underlain by the sandstone aquifer comprised of Cambrian and Ordovician sandstones, siltstones, and dolomites, which can be subdivided into upper and lower aquifers. In eastern Wisconsin, the eastern dolomite aquifer and the sandstone aquifer are separated by the Maquoketa shale, which is the major impermeable rock unit (confining bed) in Wisconsin. Locally, the shale and Precambrian rocks are minor aquifers that are used where other aquifers are absent or yield poor-quality water.

The following descriptions of the nine hydrogeologic districts define the geographic limits, aquifers, and ground-water recharge and movement within Wisconsin's borders. The boundaries of most districts are natural (geologic limits or changes in rock units, major rivers or lakes, and ground-water divides), except for parts of districts 1, 2, 4, 5, and 8 which are arbitrarily chosen along the state lines with the states of Minnesota, Michigan, and Illinois.

The technical terms and units used in the report are defined at the back of the report.

Hydrogeologic District No. 1 — LAKE SUPERIOR

Boundaries

South: from west to east, contact between Precambrian and Paleozoic rocks and southernmost extent of Pleistocene sand and of Precambrian sandstone; east: the Montreal River; north: Lake Superior; west: from north to south, Minnesota state line and the St. Croix River.

Aquifers

Water-bearing sandstone of Precambrian age overlain by Pleistocene glacial and fluvial deposits of varying productivity.

The Precambrian rocks consist of thick sequences of sandstone containing layers of shale and conglomerate and a sequence of basalt lava flows. The permeability of sandstone is moderate to low; it yields an adequate amount of water for domestic wells (10 to 100 gpm), and in some areas more (500 gpm). Fractures (and tubular openings) in basalt may yield small amounts of water (commonly less than 10 gpm).

The Pleistocene deposits consist of till, lake sand and silt, and fluvial sand and gravel. Sandy till yields small amounts of water (5 to 10 gpm). Yields from sand-and-gravel lenses do not commonly exceed 100 gpm, but the thick sand and gravel in the central part may yield large amounts (more than 150 gpm).

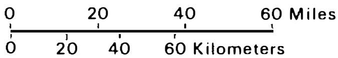
Recharge Conditions

Low-permeability red clay impedes recharge to underlying sandy deposits in the north. In other areas of the district recharge through the surface material ranges from moderately slow to moderately rapid. The greatest potential for recharge is through the sand and gravel.

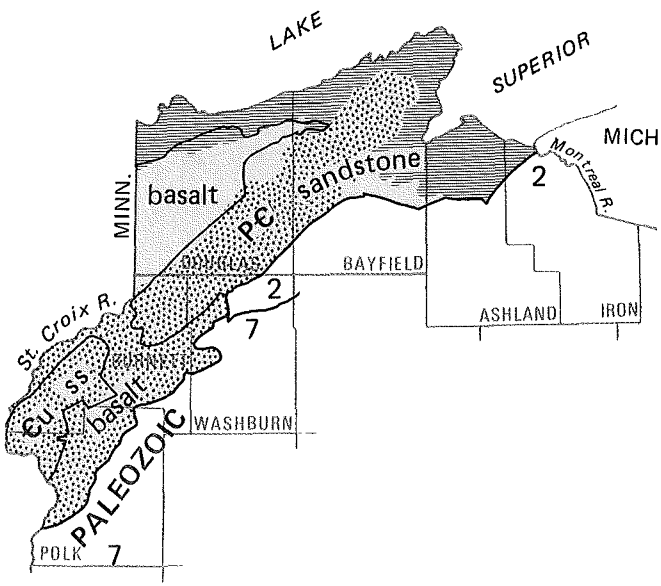
Ground-Water Movement

Regional movement is to the north into Lake Superior and to the west toward the St. Croix River. Local ground-water movement is into nearby streams and lakes. Locally, flow may be influenced by faults in the bedrock and by the shape of Precambrian surface.

LAKE SUPERIOR DISTRICT



Location of District



Geologic boundary

Red clay

Sand

2,7 Adjacent hydrogeologic districts

Hydrogeologic District No. 2 — NORTHERN DRIFT- PRECAMBRIAN

Boundaries

South: end moraines of late Wisconsin glaciation; east and west: limit of Paleozoic rocks; north: geologic limit of Precambrian sandstone and Michigan state line (in part, the Brule and Montreal rivers).

Aquifers

Generally thick, productive water-bearing Pleistocene deposits underlain by a complex of relatively nonproductive Precambrian igneous and metamorphic rocks.

The Precambrian rocks (granite, gneiss, basalt) usually yield a small amount of water (generally less than 5 gpm) from weathered and fractured zones. Large yields are rare. However, more then 500 gpm has been pumped from deep mine shafts in Iron County and from an exploration test hole in granite in Forest County.

The sand-and-gravel aquifer includes Pleistocene sand-and-gravel lenses and fluvial sand and gravel. Water yields generally are smaller in the western part of the district, where they range from 10 to 100 gpm. In the eastern part, the yields from sand and gravel are large (100 to 500 gpm) and may reach even more than 500 gpm where saturated sand and gravel is thick. In addition, recent river sediments are important aquifers in several areas.

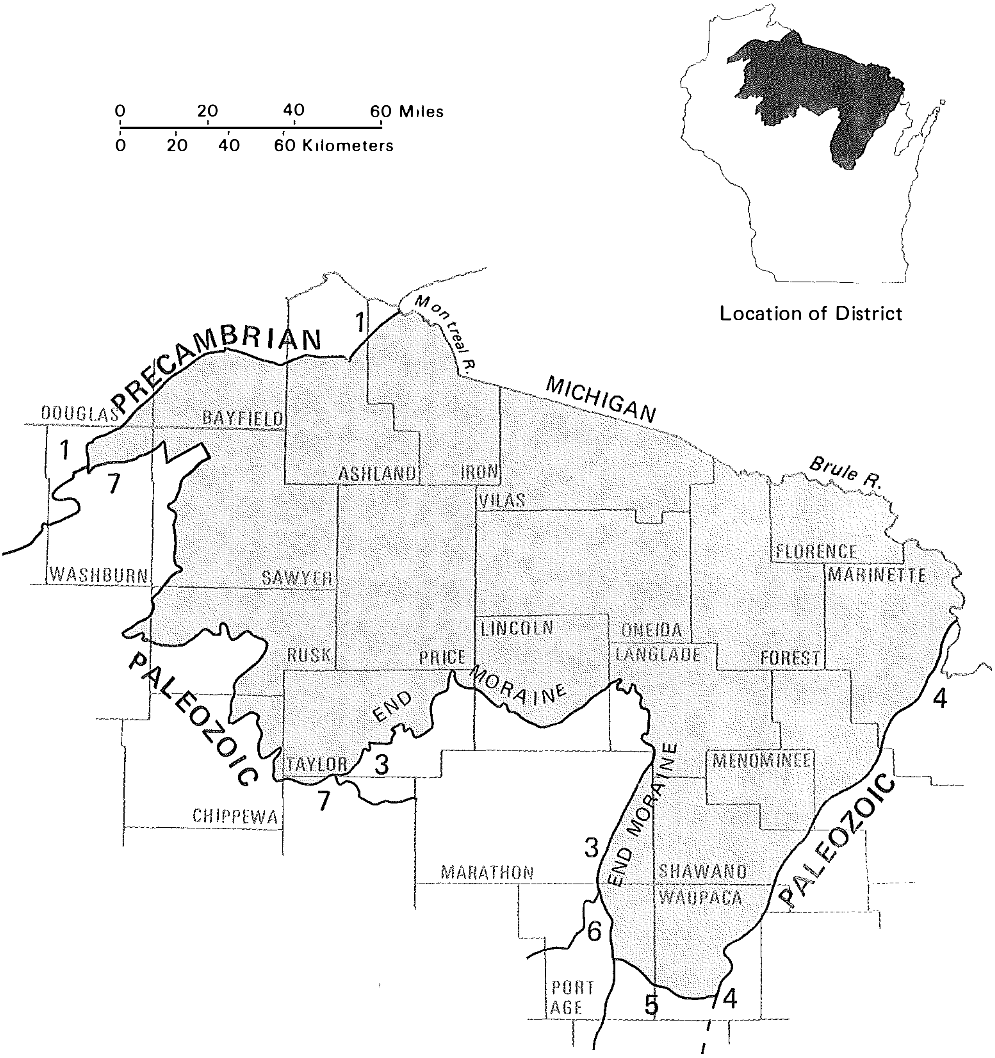
Recharge Conditions

The surface material has a wide range of permeability, but much of it is permeable and allows good local recharge.

Ground-Water Movement

Most ground-water flow systems are small and shallow. Ground water flows toward nearby lakes and streams.

NORTHERN DRIFT—PRECAMBRIAN DISTRICT



1,3,4,5,6,7 Adjacent hydrogeologic districts

Hydrogeologic District No. 3 — CENTRAL PRECAMBRIAN

Boundaries

West and south: from west to east, limit of Paleozoic rocks and northern extent of central sand plain; east and north: end moraine.

Aquifers

Poorly productive fractured rocks of Precambrian age near or at the land surface overlain in places by poorly productive till with isolated productive sand and gravel in bedrock valleys.

The Precambrian igneous rocks yield small amounts of water from weathered material at the bedrock surface and from fractures within the rock. Yields depend on the degree and depth of weathering and the size and interconnection of fractures, and generally do not exceed 20 gpm.

The Pleistocene deposits overlying the Precambrian are thin. Till may yield a very small amount of water (0.5 to 2 gpm), but generally is inadequate for domestic and stock supplies. Only sand-and-gravel deposits in bedrock valleys yield moderate to large supplies of water to wells (up to 400 gpm).

Recharge Conditions

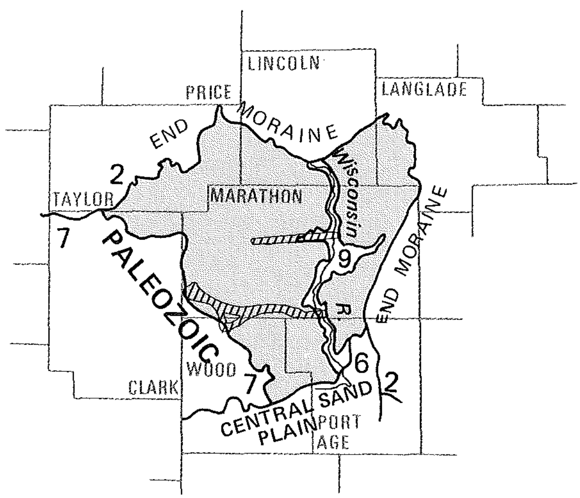
The till generally is of low permeability, and Precambrian bedrock is exposed in many places. Recharge is very slight.

Ground-Water Movement

Ground-water movement is very localized. The flow systems are very shallow and small.

CENTRAL PRECAMBRIAN DISTRICT

Location of District



Known aquifers in bedrock valleys

2,6,7,9 Adjacent hydrogeologic districts

Hydrogeologic District No. 4 — EASTERN DRIFT-PALEOZOIC

Boundaries

South: Illinois state line; east: Lake Michigan; north: the Menominee River and Green Bay. The western boundary follows, from north to south, the western extent of the Paleozoic rock and the approximate position of the ground-water divide in the deep flow system.

Aquifers

A thick productive multilayered complex of Paleozoic sandstone and dolomite interbedded with nonproductive layers and locally overlain by productive water-bearing sand and gravel.

The sandstone aquifer includes the Cambrian and Ordovician sedimentary rocks older than the Maquoketa shale. It is very thick and confined where covered by the shale. Additionally, formations of low permeability may confine water in its lower part throughout the district. The sandstone aquifer is the most heavily pumped aquifer in the state. Many municipal and industrial wells pumping large amounts (more than 500 gpm) from Cambrian sandstone have caused a gradual decline of artesian pressure. Ordovician formations contribute little water where they are overlain by the thick shale, but commonly yield water west of the Silurian escarpment (50-100 gpm), where they are overlain only by Pleistocene sediment.

The Silurian dolomite is an important source of domestic supplies in the eastern half of the district. It is essentially the sole source in the Door Peninsula, where the Pleistocene deposits are thin, and in some areas along Lake Michigan and Lake Winnebago, where the water from the underlying sandstone aquifer may be saline and the Pleistocene deposits unproductive. Well yields range from 10 to 500 gpm, and in places are even more.

The sand-and-gravel aquifer is quite discontinuous in this district. Although it is little used in most of the district, it forms important ground-water reservoirs along the Kettle Moraine and in buried bedrock valleys of Walworth, Waukesha, and Washington counties where well yields may exceed 500 gpm.

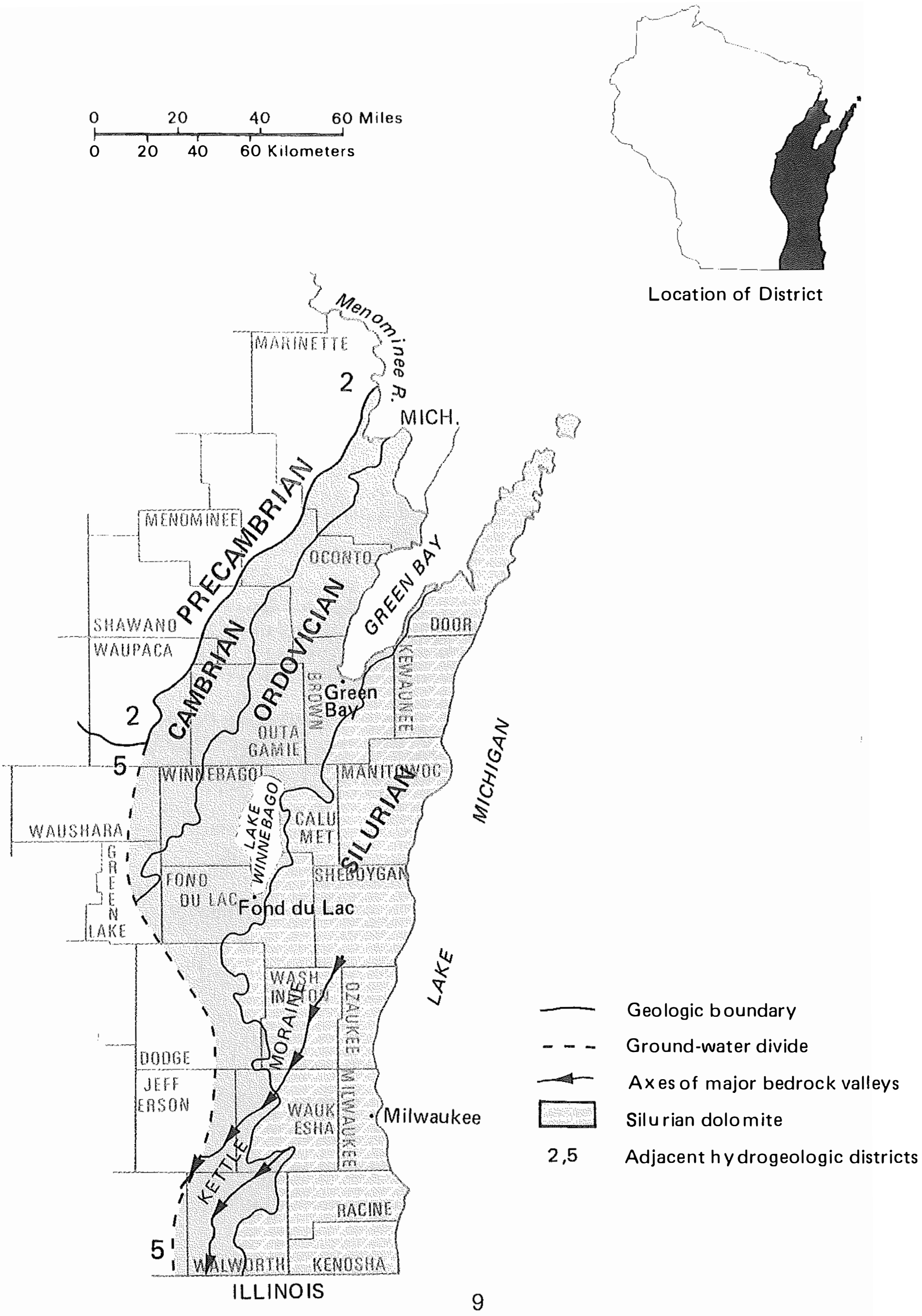
Recharge Conditions

Ground-water recharge is greater and more rapid in the areas covered by permeable sediment (northwest and southwest) than in areas covered by thick clayey till and lake clay (along the lake shore and between Green Bay and Winnebago).

Ground-Water Movement

Ground water in the district moves within two sets of systems: the shallow (water-table) systems (sand and gravel, and Silurian and Devonian dolomite) and a deeper (sandstone) system. Within the shallow systems the water moves toward nearby lakes and streams along shallow flow paths. In the deeper system, regional movement is from the west along long flow paths toward Lake Michigan or to major pumping centers (Green Bay and Milwaukee-Chicago area). In the area west of Fond du Lac, regional ground-water flow is controlled by a poorly defined series of north-south trending Precambrian ridges.

EASTERN DRIFT—PALEOZOIC DISTRICT



Hydrogeologic District No. 5 — SOUTH CENTRAL DRIFT-PALEOZOIC

Boundaries

South: Illinois state line; east: the approximate position of ground-water divide in the deep flow system; north: northern extent of the Paleozoic rock; west: from north to south, end moraines of late Wisconsin glaciation and Rock valley outwash.

Aquifers

Highly productive multilayered complex of Cambrian and Ordovician sandstone and dolomite locally interbedded with nonproductive layers and overlain by productive till and outwash sand and gravel.

Southeastward-dipping sandstone aquifer underlies the entire district. Its thickness and yields generally increase to the east. In the north, the aquifer is formed only by the Cambrian sandstone series, and it yields small to moderate amounts of water (15 to 100 gpm). In the south, the Cambrian sandstone is overlain by rock units of Ordovician age, including the Galena-Platteville unit and the St. Peter sandstone, which are the principal sources of water for domestic wells. Here the underlying Cambrian sandstone series is capable of yielding more than 1000 gpm and it is the principal source of municipal and industrial water supplies.

The Pleistocene deposits generally are moderately thin and provide small to moderate amounts of water. However, yields of more than 1000 gpm are available from these deposits where they contain a sufficient thickness of saturated outwash sand and gravel, such as in the buried preglacial bedrock valleys. Many high-capacity irrigation wells have been developed in the southern part of the district.

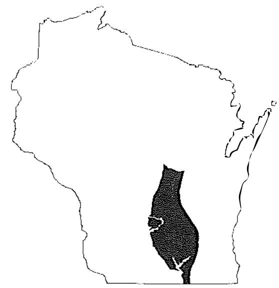
Recharge Conditions

The northern part is covered by glacial-lake deposits (fine-grained silt and clay), which impede recharge. The rest of the district is covered by moderately permeable surficial material, which allows infiltration almost everywhere. The outwash deposits are highly permeable and allow rapid recharge.

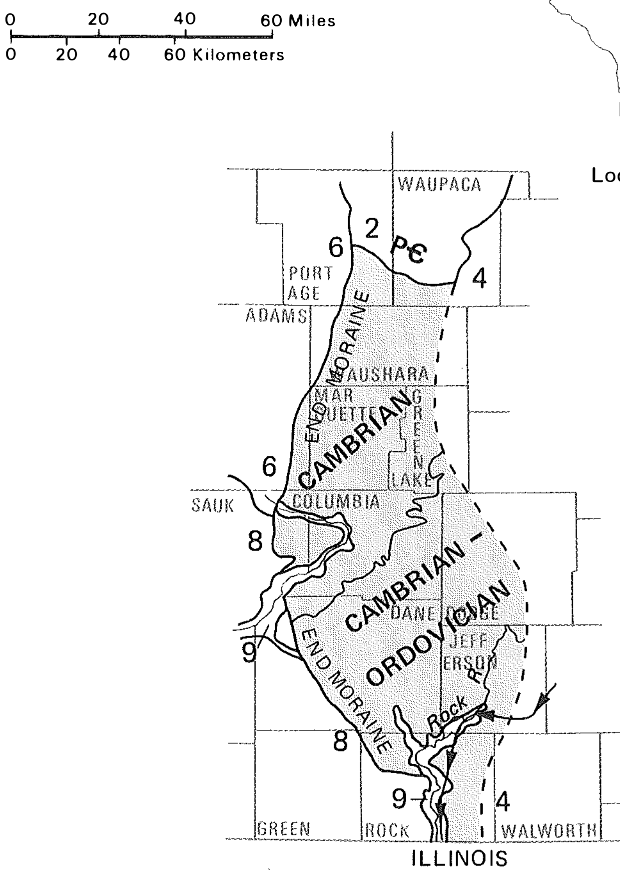
Ground-Water Movement

Local ground-water movement in Pleistocene deposits and shallow bedrock is to nearby streams and lakes. Deeper ground-water flow discharges into the Wisconsin and Rock rivers.

SOUTH CENTRAL DRIFT–PALEOZOIC DISTRICT



Location of District



——	Geologic boundary
– – –	Ground-water divide
—◄—	Axis of major bedrock valley
2,4,6,8,9	Adjacent hydrogeologic districts

Hydrogeologic District No. 6 — CENTRAL SAND PLAIN

Boundaries

East: end moraine of late Wisconsin glaciation; north, west, and south: extent of glacial-lake sand.

Aquifers

Highly productive water-bearing sand and gravel overlying less productive sandstone or essentially nonproductive Precambrian rock.

The sandstone aquifer, although permeable, is not an important aquifer here. It is thin in the northern part of the district, and is seldom tapped because of the prolific overlying sand and gravel. Only along the southwestern border have wells been drilled into this aquifer, yielding 100 to 500 gpm or more.

The sand-and-gravel aquifer includes glacial-lake deposits of fine-grained, well-sorted sand with a few thin layers of silt and clay in the west, outwash sand and gravel in the east, and alluvial sand and gravel along the Wisconsin River. Both the outwash and alluvial sand and gravel are highly permeable and have similar water-bearing characteristics. Yields ranging from 500 to more than 1000 gpm may be expected from wells in most of the district. The largest yields can be found in the northeastern part of the district.

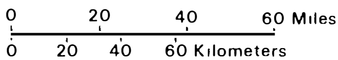
Recharge Conditions

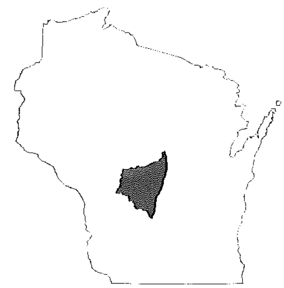
Sand and gravel is highly permeable and allows rapid recharge through much of the district.

Ground-Water Movement

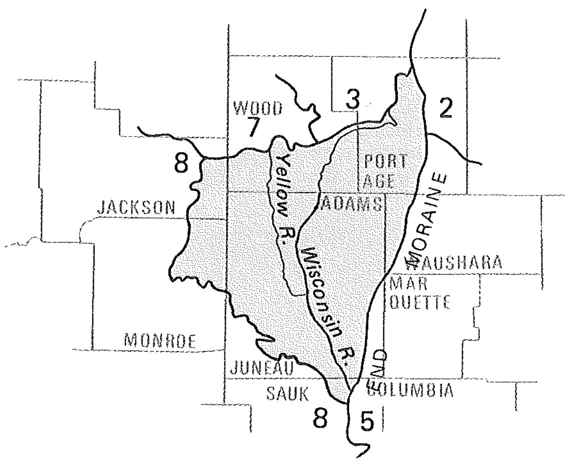
Local ground-water flow systems are difficult to define because the area is rather flat and surface drainage is poor and has been altered by extensive ditching. Ground water that does not flow into a nearby ditch or stream generally moves toward the Wisconsin and Yellow rivers. Deep flow in the sandstone aquifer is poorly understood, and it is probable that it moves toward the Wisconsin River or passes beneath the district from the north to the south as underflow. The sandstone is so much less permeable than the overlying sand and gravel that its buried ridges locally act as relative barriers to the ground-water flow.

CENTRAL SAND PLAIN DISTRICT





Location of District



2,3,5,7,8 Adjacent hydrogeologic districts

Hydrogeologic District No. 7 — WEST CENTRAL DRIFT-PALEOZOIC

Boundaries

South: from west to east, the Mississippi River valley, southern extent of glaciation, and northern extent of central sand plain; east and north: extent of the Paleozoic rock; west: the St. Croix River.

Aquifers

Sandstone aquifer overlain by Pleistocene deposits, which contain water-bearing sand and gravel primarily in bedrock valleys.

The sandstone aquifer underlies the entire district, and includes, in the southwestern part (St. Croix and Pierce counties) the sequence of Cambrian and Ordovician rocks (see cross section on back end paper), and in the rest of the district only the Cambrian sandstone series. The ability of the Cambrian sandstone to store and yield large quantities of water makes it the principal source of water for municipal and industrial supplies throughout the district. In the west, where its thickness is greatest, it yields between 100 and 1000 gpm to wells. In the east, where the Cambrian sandstone is thin, yields are less than 100 gpm. The Ordovician Prairie du Chien Group is the uppermost saturated bedrock unit in the southwest and is used extensively for domestic water supplies.

The sand-and-gravel aquifer consists of unconsolidated outwash and alluvial deposits and sand-and-gravel layers within less permeable till. Water from the sand-and-gravel aquifer is available in much of the district, but individual well yields vary widely (10 to 1000 gpm). It is the principal source of domestic supplies in the north, and it is absent in many places in the south. Major valleys containing outwash deposits cross Barron, Chippewa, Dunn, and Eau Claire counties, where yields may exceed 1000 gpm.

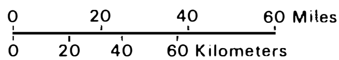
Recharge Conditions

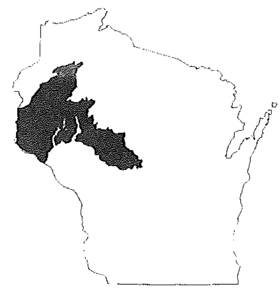
Recharge occurs over most of the district, but it is greatest through the outwash deposits. In the southwest, the sandstone aquifer is covered only by a thin layer of soil and recharge is moderate.

Ground-Water Movement

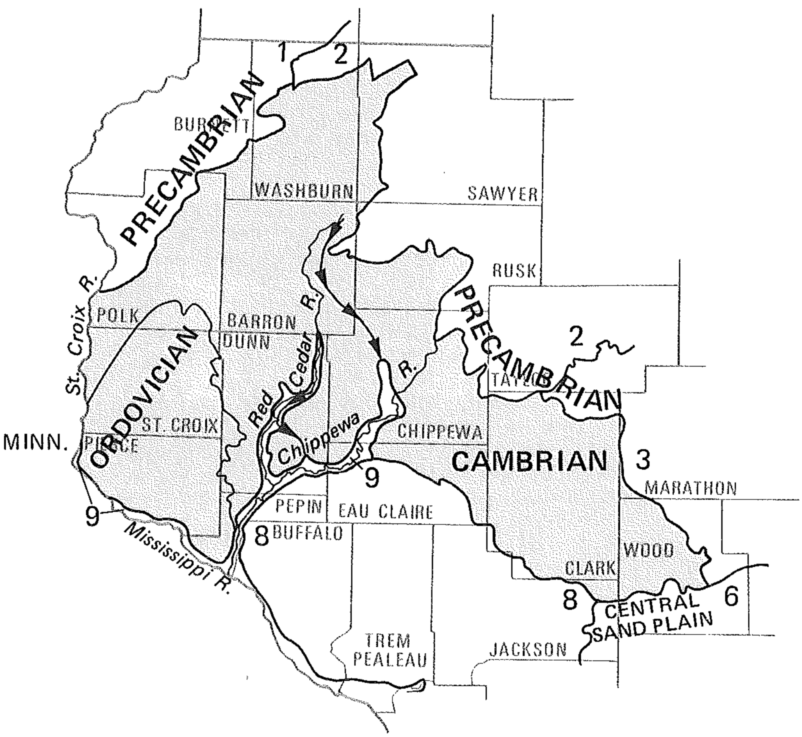
Water in the Pleistocene deposits and shallow bedrock moves to local streams and lakes. The direction of deeper ground-water flow is toward major streams: the Mississippi, St. Croix, Red Cedar, and Chippewa rivers.

WEST CENTRAL DRIFT—PALEOZOIC DISTRICT





Location of District



Geologic boundary

Axes of major bedrock valleys

1,2,3,6,8,9 Adjacent hydrogeologic district

Hydrogeologic District No. 8 — SOUTHWESTERN PALEOZOIC

Boundaries

South: Illinois state line; east: from north to south, end moraine and Rock valley outwash; north: the limit of glaciation; west: the Mississippi River alluvium.

Aquifers

Productive near-surface sandstone or dolomite covered by thin soil or loess and underlain by essentially nonproductive Precambrian rock.

The sandstone aquifer is the major source of water throughout the entire district. It consists of a thick sequence of Paleozoic sandstone and dolomite, in places interbedded with tight shale that may locally confine water in the lower part of the aquifer. Well yields vary between 15 and 1000 gpm. The Cambrian sandstone is the principal source of water in the entire district and the only source in the northern third, where it is overlain by only thin soil or loess. In the central part of the district between the La Crosse and Wisconsin rivers, adequate amounts of water for domestic supplies (15 to 100 gpm) can be obtained from the Prairie du Chien dolomite and St. Peter sandstone of Ordovician age overlying the Cambrian rock. In the southern third of the district, south of the Wisconsin River, most domestic wells take water from the Ordovician St. Peter sandstone and the overlying Galena-Platteville unit. These Ordovician formations do not form continuous aquifers; they are deeply dissected by streams. Yields are about 100 gpm.

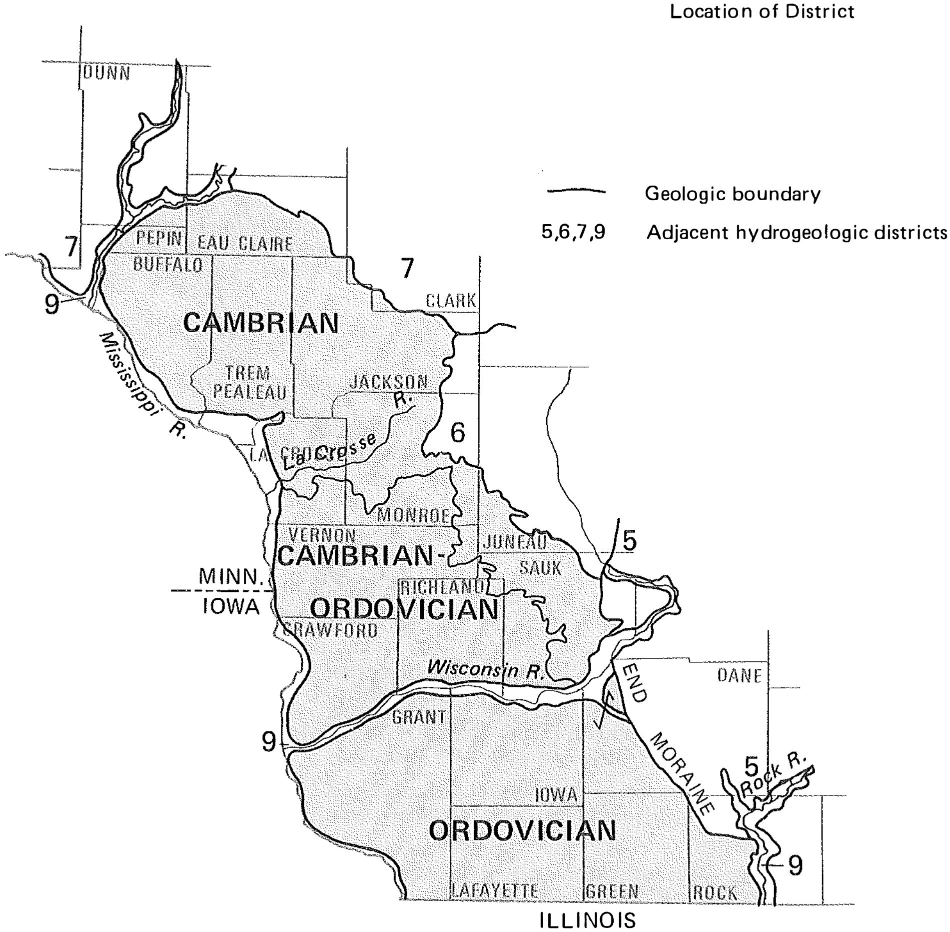
Ground-Water Movement

Recharge to sandstones and dolomites is moderate and fairly uniform over the district because the rocks are either exposed or covered by a thin veneer of surficial material.

Recharge Conditions

Local ground-water flow systems are controlled by surface topography and are well defined because of a well-defined topographic relief (alternating narrow ridges and valleys). Greater topographic relief tends to produce greater depth of the local flow systems, which discharge into local streams because lakes and wetlands are rare in this district. Regional flow is toward the Mississippi and Wisconsin rivers. Some deep ground-water flow is to the southeast toward the Illinois basin. The surface of the Precambrian rock is the lower limit of ground-water movement.

SOUTHWESTERN PALEOZOIC DISTRICT



Hydrogeologic District No. 9 — ALLUVIAL VALLEYS

Boundaries

The Alluvial Valleys District is not a single geographic entity. It includes thick sand-and-gravel deposits beneath flood plains and terraces of Wisconsin's streams. Buried valleys not occupied by streams are not included. All of the valleys shown on the map on the left are occupied by perennial streams. Only the major valleys are shown on the map. Many other smaller valleys that occur throughout the state cannot be shown because of the scale of the map. The limits of the district are the limits of the valley fills within individual river valleys.

Aquifers

Locally productive, water-bearing alluvial sand and sand and gravel, interbedded with thin layers of silt and clay.

The valley fill is commonly alluvial sand and gravel, which overlies outwash sand and gravel deposited by glacial meltwater streams. These two deposits of sand and gravel have similar water-bearing characteristics. Yields over 100 gpm may be expected from wells in the alluvial valley fill.

Recharge Conditions

The surface material generally does not impede infiltration in the district. Recharge is rapid and its vertical path is very short, because the ground water is usually close to land surface. Occasionally, the aquifers are recharged by flood waters. Recharge from the streams may be induced by pumping wells adjacent to the streams.

Ground-Water Movement

Ground water moves toward the streams or downstream parallel to the streams. Gradients are very low. The alluvial valleys of major streams are commonly the discharge points of regional ground-water flow systems. Deep ground-water flow moves upward through the valley fill into streams. A part of the deep regional flow may pass beneath the streams and continue into another district.

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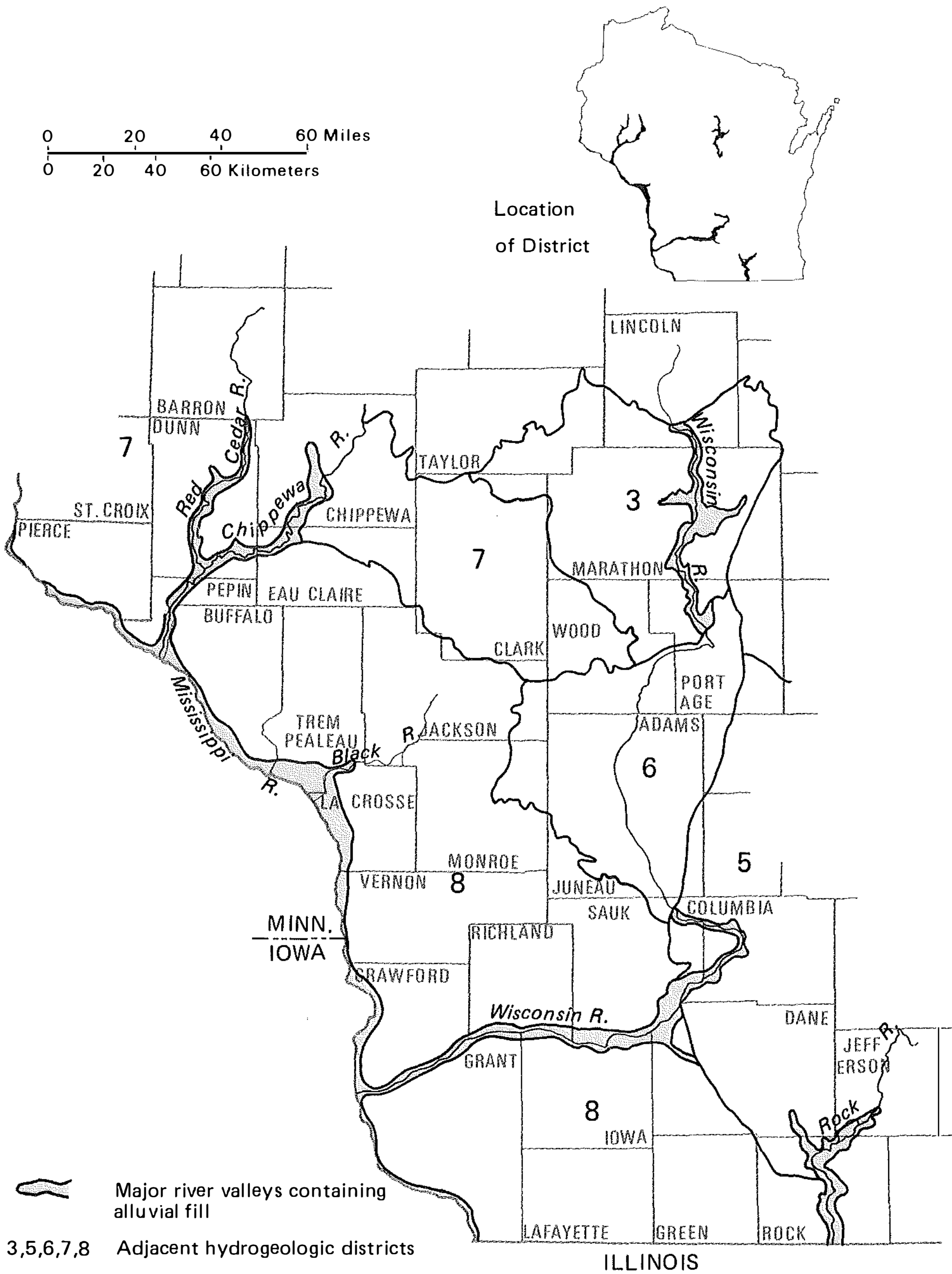
ALLUVIAL VALLEYS DISTRICT

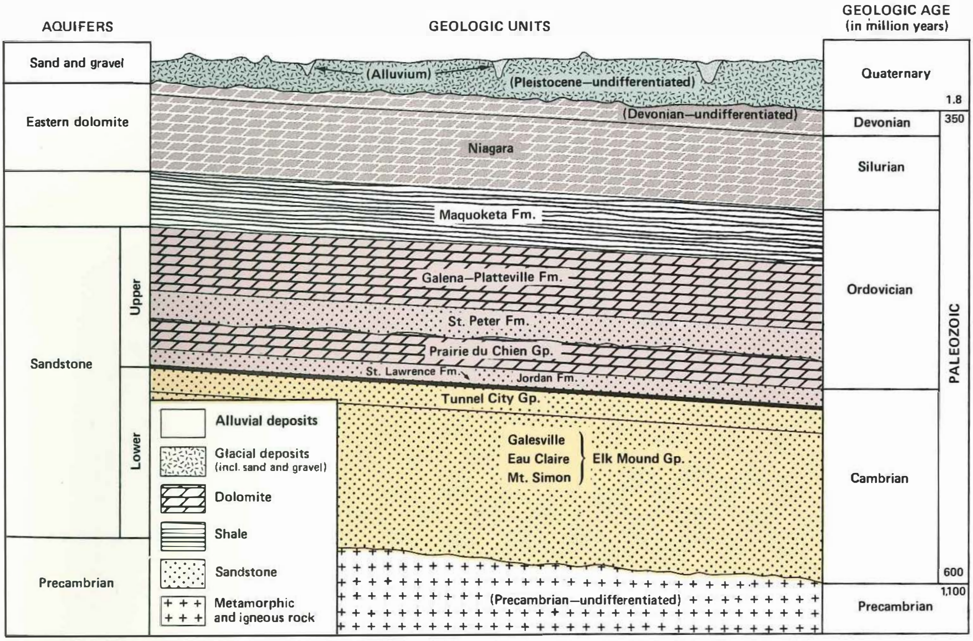


DEFINITION OF TERMS

Alluvial	Relating to alluvium (deposits resulting from the operations of modern rivers).
Artesian Pressure	Pressure necessary to raise the water level in a well above the top of the aquifer containing the water.
Aquifer	A saturated permeable geologic unit that contains and will yield significant quantities of water.
Confined Water	Ground water that completely fills an aquifer that is overlain by relatively impermeable layers.
Confining Bed	A body of impermeable material or material less permeable than that of the stratigraphically adjacent aquifers that confines the water in the aquifer beneath.
Drainage Divide	The boundary (imaginary line connecting the highest topographic elevations) that separates one drainage basin from another; the rim of a drainage basin.
Drift	Archaic term for rock material transported by a glacier and deposited by or from the ice or by or in water derived from the melting of the ice. Even though this term has been little used in modern geologic literature, we have retained it for convenience in naming the units.
gpm	Abbreviation of units (gallons per minute) used for the yield of water produced by a well (1 gpm = 5,450 liters per day).
Gradient (Hydraulic Gradient)	The rate of change of pressure head per unit of distance of flow at a given point and in a given direction.
Ground Water	That part of the subsurface water that is contained in the zone of saturation.
Ground-Water Divide	The boundary that separates one ground-water system from another across which there is no ground-water flow.
Ground-Water Flow System	Pattern of dynamic movement of ground water from a point of recharge (source) to a point of discharge (sink). Water that enters the system in a given recharge area may be discharged in the nearest topographic low (local system) or it may be transmitted to the regional discharge area in the bottom of the major valley (regional flow). Local systems are usually limited to 1 to 5 mi^2. Shallow systems refer to the maximum depth of 300 ft.
Hydrogeology	Science dealing with the origin, occurrence, distribution, and movement of ground water within the subsurface environment and its interrelations with this environment.
Infiltration	Entry of water into the ground.
Loess	Silt deposited by the wind.
Moraine	An accumulation of rock material by direct action of glacier ice.
Outwash	Sediment deposited by meltwater streams beyond active glacier ice.
Permeability	The ability of a rock or soil to transmit water.
Recharge	Addition of water to the zone of saturation, either directly by infiltration from the land surface or indirectly by way of another formation.
Till	Unsorted sediment deposited by a glacier.

GEOLOGIC UNITS OF WISCONSIN

(not to scale)



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