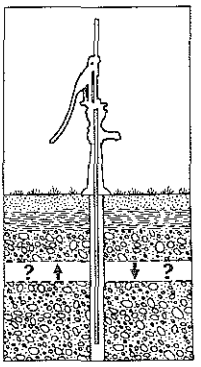
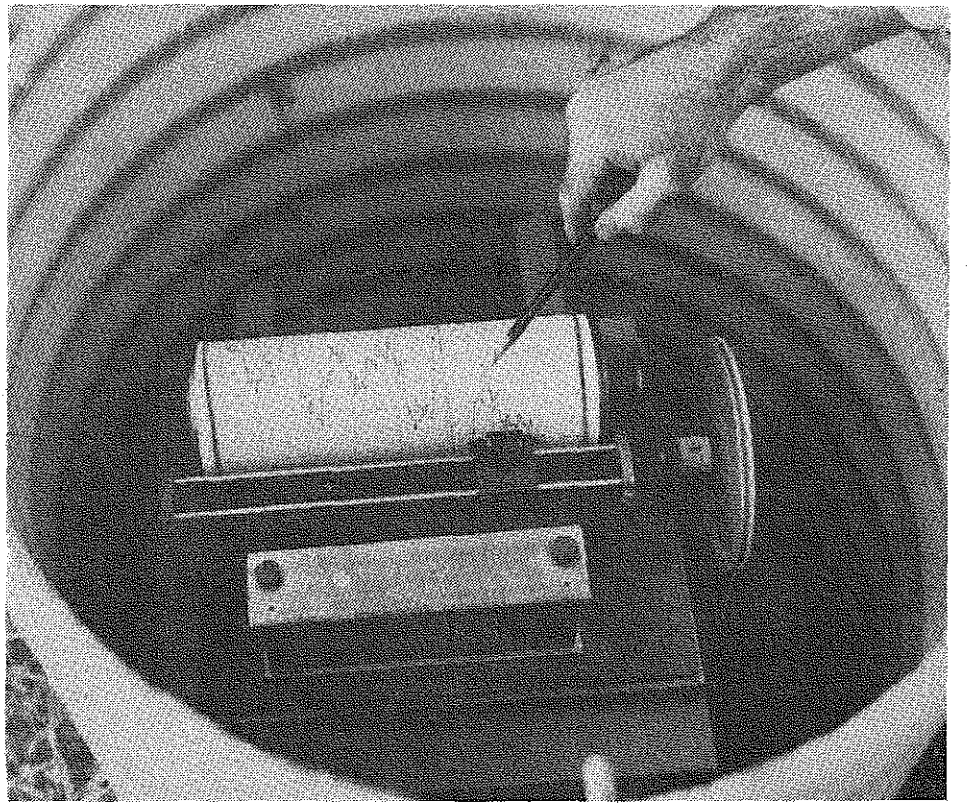


December 1982

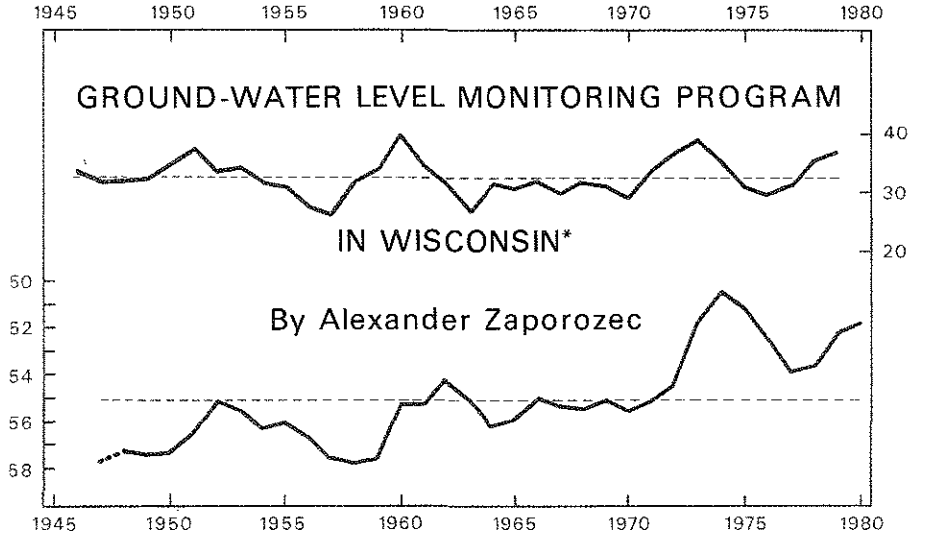
GROUND-WATER LEVEL MONITORING PROGRAM IN WISCONSIN



prepared by University of Wisconsin-Extension
GEOLOGICAL AND NATURAL HISTORY SURVEY in cooperation with
UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY

This report is a product of the Geological and Natural History Survey Water Resources Program which includes: systematic collection, analysis, and cataloguing of basic water data; impartial research and investigation of Wisconsin's water resources and water problems; publication of technical and popular reports and maps; and public service and information.

Further information and data on water-level measurements are available from University of Wisconsin—Extension, Geological and Natural History Survey, 1815 University Avenue, Madison, WI 53705-4096.



Effective management of ground water in Wisconsin requires that up-to-date information relating to water levels be readily available for efficient design of wells, water-supply facilities, buildings, and roads; for planning studies, land suitability studies, and water-quality studies; and for managerial and legislative decisions. Data on ground-water levels should not only be collected, stored, and evaluated for scientific and technical studies, but also summarized and made available in a form that is readily usable. Potential users include well drillers, consultants, local and state agencies, legislators, planners, managers, farmers, and all concerned citizens who desire or require a working knowledge of fluctuations in ground-water levels.

Even though the current observation network in Wisconsin has 200 wells, it does not include enough points to cover all local needs; and to do so would be largely impractical. However, the statewide network could and should include a sufficient number of wells with long-term records distributed in such a way that each hydrogeologic unit and each county would have access to data from at least one well from which information can be extrapolated.

Also, slow and gradual changes in ground-water levels, as compared to rapid changes in the rainfall and streamflow, require long-term measurements to document the overall trends and cycles in ground-water levels, which in some cases may span several decades. For this reason, the key wells of the observation network should be measured indefinitely to allow for the definition of such cycles.

HISTORY

Wisconsin is one of several states in which continuous records of ground-water level measurements go back more than 45 years. Shortly before the turn of the century intensive use of ground water in the states dependent on pumped water forced local authorities to monitor more closely the relation of withdrawal and natural replenishment. The earliest records of water-level measurements in the United States were kept by municipal and

*Adapted from a paper presented at the 5th Annual Meeting, Wisconsin Section, American Water Resources Association, Appleton, Wisconsin, February 20, 1981.

irrigation companies: in New Jersey since 1891, in California since 1892, and in New York since 1903. Regional measurements of ground-water levels started in the 1920's and 1930's in connection with the U.S. Geological Survey (USGS) ground-water investigations, but statewide observation networks had not developed until the late 1930's. The impetus for rapid development of ground-water level observations in the United States was the National Soil Conservation Program of the U.S. Soil Conservation Service, who in 1934 established, in cooperation with the USGS, observation wells in eight states, which became nuclei of statewide observation networks. Altogether, by 1935, observations at various levels were made in 30 states, including the then Territory of Hawaii (fig. 1).

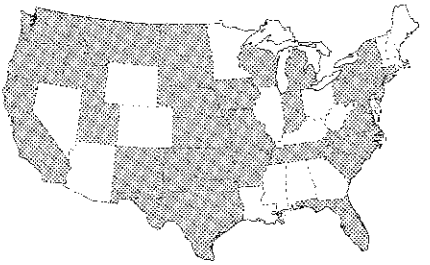


Figure 1. Observation of ground-water levels in the United States prior to 1935.

In Wisconsin, periodic measurements of ground-water levels began on June 15, 1934, when 13 observation wells were put into service in southwestern Wisconsin (in the Coon Creek area) by the U.S. Soil Conservation Service as a part of the National Soil Conservation Program. All but three of these 13 wells (Mo 2, Mo 10, and Ve 8) have since been discontinued. During the years 1935-37, ten more wells were added to the observation-well program bringing the total number to 23: one well in the Coon Creek area, and nine wells installed by the Wisconsin Conservation Department (now DNR) in each of its Forest Protection Districts in northern and central Wisconsin as a part of the shallow ground-water resource investigation (fig. 2).

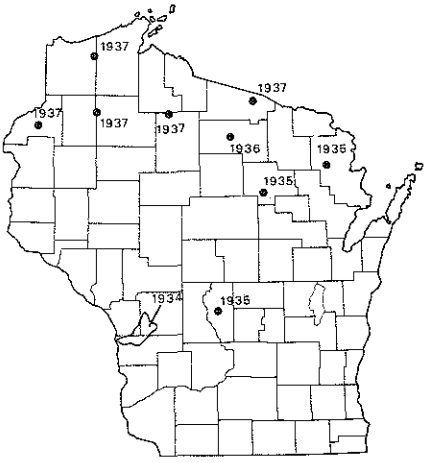


Figure 2. First observation wells in Wisconsin.

Seven of these additional wells (Ad 2, Bt 2, Ds 1, La 118, Pr 6, Sw 7, and Vi 3) have been in operation ever since. Through 1945, the number of observation wells remained below 30.

The beginnings of a statewide ground-water observation network can be traced back to 1946 when the Wisconsin Geological and Natural History Survey (WGNHS), directed by State Legislature, initiated, in cooperation with the USGS, a program to measure ground-water levels. During the period 1946-50 , 217 wells were added to the observation network (fig. 3). By 1954 the network had reached its peak of 270 wells and measurements covered 55 counties. After a revision in 1956 a substantial number of wells (34) were dropped from the program. By 1957, coverage was extended to 64 counties, although the number of wells dropped to 208. Since 1958, the number of observation wells has stabilized at a little over 200, with the exception of 1965 when the number dropped below 200. In that year, measurements were made in 196 wells in 66 counties. In 1980, measurements were made in 200 wells in 68 counties; Iron, La Crosse, and Washington counties were not covered (see map, back cover). Twenty-three of these wells were

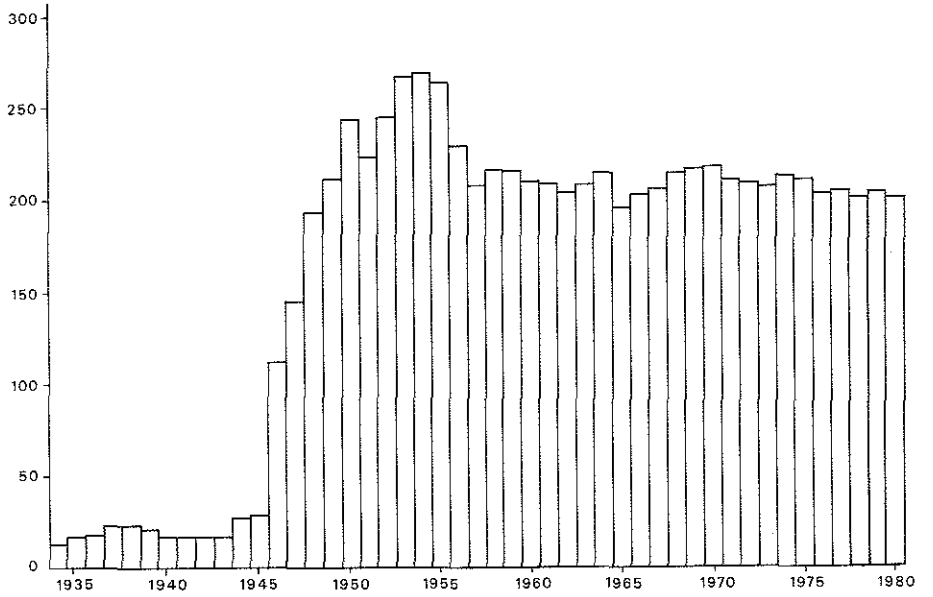


Figure 3. Number of observation wells in Wisconsin by year.

equipped with recording gages; 19 were measured weekly; and 158 were measured monthly (table 1).

CONCEPT

The monitoring network in Wisconsin was established without any formalized concept and has evolved more or less spontaneously (the same applies to all the other states). In April 1980, a standing Joint USGS/WGNHS Committee on Ground-Water Observation Network was established. The goals of the Committee are to establish criteria for planning and operation of a statewide observation network for monitoring trends in ground-water levels; to evaluate the existing network and recommend revisions as needed according to adopted criteria; and to continuously review the network, and its effectiveness, and institute any changes to meet future needs.

The guidelines for monitoring ground-water levels in Wisconsin developed by the Committee include the objectives of monitoring and network design.

Purpose and Objectives of Monitoring

The purpose of the systematic observations of water levels is to provide information needed for problem-solving and decision-making related to water and land-use planning, resource management, and environmental protection, and for prompt response to crisis situations.

In order to obtain this information, representative water-level data are needed for a continuing evaluation of the response of major hydrogeologic units to natural and human-related stresses. The primary objectives of the water-level measurement program are to: (a) determine ground-water level fluctuations and their causes, the range of fluctuations, and the long-term trends in water levels; (b) study the natural regime of ground water under different hydrogeologic conditions and to predict changes in the regime caused by human-related factors (especially in the areas influenced by major pumping centers); (c) measure changes in gradient

Table 1. Period of record and frequency of measurement of existing observation wells in Wisconsin as of December 31, 1980.

Years of Continuous Record	Number of wells	Frequency of Measurement Monthly	Weekly	Continuous
45 or more	3	3	--	--
41-44	5	--	5	--
31-40	54	35	10	9
21-30	36	27	2	7
11-20	63	60	--	3
10 or less	39	33	2	4
TOTAL	200	158	19	23

and recharge that may lead to changes in water quality; and (d) establish regional regularities of the regime, interactions of ground water and other components of the hydrologic cycle, and interactions between aquifers.

Monitoring – Network Criteria

Criteria for the network design selected by the Committee include, besides geology and hydrogeology, spatial distribution, length and continuity of record, frequency and accuracy of measurements, and well construction.

DENSITY

Observation wells are distributed areally and by aquifer to insure uniform spatial coverage and proportional coverage of natural fluctuations in both water-table and confined aquifers. Observation wells are also located in areas of heavy pumpage to monitor man-caused fluctuations.

LENGTH AND CONTINUITY OF RECORD

Observation wells are classified into one of the following categories:

(a) primary stations (key wells) with permanent continuous record to monitor time variability of the regime which could be used as reference stations;

(b) secondary stations with temporary continuous record to monitor spatial variability and to supplement record of primary stations;

(c) problem-oriented (project) stations with limited record of varying frequency;

(d) miscellaneous stations: wells measured by other agencies.

FREQUENCY AND ACCURACY OF MEASUREMENT

In order to obtain representative observations, water levels are measured monthly on all wells except the primary wells, which are measured more frequently to obtain data suitable for reliable statistical evaluation of these key points. Automatic recorders are distributed uniformly and proportionally to include all aquifers, especially those with frequent and rapid changes in water level. In addition to permanently installed recorders, several roving recorders are installed on selected wells for limited periods of time to specify the frequency of measurements in the areas of special interest.

All measurements are done with accuracy to one hundredth of a foot (3 mm) at regular intervals. Missing observations should not amount to more than three to ten percent of the record depending

Table 2. Summary of key wells by aquifer.

Shallow Aquifers		Bedrock Aquifers		Special Pupose	
Weathering residuum and alluvium	1	Niagara dolomite	4	Earthquake sensors	2
Alluvial deposits	12	Upper Aquifer	7	Pumping effects	4
Glacial deposits	21	Sandstone aquifer	8		
		Precambrian rock	4		
Total	34	Total	23	Total	6

on the frequency of measurement: 3% for recorders, 6% for weekly measurements, and 9% for monthly measurements. In addition to the objectives and design criteria, the Committee also established the requirements for observation-well construction.

WELL CONSTRUCTION

The well should penetrate an aquifer in such a way that water level fluctuations in the well are representative of groundwater conditions in the aquifer in the area being monitored.

The well should be of known construction and geologic profile. Minimum diameter of four inches is required to accommodate a recorder, if needed. If the well is designated as a primary station and does not have a known geologic profile, a test hole will be drilled in the closest proximity to obtain geologic documentation whenever possible.

All observation wells will be equipped with safe-guarding caps. The primary stations will be housed in permanent well houses; and property lease or permit for indefinite free access will be obtained.

DESIGN OF MONITORING NETWORK

Representative observations are obtained through a monitoring network consisting of observation wells for measuring the water-level fluctuations resulting from natural stresses (climate, topography, surface water), the responses of water levels to human-related stresses (pumping and dewatering, changes in recharge and discharge conditions) on both local and regional scales, and the responses of water levels to earthquakes. A group of wells will be designated as key wells, which will serve as basic, long-term reference points.

The concept of Wisconsin's observation network is built around several groups of primary stations (key wells) designated for each major aquifer in the state. The key wells will serve as reference points to which the records of other wells can be correlated. Key wells will be measured indefinitely. If irreparably damaged or destroyed, they would be replaced immediately by a new well drilled in the closest proximity to the same depth and with an identical construction to insure an uninterrupted record.

The network of key observation stations reflects the state's geology. Seven groups of key wells are being established--five groups to monitor natural fluctuations within individual aquifers, one group to monitor effects of pumping in heavily stressed areas, and one group as earthquake sensors. The proposed key wells are summarized in table 2 and shown on figure 4.

More than one half of the 63 proposed key wells (34 wells) are located in the shallow unconsolidated aquifers (alluvial and glacial deposits). Of those, 20 wells are in the glacial deposits of northern and central Wisconsin. One well will measure water-

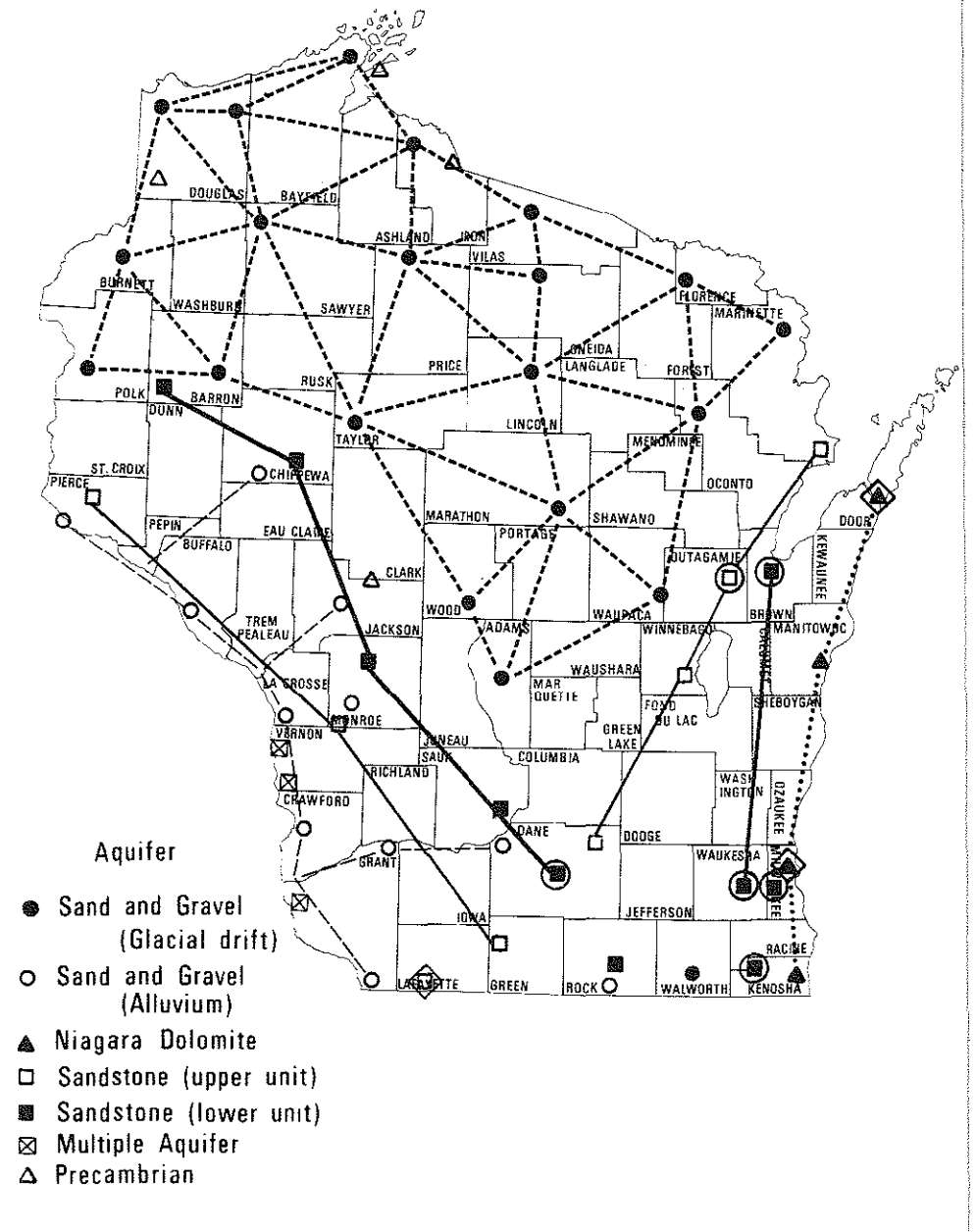


Figure 4. Proposed key observation wells.

level fluctuations in the deeper glacial deposits in southeastern Wisconsin; and one well is located in the unglaciated area of southwestern Wisconsin. The remaining 12 wells are aligned along the deep alluvial deposits of the Mississippi River and its major tributaries: Chippewa, Black, Wisconsin, and Rock rivers.

Bedrock aquifers will be monitored in 23 wells. Fifteen key wells monitor water-level changes in sandstones and carbonates of Cambrian and Ordovician age (two of them will be equipped for multiple observations); four key wells are located in the Niagara dolomite in eastern Wisconsin; and four key wells are located in Precambrian rocks.

Six key wells are designated for special purpose. Two wells will monitor earthquake effects, and four will monitor pumping effects--three in southeastern Wisconsin, and one in the Green Bay area.

The key wells are on the average 50 miles apart, with the distance ranging from 20 to 70 miles between the wells in the shallow aquifers, and from 35 to 110 miles in the bedrock aquifers. The network of key wells in glacial deposits is denser because their geologic and hydrogeologic conditions vary laterally to a greater degree than bedrock conditions.

DATA COLLECTION AND ORGANIZATION

Traditionally, the basic data collection in Wisconsin, including the ground-water level measurements, has been carried on as a cooperative program with a 50/50 cost-sharing of state and federal funds. The state (through the WGNHS) pledges its 50 percent of funding to the USGS; the federal unit matches this amount and provides the field staff. Unfortunately, there have been no substantial additions in the level of state support since 1964. With inflation, this means that the ability to evaluate the incoming data has been severely limited.

As a means to temporarily supplement the water-level measurement budget, the WGNHS started a local observer program in 1978. A letter was sent to all County Extension Offices asking them to assist in measuring ground-water levels in respective counties. The results have been successful, and today almost 50 counties cooperate in this program (fig. 5). Through this help the WGNHS and USGS were able to allot more money and manpower to the processing and evaluation of water-level measurements, and to start publishing information at the local level.

In order to meet the objectives of the observation-well network, the Joint Committee has undertaken the evaluation of existing observation wells and organization of records. Each observation well has been evaluated individually and in relation to nearby wells and classified either as a primary or secondary station. Recommendations have been made regarding the improvement of measurements, well equipment, and well records. The wells with inadequate record or wells providing duplicate record are being recommended for discontinuation; and new wells are recommended for the areas of insufficient coverage. Extensive files, including the geologic documentation and all available data, have been gathered on each well.

The records generated by and associated with the collection and evaluation of ground-water-level data will be organized in the network data file. This file for each observation well will consist of a station file, water-level data file, and original data file. By maintaining complete, orderly, and up-to-date files of data related to and collected as part of the monitoring program, the accuracy of records is ensured, the duplication of work is eliminated, and the processing and preparation of data for publication is made less complicated.

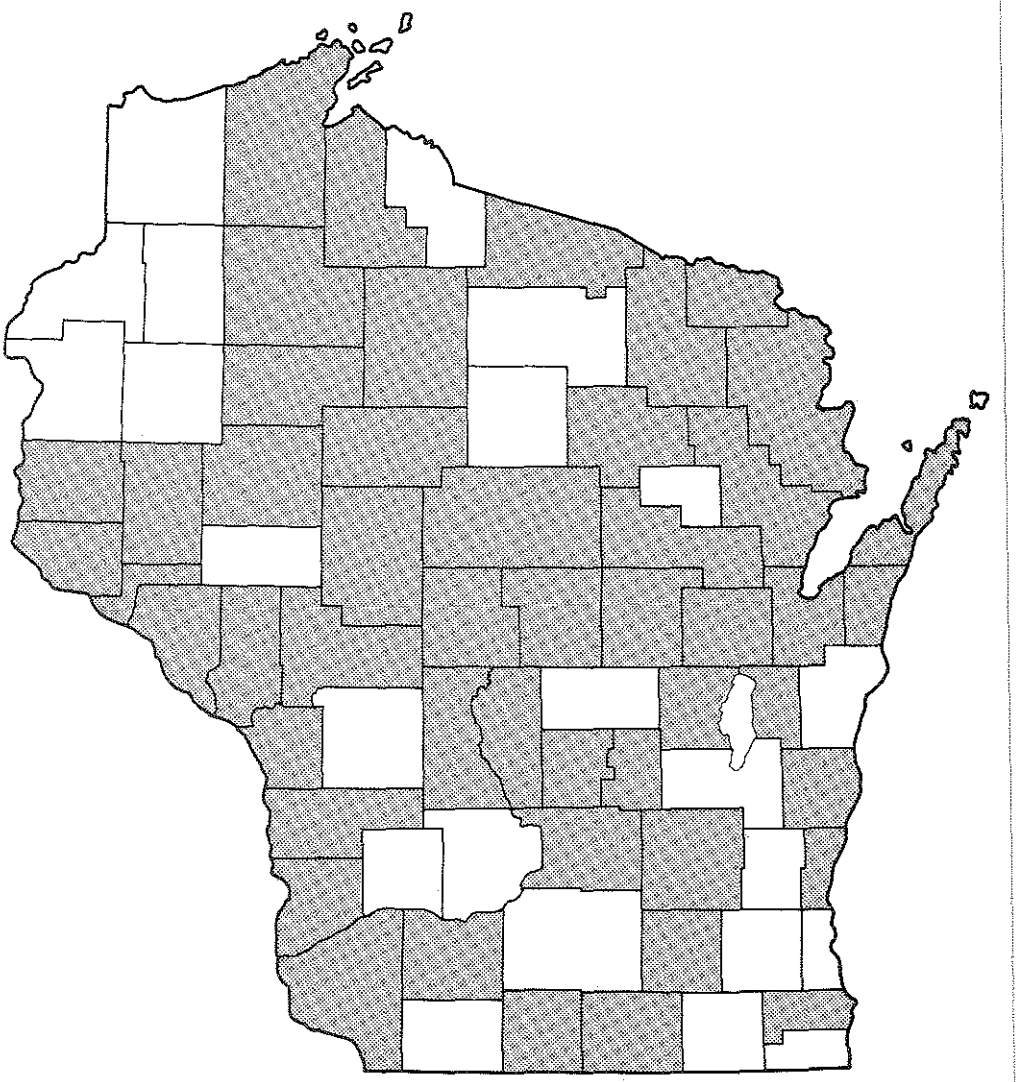


Figure 5. Counties cooperating in water-level measurement program in 1981.

DATA PROCESSING, EVALUATION, AND PUBLICATION

In the past, the collected data were mainly graphically processed (in the form of hydrographs), and they were evaluated only for individual projects. Due to the lack of funds, no systematic processing, tabulating and summarizing of data on a statewide basis was possible. Now, as part of the cooperative program, the USGS entered all historical data through 1981 into computer system 2000, and the water-level measurements on existing observation wells are being entered on a monthly basis. Information can be retrieved from this data bank either in graphical or numerical form. A number of computer programs are currently being developd by the USGS to enable statistical analysis of data.

All incoming data will be immediately checked for completeness and errors, and possible erroneous values corrected. The data will be continuously kept in tabular and graphical form. At the end of each year, all missing values will be estimated, simple statistics generated, and data will be entered into the computer storage and retrieval system.

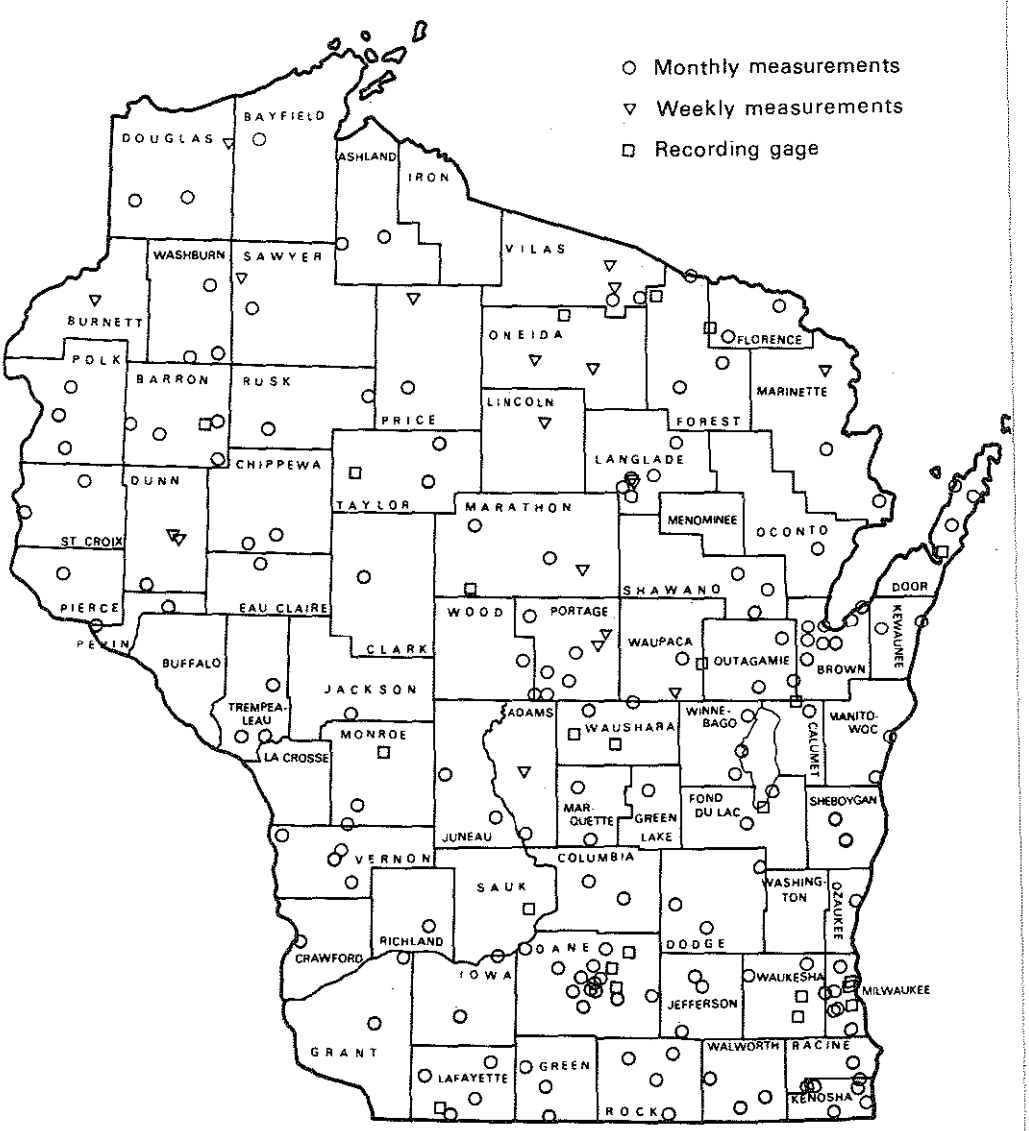
The WGNHS initiated, in July 1980, a long-range project to disseminate information on ground-water levels. Data from the existing cooperative water-level measurement program will be summarized, tabulated, and made available in two formats: popular and technical.

Popular publications will appear in a new series of pamphlets, one for each county, containing a brief explanation of the most common misconceptions about ground-water occurrence, movement, and fluctuation; location of all observation wells within the county; summmary of data; a graphical explanation of water-level trends on a well typical for the county; and implications of water-level fluctuations for water supplies and agriculture. The first of the series, Ground-Water Levels in Marathon County, has been recently published.

In addition, an annual summary of ground-water levels in the state is being published, listing observation wells measured during a preceding year and summarizing the changes in the program and in water levels. The summary also relates annual water levels to precipitation and includes an outlook for the following year.

Technical publications will present technical data on ground-water level fluctuations, and will result from a cooperative project with the USGS. Data are currently being statistically analyzed to describe the magnitude and frequency of ground-water-level fluctuations in Wisconsin; to explain normal rise and decline of ground-water levels; to relate the trends in ground-water levels to the trends in precipitation; and to show the importance of understanding the recurrence of high and low levels for Wisconsin agriculture, industry, the construction business, and water supplies. Two reports are planned--for the popular report, examples will be given on 11 wells; for the technical report, data from wells having records longer than 20 years will be presented.

By studying the ground-water level fluctuations, the state and federal geological surveys are trying to determine if the water levels follow any predictable pattern and how the fluctuations relate to climate and to location in the ground-water flow system. By establishing the patterns and general relationships, it should be possible to estimate the behavior of ground-water levels in the areas not having observation wells. Then the observation network would really serve local needs.



OBSERVATION WELLS IN WISCONSIN, 1980