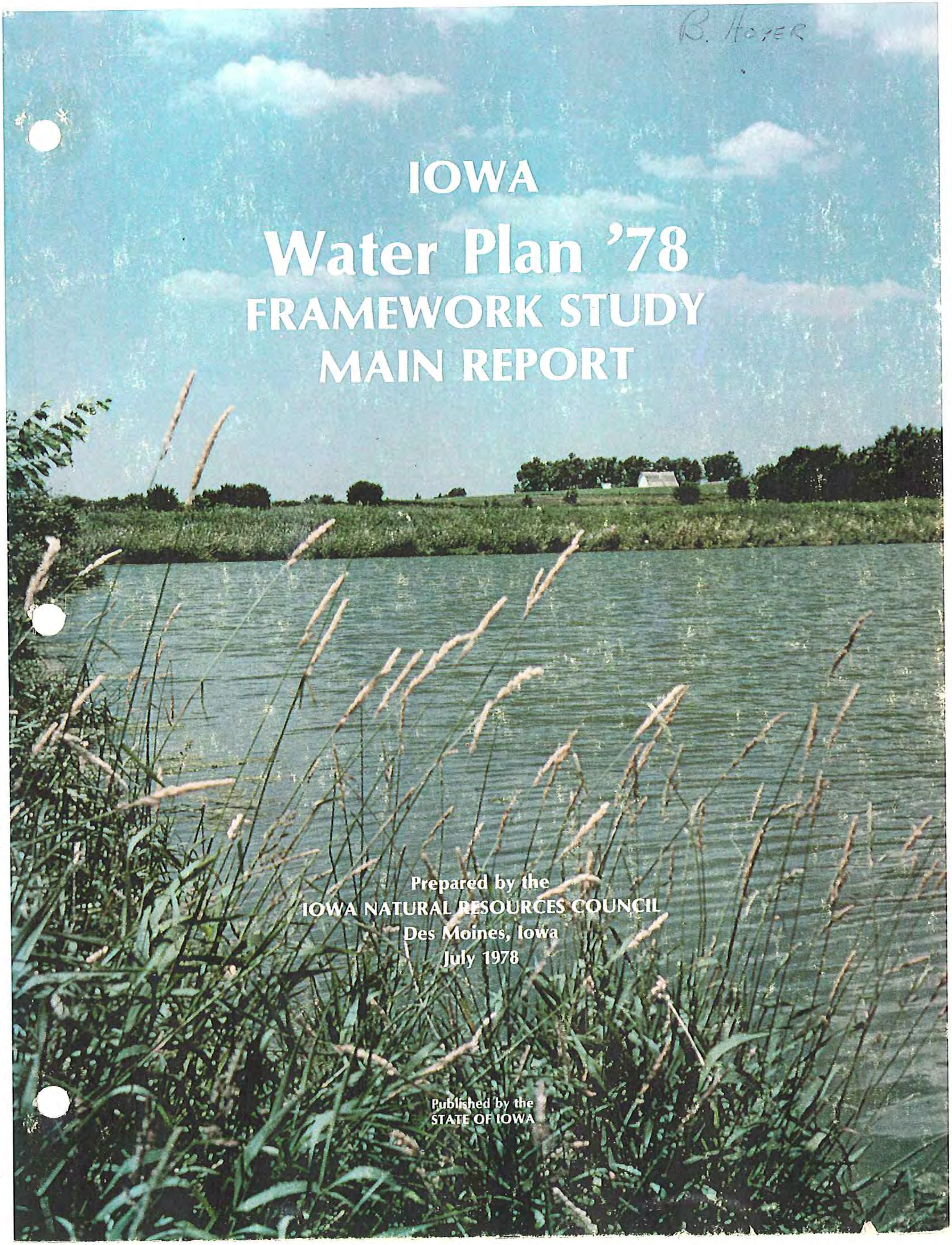

IOWA
Water Plan '78
FRAMEWORK STUDY
MAIN REPORT

Prepared by the
IOWA NATURAL RESOURCES COUNCIL
Des Moines, Iowa
July 1978

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STATE OF IOWA

B. Hoyer

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Natural Resources Council

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Des Moines, Iowa 50319
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JAMES R. WEBB, Director
LOUIS F. GIESEKE, Water Commissioner

Iowa
a place to grow

July 1978

GOVERNOR Robert D. Ray
MEMBERS of the LEGISLATURE
and THE PEOPLE OF IOWA

We are submitting herewith the Iowa Natural Resources Council's Water Plan 78, the main report of the State Water Plan Framework Study. This report is the culmination of the three-year cooperative effort between this agency and the Department of Environmental Quality, Conservation Commission, Department of Soil Conservation, and the Geological Survey, funded by the Legislature in 1978.

The report addresses major water problems in nine functional areas and recommends policy, programs, and legislative proposals to solve those problems. It will be the baseline from which detailed implementation planning will evolve in Phase II of the State Water Plan effort.

Sincerely,

James R. Webb
Director

Merwin D. Dougal
Chairman

PREFACE

This Framework Study, written under the auspices of the Iowa Natural Resources Council, is dedicated to the people of the State of Iowa. The report represents a culmination of a three year project designed to better control, utilize, and protect Iowa's water resources.

The Natural Resources Council would like to acknowledge the following groups for their assistance in preparing the Study: the Iowa Geological Survey; Iowa Department of Environmental Quality, Iowa Department of Agriculture; Iowa State Historical Department, Division of Historic Preservation; Iowa Conservation Commission; Iowa Development Commission, Department of Soil Conservation; Energy Policy Council, Citizen's Advisory Committee, U.S. Army Corps of Engineers; U.S. Soil Conservation Service; United States Geological Survey; U.S. Weather Service; Federal Insurance Administration; and Iowa State University.

Further acknowledgement is made to the numerous individuals who aided in the research and preparation of this report.

Water Policy Goals Mandated
By Chapter 455A, Code of Iowa:

- that the water resources of the state be put to beneficial use to the fullest extent of which they are capable;
- that the waste, unreasonable use, or unreasonable methods of use of water be prevented;
- that the conservation of the state's waters be exercised with a view to assuring the reasonable and beneficial use thereof in the interest of the people;
- that the public and private funds for the promotion and expansion of the beneficial use of water resources shall be invested to the end that the best interests and welfare of the people are served;
- that the state's water resources agency shall have the duty and authority to establish and enforce an appropriate comprehensive state-wide program for the control, utilization, and protection of the surface and groundwater resources of the state;
- that the protection of life and property from floods, the prevention of damage to lands therefrom, and the orderly development, wise use, protection, and conservation of the water resources of the state by the considered and proper use thereof (by beneficial user groups), is of paramount importance to the welfare and prosperity of the people of the state;
- that the comprehensive, statewide plan for the control, utilization, and protection of the water resources of the state shall include all uses and developments of water resources, and shall provide for the optimum control, protection, development, allocation, and utilization thereof;
- that the plan shall give consideration specifically to the needs of domestic households, municipal corporations, agriculture, industry, fish and wildlife, recreation, health, pollution control, and allied matters (including energy production and border river navigation) as they relate to water resources and flood control; further, that the use of water for domestic purposes (drinking water and ordinary household use) and for ordinary numbers (family-farm sustenance) of poultry, livestock, and domestic animals shall have priority over other uses (with a balancing of priorities among other users in a regional and/or groundwater aquifer sense);
- that water occurring in any underground basins (aquifers) or in any watercourse, or other natural body of water of the state, is declared to be public water and public wealth of the people of the state of Iowa and subject to beneficial use in accordance with the statutory provisions (and departmental rules and procedures) for regulated and unregulated uses;
- that no use of water shall be authorized that will impair the effect of pollution control laws as they apply both to the surface waters and the groundwater aquifers of the state, or impair or deplete the established average minimum in-stream flow (protected low flow).

Preparation and publication of this report was supported in part by grants made by the Federal Water Resources Council under Title III of the 1965 Water Resources Planning Act.

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The State
1 Water Plan

Iowa is located in the Midwest where water in general has been plentiful. However, droughts and floods occur periodically, and cause severe stress on affected persons and the state's economy when they happen. Also, there are a growing number of local and statewide problems associated with increasing demands and conflicts between water users. It is not possible to view patterns of water resource uses as a series of isolated demands. Water resource uses continually interact and sometimes conflict with one another as a few examples will show.

Iowa is an important agricultural state, and has been since statehood. In many areas, farmers could bring additional acres into production if the land was properly drained, or streams straightened and timber cleared. Although draining wetland areas for crop production has been and may continue to be of economic benefit, it destroys wildlife habitat. The remaining wetland areas are critical to migratory waterfowl and to a variety of other plants and animals considered essential to maintaining an ecological balance.

Streams serve as a valuable resource with their ability to assimilate a variety of waste materials, particularly for receiving effluent from water pollution control plants. However, continued and unlimited use of these waters to dispose of municipal, industrial, and agricultural wastes from point and nonpoint sources will further degrade the quality so that it increasingly is unsuitable for a number of other uses including water supply and recreation. In addition, increases in rowcrop acreages and production have accentuated the soil erosion problems in the state.

Construction of a reservoir can be a means of solving flood problems and meeting water supply requirements. It is also a means of providing additional acreages for water-oriented recreation; however, many recreationists prefer the natural, free flowing river environment to that of an artificial lake. In addition, there are adverse environmental effects associated with destruction of the riverine habitat, and with shoreline impact in fluctuating flood pools.

Continued growth of commercial navigation on Iowa's border rivers is considered to be essential to the agricultural and industrial economy of the state; yet, the border rivers—the Mississippi and the Missouri Rivers—are multipurpose corridors for many water resource uses. Fish and wildlife resources will be severely stressed if present patterns continue, and other recreation uses compete with commercial navigation for a limited resource.

Goals and Scope

The goal of a statewide comprehensive water program, as dictated by **Chapter 455A, Code of Iowa,** is to put the surface and groundwater resources of the state to their fullest beneficial use, to the end that the prosperity, general welfare, and best interests of the state be served.

This goal may be stated more specifically as follows:

1. To provide for the efficient use of the state's water resources, both now and in the future.
2. To conserve the water and related land resources of the state and prevent the waste thereof.
3. To provide an adequate and safe water supply for existing and future use, to meet a variety of demands.
4. To protect and enhance the quality of water in the state.
5. To consider the interrelationships among social, economic, and environmental values, and reduce adverse impacts caused by conflicts.

The Framework Study is but one element in the total and continuing program of planning for water and related land resource development. It is not intended to fulfill all objectives of Iowa's comprehensive water plan. This initial effort, summarized as **"Water Plan '78"**, is confined to a study and evaluation of existing data, and carries on into the plan development phase to the point of recommending policy and program development. It will serve as a base for more detailed regional, county, and local project planning and development, to ultimately solve those problems identified in a statewide sense in this study.

The scope of the Framework Study includes the following points:

1. Recognize the use patterns and future demands arising from the following specific beneficial user groups:
   a. **Community use**—Water supply and use for domestic, municipal, commercial, industrial, and regional-rural systems.
   b. **Water quality control**—Use of point and nonpoint source pollution control programs.
   c. **Flood plain management**—Controlling flood plain occupancy and development, and reducing flood damages.
   d. **Recreational water use and fish and wildlife propagation**—Water-oriented recreational needs in lakes, reservoirs, and rivers; preserving and enhancing wetlands, scenic areas, and sensitive water and land resources.
   e. **Water for electrical energy production**—Meeting the growing electrical energy demands for cooling water and possible coal gasification.
   f. **Navigation**—Commercial navigation on border rivers, growth of terminal facilities, and recreational navigation demands.
   g. **Agricultural water use**—Water for agricultural crop and livestock production.

2. Collect baseline data, identify needs, and establish a water resources data exchange system for Iowa.
3. Analyze existing and potential water resource problems.
4. Determine the impact of the current and potential demand of the state's water resources.
5. Suggest general program alternatives and remedial measures to alleviate problems or enhance the resource.
6. Recommend policy alternatives from which to evolve a water resources management philosophy for Iowa's consideration; within this guide, it is a key objective to achieve a continued high level of agricultural productivity and strengthened industrial development and growth, to offer increased opportunities for employing Iowa's youth and adults.

General Planning Guidelines

The Technical Coordinating Committee (TCC) which was formed in 1975, set certain guidelines to help focus the Framework Study. These guidelines determined the nature of the investigations carried out and, to a large extent, influenced the outcome of the study, now summarized as **Water Plan '78, Framework Study.** Because of their great effect, it is important that explicit recognition be given to the guidelines.

The guidelines developed by the Technical Coordinating Committee specified that the Framework Study shall:

1. **Be a statewide study**—Attention shall be given to all parts of the state, and concentrate on problems having a statewide significance.
2. **Be concerned primarily with Iowa waters**—The study shall be concerned primarily with waters that originate in Iowa, are stored in Iowa, flow through or border Iowa.
3. **Consider Iowa benefits**—The study shall give primary consideration to Iowa's interests, both beneficial and adverse. Iowa's interests within a regional perspective shall be given secondary consideration, to be evaluated in more detail in subsequent water plan studies.
4. **Plan for the utilization of Iowa's water**—The study shall work to conserve water by preventing wasteful or unreasonable use or methods of use.
5. **Be a comprehensive study**—All beneficial user groups will be considered, as specified previously.
6. **Serve the general welfare**—The study shall strive toward a balance of economic, social, and environmental objectives. The quality of life in present and future Iowa shall have equal consideration in evaluating agricultural, community, and industrial growth opportunities.
7. **Consider data by Conservancy Districts**—Wherever possible, each task force's data shall be broken down by the six Iowa Conservancy Districts that are comprised of individual river basins or groups of river basins (Figure 1-1 and Table 1-1).
8. **Emphasize a multifunctional approach and multipurpose solutions**—Problems, opportunities, and needs are related to the functional areas listed under beneficial user categories. This approach recognizes related problems in these functional areas and suggests alternatives which can provide beneficial effects to more than one function (multipurpose solutions).
9. **Provide guidance and direction**—The study shall guide and direct the state's resource agencies having responsibilities for water-related programs and activities, and shall assist the Legislative and Executive Branches to these ends.

FIGURE 1-1 Iowa Conservancy Districts

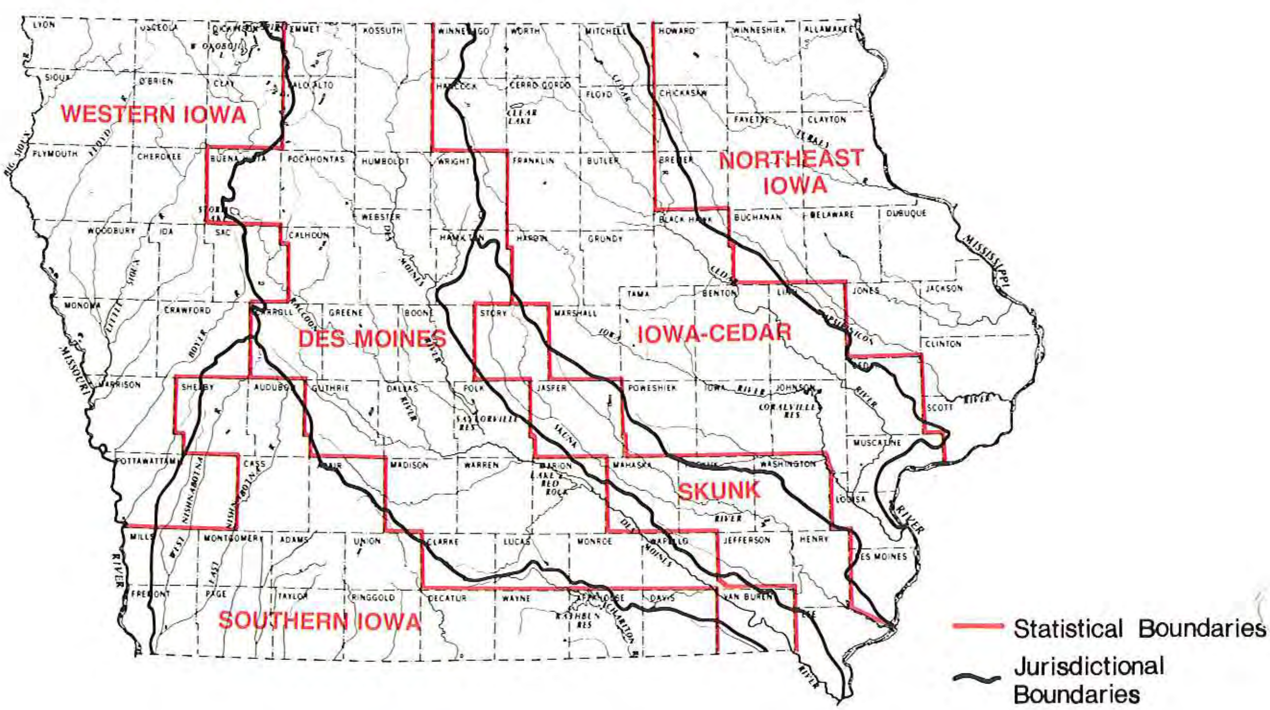


TABLE 1-1 Counties Comprising Iowa Conservancy Districts

Western Iowa Conservancy District

Lyon	Woodbury
Osceola	Ida
Dickinson	Sac
Sioux	Monona
O'Brien	Crawford
Clay	Harrison
Plymouth	Pottawattamie
Cherokee	

Southern Iowa Conservancy District

Shelby	Fremont
Audubon	Page
Cass	Taylor
Adair	Ringgold
Mills	Decatur
Montgomery	Wayne
Adams	Appanoose
Union	Davis

Des Moines Conservancy District

Emmet	Boone
Kossuth	Guthrie
Palo Alto	Dallas
Buena Vista	Polk
Pocahontas	Madison
Humboldt	Warren
Wright	Marion
Calhoun	Clarke
Webster	Lucas
Hamilton	Monroe
Carroll	Wapello
Greene	Van Buren

Iowa-Cedar Conservancy District

Winnebago	Marshall
Worth	Tama
Mitchell	Benton
Hancock	Linn
Cerro Gordo	Poweshiek
Floyd	Iowa
Franklin	Johnson
Butler	Cedar
Hardin	Muscatine
Grundy	Louisa
Black Hawk	Des Moines

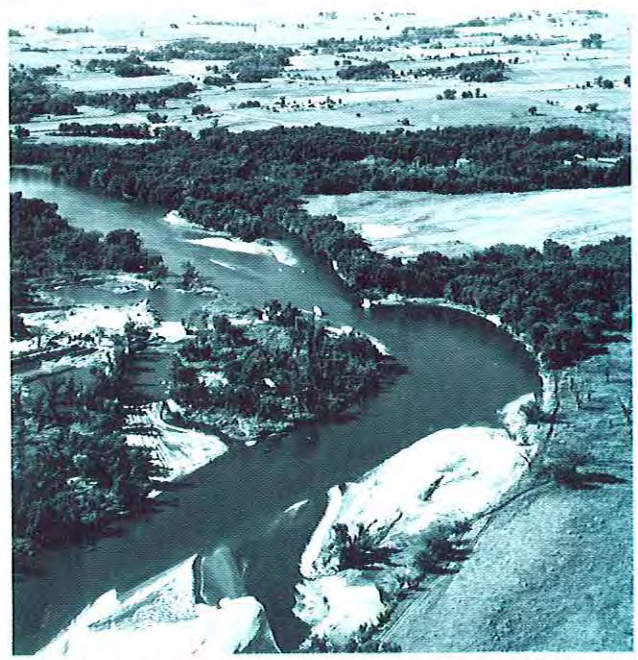
Northeast Iowa Conservancy District

Howard	Buchanan
Winneshiek	Delaware
Allamakee	Dubuque
Chickasaw	Jones
Fayette	Jackson
Clayton	Clinton
Bremer	Scott

Skunk Conservancy District

Story	Washington
Jasper	Jefferson
Mahaska	Henry
Keokuk	Lee

10. **Present alternatives**—The study shall evaluate the major alternatives and significant information on each alternative, and present final recommendations.
11. **Provide for a continuing planning process**—The study shall provide a framework within which the water problems of Iowa can be continually evaluated and the alternatives updated.
12. **Provide a flexible guide**—The study shall be able to accomodate substantial changes in the future. It shall serve as a basic block of information for whatever decisions are made.
13. **Consider needed changes in law**—The review of present water laws and the drafting of model legislation is intended to resolve conflicts so that Iowa will be able to properly manage its water resources. This can help solve the problems inherent in the present maze of overlapping and sometimes conflicting areas of authority dealing with competing interests and purposes.
14. **Establish general priorities**—The study shall suggest general priorities which permit needs to be met in general order of urgency. Identification of specific projects, their level of funding, and a time table for implementation will be left for subsequent phases concerned with project



Cedar River north of Cedar Rapids *W. Lonning* development, special problem area studies, and detailed programs for formulation and implementation.

Task Force Reports

In addition to the main Framework Study, a series of background reports were prepared by the study groups (task forces). These reports provide the basic information necessary for evaluating water resource problems, formulating a comprehensive plan, and implementing that plan.

In the aforementioned reports, seven categories of water management and use were analyzed. These include:

Water Supply and Use
Water Quality
Flood Plain Management
Recreation and Fish and Wildlife
Energy
Navigation
Agriculture

Other background reports were developed for the purpose of providing information for the seven water use and management reports listed above. These include:

Data Base and Needs
Socio-Economic Aspects of Water Resources
Water Resource Availability
Law and Government

The seven task force reports and the Water Availability and Law and Government background studies are the basis for Chapters 3 through 11 of this report. All task force reports have contributed measurably to the development of the final Framework Study report, **Water Plan '78.**

Task Force Goals

The Iowa Natural Resources Council, through the task force groups, developed goals relating to each particular category of water management or use. These goals are:

Water Quality

1. To protect the quality of the surface and groundwater resources for the beneficial use of the citizens of Iowa.
2. To improve the aesthetics of Iowa rivers and lakes and to protect, enhance, and maintain aquatic life and recreational opportunities.

Domestic, Municipal, Commercial, and Industrial Water Supply

1. To ensure water supplies of adequate quantity and quality to meet short and long range needs.
2. To ensure that all citizens are served by adequate supplies of potable water to enhance their health and well-being.

Flood Plain Management

1. To guide an orderly development and effective management of the flood plains in the state, within a design that will minimize the intensive urban occupancy of these flood plains in the future.
2. To protect against needless loss of life and reduce damages to land and property by floods.

Missouri River Flood at Percival, Fremont County, April, 1952 — *Soil Conservation Service*

Channelization of Little Sioux River, Harrison County *Corps of Engineers*

Water-Oriented Recreation and Fish and Wildlife

1. To assure a quality water-oriented recreation experience for present and future generations of Iowans by providing water and related land resources of sufficient quantity and quality to meet present and future needs.
2. To enhance or improve the quality of the natural, scenic, fish and wildlife resources, and preserve the remaining wetlands and unique scenic or sensitive water and related land areas for the benefit of all.

Water for Energy Production

1. To enhance economic development in Iowa by providing the quantity and quality of water needed to meet present and future needs for energy production.
2. To enhance the quality of Iowa's environment through the proper management of water and related resources used for energy production.

Commercial and Recreational Navigation

1. To enhance economic development by use of commercial river navigation and barge terminal facilities as necessitated by concerns for economic efficiency.
2. To enhance the quality of the border river corridors for recreation and other uses, and restoration of the quality of certain natural and cultural resources and ecological systems.

Agriculture

1. To improve the economic well-being of Iowa; (a) by providing the quantity and quality of water required as an input for agricultural production levels determined by commodity demands, and (b) by improving water use efficiency by agriculture in the state.
2. To enhance the quality of Iowa's environment through the management, conservation, or improvement in quality of the natural, cultural, or ecological resources affected by agricultural production and related water use. Included are the related land use relationships and soil and water conservation practices affecting the future of Iowans.

Additional task force reports were developed by support groups to furnish basic data and background information for use in the water use and management reports. Included in these supporting documents are:

Data Base and Needs

1. To establish a common boundary for delineation of hydrologic boundaries, and to assure that common units are utilized by other task forces.
2. To examine data shortages, data use, and data needs pertaining to Iowa's water resources.

Socio-Economic and Legal and Institutional Aspects of Water Resources

1. To examine present legal, institutional, demographic, and socio-economic trends.
2. To relate these policies, laws, and trends to the projected demands on water and related land resources.

Water Resources Availability

1. To review the systems used for collection and analysis of basic water and related land resources data.
2. To determine location and availability of the surface and groundwater resources within the state.
3. To compile information on quantity and quality of Iowa's water resources for use by other task forces.

Junction of the Des Moines and Raccoon Rivers, Des Moines *Corps of Engineers*

Organization of the Participants

The organizational structure developed for the preparation of the Framework Study was designed to provide efficient and timely formulation of a state water plan. The principal working group was the Technical Coordinating Committee (TCC), which provided technical guidance and coordinated the efforts of the various participating agencies and task forces.

The TCC was comprised of representatives from the various state agencies concerned with natural resources. They directed the overall work effort of the Water Resources Framework Study, including coordination between participating agencies, and technical review of procedures and reports. Most TCC members chaired or co-chaired one of the ten task force groups. The TCC was comprised of representatives from the following state agencies:

- Department of Environmental Quality
- Department of Soil Conservation
- Iowa Conservation Commission
- Iowa Geological Survey
- Iowa Natural Resources Council
- Office for Planning and Programming
- Energy Policy Council
- Department of Transportation

Representatives from the Attorney General's Office and the Iowa State Water Resources Research Institute served as advisors to the TCC.

Task Force Membership

Members of the individual task force groups were selected for their expertise in their particular water use area. Representatives from state and federal agencies as well as from the private sector were included. A representative from the Technical Coordinating Committee and Iowa Natural Resources Council planning staff provided the leadership for the individual task forces. Agencies and groups contributing to the task force reports are listed below:

State Agencies

Iowa Geological Survey
Department of Environmental Quality
Iowa Natural Resources Council
Energy Policy Council
Iowa Commerce Commission
Iowa Conservation Commission
Iowa Department of Transportation
Iowa Department of Agriculture
Iowa Development Commission
Iowa Department of Soil Conservation
State Office of Disaster Services
Iowa State University and the Water Resources Research Institute
University of Iowa and the Iowa Institute for Hydraulic Research
State Hygienic Laboratory

Federal Agencies

U.S. Fish and Wildlife Service
U.S. Department of Housing and Urban Development
U.S. Geological Survey
U.S. Army Corps of Engineers
U.S. Coast Guard
U.S. Environmental Protection Agency
U.S. Soil Conservation Service
U.S. National Weather Service

Other Groups

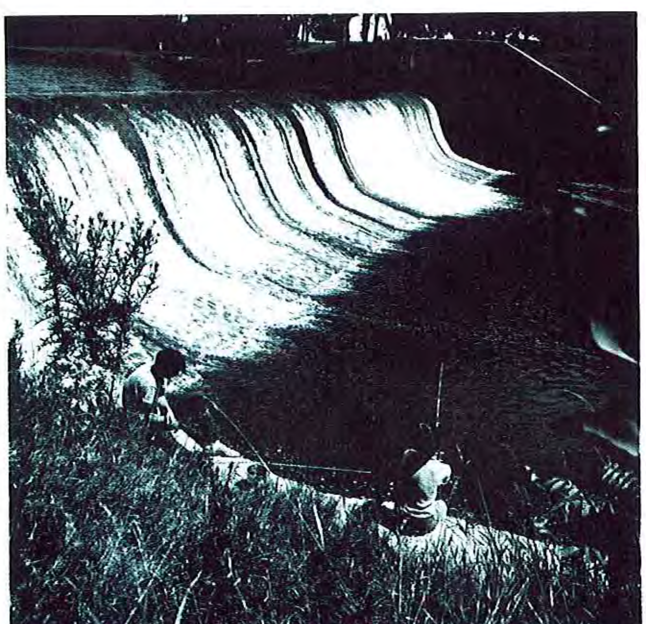
Iowa Association of Rural Water Districts
Mid-America Power Pool
Iowa Utility Association
The Izaak Walton League of America
Several community and local agencies

Basic Data and Water Availability Study Needs

Wise planning requires information to support the decision-making process. Baseline information concerning quantity and quality of Iowa's water resources, as well as water requirements of different user groups, has been incorporated into the task force reports of the Iowa Water Resources Framework Study. However, the need for information is ongoing. The Iowa Water Resources Data System (IWARDS) is being developed to support state comprehensive water planning and management by improving the availability and usefulness of water resources data.

While the main thrust of IWARDS is toward the development of a computerized storage-retrieval system for raw data, its scope is not limited to that activity alone. Specific objectives for the system are listed below:

1. To develop a management structure within which the development and operation of the system may proceed in the most cost-efficient manner;
2. To encourage inter-agency and state-federal cooperation in the use of water, and related resource data;
3. To design and implement a computerized water resource data storage and retrieval system;
4. To develop standards for the inclusion of geographic and site identifiers in the coding of data for computer storage and processing;
5. To continue and expand required or necessary basic data collection systems;
6. To identify, and eliminate where possible, unnecessary duplication in the collection, storage, and processing of data;
7. To compile and publish catalogs of certain types of water-related information which are not suitable for inclusion in the computerized storage-retrieval system.



Dam at Backbone State Park
Iowa Conservation Commission

Primary information systems are already in existence in agencies and institutions to support the functions of the IWARDS system. In this respect, the role of IWARDS is secondary; it is not intended to supplant existing systems, but to supplement them and enhance their usefulness by improving inter-agency communication of water-related data.

The role of IWARDS will take on increased importance in Phase II in the development of a comprehensive state water plan — the planning, development, and construction of projects, and formulation and implementation of detailed programs. These valuable data are needed to provide a sound social, economic, technical, and engineering basis for making future decisions for managing Iowa's water resources.

Related Studies

There are several completed and ongoing studies in state and federal agencies that relate to the planning efforts of the Iowa Water Resources Framework Study. None of these studies or programs were initiated specifically for the Framework Study; however, the information from these reports has been a valuable source of reference material. Demographic and economic studies were of value early in the Framework Study. Other ongoing programs in water quality, outdoor recreation, and other beneficial use studies complimented the task force studies.

Advisory Groups

Although not members of a particular task force, several groups served as advisors at one time or another during the study. These include the Missouri River Basin Commission and the Upper Mississippi River Basin Commission. In addition, many individuals, some from the state universities, were consulted throughout the study and provided valuable assistance.

Citizens Advisory Committee

The Citizens Advisory Committee was established to create a liaison with the public without having to meet with every affected individual or group in the state. This group is comprised of representatives from established statewide organizations and groups having a particular interest in water resources. Care was taken to choose groups with differing interests in water so that the Committee would not be biased toward one particular aspect of water resources development or management.

Summary

To sustain the quality of life enjoyed in Iowa, and support the orderly growth and development of our economy, we must make a commitment to more refined utilization and development of our basic water and land resources. Although these two resources are highly interrelated in both the managerial and utilitarian sense, the Iowa Legislature and the resource agencies decided to begin with water resources planning.

The management and development of the state's surface and groundwater resources has been governed by several different agencies, each vested with the authority to regulate and protect specific uses of the resource. Up to now, this technique has been fairly successful in managing the resource. However, the problems we are beginning to face, and will face in the future, cannot be met by this singular, separate approach. The water plan will guide and coordinate the activities of the many agencies and management interests involved in water resource planning and regulation. **Water Plan '78** completes the first phase of comprehensive water planning for the state of Iowa.

The primary objectives of the state water plan, stated in Chapter 455A.17 of the **Iowa Code,** are keyed to the management, utilization, and protection of the state's water and related land resources. As an initial effort to reach these goals, the Iowa Water Resources Framework Study has investigated and documented:

—The current quantity and quality of the state's water resources;

—Provision for adequate municipal, rural, agricultural, and industrial water supply;

—Provision for the protection and enhancement of water-related recreational opportunities;

—Conservation and development of fish and wildlife resources;

—Provision for commercial and recreational navigation;

—Water needs for energy development;

—The quality of Iowa's surface and groundwater, and needs for improvement;

—Causes and damages of floods, and various approaches to flood plain management;

—Planning alternatives that satisfy the multiple objectives of development, management, and protection of these resources;

—Techniques for increasing the water resource base to meet projected future demands;

—Legislative needs, suggested priorities, and suggestions for the implementation of the plan.

The summaries of the technical task force reports follow in Chapters 3 through 11; a final chapter — Chapter 12 — on **Directions for the Future**, concludes **Water Plan '78**, which specifically was directed to the policy and program level of planning.

Missouri River Flood, Pottawattamie County, April, 1952 *Soil Conservation Service*

Northeastern Iowa, Driftless Area — *W. E. Akin*

Central Iowa, Des Moines Lobe — *J. C. Prior*

Western Iowa, Loess Hills — *Iowa Conservation Commission*

2 Iowa in Perspective

Iowa's geology, physiography, and climate interact to determine the quantity and natural quality of our water resources. The human resources of the state, in turn, interact with this physical resource base and determine the present and future demands that will be levied against it. An understanding of both the physical and human aspects of the water problem, including patterns and trends of social and economic activity, will help identify areas in which competition and conflicts among water users exist or may arise.

This chapter will summarize those physical and cultural characteristics of Iowa that have an important bearing on water resources. These resources must be considered as policies and programs are developed to assure their wise and prudent use.

The Water Cycle

The earth's water is constantly in motion, from the oceans to the atmosphere, to the land, and back to the oceans, as shown schematically in Figure 2-1.

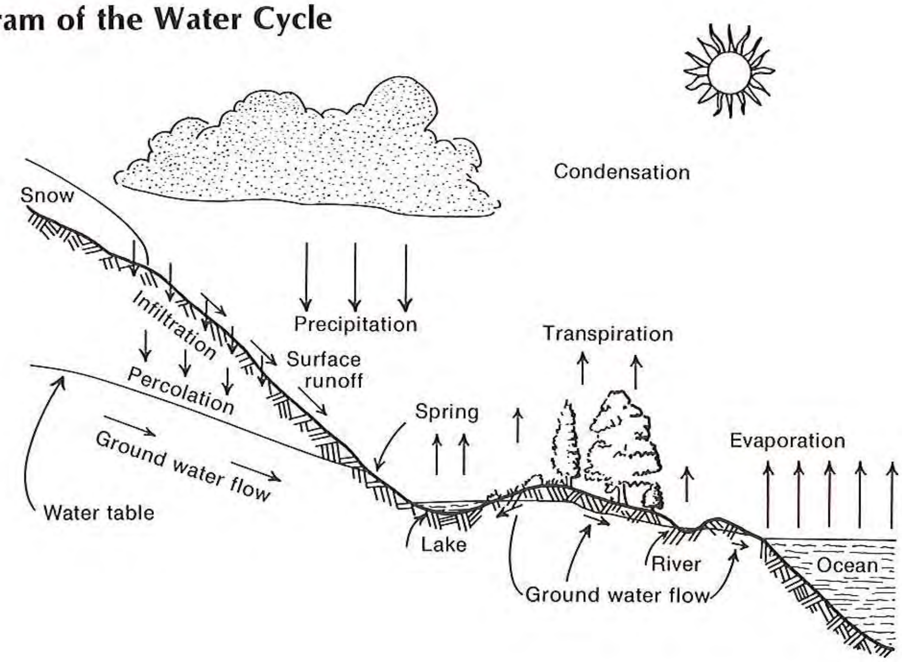
Most of the precipitation that falls in Iowa infiltrates through the ground surface into the soil profile. Of the average annual 32 inches of precipitation, about 75 percent is returned by evapotranspiration (evaporation and transpiration by plants). About 20 percent of this precipitation becomes runoff and eventually leaves the state as streamflow. The remaining few percent percolates slowly downward beyond the soil moisture zone to become groundwater. During dry periods, the majority of perennial streams owe most or all of their flow to the discharge of groundwater back to the surface. Figure 2-2 summarizes the movement of water in Iowa's hydrologic cycle.

Water resource planning requires a detailed knowledge of all aspects of the water cycle. Climate plays a major role in contributing water to the water budget through precipitation, and removing water by influencing the rate of evapotranspiration through temperature and growing season. The rate of surface runoff and infiltration to the groundwater reservoirs are largely functions of the topography and geology of the state. This chapter summarizes those factors affecting Iowa's water supply and contributing to water problems; other chapters deal more specifically with their relationships to water supply, water use, and associated water problems.

Climate

Climate is the most variable of the elements involved in the supply of water available within the state. Iowa's "normal" climate approaches the optimum for agriculture, and would assure a plentiful supply of water; but the normal climate, in the sense of "average", is rarely experienced. Major and prolonged departures from statistical normal climate may have serious consequences.

FIGURE 2-1 Diagram of the Water Cycle



Deficiencies may cause reduced crop yields, or even crop failures, and may cause local water shortages. Conversely, excesses often produce destructive floods. Particularly critical are extreme heat, prolonged droughts, excessive precipitation, damaging winds, and unseasonably low temperatures that produce early and late frosts.

Iowa has a humid continental climate; that is, average summers are hot and humid, and winters are cold and relatively dry. The seasonal distribution of average annual precipitation is highly favorable for crops with over 70 percent falling in the warm half of the year when it is most needed. Although Iowa has lower average annual precipitation than states to the east, rainfall is equal or higher during the crop season. Most of Iowa's precipitation, both winter and summer, comes from warm, moist air masses moving northward from the Gulf of Mexico; the prevailing southerly winds of spring and summer favor increased rainfall, while the dominance of cold polar air masses in winter often blocks the access of moist tropical air to the continental interior.

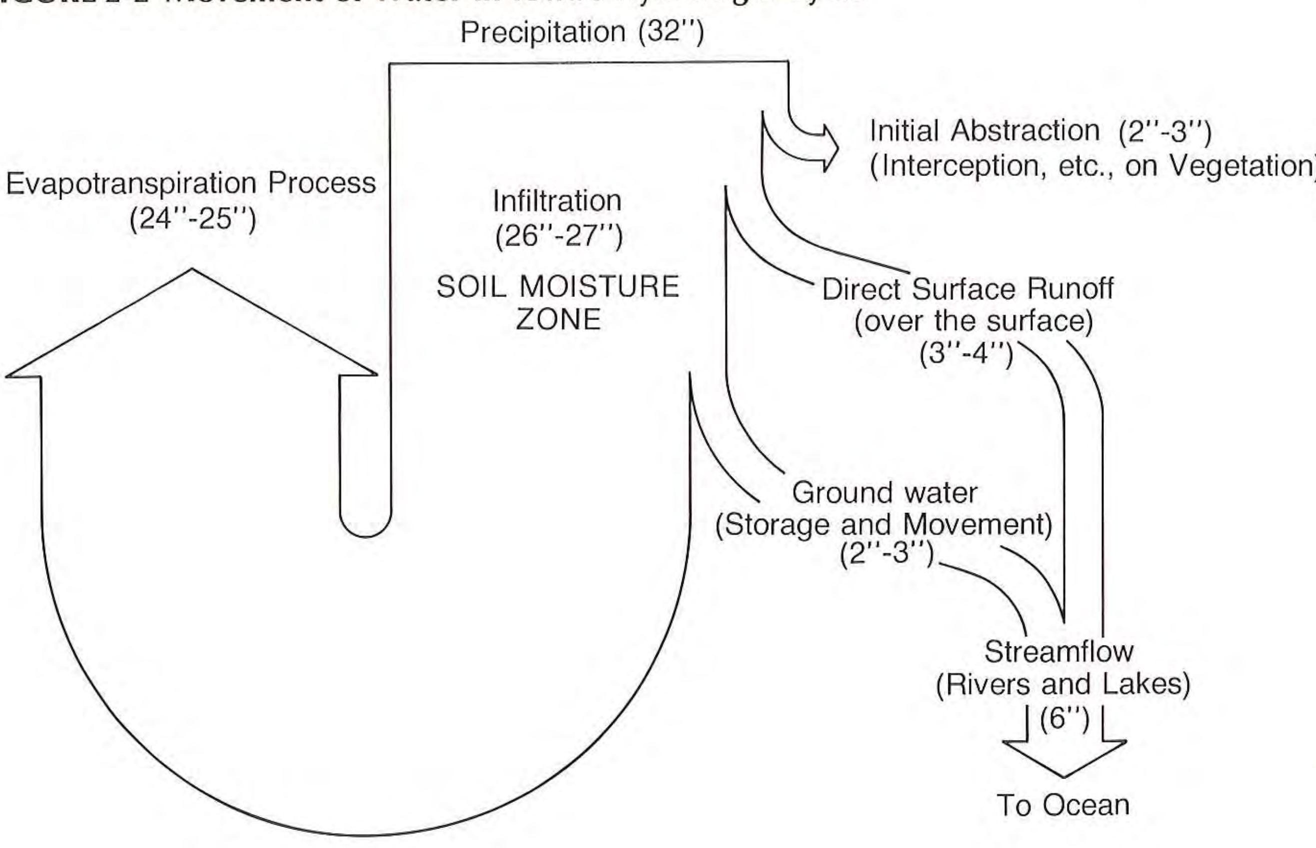
Marked seasonal variations in Iowa's weather results from the conflict of air masses of different origins. Climatic patterns are the product of the general circulation of the earth's atmosphere that determines the movement of air masses and their attendant weather. If the patterns change frequently, weather alternates between moist and dry and warm and cool, generally benefiting growing crops. If a particular pattern becomes established for too long a time, we may be faced with prolonged drought, excessive precipitation and floods, or extended periods of extreme cold or heat. Many climatologists believe that weather patterns have been unusually favorable for agriculture throughout most of the present century, particularly during the last 10 to 20 years; what the climatic future holds is subject to considerable debate. Unquestionably, an understanding of the uncertainties of climate and recognition of their potential impact on water resources is vital to the development of a successful water plan.

Temperature

Temperature plays an important role in water resources availability since the effectiveness of precipitation is, in part, a function of temperature. High temperatures mean increased evaporation from soil and water surfaces and more rapid transpiration by plants. The term **evapotranspiration** refers to the combined effect of these two factors. Potential evapotranspiration in Iowa generally exceeds normal precipitation during June, July, August, and September; thus, runoff and groundwater recharge is minimal or nonexistent during most summers, although this period has the most precipitation in an average year. Evapotranspiration amounts experienced during normal summer weather varies from 1 to 3 inches per day.

Average annual temperatures range from 46°F (8°C) in the northern counties, to 52°F (11°C) in the southeastern counties (Figure 2-3). July is the hottest month with average daily maximum temperatures around 85°F (29°C), and daily minimums mostly in the lower sixties. In January, daily maximums range from 24°F (-4°C) to 34°F (1°C), north to south across the state, and the minimums from 4°F (-16°C) to 14°F (-10°C). Extreme temperatures have varied from 118°F (48°C) at Keokuk on July 20, 1934, to -47°F (-43°C) at Washta on January 12, 1912. In almost every year at some location in the state, a maximum exceeding 100°F (38°C) and a minimum of less than -20°F (-29°C) occurs. In half the years of record, the maximum exceeds 104°F (40°C) and the

FIGURE 2-2 Movement of Water in Iowa's Hydrologic Cycle



Source: Merwin D. Dougal

minimum falls below -31° (-35° C). The average number of days with temperatures 90° F (32° C) or higher range from forty-seven at Shenandoah to six at Waukon and Saratoga. The number of days with zero (-17.8° C) or lower temperatures range from about 10 per year in the south to thirty in the north. Prolonged periods with temperatures above 90° F (32° C) are especially detrimental to crops, particularly at certain stages in plant development.

Growing Season

The crop growing season is largely limited by the dates of the last spring freeze and the first autumn freeze. The average length of the freeze-free season in Iowa ranges from a high of about 175 days in the southeastern corner of the state, to a low of 135 days or less in the northeast (Figure 2-4).

On calm, clear nights temperatures may drop several degrees lower in valleys and lowland rural areas than those measured in urban or upland locations; thus, in "cold" areas the freeze-free season may be shortened by several days in comparison to upland or urban areas. The freeze-free season has begun as late as the general freeze that occured on May 29, 1947 — in a few northern locations the season was delayed until June 21-22. The earliest general freeze occured September 8-9, 1883; however, corn was killed by frost in some lowland localities in northern Iowa on August 1 and August 8, 1927.

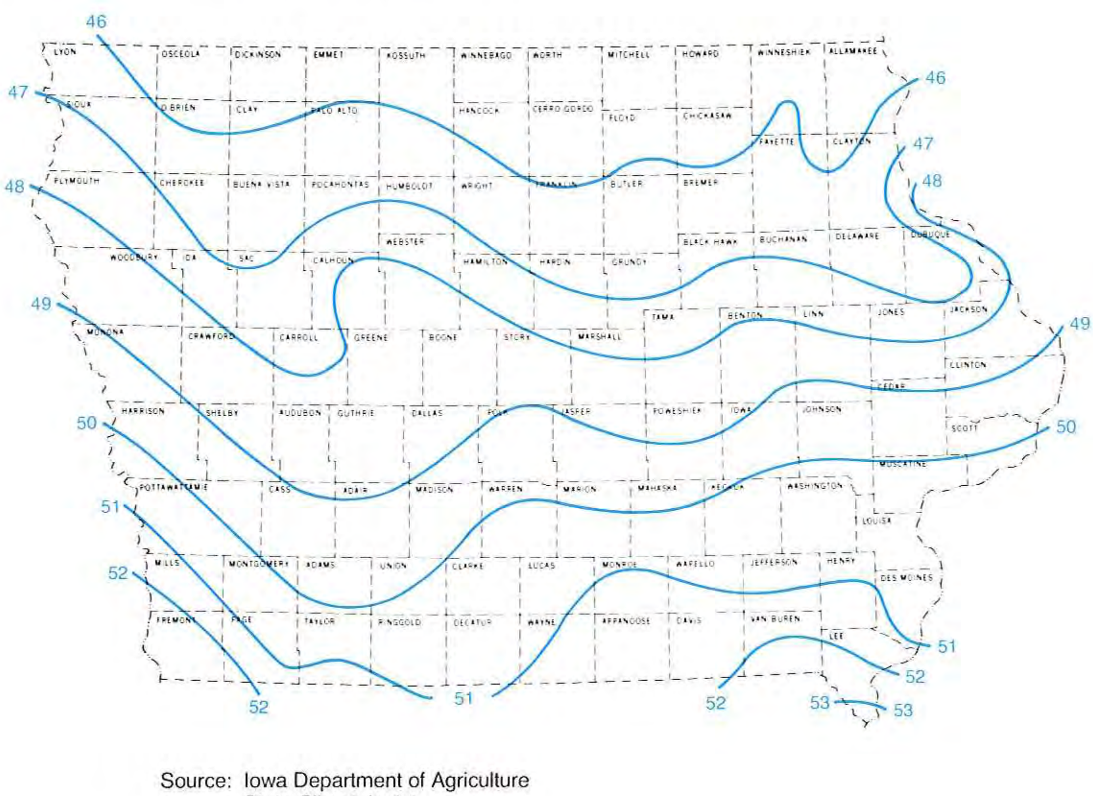
Precipitation

Precipitation is the basic source of water supply in Iowa and consists primarily of rain (90 percent), and snow (10 percent). Average annual precipitation ranges from 24.7 inches (637 mm) at Inwood in the northwest, to 35.6 inches (904 mm) at Keosauqua in the southeast (Figure 2-5). About two-thirds to three-fourths of the average annual precipitation comes during the growing season from April through September (Figure 2-6). However, annual and regional variability is considerable, with 1881 being the wettest year of record for the state as a whole, and 1910 the driest (Figure 2-7). The highest annual rainfall recorded in Iowa was 74.50 inches (1,892 mm) at Muscatine in 1851, and the smallest was 12.11 inches (308 mm) at Clear Lake in 1910. More recent extremes were experienced in 1973, when an annual total of 64 inches (1,625 mm) was reported for Mount Pleasant; and in 1976, when Remsen received only 13.67 inches (346 mm) for the year. Measurable precipitation occurs on about 90 days per year in the extreme northwest, and on about 110 days per year along the eastern border of the state.

The amount of precipitation received at any location varies considerably from year to year. Figure 2-8 shows the recorded annual precipitation at Le Mars, Des Moines, and Burlington for the fifty years between 1926 and 1976, compared to the average for each station. These graphs show that very few years between 1926 and 1976 were average, with periods of below average precipitation alternating with periods of high precipitation. The most noticeable droughts occured in the 1930s, mid-1950s, and mid-1970s, but note that specific years were not uniformly dry at all three stations.

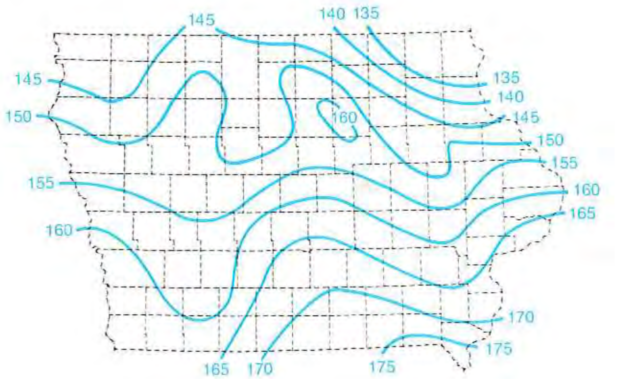
Precipitation variability is more closely associated with crop production than any other single climatic element. Normal to somewhat above normal precipitation is associated with the best crop production years in Iowa.

FIGURE 2-3 Iowa Mean Annual Temperature



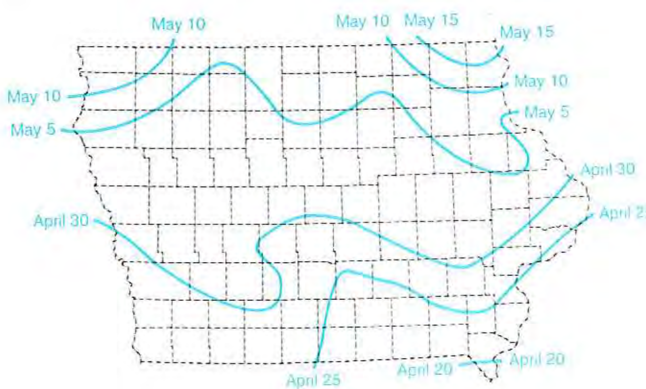
Source: Iowa Department of Agriculture
State Climatologist

FIGURE 2-4 Iowa Average Freeze Days



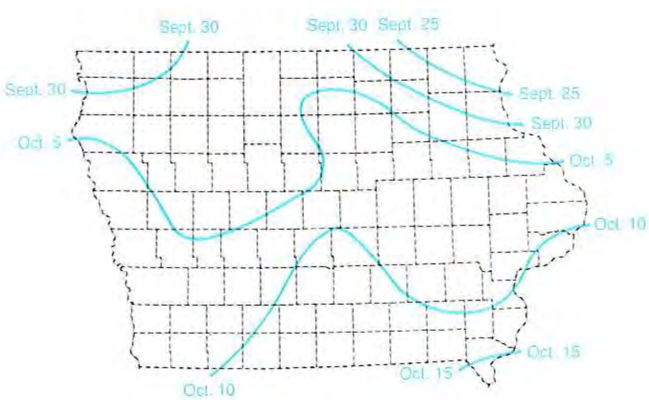
The average number of consecutive freeze free days. 1941-1970 base.

a. Freeze-Free Season



The average date of the last 32° freeze in the spring. 1941-70 base.

b. Last Spring Freeze



The average date of the first 32° freeze in the fall. 1941-70 base.

c. First Fall Freeze

Source: Paul J. Waite, Planting to Harvest—Annual Crop Weather Summary, Iowa Crop and Livestock Reporting Service 1976

The 1970s serve to illustrate this long established association rather well. Record crop production in the years 1972 and 1973, the two wettest consecutive calendar years of record in Iowa, illustrate the Iowa crop production capability with adequate moisture. Lower crop production in the following three years, with varying degrees of drought over parts of the state, illustrates the crippling effect of drought. In 1976, the fourth driest year of record in Iowa, conditions moved from warm and wet early in the year, to a cold, dry late-year pattern, and Iowa experienced its worst drought since the 1950s, and possibly the 1930s.

Intense rainfall has produced flash floods that are often costly to human life and property. The official maximum 24-hour rainfall recorded in the state is 12.99 inches (330 mm), measured at Larrabee in June, 1891. However, unofficial measurements in excess of 17 inches (432 mm) in 24 hours or less have been reported. On July 16-17, 1968, an unofficial 24-hour amount of 16.20 inches (411 mm) occurred at Waverly in the most severe northeast Iowa storm of record. Theoretical calculations place the maximum probable amount for a 6-hour period in a 10-mile square area in Iowa at 24 to 26 inches (610 mm to 660 mm). Although these extremely high rainfalls are rare at any given point in the state, the possibility of their occurrence must be taken into account in planning and implementing a flood plain management program for Iowa.

Snowfall averages a little more than 30 inches (762 mm) per year in Iowa and contributes both to water supply and water problems. Figure 2-9 shows the average annual snowfall for the state. Melting snow helps recharge our groundwater and surface water supplies, but also may contribute to the flood potential in the spring. Based on state averages, snowfall has varied from 11.9 inches (302 mm) in 1965-66, to 59.0 inches (1,499 mm) in 1961-62. The snowfall season in Iowa normally extends from November to March or early April, but measurable snow has fallen as late in the season as May 28, 1947, and as early as September 25, 1942. The average number of days with one inch (25.4 mm) or more of snow cover ranges from less than 40 in the southern counties, to more than 90 in the northeast. It is interesting that the annual precipitation extremes were experienced prior to 1910, but the snowfall extremes have occurred more recently, as have severe snowmelt floods.

Thunderstorms and Violent Weather

Most of Iowa's violent weather is associated with thunderstorms that occur with greatest frequency during the warm half of the year. Substantial crop and property losses occur in most years from high wind, hail, lightning, excessive rainfall, and occasional tornadoes associated with some thunderstorms. Thunderstorms occur on an average of 40 days per year in the northern part of the state, increasing to about 50 days in the south, with a majority of the storms occurring at night. This poses a real hazard to flood plain occupants in flash flood areas. About 20 percent of Iowa's thunderstorms occur in June, 16 percent in July, and 14 percent each in May and August. Hail frequencies follow a similar pattern, reaching a peak in June and July.

Tornadoes, often a by-product of thunderstorms, are most frequent in May and June, with the effective season extending from April through September. From the average number of about 30 tornadoes per year, two or three may be very destructive; yet, in most years, lightning causes greater loss of life to farm operators than tornadoes, and windstorms or hail usually cause greater crop loss.

FIGURE 2-5 Normal Annual Precipation

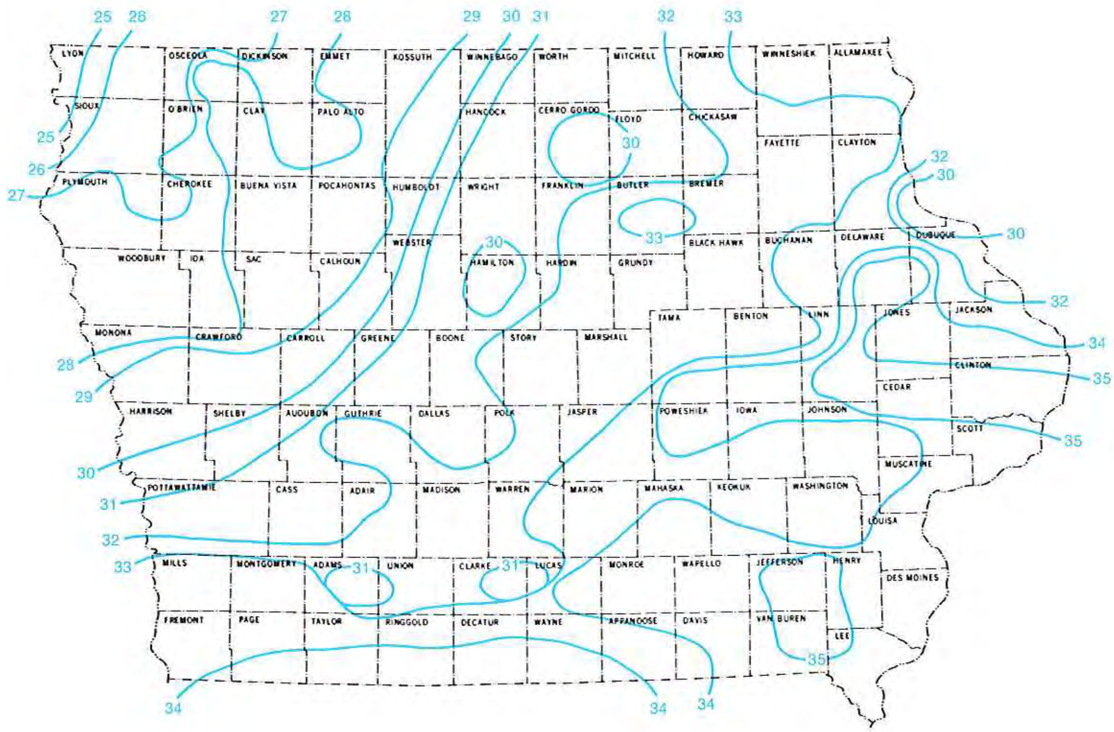


FIGURE 2-6 Normal Crop Season Precipitation

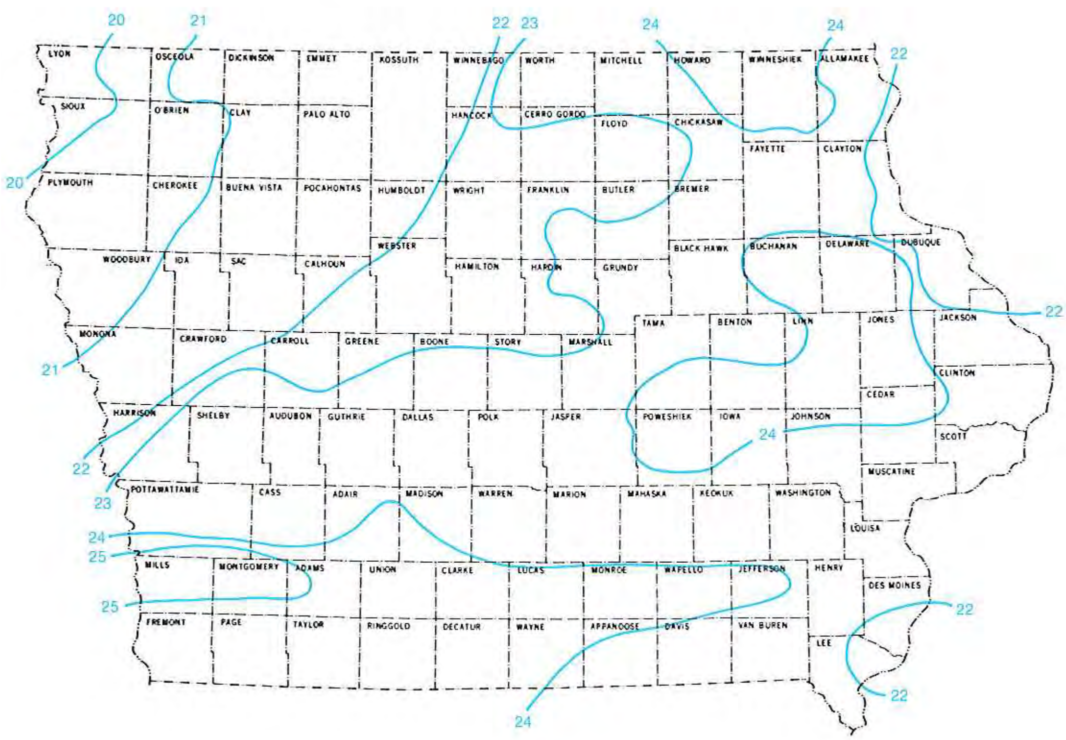
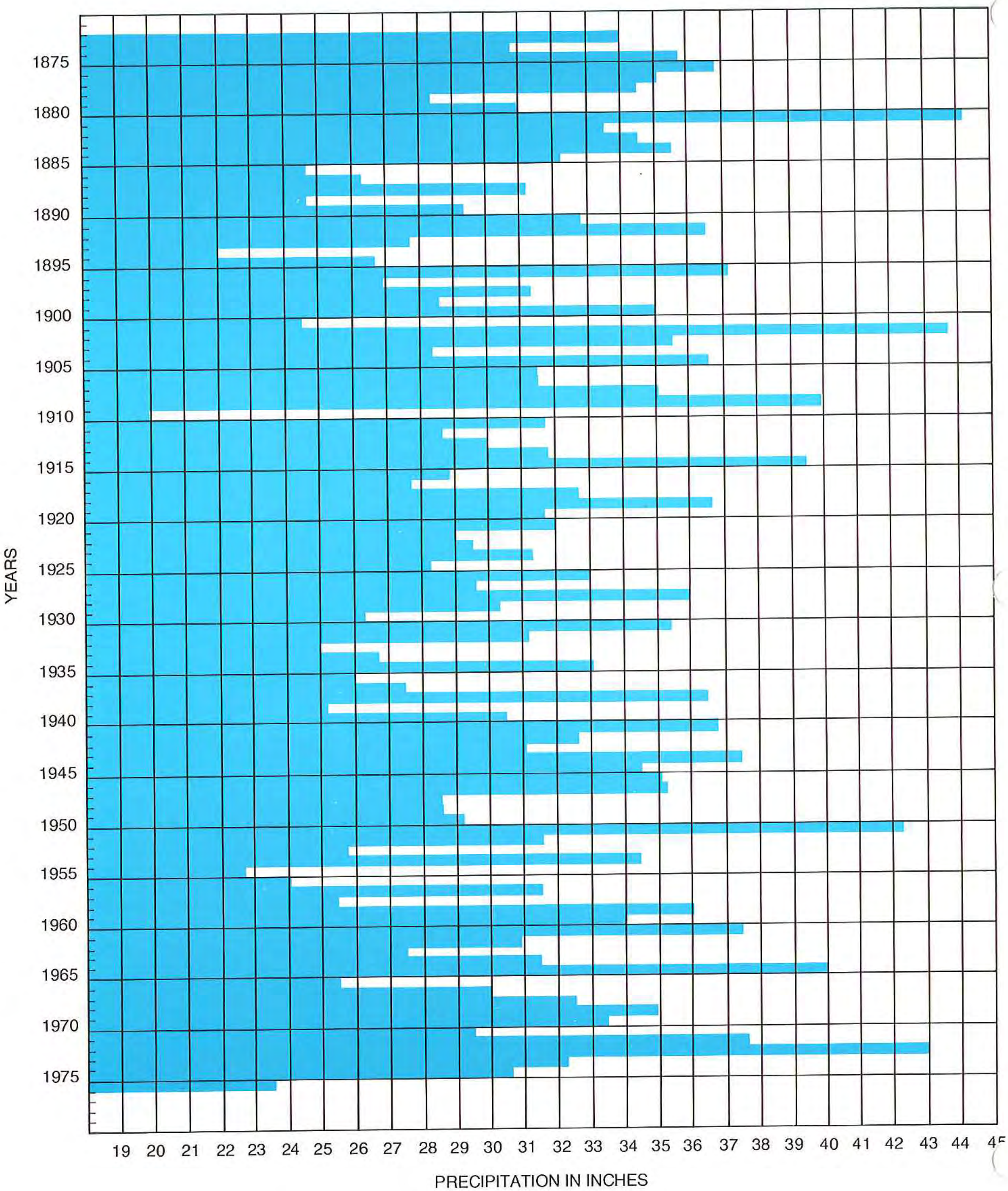


FIGURE 2-7 Average Annual Precipitation for Iowa (1873-1976)

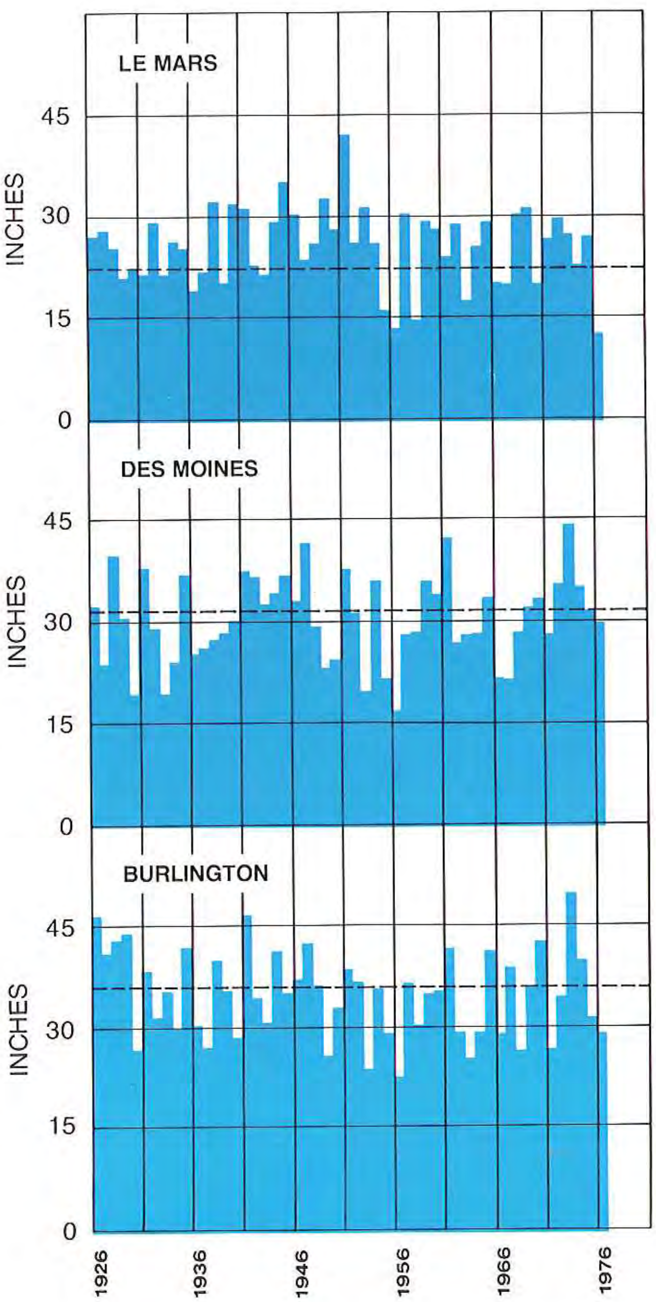


Source: Iowa Department of Agriculture
State Climatologist

Evapotranspiration and Iowa's Water Budget

Evapotranspiration was defined in the section on temperature as the total loss of moisture from land and water surfaces to the atmosphere. It includes the loss through evaporation from free-water surfaces, moist soil, and from vegetation. A plant extracts soil moisture through its roots, circulates it through the plant tissues, and transpires it into the atmosphere from leaf surfaces.

FIGURE 2-8 Comparison of Precipitation, 1926-1976, for Iowa Stations



Dash line indicates annual average (1926-1976)
Source: U.S. Weather Bureau Climatic Summaries

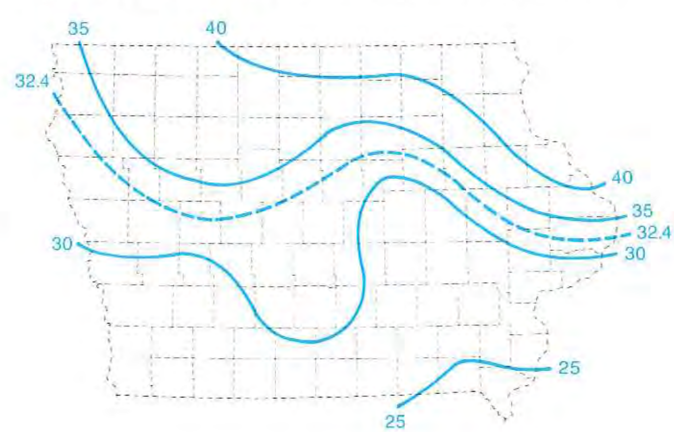
Evapotranspiration, unlike temperature and precipitation, cannot be measured directly with simple instruments. Records are available for many stations from evaporation pans, estimates of lake evaporation are published by the U.S. Weather Service, and empirical methods for calculating potential evapotranspiration losses from vegetation and land surfaces have been devised. These calculations utilize factors such as temperature and length of daylight to estimate potential evapotranspiration (PE). A method for estimating PE that is commonly used is that developed by C. W. Thornthwaite. Calculated values derived by this method are published for many stations, including a number in Iowa. Table 2-1 compares values for pan and lake evaporation in Iowa with PE calculated by the Thornthwaite method. Other methods for estimating evapotranspiration losses are available and give different but comparable results. Under normal summer conditions, the daily values can reach 0.2 to 0.3 inches per day, and 0.5 inches on a hot, windy day. This means that Iowa's farmers appreciate an inch of rainfall each week.

Average annual pan evaporation values for Iowa exceed estimated lake evaporation by about 30 percent, and average annual percipitation by about 56 percent. Pan evaporation is almost double the calculated Thornthwaite PE values, and estimated lake evaporation exceeds calculated PE by about 20 to 30 percent. Fortunately, annual precipitation offsets the annual lake evaporation, to the benefit of lake recreation and water supply reservoirs. However, during droughts, net lake evaporation accumulates rapidly and lake levels drop.

Figure 2-10 summarizes the water budget for Des Moines in graphic form. Actual evapotranspiration (AE) and PE are equal so long as there is a water surplus, as is the case for Des Moines between October and May. From June through September, PE exceeds the moisture available, and the rate of AE is estimated to be proportional to the available soil moisture — that is, if soil moisture is at 60 percent of capacity, the rate of evapotranspiration will be about 60 percent of the PE.

Moisture demands by crops and other vegetation exceed precipitation during an average Iowa summer; thus, soil moisture reserves must make up the difference.

FIGURE 2-9 Average Seasonal Snowfall



Source: P.J. Waite, Iowa Precipitation: Water Resources of Iowa, Iowa Academy of Science, 1970.

TABLE 2-1 Comparative values for Pan, Lake, and Calculated Potential Evapotranspiration for Iowa.

Area	Pan[1]	Lake[1]	Lake / Pan	PE (Thornthwaite)[2]	PE / Pan	PE / Lake
Northeast	43 in. (1,092 mm)	30 in. (762 mm)	.70	24 in. (610 mm)	.56	.80
Central	50 in. (1,270 mm)	36 in. (914 mm)	.72	27 in. (686 mm)	.54	.75
Southwest	60 in. (1,524 mm)	42 in. (1,067 mm)	.70	29 in. (737 mm)	.48	.69

[1]Source: U.S. Department of Commerce (ESSA), Climatic Atlas of the United States, U.S. Government Printing Office, 1968.
[2]Source: C. W. Thornthwaite Associates, **Average Climatic Water Balance Data of the Continents**, Publications in Climatology, Vol. XVII, No. 3, Centerton, N.J. 1964.

From October through February, there is an excess of moisture since plants are dormant and the soil moisture supply, that was depleted during the summer months, is recharged. By February, the soil is again recharged to capacity and there is a surplus of water between February and May to supply surface and groundwater runoff. Although all Iowa stations have a few summer months of net moisture deficiency, in an average year annual precipitation exceeds PE, giving the state a humid climate.

Figures 2-11, 2-12, and 2-13, depict the pattern of average annual PE, average water surplus from March through May, and average water deficiency from June through September. The pattern and magnitude of the water surplus for the state parallels the pattern of stream runoff illustrated in Figure 3-3. It is not surprising that the normal pattern of stream discharge reflects the seasonal and regional pattern of water surplus and water deficiency. Stream discharge is generally at a peak during the water surplus period, and at a minimum during the water deficiency period. Also, streams in northwestern Iowa have very poor minimum-flow characteristics during the summer, while northeastern Iowa streams are more dependable. Regional variations in the water budget must be taken into consideration in planning for the optimum use of Iowa's water resources.

Iowa Geology and Hydrology

The ultimate controlling factors that determine the quality, movement, and distribution of water received as precipitation are geologic and hydrologic. Topography, vegetation cover, and the nature of earth materials influence the pattern by which precipitation runs off or infiltrates the ground. Underground, as well as at the surface, the elevation and attitude of soil and bedrock layers are factors in the rate and direction of water movement. The quality of water frequently reflects the chemistry of the soils and rock materials in which it is found. Permeable soil materials and rock formations act as reservoirs—called aquifers—that store and transmit water. They allow groundwater to flow into wells and their character controls the amount of water available. Unfortunately, these underground reservoirs are not uniformly distributed across the state; neither is the quality of the water they contain nor the prospect of a given rate of yield.

Iowa's water resources occur in many different but related geologic and hydrologic contexts. To understand their occurrence, one must be acquainted with a few particulars of the geology and hydrology of the state.

Geology

Iowa lies in the Western Young Drift section of the Central Lowland physiographic provinces of the United States. Landscapes consist of subtle features of low relief formed by the action of water, glacial ice, and wind. Surface features are mostly developed in the relatively young, unconsolidated sediments that mantle the bedrock. Thus, two vastly different sequences of earth materials, that function interdependently, form the geologic framework that influences the occurrence of water resources in Iowa. The materials of the uppermost (youngest) of the two sequences are mostly unconsolidated sediments of glacial origin. The lower, older sequence consists of alternating layers of consolidated rock, mostly limestone, dolostone, shale, and sandstone.

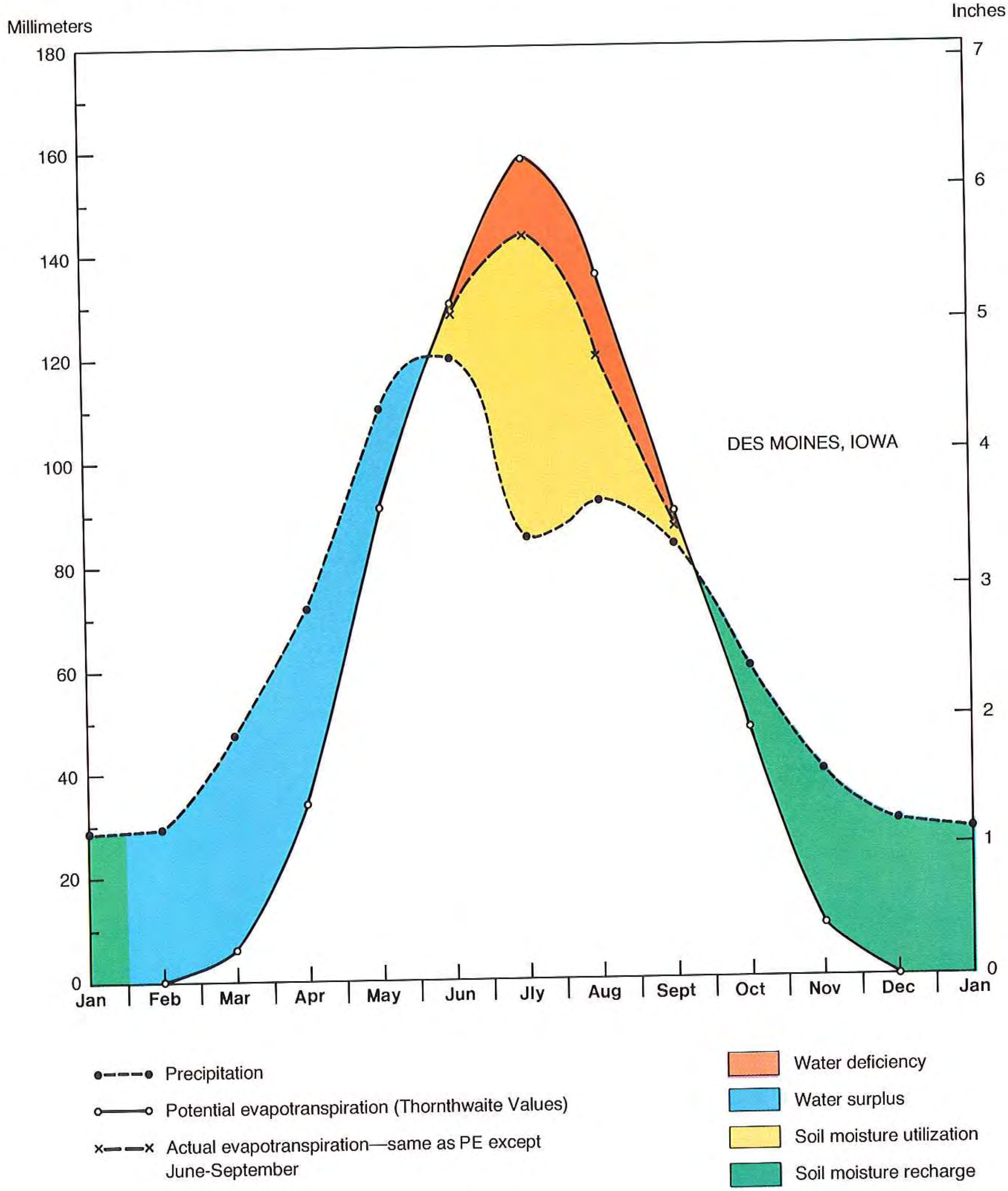
Unconsolidated Sequence of Iowa

Iowa's undulating topography and her rich soils are developed almost exclusively on unconsolidated sediments of glacial origin. Exceptions occur where bedrock has been exposed or where the products of water erosion have been deposited as alluvial fill in and along stream valleys.

During several episodes of the geologic past, dating back some two million years, continental glaciers advanced into and across Iowa. Each episode deposited

Ledges State Park in January
Iowa Conservation Commission

FIGURE 2-10 Water Budget for Des Moines



its own mantle of sediment—called drift—upon a pre-existing bedrock or drift surface. Today, only the features of the most recent deposits are recognizable on the surface. In north central Iowa, young glacial drift of the most recent Wisconsinian glacial advance forms most of the surface materials in the Des Moines Lobe. In southern Iowa, older glacial drifts have been extensively eroded by stream action and subsequently capped by deposits of wind-blown sediments called loess. The northeastern corner of Iowa was glaciated at a very early period, but was never again invaded by glacial ice, and subsequent erosion has stripped away most of the drift cover, leaving a topography developed on the bedrock; thus, the term "Driftless Area".

The materials and terrain features of Iowa are shown in Figure 2-14. Drift thickness ranges from a feather edge in bedrock outcrop areas of the northeast to 600 feet in Crawford County in the west. Over much of northwest Iowa, the drift is 300-500 feet thick. In the "Driftless Area" of northeast Iowa, drift occurs only as very small scattered remnants. Stream-deposited alluvium is shown only in the Mississippi and Missouri River valleys because elsewhere it cannot be suitably mapped on an illustration of this scale.

Sediments belonging to the unconsolidated sequence in Iowa are predominately composed of uncemented clay, silt, sand, and gravel. The proportion of these constituents varies considerably with the age, origin, vertical position, and the areal distribution of a particular deposit.

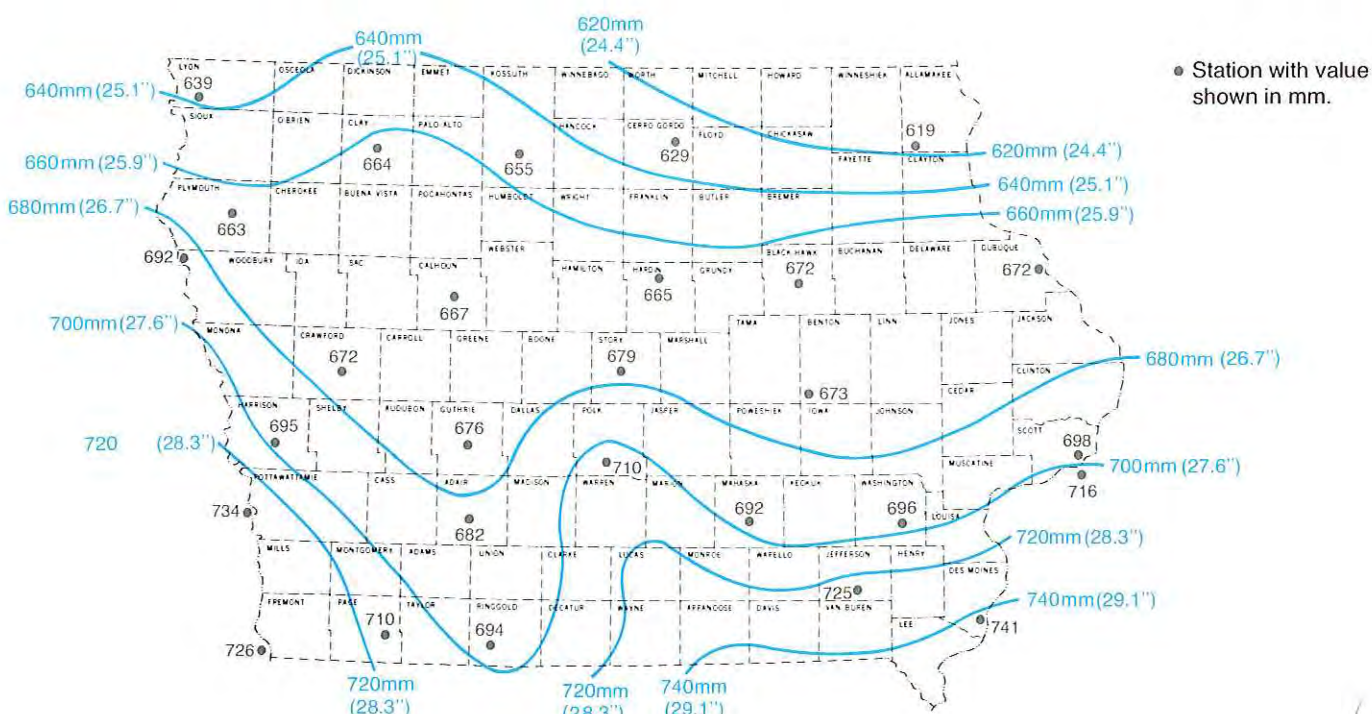
Alluvial materials characteristically are more granular and well drained, often furnishing large supplies of relatively shallow water in the larger river flood plains of the state. Most glacial drift areas are dominated by poorly permeable materials, consisting of admixtures of clay, silt, and sand, but may contain lenses of clean sand and gravel. The younger drifts of north central Iowa have a higher overall proportion of sand and gravel than do the older drifts lying outside the Des Moines Lobe. Loess consists largely of silt and clay, with clay content increasing from west to east across the state. Loess is highly permeable in areas where silt-sized materials make up a high percentage of the loess, but water movement may be restricted where clay content is high and clay pans have developed in the soils.

The Bedrock Sequence of Iowa

In the interior United States, during an interval in geologic time much more remote than the Pleistocene (glacial age), shallow inland seas inundated most of the now existing land area. Throughout a time span of nearly 600 million years, these seas alternately advanced across the region and retreated, leaving thick sedimentary deposits as a record of the region's geologic history. They record the nature of life forms of that remote age, environmental and climatic conditions, the position of the seas and land areas, where the geologic record is broken or missing, and indicate periods when the seas receded and the region emerged to be exposed to erosion. Of greater significance with respect to water resources is the fact that now these layered rock formations collectively form a vast reservoir in which water is stored.

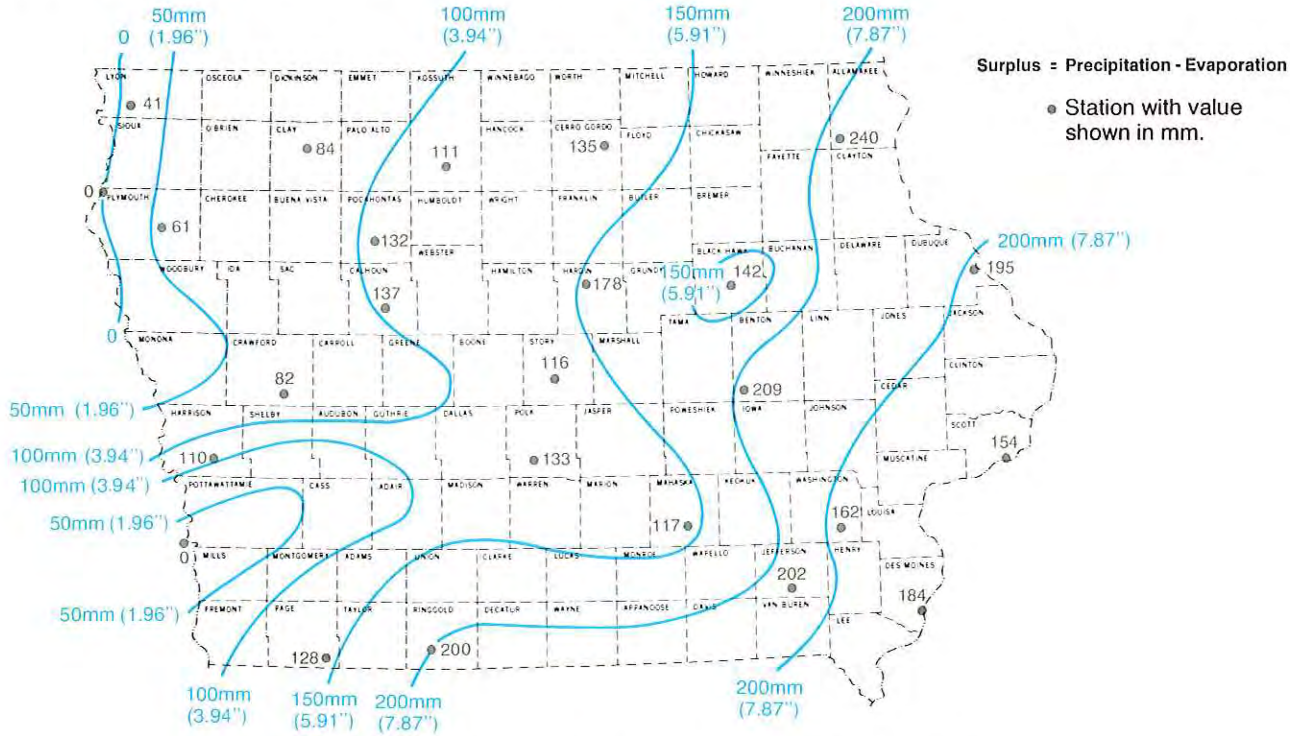
The sequence of layered rock formations in Iowa is variable in thickness and is overlain nearly everywhere by unconsolidated materials. It rests on a foundation of much older, non-water bearing crystalline and altered

FIGURE 2-11 Potential Evapotranspiration for Iowa



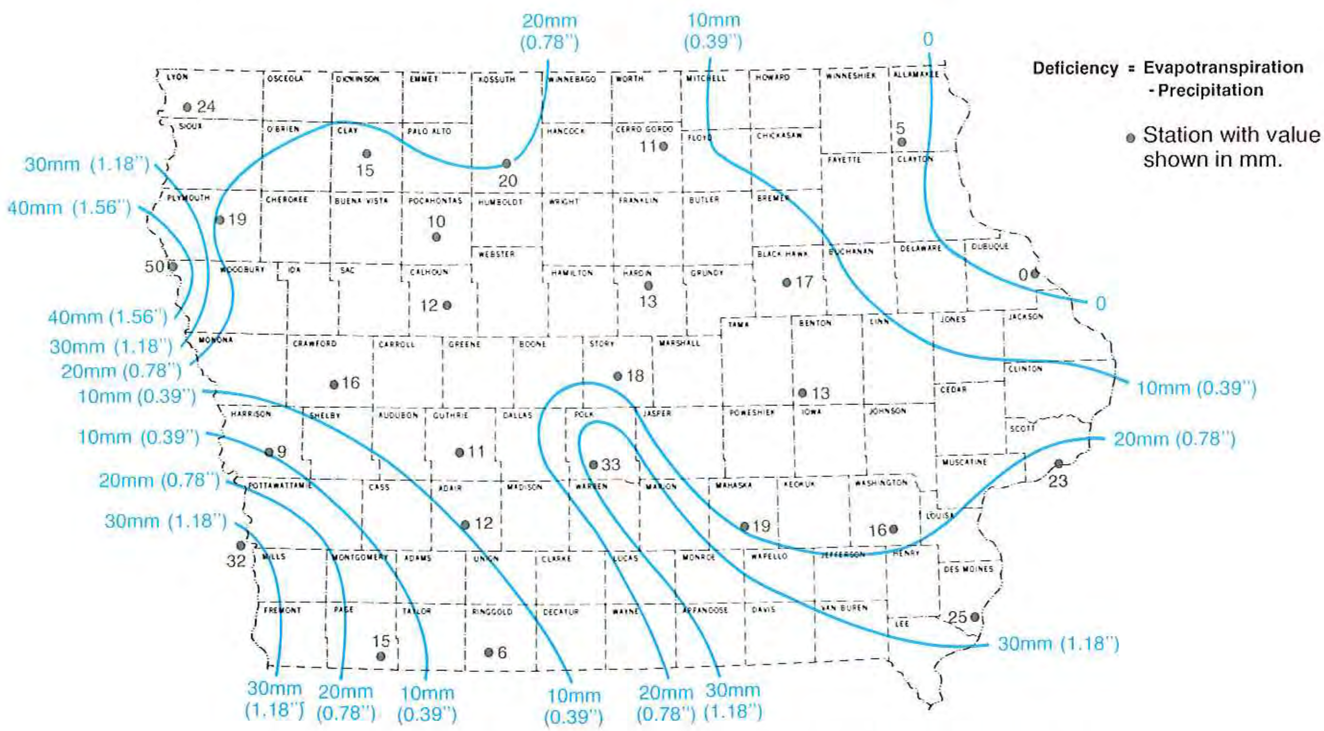
Source of Data: J.R. Mather, Edit., Average Climatic Water Balance Data of the Continents: Part VII United States, C.W. Thornthwaite Assoc., Centerton, N.J., 1964.

FIGURE 2-12 Water Surplus, March-May



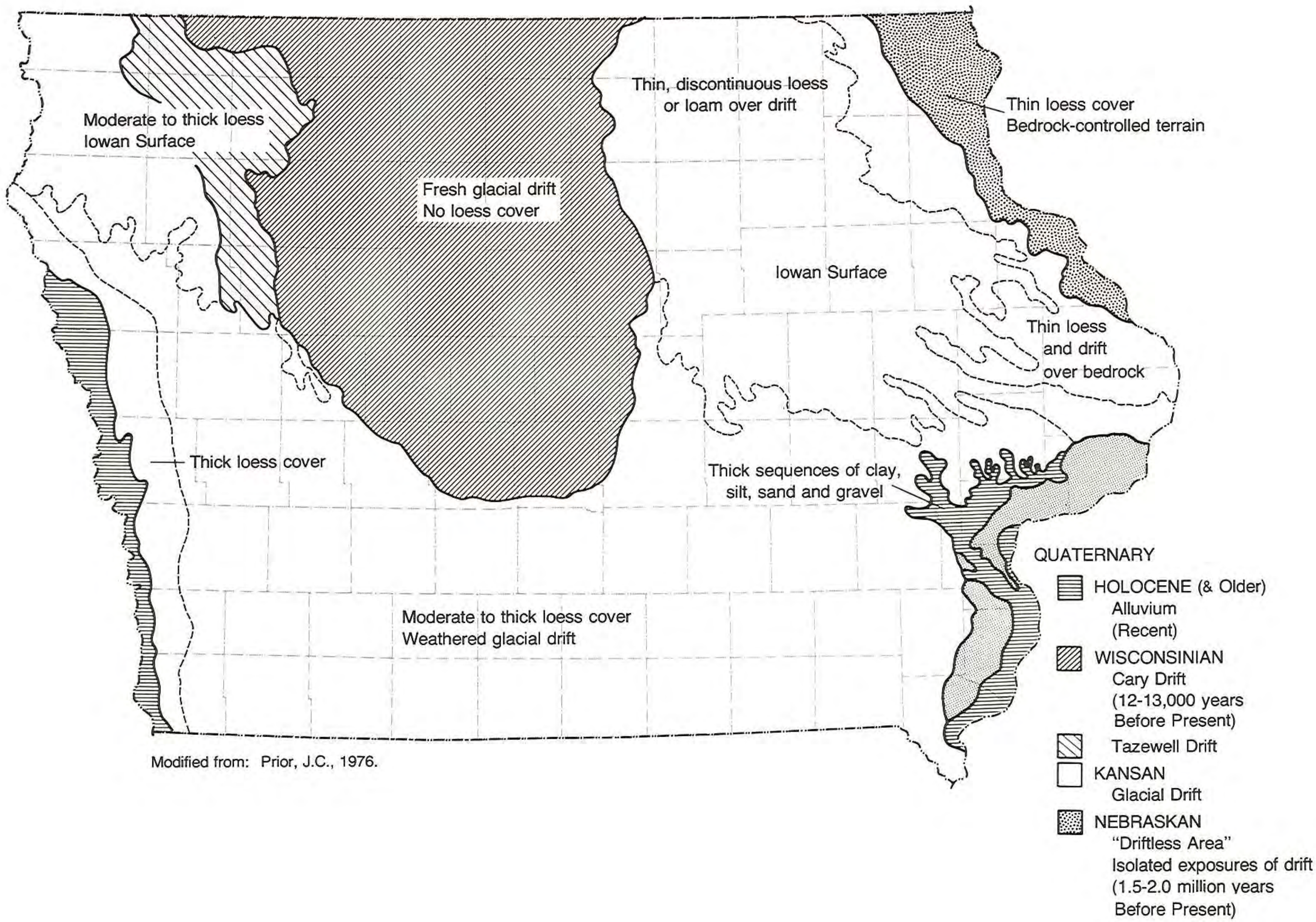
Source of Data: J.R. Mather, Edit., Average Climatic Water Balance Data of the Continents: Part VII United States, C.W. Thornthwaite Assoc., Centerton, N.J., 1964.

FIGURE 2-13 Water Deficiency, June-September



Source of Data: J.R. Mather, Edit., Average Climatic Water Balance Data of the Continents: Part VII United States, C.W. Thornthwaite Assoc., Centerton, N.J., 1964.

FIGURE 2-14 Terrain and Surface Materials in Iowa



Modified from: Prior, J.C., 1976.

sedimentary rocks collectively called Precambrian. The sequence of sedimentary rocks ranges from a few hundred feet in thickness in the northeast to nearly 5000 feet in southwest Iowa. In extreme northwest Iowa, it thins to a feather edge and the underlying, older Precambrian rocks are exposed. Vertically the sedimentary rock section in Iowa is dominated by alternating "layer cake" strata of limestone, dolostone, sandstone, and shale. A detailed summary of these strata and their water bearing characteristics is given in Chapter 3 (Table 3-2).

If the overlying unconsolidated materials were stripped away, one would see the beveled edges of the bedrock formations appearing as broad arcuate bands opening toward the southwest (Figure 3-15). This pattern is created by the gentle regional downwarping of the layered rocks toward a shallow basin centered near southwestern Iowa; thus, as one traverses across the state from northeast to southwest, he progresses from older rocks to younger rocks. In northwest Iowa, the older sedimentary rocks (Paleozoics) are mantled by much younger, nearly flat-lying sediments of Cretaceous age. These younger sediments, thus, mask the banded pattern of the underlying and older Paleozoic units.

A more detailed treatment of the significance of geology and geologic materials to Iowa's water supply is given in Chapter 3, **Water Resource Availability.**

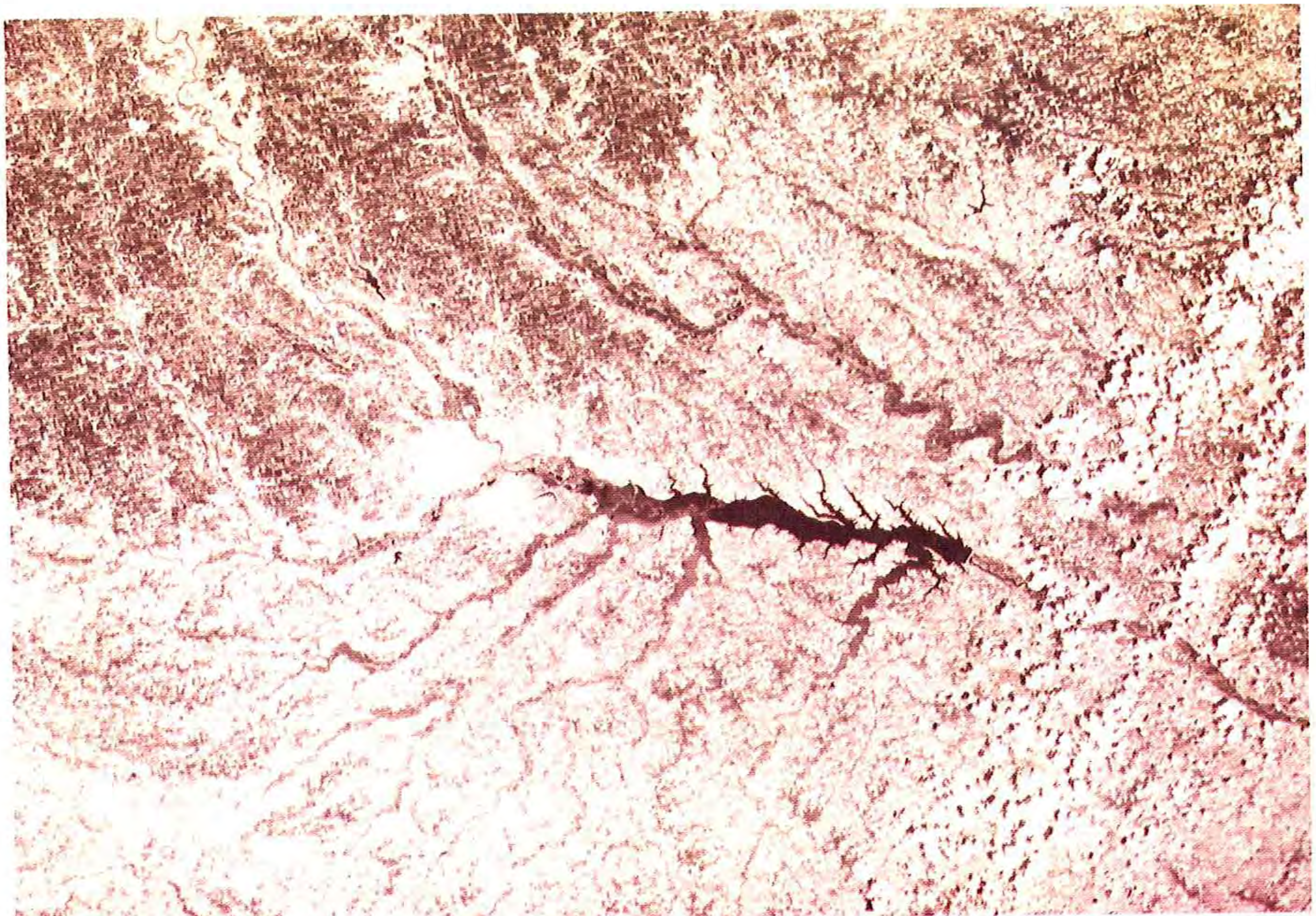
Hydrology and the Geology of Groundwater

Functioning together, the unconsolidated sediments and rock units of Iowa form a vast natural storage-distribution system for water. Through the inter-connected voids within rock and soil materials, water is "piped" from locality to locality across the state. The rate at which it moves is governed primarily by differences in elevation and the slope between one part of a formation and another (piezometric head and gradient), and the size and degree of inter-connection (permeability) of the openings in soil and rock. These rates of migration are generally small; they range from a few inches to several hundred feet per year in uniform sand and gravel formations. However, in certain areas of the state, under unique circumstances, groundwater moves very rapidly. In the karst (sinkhole) area of northeast Iowa where soluble carbonate bedrock (limestone, dolomite) lies near the surface, percolating water has enlarged pre-existing cracks and crevices in the rock to the extent that they now facilitate the rapid flow of large volumes of water. Similarly, water can move rapidly to wells drilled into fracture planes and joints in carbonate bedrock formations.

Groundwater in Iowa occurs in several different water-bearing units or aquifers. In simple terms, an aquifer is a body of natural earth material (soil or rock) of sufficient volume, porosity and permeability to store and transmit water. The aquifers of Iowa are subdivided into two general categories. The first category includes several types of sand and gravel aquifers within the surficial (unconsolidated) materials that mantle the bedrock. The principal **surficial aquifers** in this category are: localized sand and gravel bodies within the glacial drift (collectively the glacial drift aquifer); sands and gravels associated with the major streams of the state (alluvial aquifers); and sands and gravels buried in pre-glacial bedrock valleys (buried channel aquifers). The second category of aquifers is comprised of water bearing limestone and sandstone units at several horizons in the bedrock beneath the state—**bedrock aquifers.**

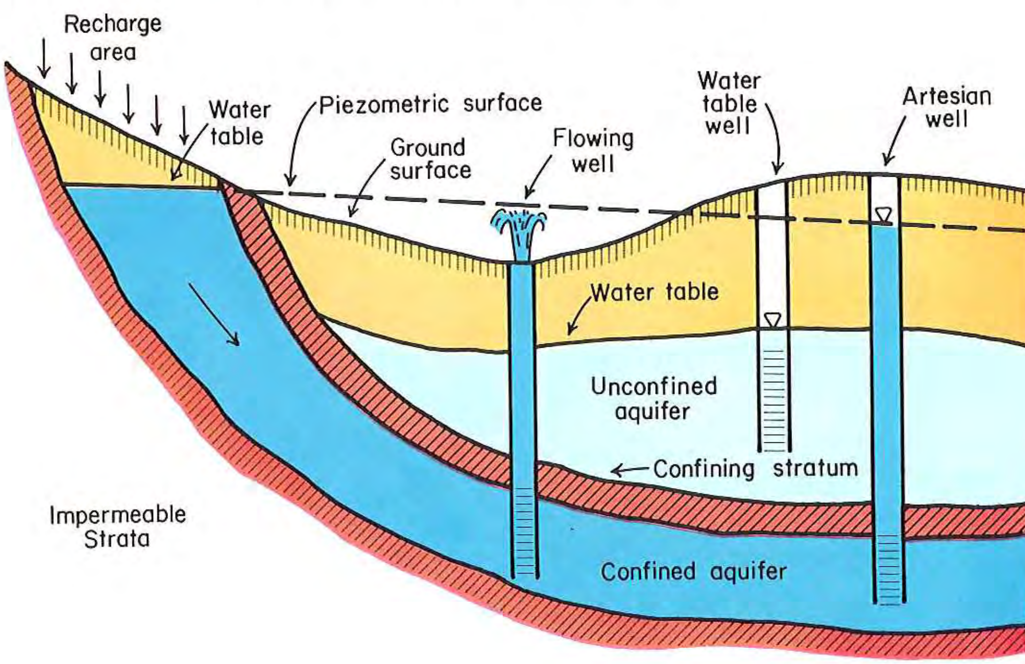
Groundwater is stored and transmitted under two hydraulic conditions—artesian (confined) and water table (unconfined). The water in artesian aquifers is confined under pressure by overlying, impermeable formations. In a well penetrating such an aquifer, water will rise above the bottom of the confining bed, shown in Figure 2-15. Water enters confined aquifers at a distant point where the aquifer first dips below the surface, or where the confining bed ends underground (Figure 2-16). An unconfined aquifer is one in which a water table develops (the upper limit at which the ground is saturated with water). Water levels in unconfined aquifers correspond to the undulating form and position of the water table. Regionally, the water table generally follows the land surface, rising beneath hills, declining toward stream valleys and intersecting the surface in streams, lakes, and ponds (Figure 2-17).

Loess Hills, Monona County *Soil Conservation Service*



Satelite infrared image of Redrock Reservoir and Des Moines area NASA

FIGURE 2-15 Schematic of Artesian Aquifer System



Streams

Streams are a valuable resource for the state, contributing vast quantities of water for municipal, industrial, and agricultural uses. In addition, they support fish and wildlife needs and furnish recreational opportunities for the citizens of Iowa. The Mississippi and Missouri River, in addition to these contributions, furnish important routes of transport for the products of the state's farms and factories. Detriments also exist: streams present problems of flooding and may be subject to pollution by some that diminish their usefulness to others.

Streamflow

Iowa's major drainage basins and River Basin Planning Areas are identified in Figure 2-18. Some 69 percent of Iowa's land surface drains into the Mississippi River, while the remaining 31 percent lies within the Missiouri River drainage basin. The flow observed in our streams has its origin in surface runoff from precipitation, and discharge from underground sources. Streamflow supplies water for human consumption, agricultural uses, industrial operations, cooling purposes, generating hydro-electric power, recreational needs, accepting and assimilating effluents from water pollution control facilities, and other uses. It is obvious that many of these beneficial uses are also conflicting uses requiring the establishment of priorities and control of use.

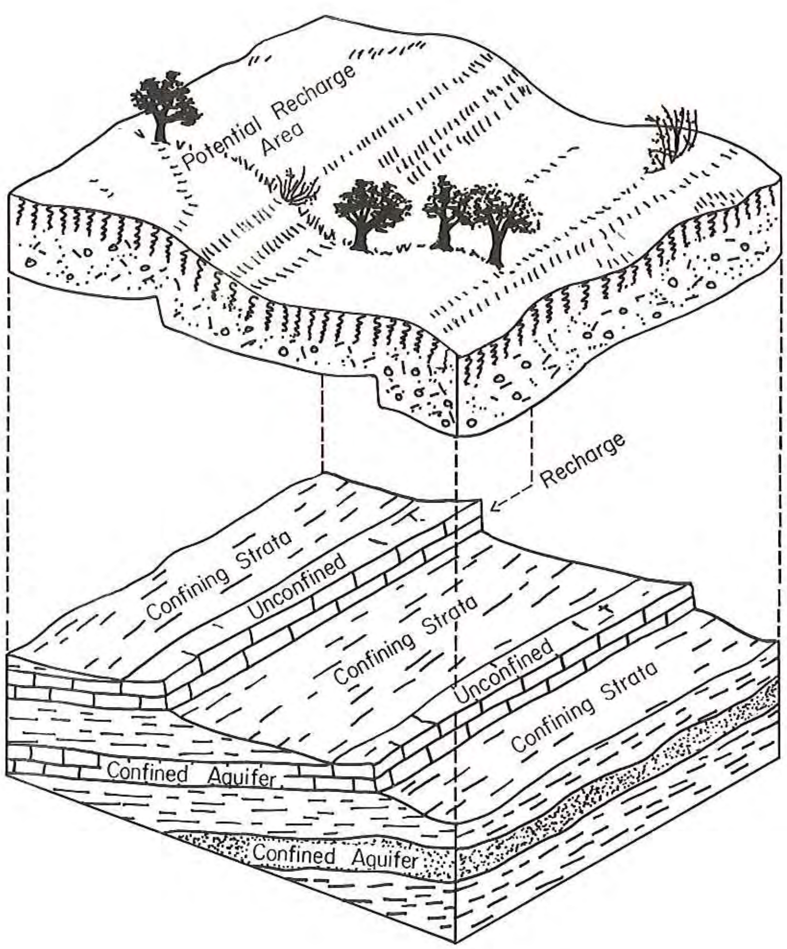
Streamflow records at gaging stations over a period of years reflect a stream's discharge characteristics and provide essential data for water use and water control planning. In water resources planning, the maximum and minimum flow each year and annual runoff, or water yield, are important. Maximum flows are a measure of flood potential, and minimum flows indicate limitations on beneficial use of the streamflow in the absence of storage reservoirs. The maximum and minimum daily discharges vary greatly on all Iowa streams. For example, the discharge of the Des Moines River at Ottumwa has varied from a low of 30 cfs (cubic feet per second) in 1940, to a high of 135,000 cfs in 1947, during the period of record, 1903-1978. The Skunk River near Ames has experienced a zero low flow and a peak discharge of 14,700 cfs.

Average annual runoff of Iowa streams, prorated over the areas of the basins in inches depth of water, is shown in Figure 3-3. The runoff pattern correlates with the average distribution of precipitation, with the most deficient areas of both precipitation (less than 28 inches) and runoff (less than 2 inches) occurring in northwest Iowa.

Floods

Because of the critical problems related to floods, they are considered apart from the overall picture of streamflow. Periodic heavy runoff at rates high enough

FIGURE 2-16 Idealized Diagram Typifying the Groundwater Environment of Iowa



Upper Iowa River near Bluffton, Winneshiek County *K. Formanek*

to produce flooding occurs in all parts of the state. Floods may be the result of intense or prolonged rainfall, melting snow cover, or a combination of both. Flash flooding of Iowa's smaller tributary river valleys, generally in the summer months, is caused by local cloudbursts. Regional flooding which may affect all or a major part of the state may be caused by prolonged rains of great areal extent, generally in spring and summer. Snowmelt, or a combination of prolonged rainfall and melting are generally a spring phenomenon and frequently result in flooding of Iowa's major rivers and the bordering Mississippi and Missouri Rivers.

Flooding at some point within the state is an annual occurrence and these events become too numerous to mention. Some floods, however, have been so notable in terms of record stages, depths and peaks, loss of life, and property damage as to warrant special attention. Both the Mississippi and Missouri Rivers have produced major floods in Iowa in recent decades. The floods of early spring in 1950 and again in 1952 were caused almost entirely by melting snow on the northern plains. Today, the average flood damage along the Missouri River has been reduced by 70 percent by the main stem reservoirs in the Dakotas and agricultural levees along the main channel. However, tributary streams still contribute large volumes of flood water and cause considerable flood damage.

On the main stem of the Mississippi River the April, 1965 flood was the greatest of record for the 700-mile stretch from Royalton, Minnesota to Hannibal, Missouri. The peak discharge at Clinton, with 92 years of record, exceeded the highest previous stage by 3.7 feet, and the maximum flow was 307,000 cfs. During the same period of 1965, most central and eastern Iowa tributaries of the Mississippi River, including the Iowa-Cedar, Skunk, and Des Moines Rivers, were also in flood but below record stages. The record runoff experienced in 1965 was the result of a combination of conditions. Severe cold weather in late March and early April, and a heavy March snowfall on saturated and frozen ground, prevented gradual runoff of the snowpack. Again in 1969, major snowmelt floods occurred in the Mississippi River Valley, but along the Iowa borders the stages were lower than in 1965.

Two of the most widespread periods of late spring and summer flooding in Iowa occurred during May, 1944, and May and June of 1947. As the result of severe and widespread thunderstorms in 1947, record breaking floods occurred several times on some streams within five weeks. Three great floods occurred at intervals of about one week in the Des Moines River Basin, and record floods were experienced at many stations in the Iowa-Cedar River Basin.

The most recent severe flood in an urban area occurred on June 27, 1975, when the city of Ames and Iowa State University experienced the most severe flood on record from Squaw Creek and the South Skunk River. Losses were estimated to be over a million dollars and one person drowned. Although the storm that preceded the flooding was not particularly outstanding in intensity and duration, antecedent conditions plus the timing and direction of the storm were "ideally timed" to cause the flood.

Flash floods have taken a heavy toll of life and property in Iowa. One of the most catastrophic occurred in July, 1958, when unprecedented rains fell in Audubon and Guthrie Counties over the headwaters of the East Nishnabotna and South Raccoon Rivers. The maximum rainfall reported was 12.35 inches at Audubon; a recording gage in the area measured 7 inches between midnight and 2:30 A. M. on July 2. The high intensity of the rainfall on the rolling hillsides resulted in rapid runoff and flash flooding on most of the streams in the area. Major damages were caused by the East Nishnabotna and its tributaries, especially Blue Grass, David's, and Troublesome Creeks, and by the South Raccoon and some of its tributaries. These floods resulted in the loss of 19 lives and extensive damages to urban and rural property, roads, railroads, bridges, livestock, and agricultural crops. Total damages in the Nishnabotna River Valley totaled approximately $14,500,000. Flash floods have continued to plague the state almost every year, giving a warning each time that nature has first claim on the flood plains.

In 1972, major flooding was experienced again in the Nishnabotna River Valley and in other western Iowa stream valleys. Rainfall amounts in excess of 20 inches fell at Dunlap and Harlan in a three day period, September 10-12, 1972. Two lives were lost in the upstream reaches when automobiles plunged into the floodwaters because of washed-out bridges. The lower reaches of these basins were particularly hard hit at harvest time, with considerable loss of matured crops.

Other Natural Resources

Soils

Iowa's agriculturé owes much of its excellence to a fortuitous combination of climate and soils. Soils, in turn, have developed through a complicated interplay of parent materials, climate, and natural vegetation.

The principal parent materials of Iowa soils are (1) glacial drift, (2) loess, and (3) alluvium. Figure 2-14 indicates the distribution of these parent materials within the state. Alluvium is found in all areas of the state, but only along the flood plains of the Missouri and Mississippi rivers is its areal extent sufficient to map at a small scale.

Trumbull and Lost Island Lakes—natural morainal lakes on the Des Moines Lobe
NASA

Approximately 95 percent of the soils of the state formed from the above three parent materials, while the remaining 5 percent formed from colluvium, residual bedrock materials, and organic deposits.

FIGURE 2-17 Idealized Diagram of Water Under Unconfined Conditions

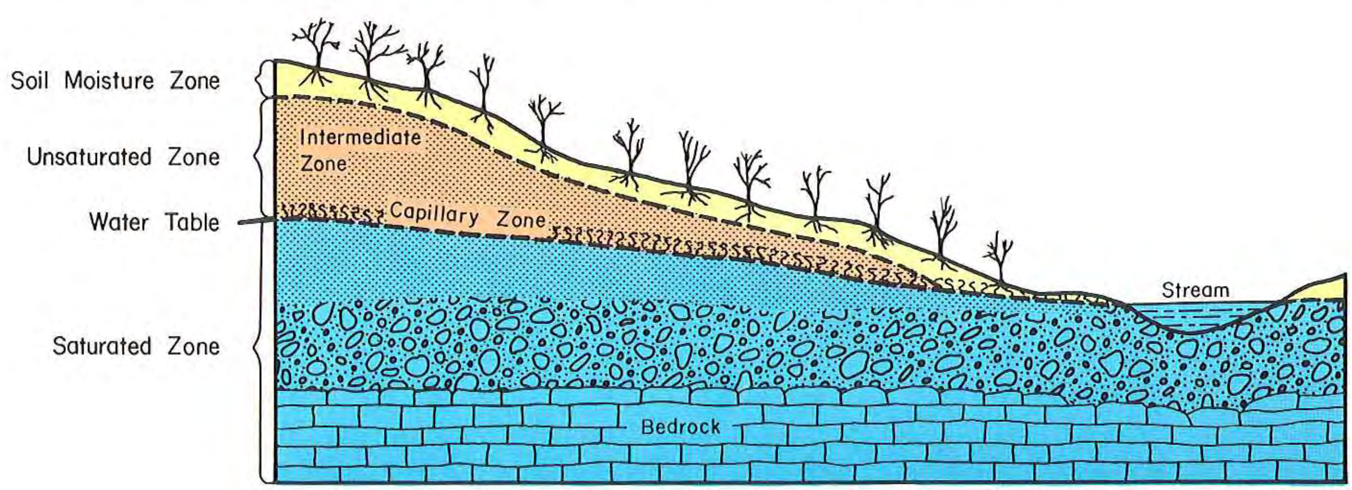
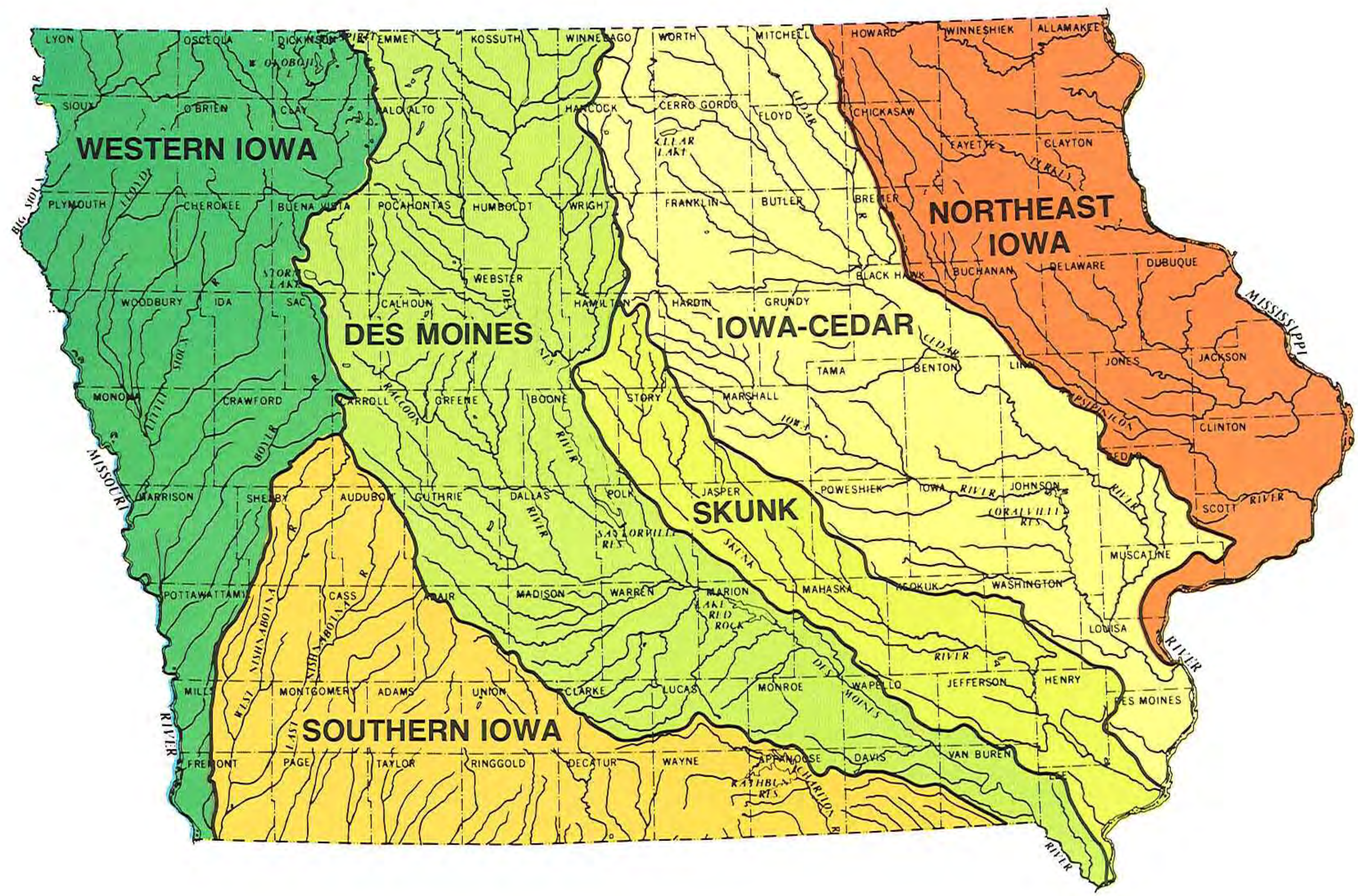


FIGURE 2-18 River Basin Planning Areas



Giant elm tree in Ledges State Park, 1937
Des Moines Register and Tribune

An important factor in soil formation is the natural vegetation. In Iowa the vegetation cover consisted of prairie grasses in large areas of the state, while deciduous forests dominated the east and the river valleys. Some of the state's finest soils are the prairie soils formed on the younger glacial drifts of north central Iowa, and the loess of the south and west. On the younger drifts, artificial drainage by tile and ditch is required to assure maximum productivity. Although the forest soils may be naturally less-fertile, compared to the grassland soils, they respond well to proper treatment and can be highly productive.

Vegetation

The prairie grasslands of Iowa have almost disappeared; an inevitable result of occupying some of the most desirable agricultural lands. Only in a few preserves can native grasses be seen in something approaching their natural state.

Considerably more forests are preserved, in part, because they tended to occupy rougher lands that were less suitable for cultivation (Figure 7-1). Control of prairie fires that had been a factor in repulsing the invasion of trees onto the prairies, actually caused some increase in forest range. Nevertheless, the net effect of settlement was to drastically reduce the forest acreage of the state. Today, increased land values have stimulated further clearing of the few remaining woodlands, sometimes with serious adverse environmental effects.

The forests of Iowa have many values including commercial use, recreational use, wildlife habitat, soil protection, and aesthetic contribution for the enjoyment of Iowa's people. Steps should be taken to assure the wise use, preservation, and restoration of the state's forest resource. With our extremely limited forest acreage, even the smallest loss in forest cover can adversely affect wildlife populations, outdoor recreation opportunities, as well as scenic beauty, and may increase runoff rates and erosion potential.

Fish and Wildlife

Fish and wildlife resources are closely related to Iowa's water resources. Altering the habitat through draining of wetlands, cutting of forests, and eliminating prairies all had a detrimental impact on the rich wildlife resources found in the state by the early settlers. Many species, such as the buffalo and other large herbivore, have disappeared; a few, including deer and wild turkey, have been reestablished and are prospering; and some new species such as the ringneck pheasant, introduced in 1900, have been a spectacular success.

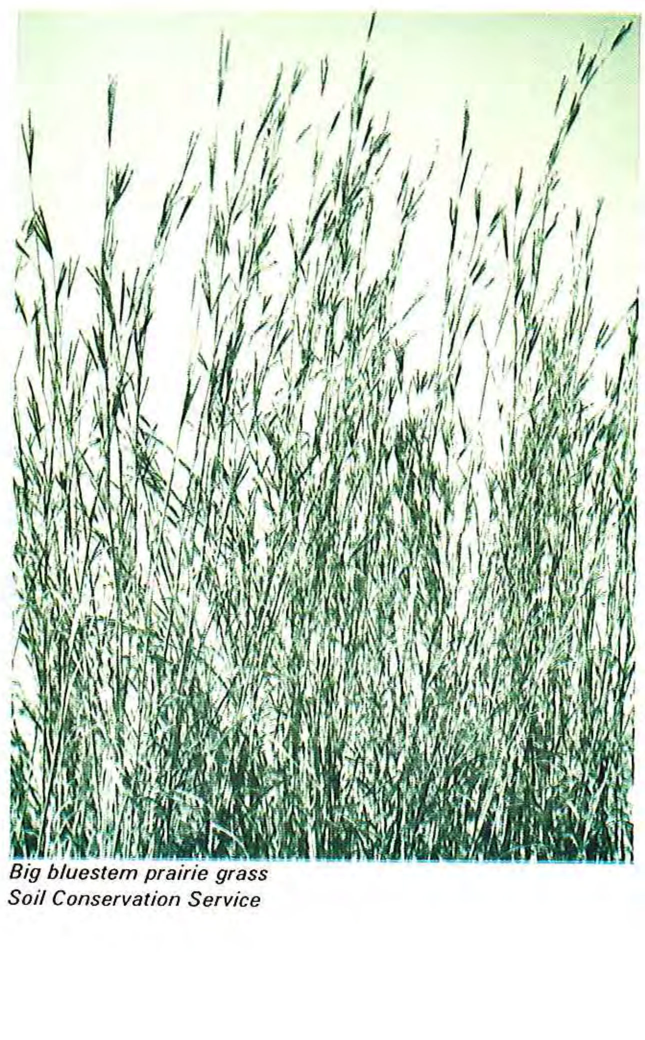
Wildlife management programs in Iowa are administered by the Iowa Conservation Commission, and their relationship to water resources is considered in some detail in Chapter 7.

Mineral Resources

There are five major categories of mineral production in Iowa: cement, stone, sand and gravel, gypsum, and coal. These minerals have a total annual value of about $200 million, of which cement makes up 40 percent of the value, followed by stone—34 percent, sand and gravel—15 percent, gypsum—4 percent, and coal—4 percent. Silica, clay, peat, and shale are mined in small quantities.

Carbonate rocks—consisting of combinations of the common carbonate minerals, calcite and dolomite, have a wide variety of uses: raw material for portland cement, crushed stone for use in portland cement and asphalt concretes, road gravel and highway sub-base material, agricultural lime, lime or hydrated lime, and building stone. Iowa has enormous reserves of this low-cost but commercially important industrial mineral.

Sand and gravel are produced in 81 counties and limestone is mined in 64 counties. The wide distribution and availability of these aggregates is important in many ways, especially in keeping costs of construction and road building low. The gypsum of economic importance occurs in a massive, compact, finely crystalline form called gypsum rock. Iowa currently ranks second in the nation in terms of gypsum production. Large deposits are found near the surface in the Fort Dodge area where it is



Big bluestem prairie grass
Soil Conservation Service

mined by open pit methods. Gypsum is mined by underground methods near Sperry in Des Moines County. Beds of gypsum and anhydrite, a chemically related mineral, exist deep in southern and south central Iowa, but have not been commercially exploited. The majority of products of the gypsum industry are used for construction purposes. The principal products are wallboard, sheeting board, lath, and tile.

Coal is found in south central Iowa over an area of at least 20,000 square miles (Figure 8-3). At least four major coal seams occur in this region. The original coal reserves for 4,100 square miles of Iowa's principal coal producing area have been estimated at more than seven billion tons, half of which are readily available. Iowa coal is characteristically bituminous with heat values that average between 10,000 and 11,000 BTU's per pound, ash contents of 8 to 10 percent, and sulfur contents around 5 percent.

In 1975, Iowa produced about 622 thousand tons of coal per year valued at more than $6.8 million. Since 1975, coal production has increased in response to the energy shortage, but still accounts for a relatively small part of Iowa's total mineral production. About 50 percent of the coal is mined by open pit methods, the balance by underground methods. Most of Iowa's coal is used by power plants to produce electrical energy. If Iowa's coal can be sufficiently upgraded through beneficiation or otherwise be used in environmentally acceptable ways, such as gasification, it has tremendous potential in meeting future energy needs. Unfortunately, gasification requires large quantities of water, a commodity in short supply in most of the coal mining areas of southern Iowa (see Chapter 8).

The People

Knowledge about the size, composition, and distribution of a population in the future is essential to planning for economic and social development. It is only when the future demands for goods, services, and facilities are known that these demands can be met and dealt with in an orderly and adequate manner. Future demands of a population depend upon the size and characteristics of that population—the number of total population, the number of young, old, and working people, etc. Whether planning for water resource management or for schools, churches, medical service, transportation, utility, welfare or business, population projections will provide a rough guide for estimating future needs.

TABLE 2-2 Population of Iowa: 1840 to 1970

[A minus sign (-) denotes decrease]

Census	Population	Increase Over Preceding Census	
		Number	Percent
1970	2,825,041	67,504	2.4
1960	2,757,537	136,464	5.2
1950	2,621,073	82,805	3.3
1940	2,538,268	67,328	2.7
1930	2,470,939	66,918	2.8
1920	2,404,021	179,250	8.1
1910	2,224,771	-7,082	-0.3
1900	2,231,853	319,556	16.7
1890	1,912,297	287,682	17.7
1880	1,624,615	430,595	36.1
1870	1,194,020	519,107	76.9
1860	674,913	482,699	251.1
1850	192,214	149,102	345.8
1840	43,112[1]	—	—

[1] Includes population of area now constituting that part of Minnesota lying west of the Mississippi River and a line drawn from its source northward to the Canadian boundary. This area formed a part of Iowa Territory in 1840.

TABLE 2-3 United States and Iowa Population Trends, 1900-1970.

Census Year	Population Totals		Percentage Change		Iowa's Rank Among States
	United States	Iowa	United States	Iowa	
1900	75,994,575	2,231,853	—	—	10
1910	91,972,266	2,224,771	+21.0	-0.3	15
1920	105,710,620	2,404,021	+14.9	+8.1	16
1930	122,775,046	2,470,939	+16.9	+2.8	19
1940	131,669,275	2,538,268	+ 7.2	+2.7	20
1950	150,697,361	2,621,073	+14.5	+3.3	22
1960	179,323,175	2,757,537	+19.0	+5.2	24
1970	203,184,772	2,825,041	+13.3	+2.4	25

Source: U.S. Bureau of the Census

Population Growth

Archaeological evidence indicates that prehistoric Indians arrived in this area sometime before 10,000 B. C. Throughout the long span of time before European settlement, there were many cultures that prospered and then disappeared, leaving little permanent mark on the natural environment. An exception might be the possible role of the Indians in maintaining the prairies by intentionally or accidentally setting fire to the grass. With the coming of permanent European settlement in the 19th century, drastic changes were wrought in Iowa's landscapes, and increasing demands were made on the land and water resources.

On July 4, 1838, the Territory of Iowa was established with 22 counties and some 23,000 inhabitants. Included within the boundaries of Iowa Territory was that part of Minnesota lying west of the Mississippi and a line from its source northward to the Canadian border. By 1840, the census showed some 43,000 persons living in the Iowa Territory. In 1850, four years after Iowa became a state, the population had mushroomed to 192,000 (Table 2-2).

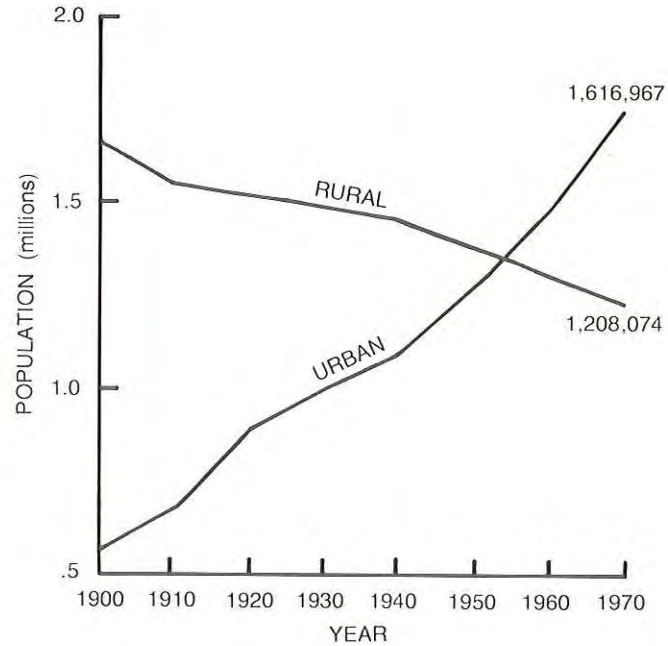
Today, Iowa has more than 2.8 million people and ranks 25th in population among the states of the nation. Although the growth rate has been steady, the population of the state has not grown as rapidly as that of the nation as a whole. While the United States experienced a 167 percent growth between 1900 and 1970, Iowa's population only increased about 27 percent (Table 2-3).

The birth rate has declined greatly in recent decades, dropping from about 24 births per 1,000 total population in 1955, to about 16 per thousand in 1972. Iowa's death rate was 10.4 per 1,000 population in 1972, compared with a national rate of 9.4. The state's higher death rate reflects the large percentage of its population in the older age group; in 1970, 12.4 percent of Iowans were over 65, a figure exceeded only by Florida.

Iowa's population increased 67,500, or 2.4 percent, in the decade between 1960 and 1970. The natural increase (the number of births minus the number of deaths) was 247,544 in the same period; the difference between the natural and the actual increase being accounted for by out-migration (Table 2-4). The out-migration in this past decade has slowed somewhat compared to the two preceding decades.

Iowa's modest rate of population growth probably will hold for the next several decades, a factor that will aid in the orderly development of the state's land and water resources.

FIGURE 2-19 Rural and Urban Population Trends in Iowa (1900-1970)



Rural-Urban Migration

In 1900, 75 percent of Iowa's people were considered rural; that is, they were living in communities of less than 2,500 people, or living on farms. It was not until 1960 that the census first showed a majority of Iowans, 53 percent, dwelling in urban areas. By 1970, the percentage of urban residents had risen to 57 (Figure 2-19).

The urbanization of Iowa's people has followed the increased application of technology on the farm. With more efficient farm practices and more mechanization, Iowa's farms are employing fewer and fewer people, requiring more farm families to move to the cities to find employment.

The greatest urbanization in the past decade has taken place in the large metropolitan areas. Meanwhile, those communities that experienced the smallest growth were those under 1,000 population.

TABLE 2-4 Iowa migration trends, 1940-1970.

Years	Beginning of Decade	Population end of Decade	Actual Change	Percent Change	Natural Increase[1]	Potential Population[2]	Net Change[3]	Percent Net Migration
1940-1950	2,538,268	2,621,073	82,805	+3.3	265,317	2,803,585	-182,512	-7.2
1950-1960	2,621,073	2,757,537	136,464	+5.2	372,779	2,993,852	-236,315	-9.0
1960-1970	2,757,537	2,825,041	67,504	+2.5	247,544	3,005,081	-180,040	-6.5

Excess of births over deaths.

[2]Total of population at beginning of the decade plus the natural increase.

[3]Potential population minus actual population at the end of the decade.

Sources: Computed from U.S. Bureau of the Census and Vital Statistics data.

Urban growth has a greater potential impact on water demands than does the overall population growth. As people concentrate in a few large metropolitan areas, resources in their vicinity may be overtaxed to supply water for domestic and industrial use, to handle the high concentrations of waste materials, and to furnish opportunities for water-based recreation.

Economy of Iowa

Agriculture

Iowa has depended on agriculture for her economic well-being for more than a century. Iowa's farmers sell $6.6 billion in agricultural products each year. Livestock sales make up $3.9 billion in cash receipts; crops bring $2.7 billion. A large share of the new and expanding industry in Iowa is related to agriculture. Nearly 80 percent of all workers in Iowa depend at least indirectly on agriculture for their jobs, in actual farm labor, chemical and fertilizer production, seed and livestock businesses, or machinery manufacturing.

Water availability for crop production is determined largely by precipitation, although irrigation has been growing in areas with especially favorable water supplies such as the Missouri River bottom lands. Generally, water supplies for rural domestic and livestock uses are adequate, but some areas of western and south central Iowa may encounter problems in dry years. Chapter 10 deals with water-related problems of agriculture and their place in a comprehensive water plan.

Industry

In the past 10 years, 259 companies built or expanded plants in Iowa, providing 113,457 new jobs and $2.6 billion in new capital. Iowa's central location and excellent transportation system have contributed to this influx. One-third of **Fortune Magazine's** list of the top 500 companies have plants in Iowa; included are manufacturing companies, chemical industries, meat and food processors, communications industries, and transportation companies.

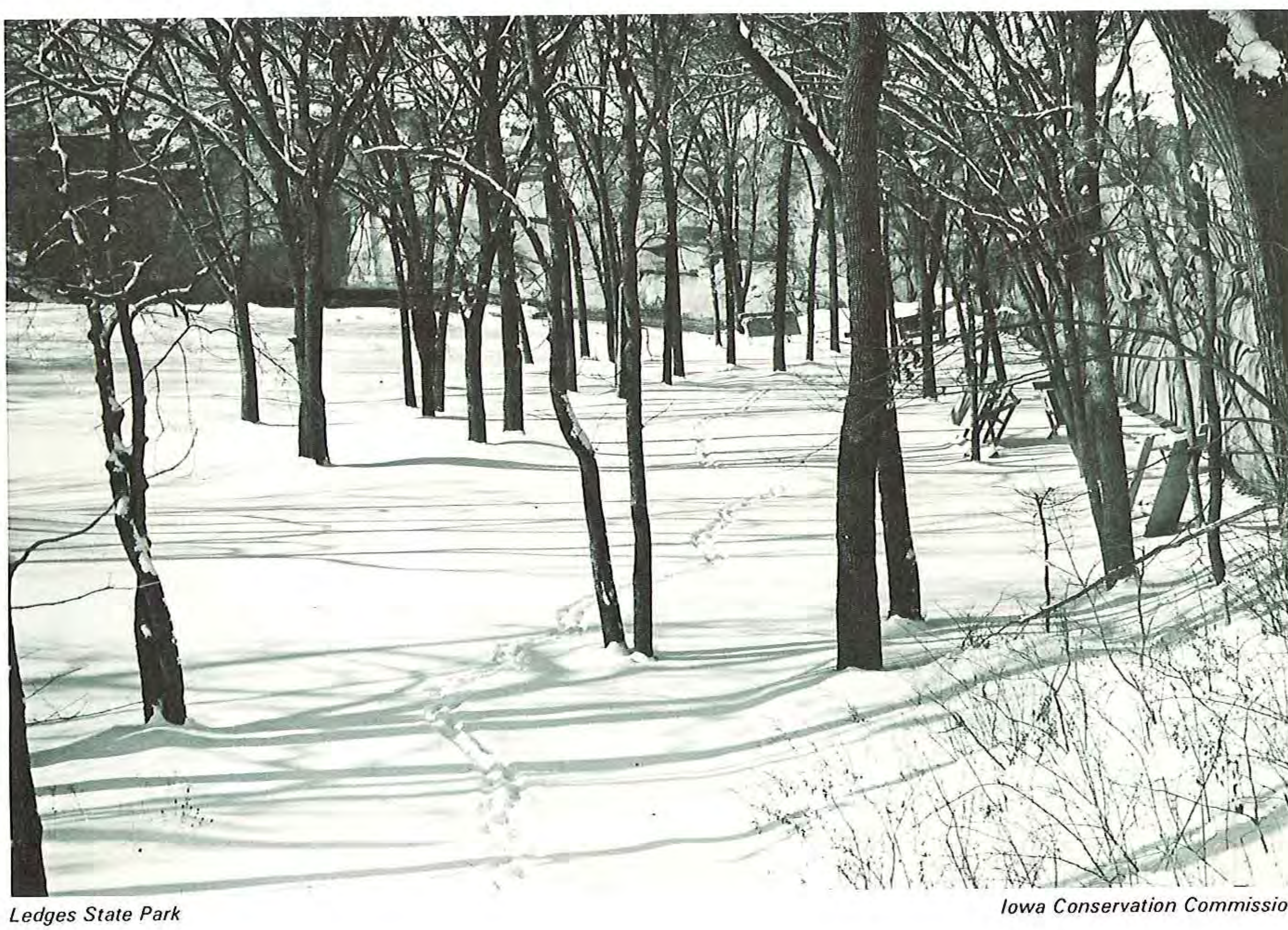
Nearly one million Iowans are employed in non-agricultural pursuits, compared to 250,000 employed on Iowa farms. Almost 230,000 Iowans are employed in manufacturing, with machinery and food processing accounting for 106,000 jobs. Wholesale and retail trade and service industries account for more than half of the non-farm jobs outside the manufacturing sector.

Iowa ranks third nationally in per capita exports, with overseas sales amounting to $3 billion annually. Farm products, such as meats, grains, and related products, account for half of that trade.

Industry, of course, has a vital interest in water resource availability, water quality, and water use policies such as pollution control and flood plain management. The importance of water to industry is considered in several chapters of this report.

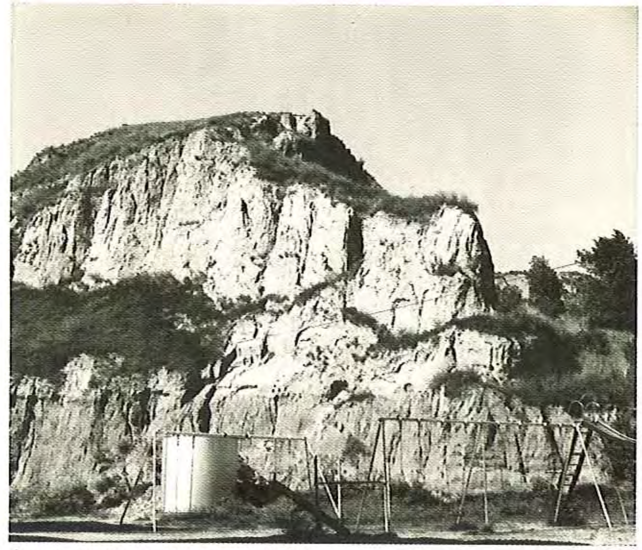
Quality of Life and Environment

Iowa is viewed by many as a land of clean air and water, unspoiled by modern industrial society. In a



Ledges State Park *Iowa Conservation Commission* relative sense, this image may be true. Iowa does not face the severe pollution problems of the more densely settled and highly industrialized states, but population growth, intensive agriculture, and industrialization have changed the state. Following the example of the early settlers, modern Iowans continue to alter their environment, a process that is inevitable, but one which should be directed to assure minimal environmental impact and to guard against deterioration of the quality of life.

Most of Iowa's streams now have some degree of pollution, air pollution plagues our urban areas, and soil erosion and indiscriminate urban sprawl have scarred the landscape. A carefully formulated plan for future development of Iowa's water resources must address itself to reversing some of these undesirable trends, while maintaining a level of growth and development commensurate with a high quality of life.



Loess bluffs at Missouri Valley *W. E. Akin*

Stream gaging station on Raccoon River at Panora *L. Gieseke*

3 Water Resource Availability

Iowa's early communities were established adjacent to the Mississippi and the state's interior rivers, lakes, and springs where water was readily available. The demand for water in Iowa's early history was small compared to the present. In Iowa, water is now used at a rate of 60 to 150 gpcd (gallons per capita per day), varying with the size and economic characteristics of communities. In 1970, the total water withdrawn from surface and ground water sources was about 2.5 million acre-feet, or about 2 billion gallons per day. By 1975, this amount more than doubled to 5 million acre-feet and is projected to reach at least 10 million acre-feet by the mid 1990's (Barnard and Dent, 1976, Projections of Population, Employment, Income and Water Use for Iowa River Basins, 1975-2020).

As the use of water continues to increase, the role of water in providing goods and services becomes even more critical. The production and processing of livestock and crops, building materials, energy, manufacturing, and mining all require great amounts of water. For instance, it takes about 5 gpd (gallons per day) to water each head of hogs and about 10 gpd per head of cattle; it takes about 4,000 gallons of water to process 1,000 pounds of beef and 1 acre-foot (325,850 gallons) of water to irrigate an acre of land. All human activity, in some way, depends upon adequate and suitable supplies of fresh water.

In the past, Iowans have grown to accept a philosophy of water development based on faith in natural abundance and dependence upon the renewability of the supply. By and large, nature has provided abundantly, except for episodes of drought experienced during the 1930s, 1950s, and again in the 1970s. However, this philosophy has neither been totally satisfactory nor has it benefited all water interests in the state, and holding to it has caused some disconcerting precedents to be set in water resources development. Conflicts between water user groups are becoming much more common as each sector attempts to meet its demands for larger and more reliable water supplies. A quick look into the future indicates that Iowans are only beginning to feel the gravity of the imbalance between water supply and demand. Very soon water managers and developers must fully address the issue of water resources allocation which, in the past, was a mechanism used only by those states with less abundant water than Iowa.

The information presented in this chapter is based on the comprehensive "Task Force Report on Water Resources Availability," prepared by the Iowa Geological Survey and filed with the Iowa Natural Resources Council.

What then is this water resources trust that Iowans must protect, conserve, manage, and allocate?

The relationship of water to climate and geology was indicated in Chapter 2. In this chapter we will expand on the generalizations about water resources made in the previous section by evaluating major sources of water. These sources are the natural lakes and reservoirs, streams, and groundwater aquifers of the state. Because of the complex nature and regional diversity of groundwater resources, considerably more space is devoted to their consideration than to surface sources.

Natural Lakes and Reservoirs

Approximately 870,000 acre-feet of water is impounded by Iowa's lakes and reservoirs. The total surface area of impoundments in the state exceeds 130,000 acres, which is equal to only about 0.4 percent of the state's land.

The natural lakes of Iowa are generally shallow and small, ranging in surface area from 5,684 acres (Spirit Lake) to fewer than 10 acres (Lake Park Pond in Dickinson County). These lakes have maximum depths which vary from 4 to 134 feet, the latter being the maximum depth of West Okoboji. Most of Iowa's natural lakes are in the north central part of the state. The water stored in these lakes is estimated at about 300,000 acre-feet. State-owned reservoirs (artificial lakes) are estimated to contain an additional 50,000 acre-feet of water.

There are over 47,000 farm ponds in Iowa, and their total storage capacity exceeds 119,000 acre-feet (Figure 3-1). Most of these are located in the southern half of the state, where surface water is limited during dry summer months and groundwater is sometimes chemically unsuitable or too deep to develop economically.

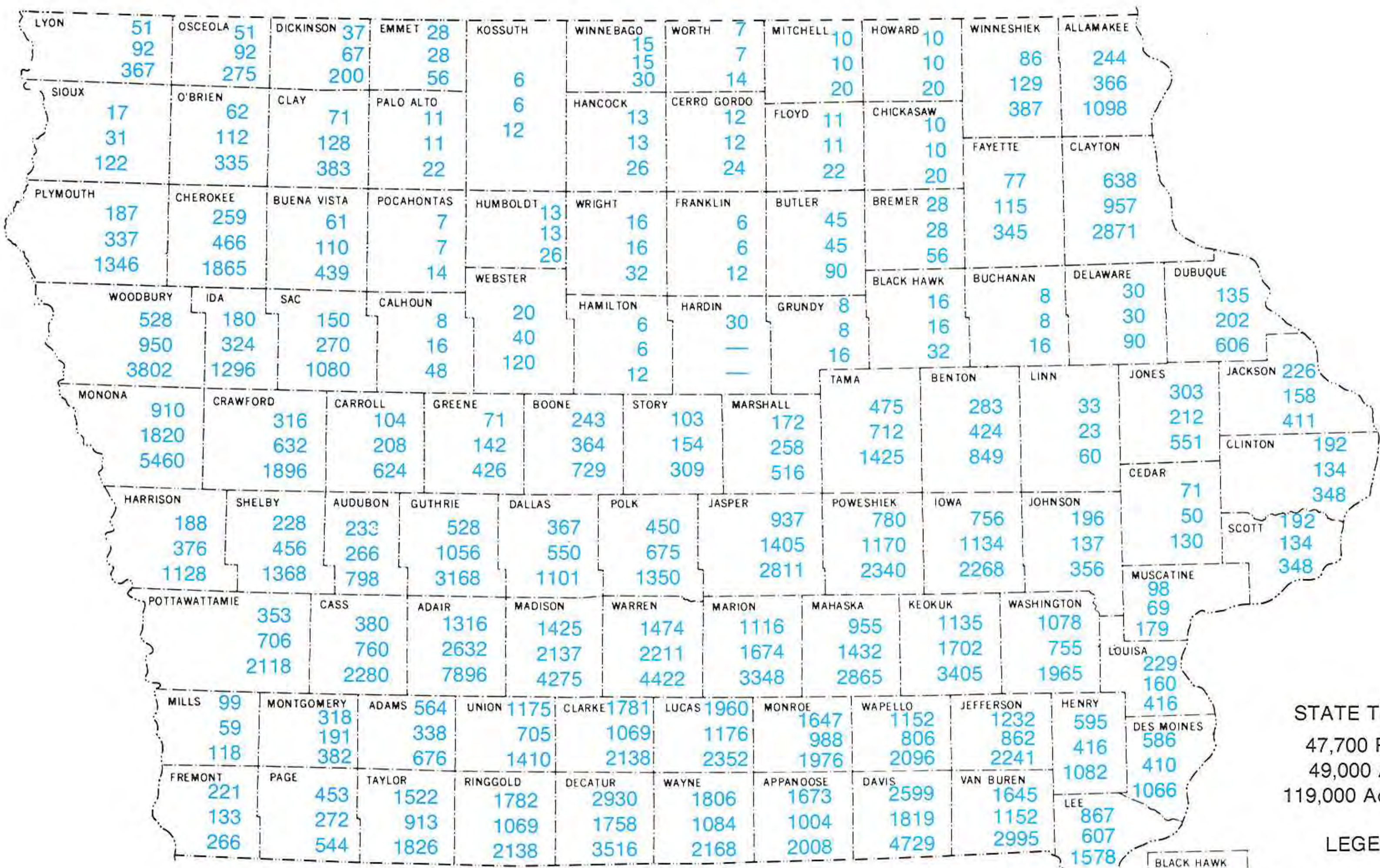
There are four U.S. Army Corps of Engineers multiple-purpose reservoirs in Iowa: Coralville, Redrock, Rathbun, and Saylorville (Figure 3-2). At normal pool level these reservoirs have a total combined storage capacity of about 400,000 acre-feet.

Streamflow

River Basins and Annual Runoff

Figure 3-3 shows the six major river basin districts of Iowa and the pattern of average annual runoff. The spatial variablility of flow in Iowa's interior streams ranges widely. For these streams, average runoff varies between 8 inches in the eastern part of the state, to less than 2 inches in northwestern counties. Annual runoff, averaged for the state, equals about 6 inches, or a total flow of 18 million acre-feet. Figure 3-4 shows the average yearly flows for the principal rivers of Iowa. Usually, peak flows

FIGURE 3-1 Farm Ponds in Iowa



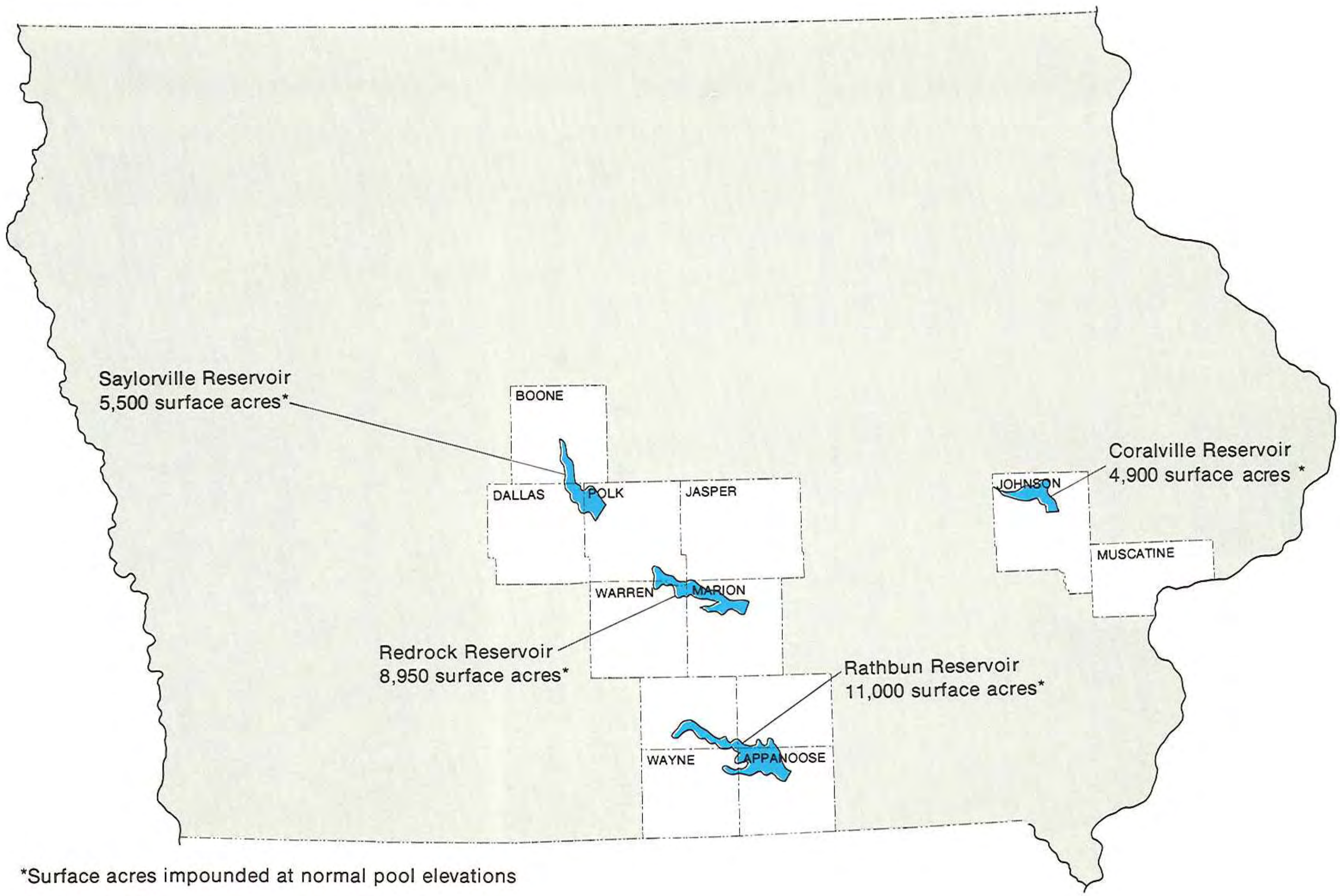
Data Source: Iowa 99D Report, Fiscal 1973, Soil Conservation Service.
11-22-74

STATE TOTALS
47,700 Ponds
49,000 Acres
119,000 Acre/feet

LEGEND

BLACK HAWK
16 . . . . .Number of Ponds
16 . . . . .Surface Area (acres)
32 . .Storage Volume (acre-feet)

FIGURE 3-2 Federal Reservoirs



*Surface acres impounded at normal pool elevations occur in the spring and/or early summer, with low flows occurring in the late summer and winter months.

The Border Rivers of Iowa

The Mississippi River at McGregor has an average (39 year) discharge of 33,830 cfs (cubic feet per second) or 24,510,000 acre-feet per year, and 62,570 cfs (97 year) or 45,300,000 acre-feet per year at Keokuk. The Missouri River at Sioux City has an average (78 year) discharge of 31,910 cfs or 23,120,000 acre-feet per year, and 34,960 cfs (46 year) or 24,330,000 acre-feet at Nebraska City, Nebraska.

Water Quality in Iowa Streams

During periods of high runoff and above average flow, Iowa rivers usually have relatively low concentrations of dissolved solids. However, during low flow periods, when stream flows are largely sustained by groundwater discharges, dissolved solids concentrations in streams increase. In terms of dissolved solids concentration, the water in Iowa streams is generally ranked as being of good to excellent quality.

Sediment is a problem in many Iowa streams. Historical data clearly shows the major factors that determine the amount and rate of sediment discharge are precipitation, terrain, soil type, and vegetation cover. Sediment discharges are higher in the hilly western and south central part of the state than in the flatter areas of north central and eastern Iowa. Stream sediment measurements indicate losses of about 10 tons per square mile per day along the East Nishnabotna at Red Oak. However, only about one-sixth this amount is indicated for the Iowa River at Iowa City (before construction of the Coralville Reservoir), and less than one-tenth of this amount for the Turkey River at Garber.

Surface Water Availability In Iowa

Not all of the water flowing in the streams of Iowa is available for use. When the flow at any location on a river is equal to or less than 84 percent duration flow, water cannot be withdrawn for consumptive purposes. The 84 percent duration flow is the regulated "protected flow" for streams and rivers in Iowa.

The combined yearly stream flow for the interior rivers of Iowa is estimated to be about 18 million acre-feet; that which is in excess of protected flow amounts could potentially be made available for use. This volume is associated with peak discharge periods, occurring primarily from April through September, and can only be made available by a system of storage and flow regulation structures. Table 3-1 shows the estimated total runoff and the potential yield (assuming 100 percent retention of all water above the 84 percent duration flow) that can be developed or withdrawn from the river basins of Iowa. All estimates are based on averaged values.

Groundwater Sources and Supplies

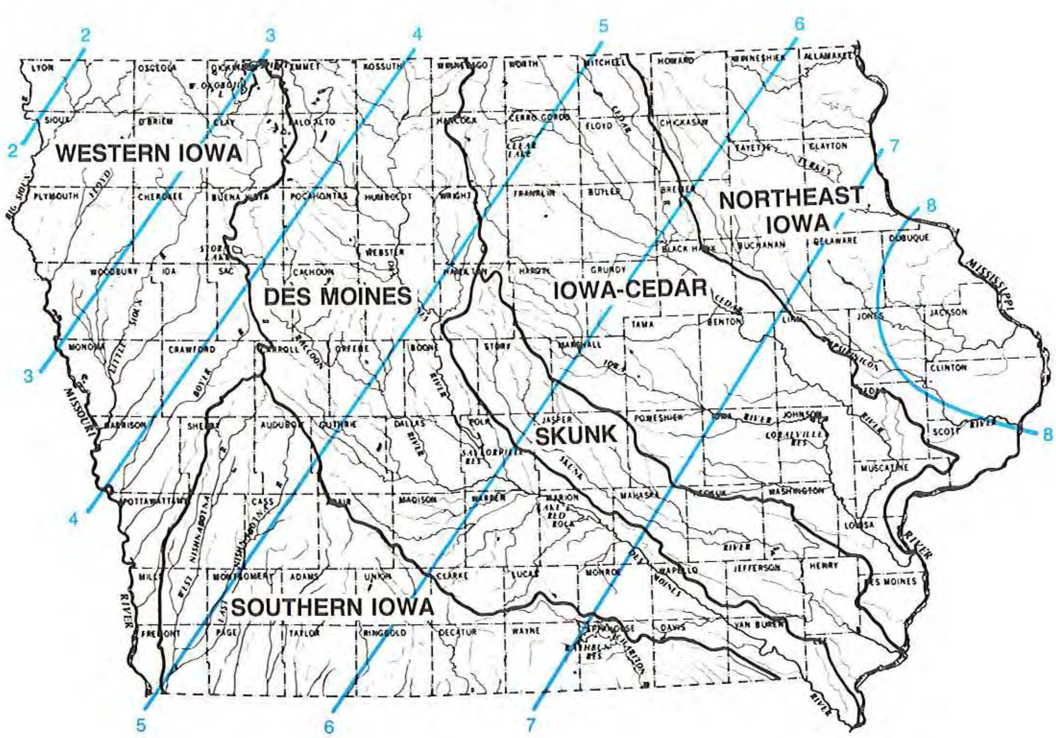
In Chapter 2, the occurrence and behavior of groundwater was related to the geology of Iowa. In this section, the various aquifers that supply water will be described and evaluated; included are glacial drifts, alluvial deposits, buried channels, and specific bedrock aquifers of the state.

Unconsolidated Aquifers of Iowa

Glacial Drift Aquifer

At comparatively shallow depths over most of the state, generally less than 100 feet, small quantities of water can usually be obtained from wells drilled into the glacial drift. Typically, drift wells penetrate local, thin pockets of sand and/or gravel. During dry periods, in the southern and western parts of the state, these wells frequently "go dry" because of seasonal declines in the elevation of the water table. Figure 3-5 shows the distribution and storage estimated for the drift aquifer.

FIGURE 3-3 River Basin Districts and Average Annual Runoff



The Alluvial Aquifer

Many communities and large industrial water users in Iowa currently depend on alluvial sands and gravels as sources of water supply. Deposits of this type are associated with most of Iowa's major rivers and streams. Figure 3-6 shows the distribution, storage estimates, and yield potential for some of the major alluvial systems of the state.

Buried Channel Aquifers

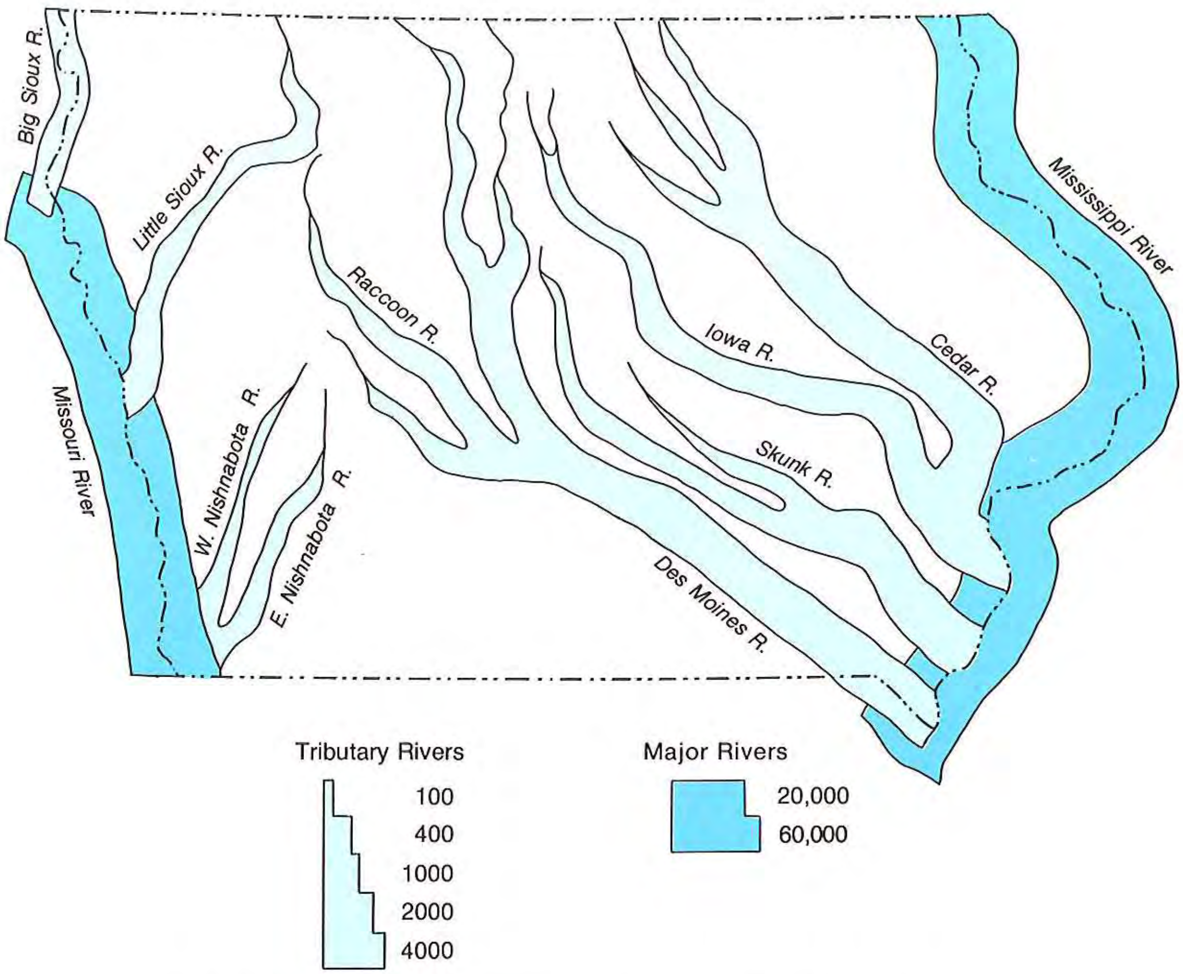
In certain areas of the state, predominantly in central and east-central Iowa, pre-glacial bedrock valleys exist beneath the glacial drift (Figure 3-7). Buried channel aquifers frequently are connected with overlying alluvial aquifers, and the two systems function as a single aquifer.

Bedrock Aquifers of Iowa

In the subsurface, beneath the unconsolidated materials of Iowa, the Paleozoic (Cambrian through Pennsylvanian) bedrock formations of the state slope toward a shallow basin, centered in the southwestern corner of the state. These older rock units (Paleozoics) constitute a relatively thick sequence of alternating rock layers comprised of limestone, dolomite, shale, siltstone and sandstone (Table 3-2). Within the sequence the thicker carbonate formations (limestones and dolomites) that were fractured, creviced, and otherwise made permeable, function as aquifers. The Mississippian and Silurian-Devonian aquifer systems are of this type. The lower portion of the Paleozoic sequence in Iowa contains several thick, permeable sandstone formations or units which are aquifers, notably the Jordan formation and the Dresbach group (Figure 3-8). As Table 3-2 shows, not all of the bedrock formations beneath Iowa are water producers. Many of these are comprised of dense, only slightly permeable siltstone, carbonate, and shale formations. In many cases these units exist as impermeable barriers (aquicludes) which inhibit the cross flow of water between aquifer formations.

The northwestern part of the state is underlain by Cretaceous rocks which are younger (deposited later) than the Palezoic units of the rest of the state. The rocks of the Cretaceous system are dominantly comprised of shales and sandstones. Within this sequence the Dakota sandstone formation is an important regional aquifer.

FIGURE 3-4 Average Discharge of the Principal Rivers



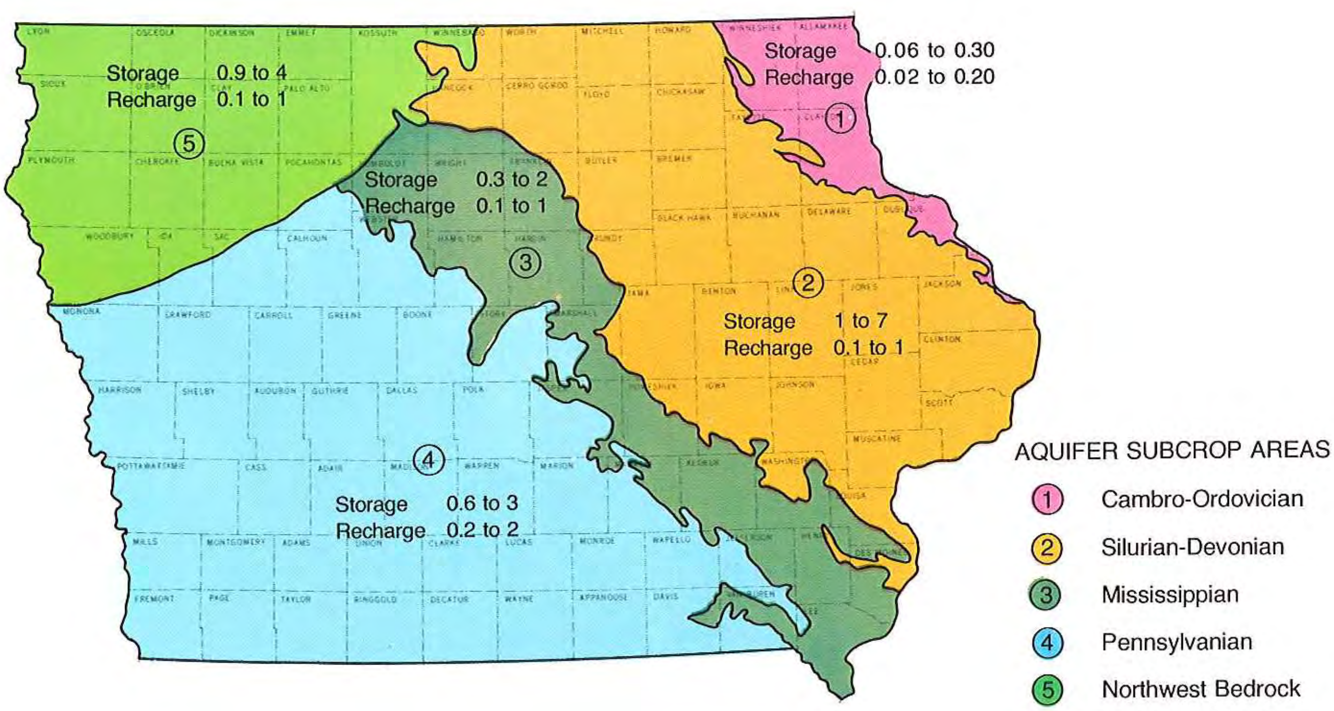
Width of river indicates average discharge in cubic feet per second.

Source: U.S.G.S. Surface Water Division, Iowa

TABLE 3-1 Estimated Yearly Streamflow and Potential Yield in Acre-feet

River Basin	Estimated Average Total Runoff (acre-feet/year)	Estimated Average Potential Yield (acre-feet/year)
1. Northeast	3,379,000	2,032,120
2. Iowa-Cedar	4,301,000	3,189,170
3. Skunk	1,720,000	1,459,430
4. Des Moines	4,065,000	3,408,860
5. Western	1,807,000	1,783,240
6. Southern	2,727,000	2,138,870
Total	**17,999,000**	**14,011,690**

FIGURE 3-5 Glacial Drift Aquifer



Glacial Drift Aquifer Subareas correspond to the subcrop areas of Iowa's principal bedrock aquifers.

The Dakota Aquifer

Although more information is needed to adequately define the geology and hydrology of the Dakota aquifer, its known extent and estimates of storage are given in Figure 3-9. Throughout most of its area of occurrence, the Dakota aquifer contains considerable amounts of shale and has water-bearing sands in both its upper and lower parts. In the eastern-most counties where the Dakota is present, only a single sandstone unit usually is found. The Dakota attains a maximum thickness of about 260 feet and averages 50-75 feet.

The Mississippian Aquifer System

The Mississippian aquifer system is variable in thickness, ranging from 0 to 600 feet with an average thickness of approximately 350 feet. Its distribution and estimates of storage are given in Figure 3-10. The system is exposed at the surface, or in the bedrock immediately beneath the unconsolidated materials, in a band from north central Iowa to the southeastern corner of the state. In southwestern Iowa the system is confined by younger sedimentary rocks that lie on top of it.

The Silurian-Devonian Aquifer System

The Silurian-Devonian aquifer system is comprised of a thick sequence of predominantly carbonate rock formations whose porosity and permeability are principally dependent on fractures, joints, and solution openings. Where these features are poorly developed or are absent, the water-producing capability of the aquifer diminishes. The aquifer thickens progressively from its exposed thin edge in eastern Iowa to a maximum of 650 feet in western Iowa. Storage estimates and the distribution of the aquifer are given in Figure 3-11.

The Cambro-Ordovician Aquifer System

Except for a few northwestern Iowa counties, the Cambro-Ordovician aquifer system underlies the entire state (Figure 3-12). This aquifer, particularly the Jordan and St. Lawrence formations, is used as a major water supply source by communities and industry in nearly three-fourths of the state. The upper rock formations of the aquifer system are exposed at the surface in limited areas in northeast Iowa, and to the northwest they lie beneath younger Cretaceous rocks. In southwest Iowa, the aquifer is buried under more than 3,000 feet of younger rock and unconsolidated materials. The total thickness of the Cambro-Ordovician aquifer system ranges between 0 and 600 feet and averages between 400 and 500 feet in thickness across the state.

Groundwater Availability in Iowa

Iowa's stored groundwater reserves, including annual replenishment through natural recharge, probably represent more water than future Iowans might conceivably use. However, because much of this water is of unacceptable quality, is difficult to extract, or is not uniformly distributed across the state, only a small proportion is available to users. An economically developable groundwater supply must meet several criteria. First, it must be accessible by wells of reasonable depth and at costs that are within limits determined by the user. Second, it must be extractable at sustained rates of

FIGURE 3-6 Established Aquifer Storage and Potential Yield-Alluvial Aquifer

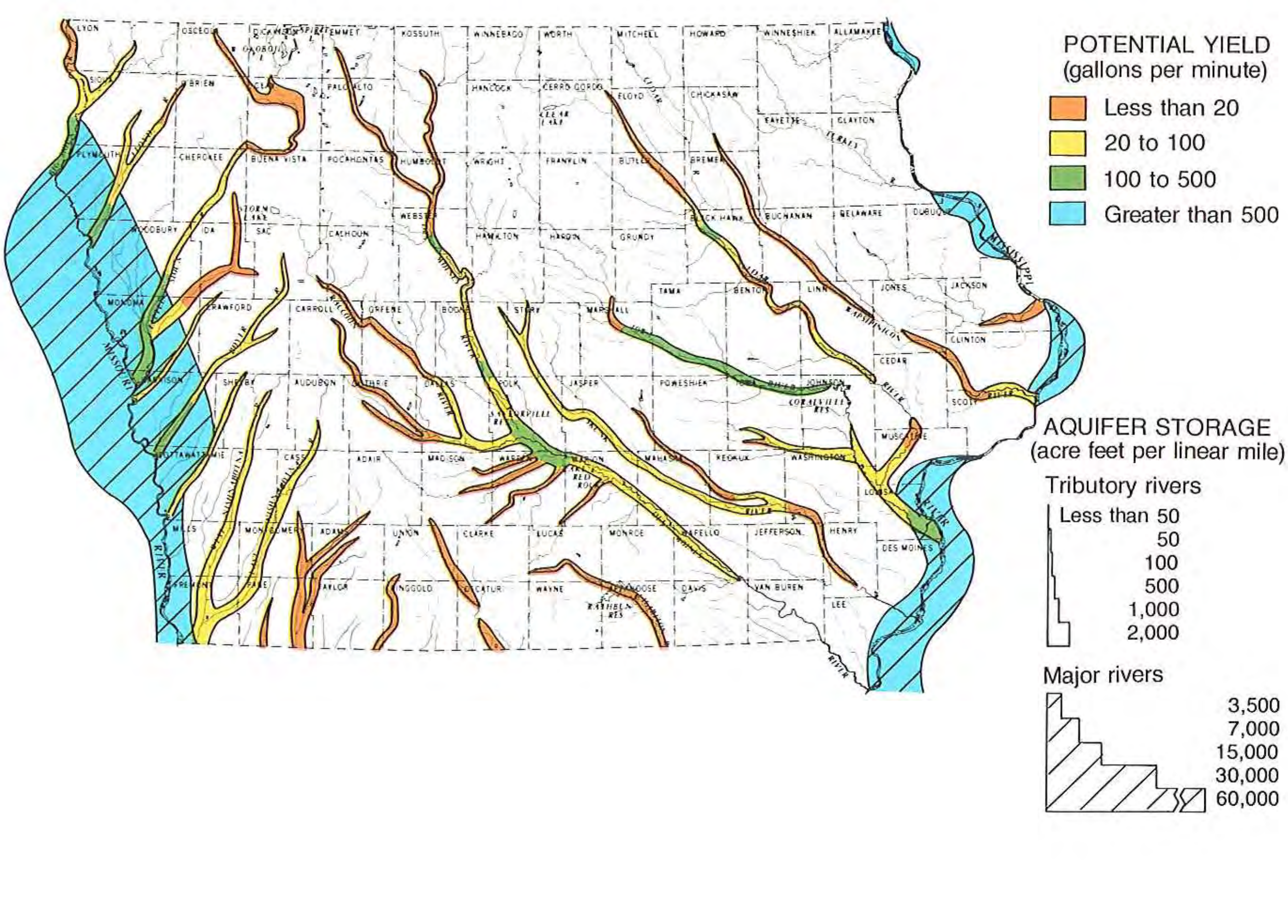
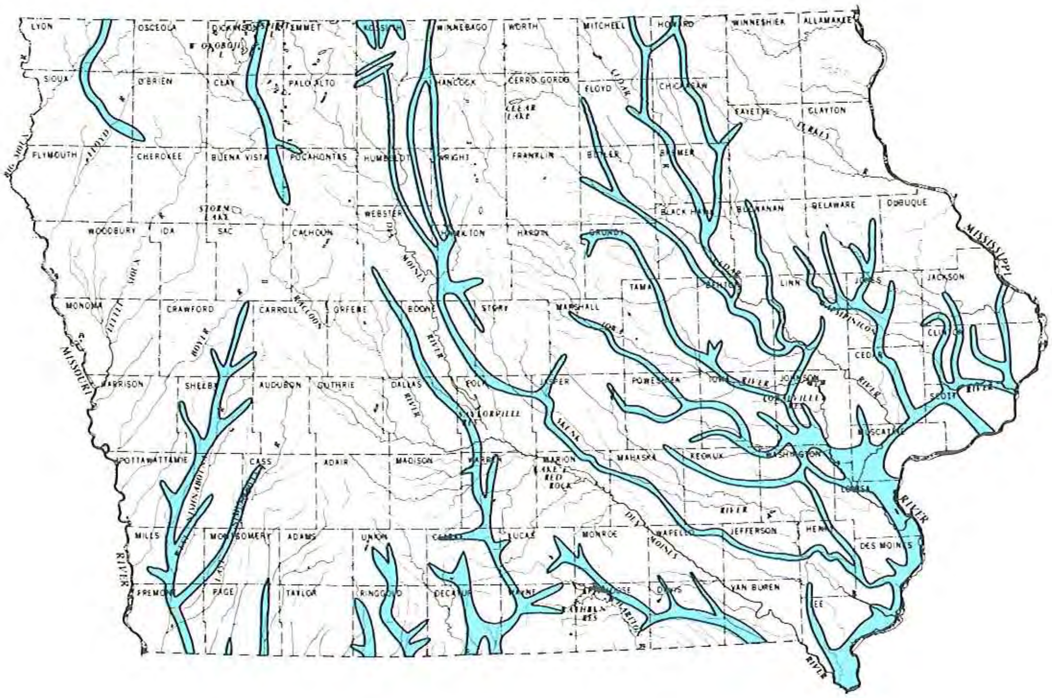


FIGURE 3-7 Recognized Buried-Channel Aquifer Systems



yield that will satisfy anticipated or required delivery rates. Finally, it must be of a quality suitable to meet the developer's use or be treatable.

The distribution of Iowa's groundwater resources and many of the state's availability problems relative to quantity and quality are most easily defined on a regional basis. For this reason, the state has been sub-divided into four groundwater districts (GWD): The Northeastern, Central, Southwestern, and Northwestern (Figure 3-13). These districts are based on hydrologic and geologic similarities. The various potential sources of groundwater supply for each groundwater district are evaluated in terms of: median storage (a middle value gross storage estimate), median annual recharge (a middle value gross annual recharge estimate), potential yield (expected yield rate according to historical pumping data), accessibility (depth to aquifer) and finally, general water quality (based on acceptability for drinking according to the U.S. Public Health Service standards).

Groundwater Availability in the Northeastern GWD

The most abundant and best quality groundwater in the state occurs in this district. The major aquifers that have been developed here are the glacial drift, alluvial deposits of interior streams and the Mississippi River, and the Silurian-Devonian, Cambro-Ordovician, and Dresbach aquifer systems.

Storage and Recharge. It is estimated that the groundwater reserves from all available sources of this district exceed 50 million acre-feet. The annual rate of recharge to all aquifers of the district is estimated to be in excess of 1.5 million acre-feet. Figures 3-14a and 3-15a indicate that the unconfined portions of the Silurian-Devonian and Cambro-Ordovician aquifer systems, the glacial drift, and Mississippi River alluvium account for the majority of water in storage. They also receive the largest volumes of annual recharge. The Dresbach aquifer is a significant groundwater source only along the eastern margin of the district. Because it is only locally important, the Dresbach aquifer is not discussed in this summary.

Yield and Accessiblity. Many domestic wells in the Northeastern Ground Water District obtain their water from the glacial drift. Although the drift stores large volumes of water, and its annual recharge is significant, the potential for its development is limited by low yields. Drift wells seldom yield more than 10 gpm and more commonly only between 3 and 5 gpm (Figure 3-16). There are several local exceptions in the north-central part of the district where basal drift sands, gravels, and drift-filled bedrock valleys are highly productive, often yielding up to 500 gpm.

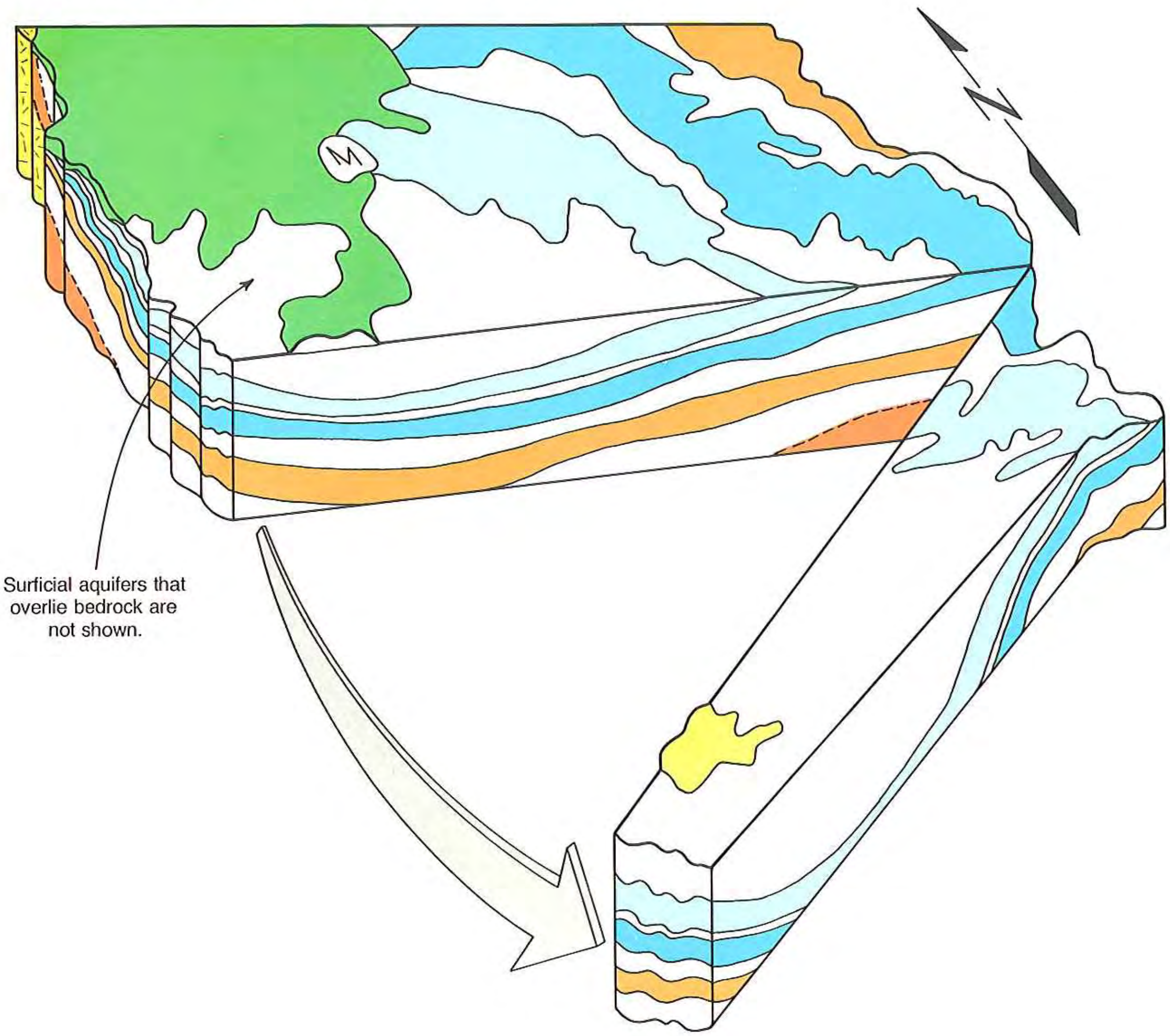
Alluvial deposits along the Mississippi River and major interior streams are sources of large volumes of groundwater. Water from these sources generally can be obtained from wells not exceeding 100 feet in depth. About 95 percent of the wells developed in deposits of the Mississippi River alluvial system are capable of delivering more than 1,000 gpm on a sustained basis. The remaining 5 percent probably can produce between 500 and 1,000 gpm. Along the major interior streams, alluvial sands and gravels generally support yields at rates between 200 and 400 gpm. There are notable exceptions where much larger yields are obtained because of significant, induced recharge from adjacent streams. Examples of this are wells at Waterloo, where yields of 2,000 gpm have been achieved, and at Cedar Rapids, where alluvial wells produce between 500 and 1,000 gpm.

TABLE 3-2 Geologic and Hydrogeologic Units in Iowa

AGE		ROCK UNIT	DESCRIPTION	HYDROGEOLOGIC UNIT	WATER-BEARING CHARACTERISTICS
Cenozoic	Quarternary	Alluvium	Sand, gravel, silt and clay	Surficial aquifer	Fair to large yields
		Glacial drift (undifferentiated)	Predominantly till containing scattered irregular bodies of sand and gravel		Low yields
		Buried channel deposits	Sand, gravel, silt and clay		Small to large yields
Mesozoic	Cretaceous	Carlile Formation Granerous Formation	Shale	Aquiclude	Does not yield water
		Dakota Group	Sandstone and shale	Dakota aquifer	High to fair yields
	Jurassic	Fort Dodge Beds	Gypsum, shale	Aquitard	Does not yield water
Paleozoic	Pennsylvanian	Virgil Series Missouri Series	Shale and limestone	Aquiclude	Low yields only from limestone and sandstone
		Des Moines Series	Shale; sandstones, mostly thin		
	Mississippian	Meramec Series	Limestone, sandy	Mississippian aquifer	Fair to low yields
		Osage Series	Limestone and dolomite cherty		
		Kinderhook series	Limestone, oolitic, and dolomite, cherty		
	Devonian	Maple Mill Shale Sheffield Formation Lime Creek Formation	Shale; limestone in lower part	Devonian aquiclude	Does not yield water
		Cedar Valley Limestone Wapsipinicon Formation	Limestone and dolomite; contains evaporites in southern half of Iowa	Silurian-Devonian aquifer	High to fair yields
	Silurian	Niagaran Series Alexandrian Series	Dolomite, locally cherty		
	Ordovician	Maquoketa Formation	Shale and dolomite	Maquoketa aquiclude	Does not yield water, except locally in northwest Iowa
		Galena Formation	Limestone and dolomite	Minor aquifer	Low yields
		Decorah Formation Platteville Formation	Limestone and thin shales; includes sandstone in SE Iowa	Aquiclude	Generally does not yield water; fair yields locally in southeast Iowa
		St. Peter Sandstone	Sandstone		Fair yields
		Prairie du Chien Formation	Dolomite, sandy and cherty	Cambrian-Ordovician aquifer	High yields
	Cambrian	Jordan Sandstone	Sandstone		
		St. Lawrence Formation	Dolomite	Aquiclude (wedges out in northwest Iowa)	Does not yield water
		Franconia Sandstone	Sandstone and shale		
		Dresbach Group	Sandstone	Dresbach aquifer	High to low yields
Precambrian		Sioux Quartzite	Quartzite	Base of groundwater reservoir	Not known to yield water except at Manson cryptovolcanic area
		Undifferentiated	Coarse sandstones; crystalline rocks		

*Adapted from Steinhilber and Horick

FIGURE 3-8 Generalized Bedrock Section of Iowa



EXPLANATION

Manson Anomalous Area
Believed to be a cryptovolcanic structure (Hoppin and Dryden, 1958)

AQUIFERS

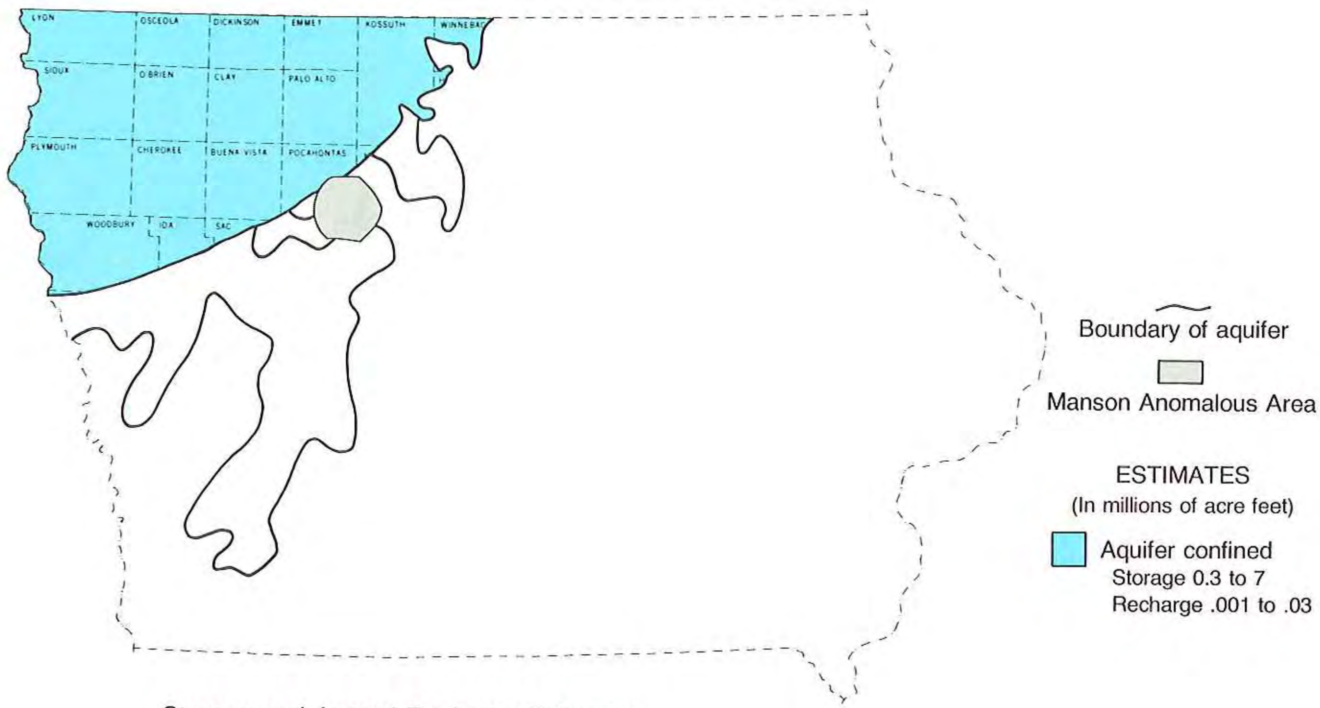
- Cretaceous
- Paleozoic:
  - Mississippian
  - Silurian-Devonian
  - Cambrian-Ordovician
  - Dresbach

CONFINING BEDS

- Sedimentary rocks
- Precambrian crystalline rocks

Source: Modified from Steinhilber and Horick, 1970

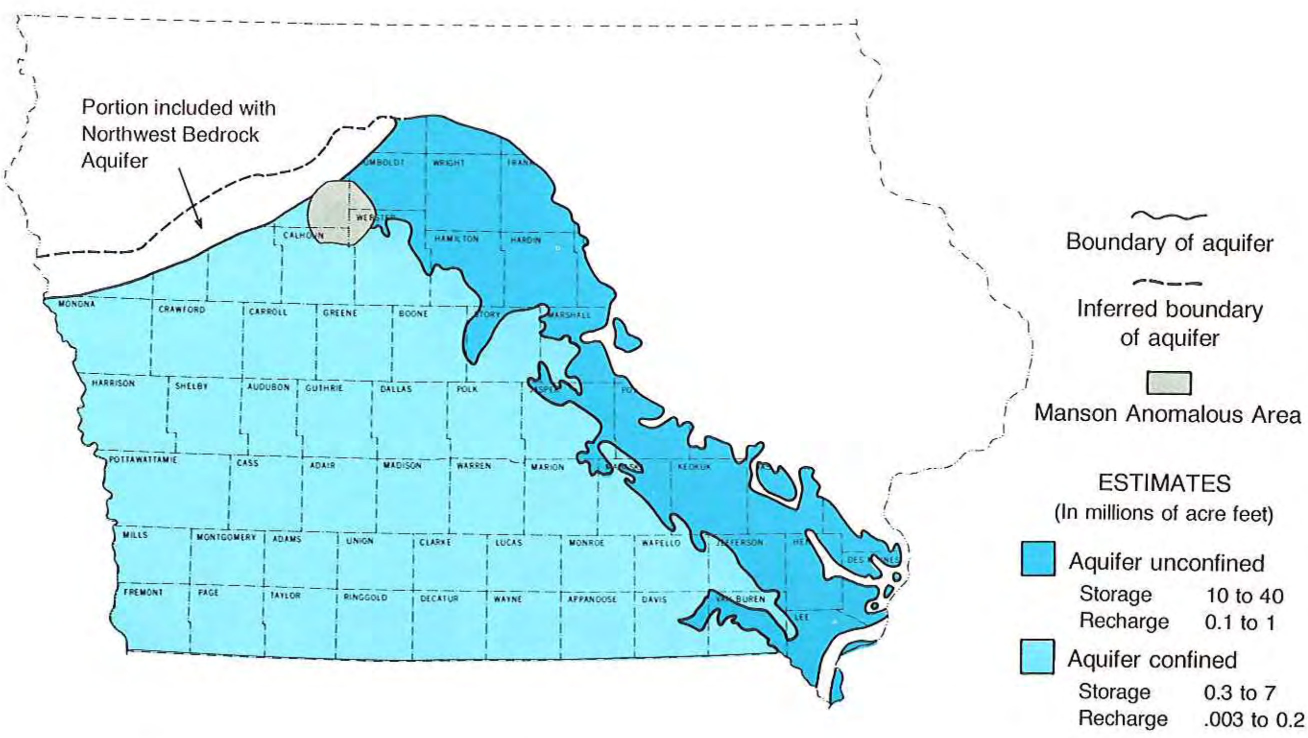
FIGURE 3-9 Northwest Bedrock Aquifer System



Storage and Annual Recharge Estimates

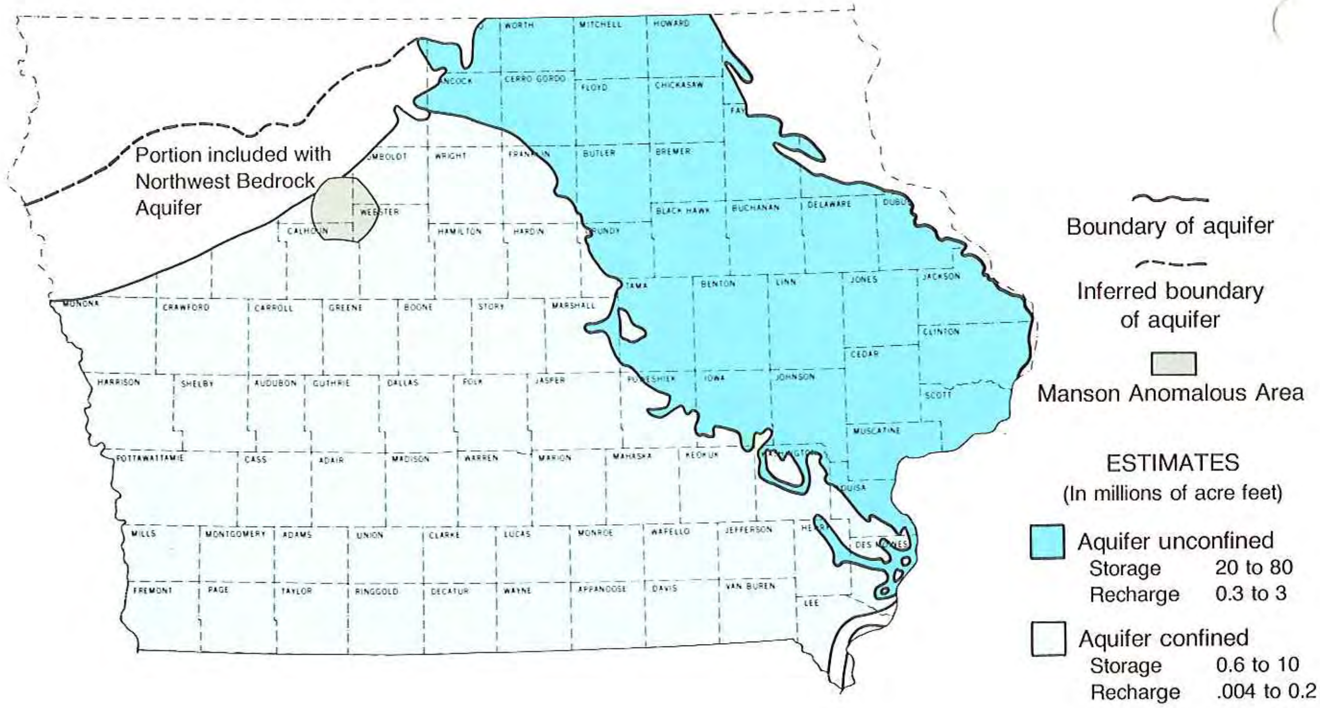
*Primarily the Dakota, but includes portions of the Mississippian, Silurian-Devonian, and Cambro-Ordovician.

FIGURE 3-10 Mississippian Aquifer System



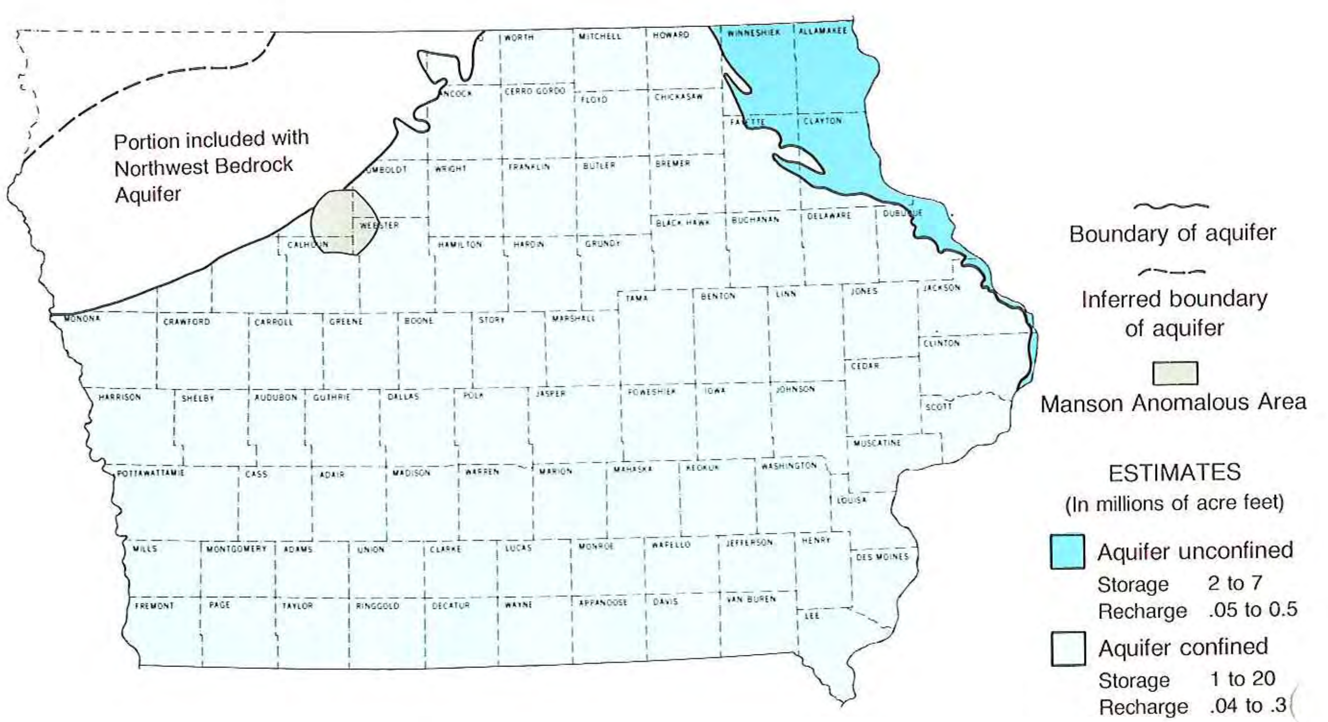
Storage and Annual Recharge Estimates

FIGURE 3-11 Silurian-Devonian Aquifer System



Storage and Annual Recharge Estimates

FIGURE 3-12 Cambro-Ordovician Aquifer System



Storage and Annual Recharge Estimates

. .GURE 3-13 Iowa Groundwater Districts

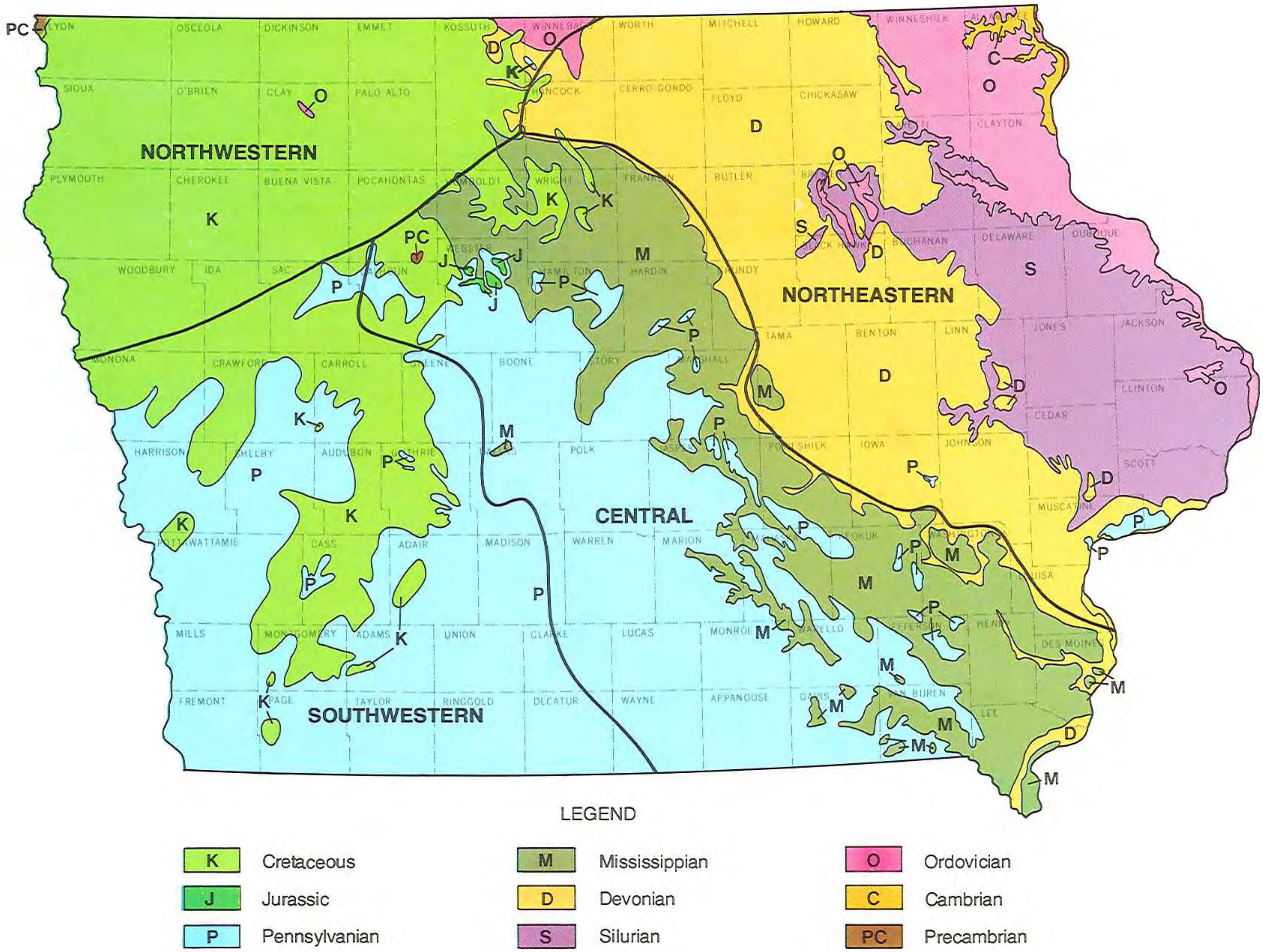
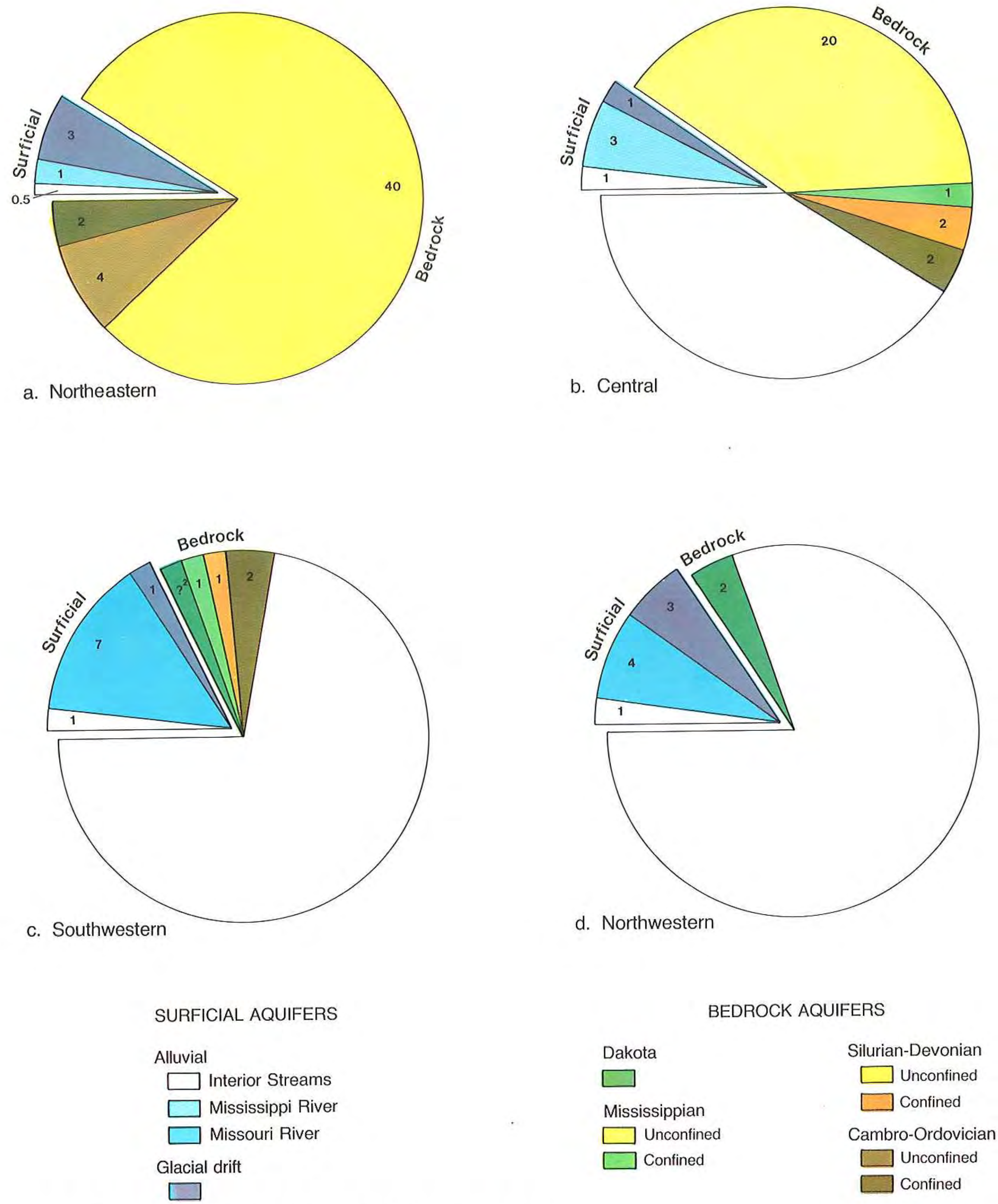


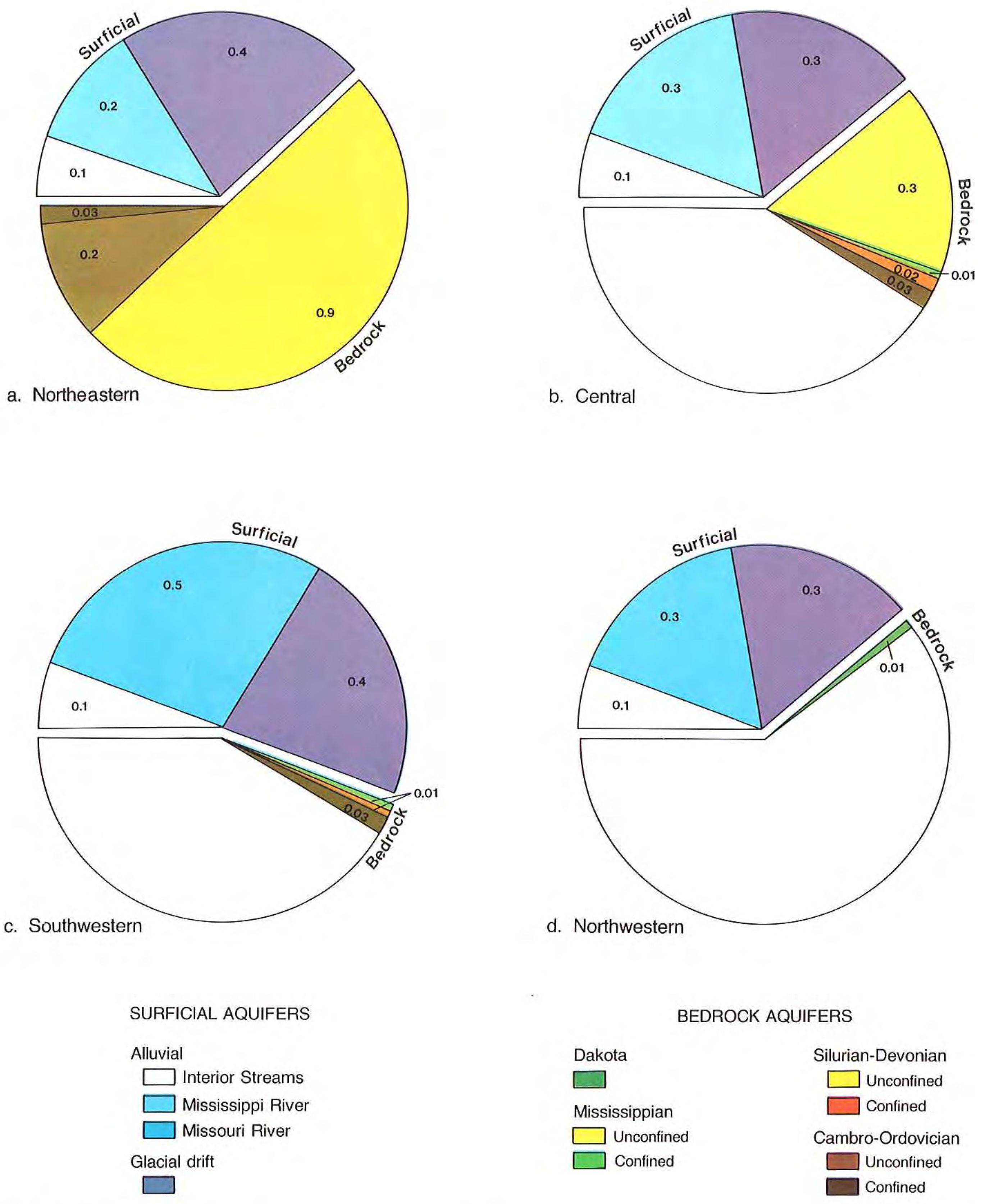
FIGURE 3-14 Groundwater Storage by Aquifers



1 Based on median values obtained from annual recharge range estimates.

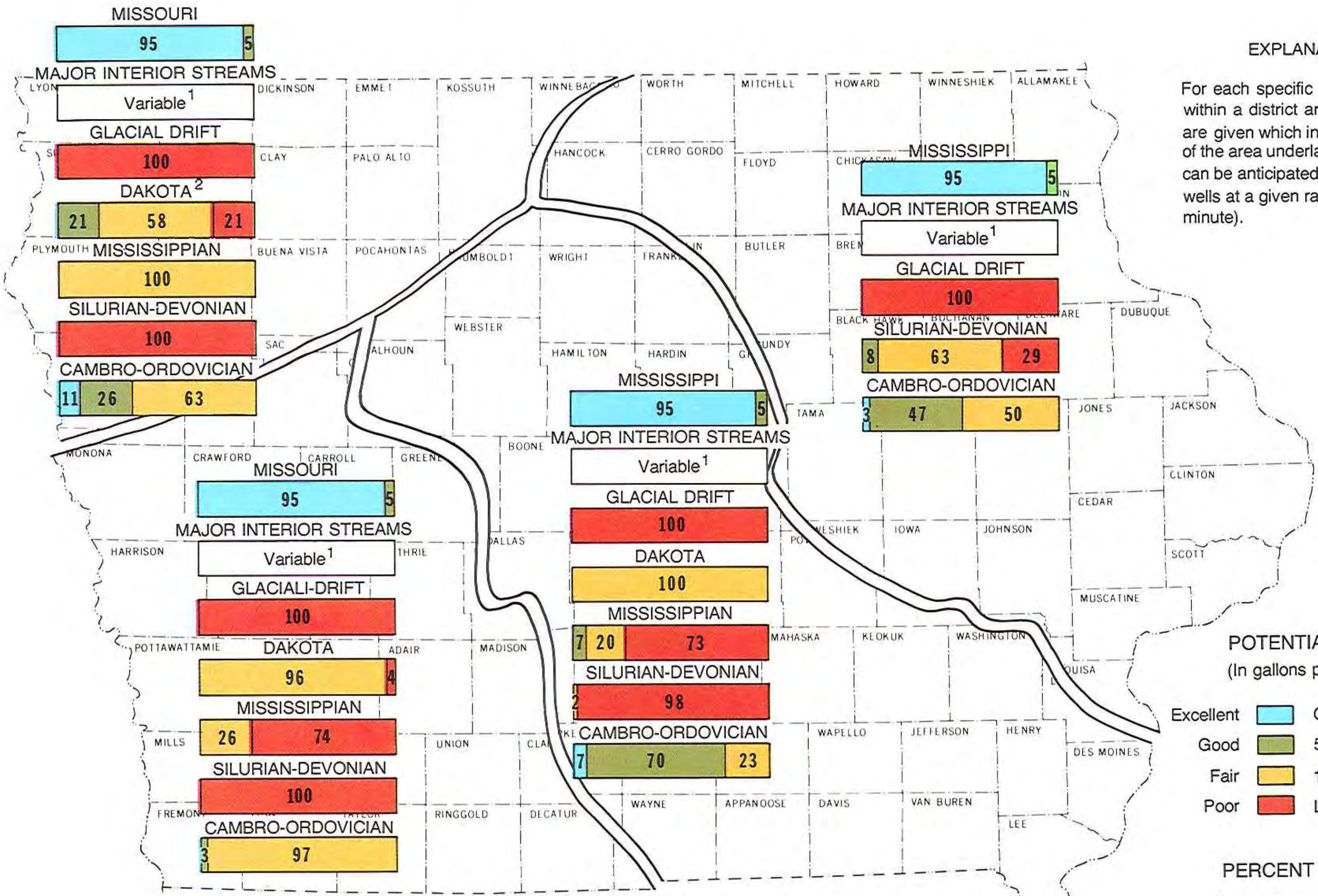
2 No estimates were made for the Dakota outside of the Northwestern Aquifer District owing to its obscure geologic and hydrologic relations.

FIGURE 3-15 Groundwater Recharge by Aquifers



[1] Based on median values obtained from annual recharge range estimates.

FIGURE 3-16 Potential Yield by Aquifer by Groundwater District



[1] See text
[2] The major unit in the Northwest Bedrock Aquifer

EXPLANATION

For each specific aquifer present within a district area, percentages are given which indicate how much of the area underlain by the aquifer can be anticipated to yield water to wells at a given rate (in gallons per minute).

POTENTIAL YIELD
(In gallons per minute)

Excellent — Greater than 1000
Good — 500 to 1000
Fair — 100 to 500
Poor — Less than 100

PERCENT OF AREA

20	40	20	20

FIGURE 3-17 Accessibility of Individual Aquifer by Groundwater District

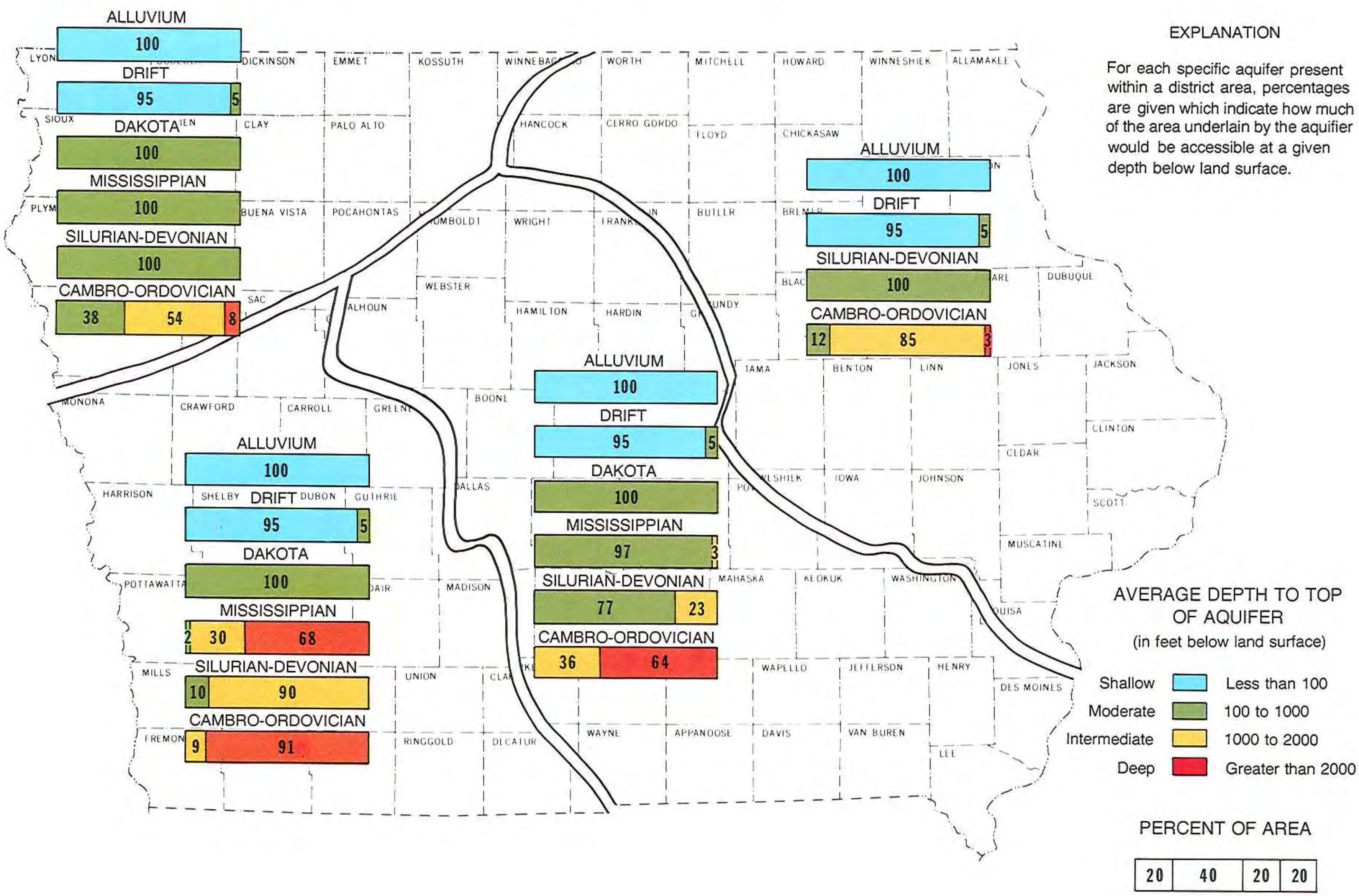


FIGURE 3-18 Groundwater Quality for Individual Aquifers by Groundwater Districts

EXPLANATION

For each specific aquifer present within a district area, percentages are given which indicate how much of the area underlain by the aquifer can be anticipated to yield water of a given quality. The index of water quality is the U.S. Public Health Service drinking water standard for total dissolved solids concentrations.

WATER QUALITY
(Total dissolved solids in mg/1)

Less than 1000
Acceptable 1000 to 1500
Unacceptable Greater than 1500

PERCENT OF AREA

20	60	20

Two bedrock aquifer systems, the Silurian-Devonian and the Cambro-Ordovician, underlie nearly the entire district. Throughout most of the area (Figure 3-17), wells penetrate these aquifers at shallow to intermediate depths. In about 60 percent of the district, Silurian-Devonian wells can be expected to yield from 100 to 500 gpm and in the remaining 40 percent less than 100 gpm. The Cambro-Ordovician is deeper throughout the district, but its yield potential to wells is greater—500 to 1,000 gpm or more for 50 percent of the district and between 100 and 500 gpm throughout the remainder.

Adequate supplies for most domestic uses may be obtained at shallow to moderate depths from the glacial drift, alluvial, and the Silurian-Devonian Aquifer System. Greater demands (100-500 gpm), such as those of smaller communities, light industry, and large livestock operations, can be satisfied at shallow to moderate depths from the alluvial and Silurian-Devonian aquifers, but only rarely from the glacial drift. At moderate depths in the northeastern part of the district, and at intermediate depths throughout the rest of the district (Figure 3-17), The Cambro-Ordovician aquifer will supply these same demands. Very large (greater than 1,000 gpm) groundwater demands, such as those of heavy industry and large municipal supplies, can generally be met only by wells in the alluvial deposits of the Mississippi River and from the Cambro-Ordovician aquifer. Infrequently, yields in this range have been obtained from the alluvium of interior streams and the Silurian-Devonian aquifer, where induced recharge is the major contributor (mainly along the Cedar River).

Water Quality. Groundwater quality is generally not a problem within the Northeastern Iowa Ground Water District. Although hardness is a common problem in the district, as it is for much of Iowa, water quality, indexed by total dissolved solids concentrations, is not. As noted in Figure 3-18, most of the groundwater in this region is of good to fair quality (less than 1,000 mg/1 TDS).

Groundwater Availability in the Central Iowa GWD

The groundwater reserves of the Central Iowa Ground Water District are nearly as large as those of the Northeast District. However, they are unevenly distributed relative to quantity, quality, and potential yield. Within this district, there is a marked imbalance in the available water between the northern and southern halves of the region, primarily in terms of low yield potentials and inferior water quality.

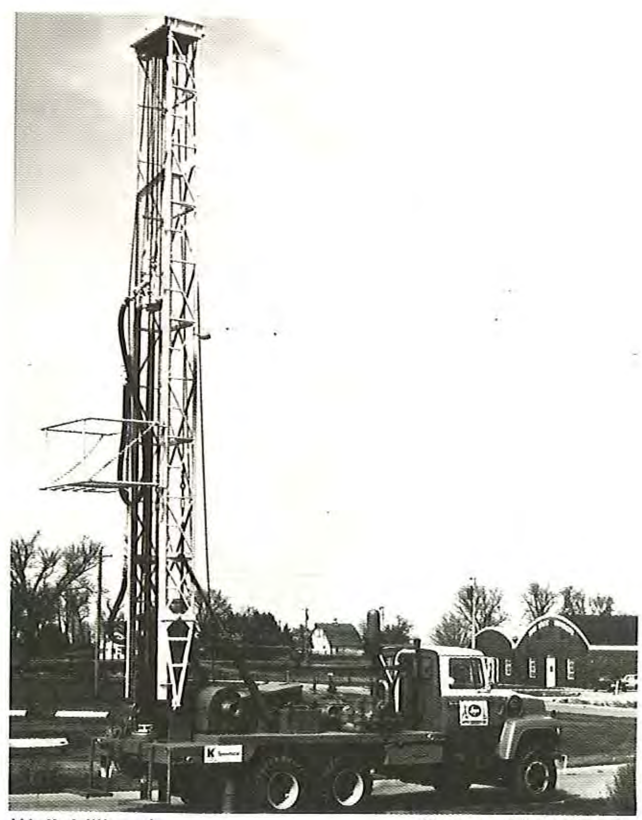
Storage and Recharge. Figures 14b and 15b present median estimates for storage and annual recharge. The aggregate totals for the district are 30 and 1 million acre-feet respectively.

About 70 percent of the groundwater stored within this district is present within the unconfined (water table) portion of the Mississippian Aquifer System. These reserves are predominantly limited to the eastern one-third of the district. The remaining reserves of the district are about equally divided among the various unconsolidated aquifer units and the confined (artesian) portions of the Mississippian, Silurian-Devonian, and Cambro-Ordovician bedrock aquifer systems. The alluvial sediments of the Mississippi River, the glacial drift, and the unconfined portion of the Mississippian aquifer receive about equal annual recharge. In combination they receive about 90 percent of the district's annual total. In the central portion of this district, Pennsylvanian sandstones are locally important sources of water for several small communities and farmsteads. The development potential and reserves of these sandstone units are not large and, therefore, are not discussed in this regional summary.

Yield and Accessibility. A great number of the private domestic and/or farmstead water systems in the Central Iowa District are supplied by shallow wells developed in the drift aquifer. Most wells developed in the drift aquifer in the northern part of the district are capable of yielding water at rates of 3 to 5 gpm and in many instances up to 10 to 20 gpm. To the south, drift wells rarely supply more than 5 gpm and generally range between 1 and 3 gpm. During extended dry periods, when the water table recedes markedly, the yields of drift wells in the southern part of the district are impaired, and frequently many wells "go dry".

The sands and gravels of the alluvial systems associated with the Raccoon, Iowa, Skunk, and Des Moines rivers are important shallow sources of groundwater in this district. Generally, these sand and gravel systems will yield about 200 to 400 gpm to wells. However, on a more local scale, alluvial aquifers along all of these major streams have been reported to yield from 500 to more than 1,000 gpm to wells. Some of the notable examples are at Marshalltown, Ames, Des Moines, and Fort Dodge.

The Central Iowa Ground Water District is underlain by three bedrock aquifer systems: the Mississippian, Silurian-Devonian, and Cambro-Ordovician. Figure 3-17 indicates that about 83 percent of the available water in the district is stored within these three aquifer systems. The Mississippian Aquifer is estimated to contain the largest reserves and can be reached at moderate depths in about 97 percent of the region (Figure 3-17), but has a



Well drilling rig *Gutman Photo Service*

Water Quality. Generally, groundwater from shallow sources (alluvium and drift) in the district is of good to acceptable quality. However, within the Paleozoic aquifers underlying the region, water becomes progressively poorer in quality from northeast to southwest. In about 45 percent of the district the Mississippian aquifer is uppermost and unconfined, and the water is of good to acceptable quality. South of an east-west line extending through the city of Des Moines, water from the Mississippian aquifer is of unacceptable quality. This does not include portions of Washington, Jefferson, Louisa, and Des Moines counties, where Mississippian water is of good to acceptable quality. The water of the Silurian-Devonian aquifer system is considered unacceptable for drinking throughout the entire district, except for a limited area in Franklin, Hardin, and Grundy counties. Figure 3-18 indicates that 98 percent of the Central Ground Water District is underlain by the Cambro-Ordovician aquifer with water of acceptable quality or better. Along the eastern margin and mid-section of the district, the Cambro-Ordovician rocks yield water of good to fair quality, with concentrations of total dissolved solids fewer than 1,000 mg/1.

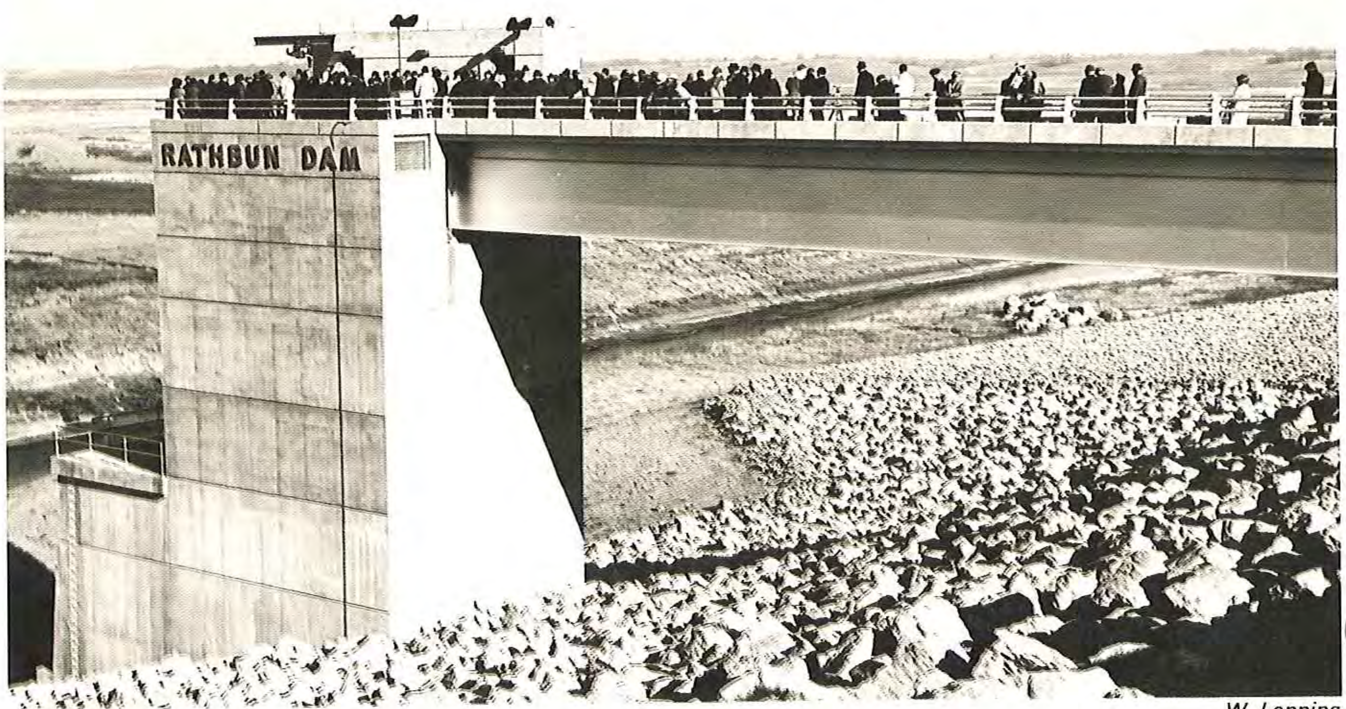
Groundwater Availability in the Southwestern Iowa GWD

This district lacks abundant and good quality groundwater. The Southwestern District and Northwestern Ground Water District, combined, represent approximately one-third of the land area of the state, but together share only about 23 percent of the estimated groundwater reserves.

Storage and Recharge. The district has estimated groundwater reserves of 13 million acre-feet in storage, about 13 percent of the total storage for the state. Over half of this water is stored in the alluvial sands and gravels of the Missouri River flood plain (Figure 3-14c). The remainder is fairly uniformly distributed across the district in the Paleozoic bedrock aquifers, drift aquifer, and alluvial deposits of interior streams. About two-thirds of these reserves are stored in the three Paleozoic bedrock aquifers underlying the district. The Dakota aquifer furnishes water for many private supplies and several communities along the northern boundary of the district, and in a wide band extending from Sac and Carroll counties to Montgomery county.

During years of normal precipitation, the aquifers in the Southwestern Ground Water District receive about 1 million acre-feet of water as annual recharge (Figure 3-15c). About one-half of the estimated recharge for the district, excluding that which the Dakota receives, (possibly 1 million acre-feet) recharges the sands and gravels of the Missouri River alluvial system. Most of the rest recharges the glacial drift. The Paleozoic bedrock units and the alluvial materials of the interior streams receive only a little over a tenth of the annual total recharge.

Yield and Accessibility. Throughout most of the district, the drift aquifer can provide only limited amounts of groundwater to shallow wells (Figure 3-16). Most of these wells do not yield more than 3 to 5 gpm. Drift wells in the area frequently "go dry" or experience significantly reduced capacity during periods of deficient rainfall. The alluvial sediments along the interior streams of the district provide adequate supplies of water to many communities and rural water developers. Shallow wells along the two branches of the Nishnabotna yield between 200



Rathbun Dam *W. Lonning*

The alluvial sediments along the interior streams of the district provide adequate supplies of water to many communities and rural water developers. Shallow wells along the two branches of the Nishnabotna yield between 200 and 400 gpm, with instances recorded where yields have exceeded 500 gpm. Alluvial wells along the smaller streams yield considerably less, and most do not deliver more than 100 gpm at a maximum. Some communities in this region encounter problems in maintaining capacity from alluvial wells because of fine sand. With extended, heavy pumping the fine sand migrates toward wells, clogging screens, filling the well bore, and drastically impairing performance of wells.

At intermediate depths, the Dakota Sandstone provides a source for water supply over approximately one-third of the district (Figure 3-17). Yields from the Dakota vary considerably, but in most cases, wells produce between 100 and 500 gpm.

Large quantities of groundwater may be obtained from the thick alluvial deposits of the Missouri River flood plain. Wells penetrating these sands and gravels are shallow, most being under 100 feet in depth. In Pottawattamie, Harrison, and Monona counties, irrigation wells sustain yields of 1,000 to 2,000 gpm. It is estimated that Missouri River alluvial deposits will provide yields in this range in nearly 95 percent of the area where they occur in the district (Figure 3-16).

The Mississippian, Silurian-Devonian, and Cambro-Ordovician aquifers are accessible to intermediate and deep wells throughout the region (Figure 3-17). The yield potential of the Mississippian and the Silurian-Devonian systems is estimated to range between 100 and 500 gpm. The deeper Cambro-Ordovician aquifer will yield water to wells at between 500 and 1,000 gpm over most of the area.

Water Quality. In the Southwest Ground Water District, the general quality of groundwater from shallow aquifers (the drift, alluvium, and the Dakota sandstone) is good to acceptable (Figure 3-18). Water from the Dakota sandstone is typically hard, as is all groundwater in this district, and in about 36 percent of the area Dakota water has high sulfate concentrations. Water from alluvial sources in some areas of the district is reported to contain excessive nitrate.

Within the district, the water of the three Paleozoic aquifer systems is nearly everywhere of unacceptable quality. A few industries and communities, in the absence of suitable alternatives, have developed wells in the Paleozoic bedrock, but water quality is usually only marginally acceptable. In some instances, these supplies are unacceptable according to U.S. Public Health Service Standards, but are still used for drinking purposes.

Groundwater Availability in the Northwestern Iowa GWD

Northwestern Iowa has the least groundwater supplies of any area in the state. Moreover, this area receives the least amount of precipitation and has lower stream flows.

Storage and Recharge. The total groundwater estimated in storage in this region is about 10 million acre-feet (Figure 3-14d). Of this amount, 40 percent is found in the alluvial aquifer system of the Missouri River. Thirty percent of the groundwater is found throughout the district in the glacial drift. Twenty percent is stored in the Northwestern Bedrock Aquifer, primarily in the Dakota Sandstone, but also in portions of the Mississippian, Silurian-Devonian, and Cambro-Ordovician systems.

Crop irrigation, Missouri River floodplain
Soil Conservation Service

Flowing artesian well in Carroll County
Iowa Conservation Commission

The alluvial sands and gravels of the interior streams are estimated to contain about 10 percent of the groundwater for the district.

Even during years of normal precipitation, it is estimated that the aquifers of this district receive annual recharge amounting to less than 1 million acre-feet (Figure 3-15d). Nearly 90 percent of the annual recharge

Pothole flooding in Webster County
Soil Conservation Service

of the district is received by the drift aquifer and the alluvium associated with the Missouri River. The alluvial aquifers of the major interior streams receive about 0.1 million acre-feet of annual recharge.

Yield and Accessibility. Wells at shallow to moderate depths in the alluvium and glacial drift of the district can produce a variety of results depending on source and location. Typically, shallow drift wells in the region yield between 3 and 5 gpm. However, in the north-eastern part of the region, drift wells may produce as much as 10 or 15 gpm. Yields are variable for wells developed in the alluvial sands and gravels along the interior streams and the Big Sioux River, but are generally less than 200 gpm and rarely exceed 400 gpm. Where conditions are favorable for recharge, yields may range from 500 gpm to more than 1,000 gpm (Figure 3-16). In Woodbury and Monona counties, yields of from 500 to more than 1,000 gpm are obtained from the Missouri River alluvium.

The principal bedrock aquifer of the region is the Dakota Sandstone which lies at moderate to intermediate depths throughout the district (Figure 3-17). In about half of the district, the Dakota Sandstone will yield between 100 and 500 gpm to wells. Near the Missouri River, in Woodbury and Plymouth counties, the Dakota Sandstone is quite productive and is known to yield more than 500 gpm. The Dakota is nearly as productive in the northeastern corner of the district in portions of Kossuth, Emmet, and Palo Alto counties. Only in about one-fourth of the district does the Dakota yield fewer than 100 gpm.

The extent of the Paleozoic bedrock aquifers in this district is not well known. Wells completed at moderate to intermediate depths in the Mississippian aquifer (where present in the district) should produce yields of between 100 and 500 gpm. At similar depths, wells in the Silurian-Devonian aquifer probably will produce fewer than 100 gpm. The Cambro-Ordovician aquifer system is generally the most productive of the Paleozoic aquifers. Most of the moderate to deep wells completed in the aquifer yield between 100 and 500 gpm. In about one-third of the district, where the aquifer is present, potential yields are estimated at between 500 and 1,000 gpm (Figure 3-16).

Water Quality. Groundwater quality is a problem in many areas of the Northwestern Iowa Ground Water District. In most instances, groundwater in the drift aquifer and in alluvial sands and gravels is of good to fair quality. However, in certain areas, mainly in portions of Osceola, Dickinson, and Emmet counties, drift and alluvial water quality is poor.

In general, the quality of groundwater from bedrock sources in the district is poor. For the Dakota Sandstone, 27 percent of its area provides water that is classified as good to fair quality, 39 percent provides water that is acceptable. Although no data is available from the Mississippian and Silurian-Devonian systems, data from other areas suggest that water quality from these aquifers is unacceptable. In about 12 percent of the district underlain by the Cambro-Ordovician aquifer, the groundwater is classified as being of good to fair quality, in 29 percent it is acceptable, and in 59 percent it is unacceptable for drinking purposes (Figure 3-18).

Conclusions and Recommendations

Interior Stream Flows

Conclusion

During normal years, Iowa's interior streams discharge an average of 18 million acre-feet of water. Most of this flow occurs during the late spring and early summer. Low flows usually occur during late summer and winter months. The larger flow volumes are generally the result of peak discharge periods of short duration. Total stream runoff ranges from 2 to 8 inches, from west to east across the state. Although large quantities of water are discharged by Iowa's streams, natural variability of flow results in only a small proportion of this water being available for consumptive purposes throughout any given year.

Recommendation

In order to increase the state's total water resources base, particularly in the northwestern, southwestern, and south central counties, programs should be developed to investigate the potential for more fully managing the water in streams and rivers. These programs should consider the feasibility of siting and constructing impoundments and structures to regulate flows in order that more water would be available throughout the year.

Mississippi and Missouri River Flows

Conclusion

Large volumes of water are available from both the Mississippi and the Missouri Rivers.

Recommendation

New water-intensive industries should be encouraged to locate in regions where they can take advantage of these sources.

Programs should be established, particularly for the more water deficient areas of western Iowa, to investigate the feasibility of transport of Missouri River water to augment existing sources.

Groundwater Supplies

Conclusion

The state's groundwater resources, with respect to quantity, quality, yield potential, and accessibility are unevenly distributed.

Recommendation

These regional imbalances should be mitigated by programs that:

a) Set priorities for water use and development in relation to the available supply within regions;
b) Define withdrawal limitations, according to use priorities, for the various aquifers within regions;
c) Determine alternative supply sources which would augment existing reserves within regions;
d) Evaluate the feasibility of treating inferior groundwater available to the region (primarily desalting); and
e) Assess regional water needs and demands to determine the effectiveness of various conservation measures for existing and/or potential deficiencies.

Options for Development

Conclusion

Some regions within the state have several options for the development of water supplies.

Recommendation

Programs and/or policies should be developed to prevent needless stresses on single aquifers. Such stresses could be prevented by allocation practices that promote conjunctive use, well spacing controls, and reversion to other available sources.

Red Rock Dam and Reservoir — *Corps of Engineers*

Des Moines Water Works Park *W. E. Akin*