INTRODUCTION

PURPOSE AND SCOPE

The purpose of this report is to describe the physical environment, availability, characteristics, distribution, movement, and quality of water in the Pecatonica-Sugar River basin. In addition, water use and water problems are summarized to give an understanding of man's management of water within the basin.

This atlas is the seventh in a series of 12 river-basin studies that describe, in general terms, the water resources of Wisconsin. The report presents general information on the basin that was derived from data obtained from many Federal, State, and local agencies. Additional data were collected for areas where available data were scarce. Detailed studies of problem areas will be necessary in the future as the need for specific information increases.

ACKNOWLEDGMENTS

Many persons and organizations assisted the study by providing data. Among the contributors were University Extension—the University of Wisconsin Geological and Natural History Survey, the Wisconsin Department of Natural Resources, Public Service Commission of Wisconsin, and Wisconsin Department of Public Instruction. Municipal officials furnished water-supply information and well records. Many individuals and companies allowed access to their wells for collection of water samples for chemical analysis.

GEOGRAPHY

The size of the study area is approximately 2,850 square miles and comprises 5 percent of the State.

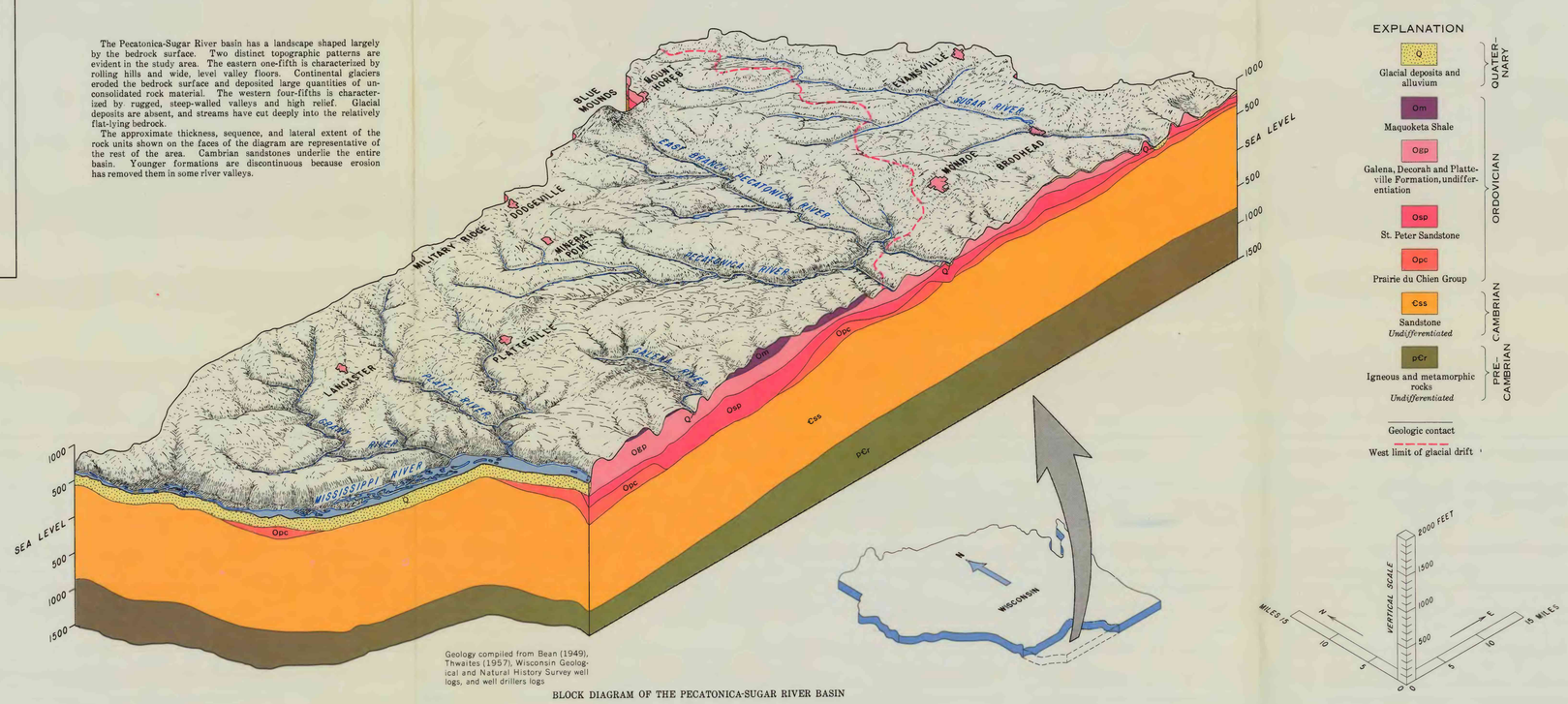
The estimated population of the study area was 102,600 in 1960 and 112,500 in 1970. The economy of the area is primarily agricultural, consisting mostly of dairy farming, manufacturing of dairy products, and beef production. Zinc-lead mining and small industries are of secondary importance.

Wisconsin has a temperate, continental climate that is characterized by the marked seasonal changes common to this latitude. In this basin average monthly air temperatures range from 20°F for January to 74°F for July, and the average growing season is 150 days. The average annual precipitation on the basin was 32.8 inches for the period 1931-60. February is normally the driest month (about 1 inch), and June is the wettest (about 5 inches). Snowfall averages about 40 inches annually.

PHYSICAL SETTING

The Pecatonica-Sugar River basin has a landscape shaped largely by the bedrock surface. Two distinct topographic patterns are evident in the study area. The eastern one-fifth is characterized by rolling hills and wide, level valley floors. Continental glaciers eroded the bedrock surface and deposited large quantities of unconsolidated rock material. The western four-fifths is characterized by rugged, steep-walled valleys and high relief. Glacial deposits are absent, and streams have cut deeply into the relatively flat-lying bedrock.

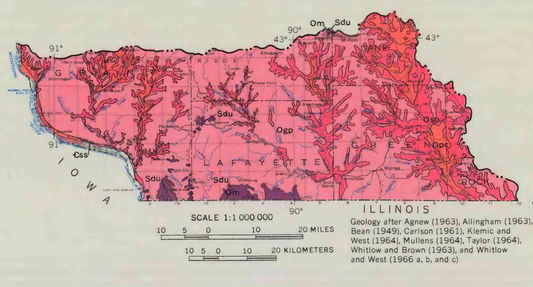
The approximate thickness, sequence, and lateral extent of the rock units shown on the faces of the diagram are representative of the rest of the area. Cambrian sandstones underlie the entire basin. Younger formations are discontinuous because erosion has removed them in some river valleys.



Geology compiled from Bean (1949), Thwaites (1957), Wisconsin Geological and Natural History Survey well logs, and driller's logs

BLOCK DIAGRAM OF THE PECATONICA-SUGAR RIVER BASIN

GEOLOGY AND SOILS



Geology after Agnew (1963), Allingham (1963), Bean (1949), Carlson (1961), Klemic and West (1964), Mullens (1964), Taylor (1964), Whitlow and Brown (1963), and Whitlow and West (1966 a, b, and c)

BEDROCK GEOLOGY

EXPLANATION

Bedrock geology and approximate thickness, in feet

SILURIAN

Sdu Dolomites, undifferentiated 0 - 200

ORDOVICIAN

Om Maquoketa Shale 0 - 240

Ogp Galena, Decorah, and Platteville Formations, undifferentiated *Dolomite and limestone* 0 - 350

Osp St. Peter Sandstone 0 - 400

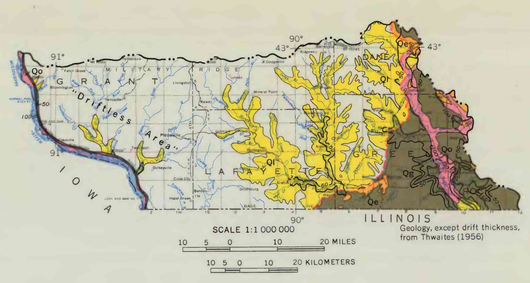
Opc Prairie du Chien Group *Mostly dolomite* 0 - 250

CAMBRIAN

Css Sandstone *Undifferentiated; includes Jordan, St. Lawrence, Franconia, Galesville, Eau Claire, and Mount Simon Formations* 700-1,500

Geologic contact

Surface-water divide



Geology, except drift thickness, from Thwaites (1956)

GLACIAL GEOLOGY

EXPLANATION

QUATERNARY

Ql Lake deposits *Contains stratified clay, silt, and sand*

Qg Ground moraine *Till; unstratified clay, silt, sand, gravel, and boulders*

Qe End moraine *Till and stratified sand and gravel*

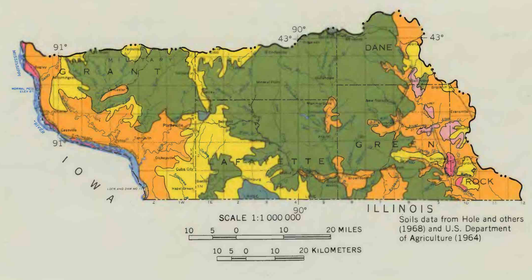
Qo Outwash *Stratified sand and gravel*

Geologic contact

West limit of glaciation

Line of equal approximate thickness of glacial drift *Interval 50 feet*

Surface-water divide



Soils data from Hole and others (1968) and U.S. Department of Agriculture (1964)

SOIL PERMEABILITY

EXPLANATION

Permeability rate in inches per hour (under a 0.5 inch head)

Less than 0.05

0.05 - 0.2

0.2 - 0.8

0.8 - 2.5

2.5 - 5

5 - 10

Area boundary

Surface-water divide

The bedrock surface is shown on this map as it would appear if the surficial unconsolidated material were stripped away. Exposed rocks in the study area are all sedimentary rocks of marine origin. Stream erosion has exposed the older rocks in stream valleys. Only a few erosional remnants of the younger rocks remain in the basin.

The rock units are not uniform in thickness. Erosion of the Prairie du Chien Group during Ordovician time has caused it to be very discontinuous. The overlying St. Peter Sandstone is thickest (about 400 feet) in the Cuba City area, where it fills erosional lows, but the thickness varies greatly. It is absent where the full thickness of the Prairie du Chien Group is present and where stream erosion has removed it. The Cambrian sandstone ranges in thickness from about 700 feet in the northeast to about 1,500 feet in the southwest. The sedimentary rocks dip to the south and southwest, and individual formations generally thicken in this direction, the direction of slope of the Precambrian surface (see block diagram). The Galena-Platteville unit thickens markedly toward the southwest because the regional dip of the sedimentary rocks exceeds the slope of the land surface in this direction.

Glacial drift as thick as 200 feet covers the bedrock in the eastern one-fifth of the study area, but the western four-fifths, part of the "Driftless Area", has no drift cover other than thick sand and gravel in the Mississippi River valley and thin glacial lake and alluvial deposits in the other river valleys. Drift is thickest in the proglacial Sugar River valley area.

Drift in the study area is composed of lake deposits, ground moraine, end moraine, and outwash. Lake deposits, laid down during the melting stages of glaciation when melt waters formed stagnant glacial lakes in the bedrock valleys, have low permeability and yield little water. Ground moraine, composed largely of till deposited by advancing glaciers, overlies much of the glaciated study area and also has low permeability, especially where it is clayey and silty. End moraines, deposited at the ice margins during pauses in glacial retreat, contain till and some stratified sand and gravel. The major end moraine deposits in the study area form part of the eastern surface-water divide, but some deposits occur throughout the glaciated area. Permeable outwash, which occurs in the Sugar and Mississippi River valleys, was deposited by streams from melting glaciers and yields large quantities of water.

A blanket of wind-blown silt (loess) covers the study area. The loess is the parent material for topsoil in most soil profiles, and its thickness ranges from 0.5 foot in the southeast to 16 feet along the Mississippi River (Hole, 1960).

Permeability is one of the important factors that determines the rate at which precipitation infiltrates the soil. The soil permeability map shows generalized areas of permeability determined for the least permeable horizon in saturated soils. The permeability rates are representative of the recharge potential to the ground-water reservoir. Soils with low permeability, less than 0.2 inch per hour, cover 52 percent of the study area.

Almost all of the soils have loess as the parent material. Differences in underlying material cause the different soil permeabilities. The most permeable soils have outwash under the loess. The less permeable soils have shale, clay, or limestone under the loess.

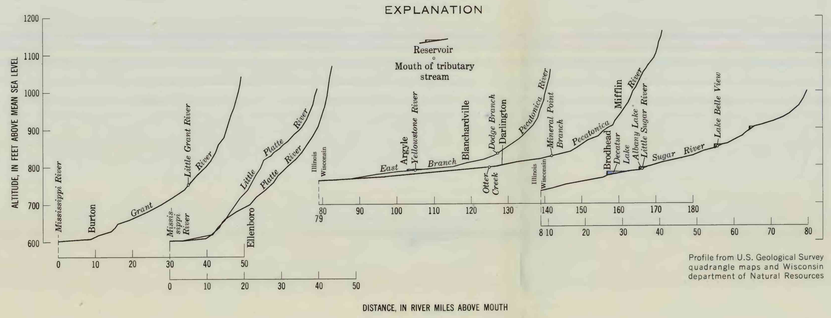
TOPOGRAPHY AND DRAINAGE

The topography of much of the basin consists of deep, steepsided valleys that have flat bottoms, and narrow rolling ridges. Level land is limited to the narrow valley bottoms. The land surface altitudes range from about 600 feet above mean sea level along the Mississippi River to 1,720 feet at Blue Mounds on the northern basin boundary.

Topography in the western four-fifths of the study area is controlled by the bedrock. Streams have eroded the bedrock, forming a rugged topography with rolling ridge lands, steep valley walls with numerous rock ledges, and rather narrow valley bottoms.

In the glaciated area the bedrock topography was subdued by glaciers that rounded the bluffs and filled the valleys, forming gentle topography and low relief.

Geologic structure completely controls the drainage pattern in the "Driftless Area" (Palmquist, 1965). The location and trends of divides, both regional and local, are influenced by the trends of structural highs within a framework of the regional dip that controls the gross drainage trends. The fine details of the drainage pattern are influenced by fold trends. Even the smallest folds and joint trends influence trends of valley segments, low-order streams, and the shape of valley bends. The interaction between these elements is complex, and the influence of one structural element may mask the effects of the other.



STREAM PROFILES

Two distinct gradients exist for streams draining the "Driftless Area" of the basin. The Grant, Platte, and Pecatonica Rivers have gradients of about 1 foot per mile in the lower reaches, where the streams meander over alluvium-filled valley bottoms. Farther upstream, where the streams cut into the underlying bedrock, gradients are about 12 feet per mile. Usually abrupt changes in gradient can be related to changes in the bedrock of the streambed. In the Little Platte River the stream gradient steepens where the stream flows from the harder dolomites and shales of the Galena-Platteville unit onto the softer St. Peter Sandstone. Average stream gradients in the "Driftless Area" are 4.3 feet per mile for the Pecatonica River, 8.5 feet for the Grant River, and 10.6 feet for the Platte River.

The Sugar River, which is the only stream draining the glaciated part of the basin, has a uniform gradient of about 3.4 feet per mile except in the extreme headwater area, where the gradient is about 12 feet per mile.

WATER USE

WITHDRAWAL USE OF WATER IN 1969, IN MILLION GALLONS PER DAY

Use	Source and type of supply: Ground water: Public supply: Municipal	Ground water: Public supply: Other	Ground water: Private supply	Surface water: Private supply	Total
Domestic	2.3	0.1	3.1	0.0	5.5
Industrial and commercial	2.2	<.1	1.0	198.2	201.4
Irrigation	.1	.0	.1	.2	.4
Stock	<.1	.0	7.5	1.8	9.3
Other	1.7	<.1	7.7	.0	9.4
Subtotal	6.3	.1	19.4		
Total		25.8		200.2	226.0

More than 82 billion gallons of water were withdrawn for use in the Pecatonica-Sugar River basin in 1969. About 11 percent came from wells, and the rest came from streams and manmade impoundments.

About 99 percent of the surface water withdrawn in the basin came from the Mississippi River and was used for cooling in steam-powered generating plants located at Cassville. In this use the only important change in the water is an increase in temperature.

Ground water is the source for all municipal and industrial supplies (with the exception of cooling for electric power generation), and for most rural supplies.

In the table above, public supply use is that of municipalities, sanitary districts, and self-supplied schools and institutions. Under public supplies, irrigation is largely for parks and golf courses, and in the use column "other" includes losses from the distribution system, use in street watering, main flushing, and fire fighting, and use in schools and other public buildings. Under private supply, "other" includes mine dewatering and losses from distribution systems. Private supply use is all other use, including rural farm and non-farm, dairies, industries, and commerce.

Total withdrawal use of water in 1969 was equivalent to about 0.7 percent of the average streamflow leaving the study area, including the Mississippi River. Excluding the Mississippi River, the withdrawal use in the study area is 29.07 mgd (million gallons per day) or about 2 percent of the streamflow actually leaving the study area. However, because water is usually discharged into the nearest stream after use, it is available for reuse downstream. Therefore, data on withdrawal includes a very small, undetermined amount of reuse of the same water.

It is estimated that less than 6 percent of the water withdrawn was consumed; that is, transported from the basin or lost to evapotranspiration.

NONWITHDRAWAL USE OF WATER

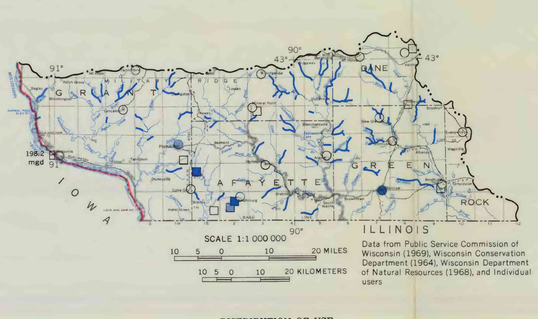
The most important nonwithdrawal uses of water in the basin are fish and wildlife habitat, recreation, transportation, and waste transport and disposal.

In Wisconsin the management of fish and wildlife habitat and recreation are extremely important because the State derives economic gain from tourism. The headwaters of all the major streams in the basin provide good trout habitat. The few wetlands in the study area make up only a small part of the fish and wildlife habitat. The major wetland areas are along the Mississippi and lower Sugar Rivers.

Recreational facilities in the Pecatonica-Sugar River basin show increasing daily and weekend use by area residents and visitors. Fishing and other water sports, along with sightseeing, camping, and hiking, are the major water-related recreation activities demanded in this area.

Water transportation on the Mississippi River provides an economical way of delivering coal to power plants at Cassville, and it also provides an additional opportunity for trade.

Many streams in the study area are used to transport treated wastes from many sources. Reaches of streams in areas of high water use and intense agriculture are subject to pollution from waste disposal and surface runoff.



Data from Public Service Commission of Wisconsin (1969), Wisconsin Conservation Department (1964), Wisconsin Department of Natural Resources (1968), and Individual users

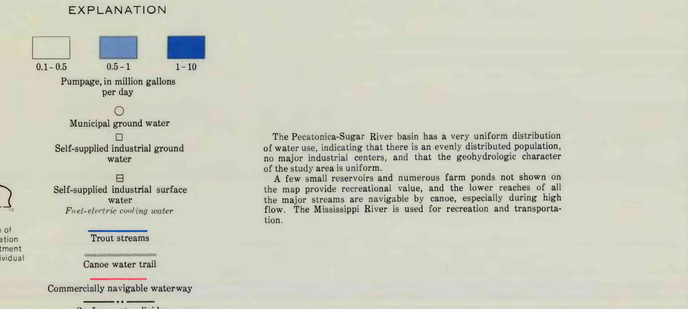
DISTRIBUTION OF USE

MUNICIPAL WATER USE IN 1969 AND SOURCE OF WATER
[Pumpage and use data from Public Service Commission of Wisconsin]

Municipality[1]	County	Population 1970	Average daily pumpage (mgd)	Maximum daily pumpage (mgd)	Use (million gallons per year): Domestic	Industrial and commercial	Public	Other	Source of water[2]
Albany	Green	875	0.063	0.192	12.18	1.78	2.44	5.67	S.
Argyle	Lafayette	673	.096	.177	17.41	.00	1.22	16.63	S.
Bagley	Grant	271	.012	.240	2.67	.36	.09	1.71	S.
Bartereld	Iowa	528	.057	.172	7.11	2.21	1.61	9.90	S.
Belleville	Dane and Green	1,063	.093	.400	14.28	14.31	.00	5.42	S.
Belmont	Lafayette	688	.092	.128	7.59	12.09	1.75	12.14	S.
Benton	Lafayette	873	.042	.130	10.55	1.99	.00	2.63	S.
Blanchardville	Lafayette	671	.084	.215	10.22	12.25	3.39	4.77	S.
Bloomington	Grant	719	.057	.130	7.32	6.40	2.43	4.60	S.
Brodhead	Green	2,515	.180	.365	31.00	17.04	15.09	2.52	S.
Brooklyn	Dane and Green	565	.038	.097	5.34	1.37	.74	5.20	S.
Browntown	Green	253	.017	.063	3.09	1.99	.09	.93	S.
Cassville	Grant	1,243	.139	.376	17.43	22.77	2.33	8.54	S.
Cobb	Iowa	410	.060	.341	4.89	16.81	.20	.04	S.
Cuba City	Grant	1,993	.181	.365	27.61	18.49	2.37	17.49	S.
Darlington	Lafayette	2,351	.285	.481	30.82	24.27	24.77	24.32	P, S.
Dickeyville	Grant	1,057	.062	.138	12.35	6.80	1.85	1.78	S.
Dodgeville	Iowa	3,255	.226	.348	38.59	12.29	6.26	25.34	P, S.
Evansville	Rock	2,982	.292	.464	40.00	18.00	10.00	38.00	S.
Fennimore	Grant	1,861	.143	.304	25.76	19.76	6.02	2.48	S.
Gratiot	Lafayette	249	.034	.122	1.83	2.26	.82	7.58	S.
Hazel Green	Grant	982	.055	.096	12.64	4.21	1.01	2.25	S.
Hollandale	Iowa	256	.017	.065	2.41	1.50	.99	1.21	S.
Lancaster	Grant	3,756	.433	.811	54.51	23.27	30.73	49.68	S.
Linden	Iowa	498	.022	.038	3.27	1.33	.15	3.30	P, S.
Livingston	Grant and Iowa	503	.036	.069	7.97	3.99	.48	.69	S.
Mineral Point	Iowa	2,305	.182	.398	29.64	15.41	5.56	15.44	S.
Monroe	Green	8,945	1.682	2.752	156.68	327.06	16.22	114.11	S.
Montfort	Grant	570	.107	.180	3.64	6.46	4.80	24.21	S.
Mount Hope	Grant	176	.016	.708	1.86	2.20	.80	.91	S.
Mount Horeb	Dane	2,402	.188	.494	30.77	32.43	3.70	1.83	S.
New Glarus	Green	1,454	.125	.244	22.21	16.15	4.12	3.24	S.
Orfordville	Rock	888	.066	.120	12.48	3.03	5.99	2.71	P, S.
Patch Grove	Grant	187	.025	.060	2.09	3.57	2.72	.72	S.
Platteville	Grant	9,599	.736	.951	105.11	46.63	75.03	41.91	S.
Potosi	Grant	1,037	.099	.300	4.77	11.41	.10	20.19	S.
Rewey	Iowa	232	.024	.070	3.04	....	.48	.45	P, S.
Ridgeway	Iowa	465	.024	.093	4.60	.44	.65	2.99	S.
Shullsburg	Lafayette	1,276	.159	.375	18.29	6.80	7.82	25.02	P, S.
South Wayne	Lafayette	436	.031	.078	5.34	3.06	1.75	1.04	S.
Tennyson	Grant	402	.034	....	4.34	5.42	1.14	1.44	S.
Verona	Dane	2,334	.317	.501	34.17	75.57	....	5.79	S.
Total		63,966	6.629		851.37	802.59	248.81	517.02	

[1]Does not include sanitary districts
[2]S, sand aquifer; P, Galena-Platteville aquifer
[3]Estimated

Total municipal water use in the study area is small, about 6.3 mgd, and is nearly equally divided between domestic and industrial uses. Monroe uses the largest amount of water; the city's average daily pumpage is about 1.7 mgd. Thirty-six of the 42 municipalities listed obtain all of their water from the sandstone aquifer, and the other six obtain their water from a combination of the Galena-Platteville and sandstone aquifers.

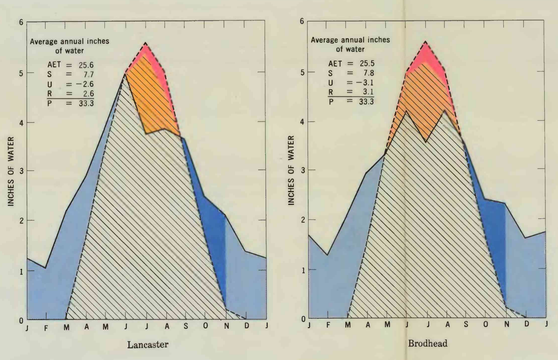


The Pecatonica-Sugar River basin has a very uniform distribution of water use, indicating that there is an evenly distributed population, no major industrial centers, and that the geohydrologic character of the study area is uniform.

A few small reservoirs and numerous farm ponds not shown on the map provide recreational value, and the lower reaches of all the major streams are navigable by canoe, especially during high flow. The Mississippi River is used for recreation and transportation.

WATER SYSTEM

MONTHLY WATER BALANCE



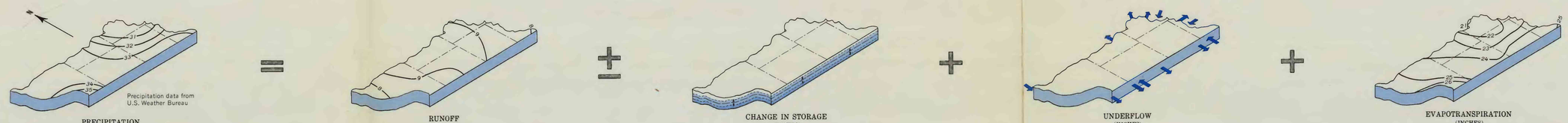
The relationship of soil moisture to evapotranspiration and precipitation varies throughout the year and with location. Estimates of monthly values of "actual" and "potential" evapotranspiration by an empirical method (Thornthwaite and Mather, 1957) illustrate the monthly water balance in the eastern and western parts of the basin at Brodhead and Lancaster, respectively.

Winter snow accumulation and spring rainfall maintain a soil-moisture surplus through spring. The monthly surplus decreases as evapotranspiration increases during the early spring until evapotranspiration exceeds precipitation in late spring, then soil moisture is withdrawn from storage. A moisture deficit begins when the soil moisture in storage is depleted and the potential evapotranspiration is greater than actual evapotranspiration during the moisture-utilization period. In the fall, as the temperature declines and transpiration by vegetation decreases, precipitation recharges soil moisture until the winter phase of surplus moisture starts again. It should be noted that the soil-moisture surplus referred to represents ground-water recharge and surface runoff.

HYDROLOGIC BUDGET

The hydrologic budget is a simplified equation that balances the basic components of the hydrologic cycle. Water input to the basin equals the algebraic sum of water output and change in storage. Precipitation and ground-water underflow, the only inputs to the basin, are balanced by outputs of surface runoff, evapotranspiration, ground-water underflow, and consumptive use by man. Both positive and negative changes in storage occur in ground and surface water, as well as in soil moisture. The quantities of these budget items fluctuate from year to year, but major variations occur only in precipitation, runoff, and evapotranspiration. Man's effects on these quantities are almost negligible in the Pecatonica-Sugar River basin. A very small part of the ground and surface water withdrawn by man is consumed; a part of the water he stores on the surface is evaporated. In the lead-zinc mining areas of Grant, Iowa, and Lafayette Counties mine dewatering has artificially lowered the potentiometric surface and increased the streamflow.

Average conditions for the period 1931-60 are illustrated on the budget maps.



Over a long period net change in ground-water, surface-water, and soil-moisture storage in the basin is negligible, and annual gains or losses of water are balanced.

Changes in ground-water storage are indicated by a rise or fall of the potentiometric surface, an imaginary surface that represents the level to which water will rise in tightly cased wells. A study of water-level records for wet and dry years shows that the potentiometric surface generally responds to changes in precipitation. The resulting net annual rise or fall during extremely wet or dry years is estimated to be about 3.5 feet and 1.3 feet, respectively. These changes in water level equal about 6.3 inches gained in storage for the wet year and 2.3 inches lost in storage for the dry year.

The amount of stored surface water in the basin is very small in comparison to the amount of stored ground water and, therefore, was not included in this budget.

Even though the seasonal change in soil moisture throughout the year may be significant, the net change during the year is insignificant.

Underflow is water entering or leaving a basin through the ground-water reservoir. The net amount of underflow from the study area is estimated to be about 0.3 inch per year around the boundary and 0.1 inch per year through the valley fill. Differences in underflow between years of normal and extreme precipitation probably are less than the 0.1 inch shown.

Underflow leaves the study area through both bedrock and glacial drift along the eastern edge of the basin where the ground-water divide does not coincide with the surface-water divide (see potentiometric map, sheet 2). A net loss also occurs along the Wisconsin-Illinois State line, which does not follow any hydrologic boundary. Elsewhere along the basin boundary, inflow approximates outflow because the ground- and surface-water divides nearly coincide, and small areas of ground-water inflow balance areas of ground-water outflow. Additional underflow leaves the study area through the valley fill of the Sugar, Pecatonica, and Galena Rivers. Ground-water inflow approximately equals outflow in the Mississippi River valley fill as the river enters and leaves the study area.

Evapotranspiration, the return of water to the atmosphere by evaporation and plant transpiration, is computed here as the difference between precipitation and the sum of runoff, change in storage, and underflow. Evaporation from open water surfaces accounts for less than 1 inch of the total average annual evapotranspiration. Man's consumptive use of water has been included in evapotranspiration but is less than 0.5 percent of the total.

Base from U.S. Geological Survey
1:500,000, 1968

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1973—W71289

WATER RESOURCES OF WISCONSIN—PECATONICA-SUGAR RIVER BASIN

By
S. M. Hindall and E. L. Skinner

1973

For sale by U.S. Geological Survey, price $1.75 per set