A Primer on Iowa's Water

THE 1985 STATE WATER PLAN

Water, Air And Waste Management Commission

Iowa

department of water, air and waste management

A Primer on Iowa's Water

prepared by:

Iowa Water, Air and Waste Management Commission

Department of Water, Air and Waste Management

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A PRIMER ON IOWA'S WATER

INTRODUCTION

Why a Water Plan?

Water is never seen as a problem -- unless we have too much, not enough, or its quality is unsuitable for our purposes.

Iowa is more fortunate than many states. The timely and generally adequate rainfall produces a bounty of food and fiber, which in turn supports agriculture and industry. Water in our rivers provides support to manufacturing, numerous municipal supplies and a medium for disposing wastes. Groundwaters supply most of Iowa's rural residents and a large share of the urban population. The Mississippi and Missouri Rivers provide a waterborne highway to domestic and international markets. Streams, lakes and reservoirs provide an opportunity for recreation.

Two other facts also apply to water in Iowa. First, Iowans have never fully examined statewide water availability and its use, and planned for its continued use and long-term supply. Second, many people may not understand the basic concepts of how water moves, how much is available, or how it changes in both quantity and quality.

In response to the first fact, Iowa has developed a comprehensive statewide water plan as mandated by the 1982 Legislature. The thrust of the plan centers on three specific tasks.

1. Identify and evaluate water availability and quality of surface waters and groundwaters.

2. Identify major water users and project the needs of each to the year 2005.

3. Develop and implement a priority allocation system for the state's water resources.

Why this Report?

This report is a primer on water resources, particularly as related to Iowa and Iowans. It was prepared to help people understand the state's water resources. This report is intended for the general reader unfamiliar with water resources. Technical jargon is minimized, but necessarily included for the benefit of introducing basic terms used in describing water resources. This report is not a comprehensive treatment of a subject that is complex and not yet completely understood even by professionals.

This report:

1. Describes the basic factors involving the movement of water;

2. Reviews the basic concepts of surface water and groundwater availability in Iowa; and,

3. Introduces some of the issues, changes and potential threats to the continued supply of quality water to the state.

Other water plan reports include the following:

Water Availability in Iowa

Water Use in Iowa

Water Resource Issues in Iowa

The State Water Plan.

The final State Water Plan Report will be provided to the General Assembly along with proposed legislation.

THE HYDROLOGIC CYCLE

Water is continually on the move. As shown in Figure 1, water moves from the atmosphere as rain or snow, across the ground into streams, lakes and oceans, and the eventual evaporation of water back into the atmosphere. This continual water flow is the hydrologic, or water, cycle.

The major components of the hydrologic cycle include the following.

1. <u>**Precipitation**</u> is water as rain, snow or some other form moving from the atmosphere to the earth's surface.

2. <u>**Abstraction**</u> is the initial loss of water to vegetation (interception) and other surfaces as it falls from the atmosphere.

3. <u>**Evaporation**</u> is the movement of water from the liquid form at the earth's surface into the atmosphere as a gas. The major source of evaporation is the surface of the oceans. Over time and space precipitation equals evaporation.

4. <u>**Transpiration**</u> is the movement of water through a living plant into the atmosphere by evaporation from the leaves.

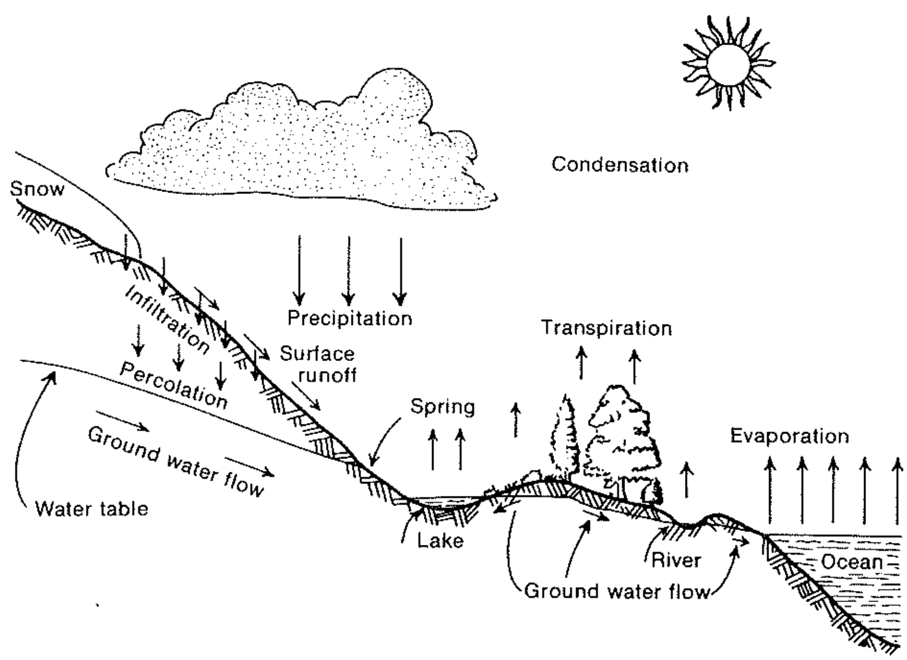


Figure 1. The Hydrologic Cycle, Including the Elements of Precipitation, Runoff, Infiltration, Evaporation, Transpiration and Underground Flow. Source: INRC.

5. **Infiltration** is the process in which water moves into the surface soil layers. Much of this water is lost back to the atmosphere via evaporation.

6. **Groundwater movement** is the flow of water through the deeper soil and bedrock formations to the water table. This is often referred to as **percolation**, or **seepage**.

7. **Runoff** is that portion of precipitation which moves across the land into channels and depressions. It is the residual quantity representing the excess of precipitation over all other components of the hydrologic cycle.

The average annual movement of water in Iowa through the processes of the water cycle is shown in Figure 2. Note that almost 25 inches of Iowa's annual precipitation returns directly back to the atmosphere without becoming a long-term surface or groundwater resource.

How Climate Affects Water Availability

The two major factors in Iowa's climate that affect water availability are precipitation and temperature.

Much of the water Iowa relies upon starts as precipitation within the state. The average annual precipitation is 32 inches. The average

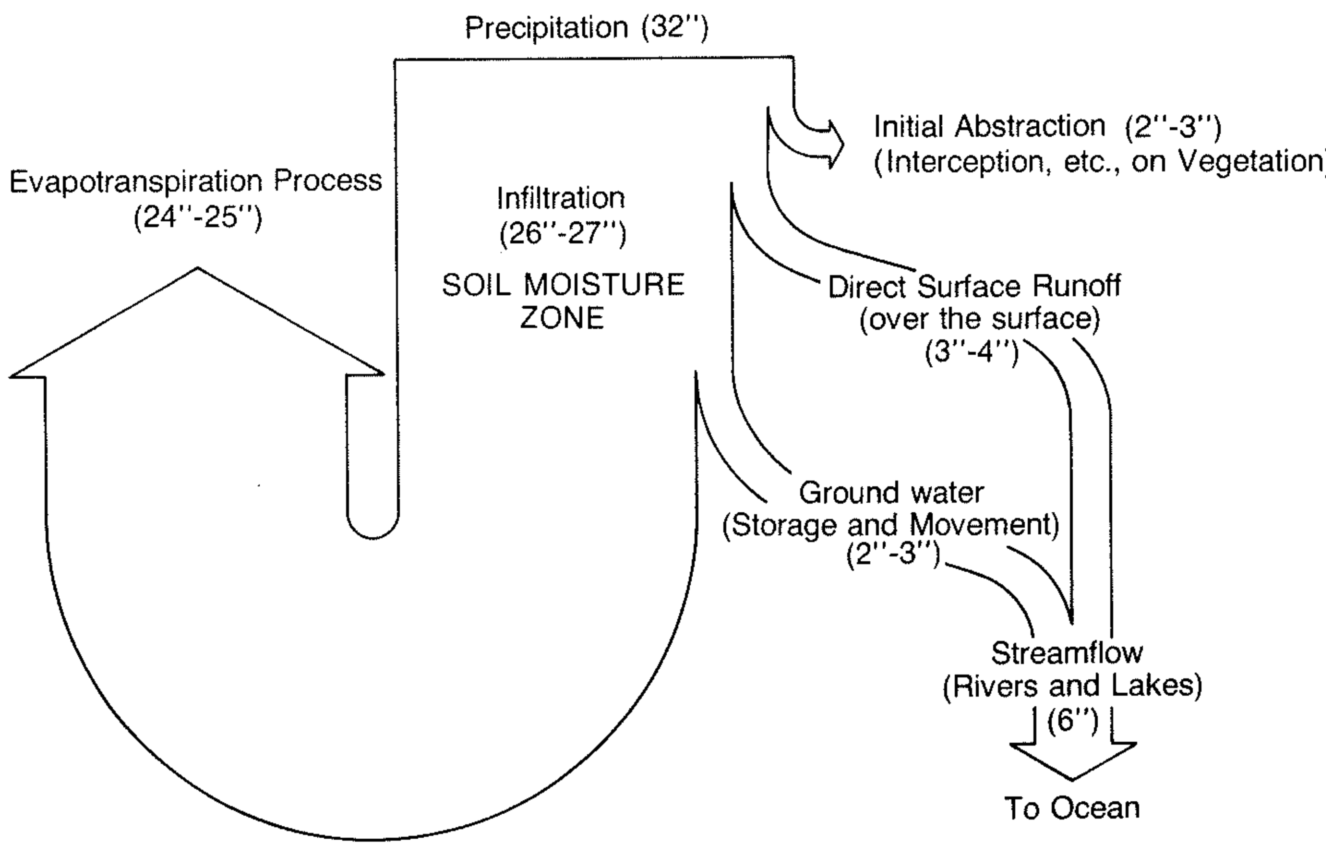


Figure 2. Average Annual Hydrologic Cycle Water Movement for Iowa.
Source: Dougal

varies across Iowa, with the southeast corner being the wettest region, as shown in Figure 3. There is also seasonal variability. As shown in Figure 4, the wettest months are usually during late spring and summer. During the last 100+ years the wettest years have received more than twice the precipitation of the driest years. An example is shown in Figure 5. The average precipitation in 1881 exceeded 44 inches, while the total in 1910 was only 20 inches.

The state's humid continental climate is marked by relatively cold dry winters and hot humid summers. The warm humid air from the Gulf of Mexico during the spring and summer carries large amounts of moisture. The meeting of warm water-rich air masses from the south with cool dry northern air results in spring and summer rains. Hotter summer temperatures provide the energy and moisture for thunderstorms. Most precipitation received during the three summer months is associated with localized rainfall, whereas the large frontal air masses of spring and fall provide more widespread precipitation.

The most severe droughts in Iowa have occurred in cycles averaging from 20 to 22 years. During this century Iowa has experienced significant dry periods during the 1930's, the mid 1950's, and the late 1970's (Figure 5). Two years, 1955 and 1956, rank as the third and fifth driest years, respectively, and are the driest two year period since records have been maintained. During the 1976-1977 drought, the governor declared a state of disaster emergency to provide assistance to many communities and other users facing water shortages. Drought periods have caused

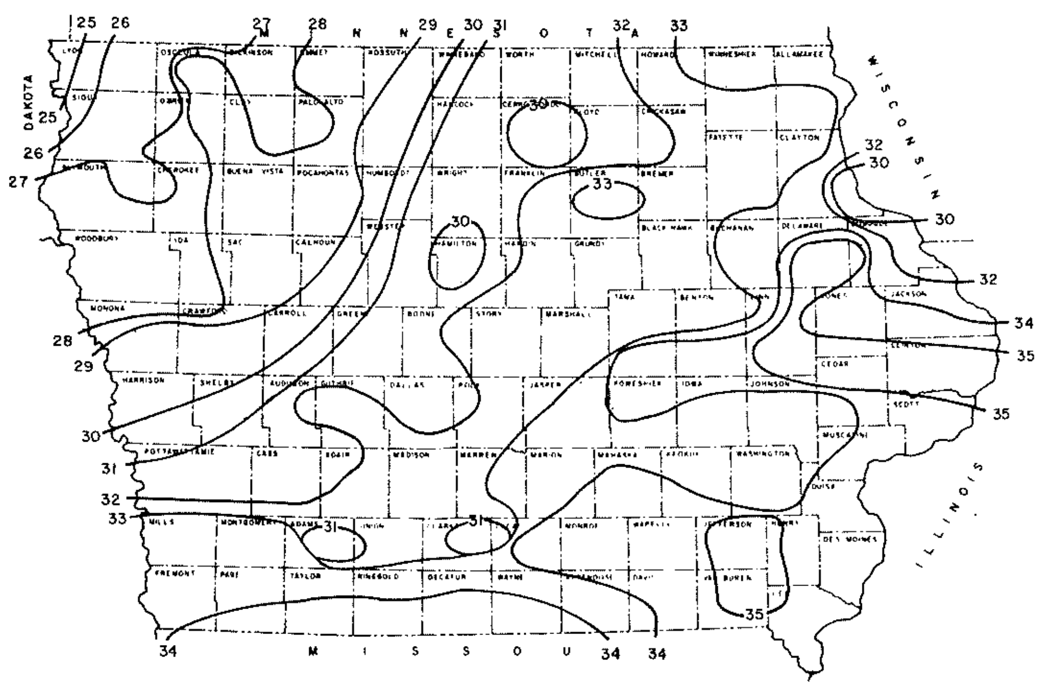


Figure 3. Map of Annual Precipitation (Inches) in Iowa Based on Historical Records. Source: Iowa Department of Agriculture.

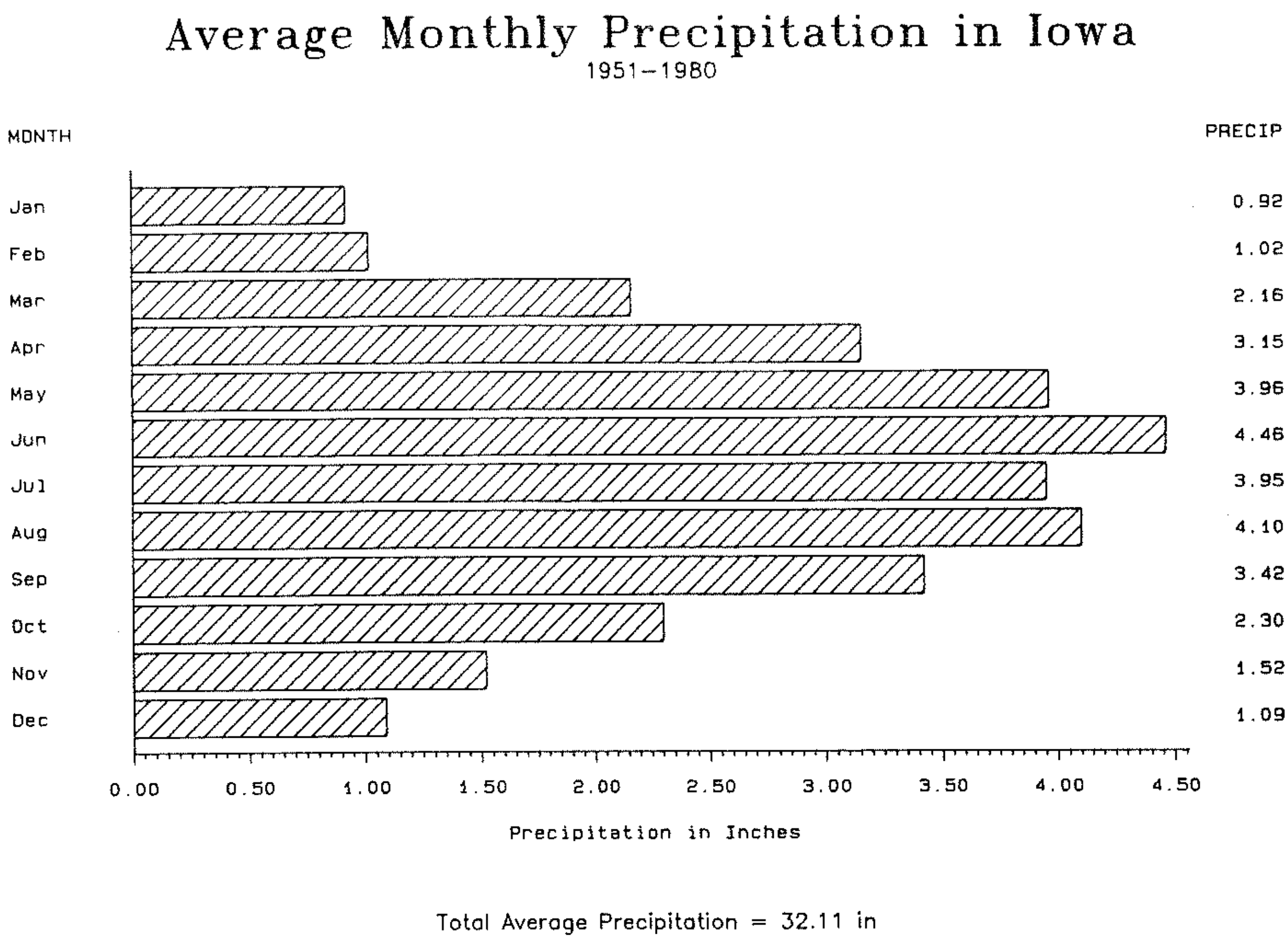


Figure 4. Average Monthly Precipitation in Iowa. Source: Iowa Department of Agriculture.

crop losses, water shortages for domestic and industrial uses, and potential health problems arising from the lack of streamflow to dilute wastewater discharges. Iowa was recently reminded of the impact of even a short-term drought during the summer of 1983.

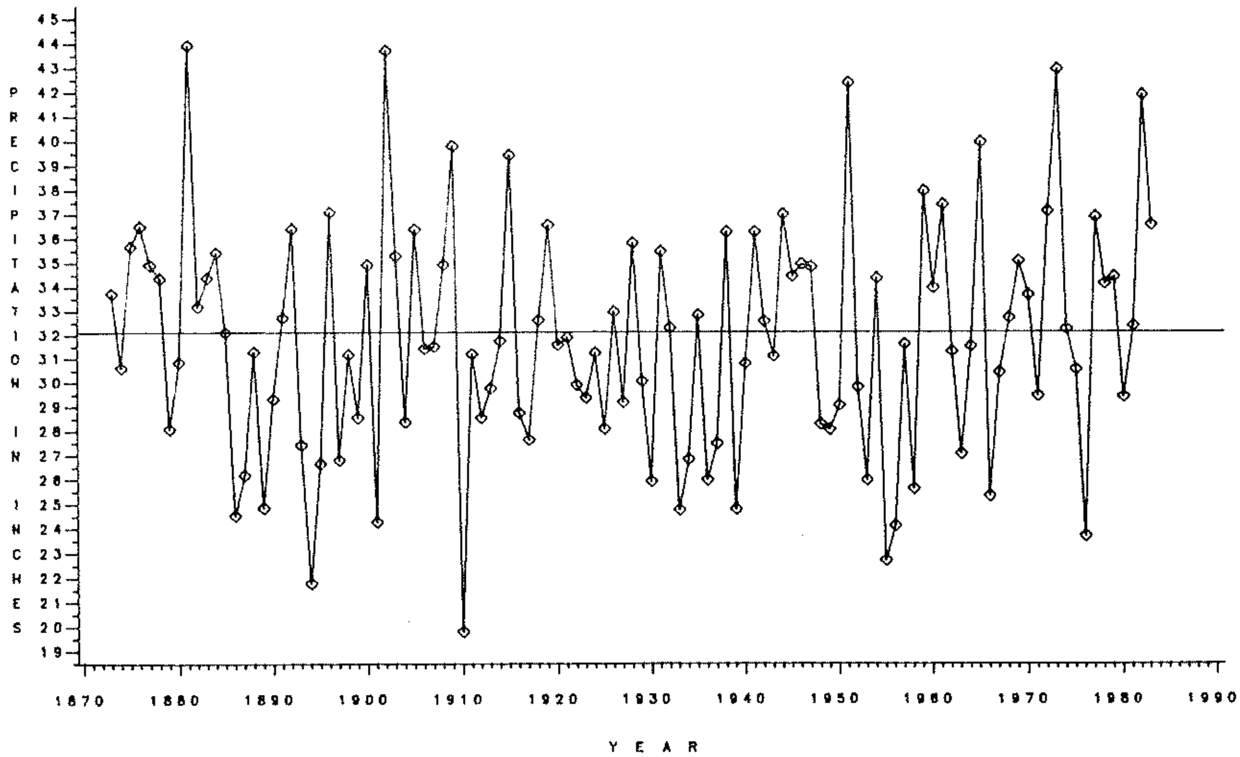
The highest floods have been associated with late spring and early summer rains. Peak floods in many parts of Iowa occurred in 1947 and 1965, both during extended periods of above normal precipitation. Localized flash floods are often the result of intense short-duration rainfall.

Large parts of southern Iowa that suffered crop failures and lowered water supply reservoirs in the late summer of 1983, had experienced localized flooding due to thunderstorms, as late as June.

Iowa receives the bulk of its precipitation during the crop growing season. Average precipitation during the period from April through September ranges from 20 to 22 inches as shown in Figure 6.

Moisture during the fall and winter helps replenish soil moisture for the following growing season. This is a

Average Annual Precipitation in Iowa



Average Precipitation = 32.11 in.

Figure 5. Average Annual Precipitation for Iowa During the Period from 1873 to 1983. Source: Iowa Department of Agriculture.

period of minimal evaporation, increasing the potential for infiltration if the ground is not frozen. Snowfall during the winter contributes to the moisture prior to the growing season. However, fast spring melt of the snow can cause flooding and loss of a significant fraction of the water. Snowfall contributes approximately ten percent of the total precipitation received in the state.

Evaporation and Transpiration

Evaporation of water occurs from surface waters, the soil and other moist surfaces. Growing plants also expend water through transpiration, or the movement of water from leaf surfaces. The combination of these two water losses is referred to as **evapotranspiration.** The rate at which it occurs is dependent upon air temperature, wind speed, and relative humidity. The highest rate of evapotranspiration occurs during hot windy summer days when vegetation growth is at its maximum. Normal summer conditions can cause the loss of 0.2 to 0.3 inch of moisture per day, and extremely hot temperatures combined with wind can increase this to 0.5 inch per day.

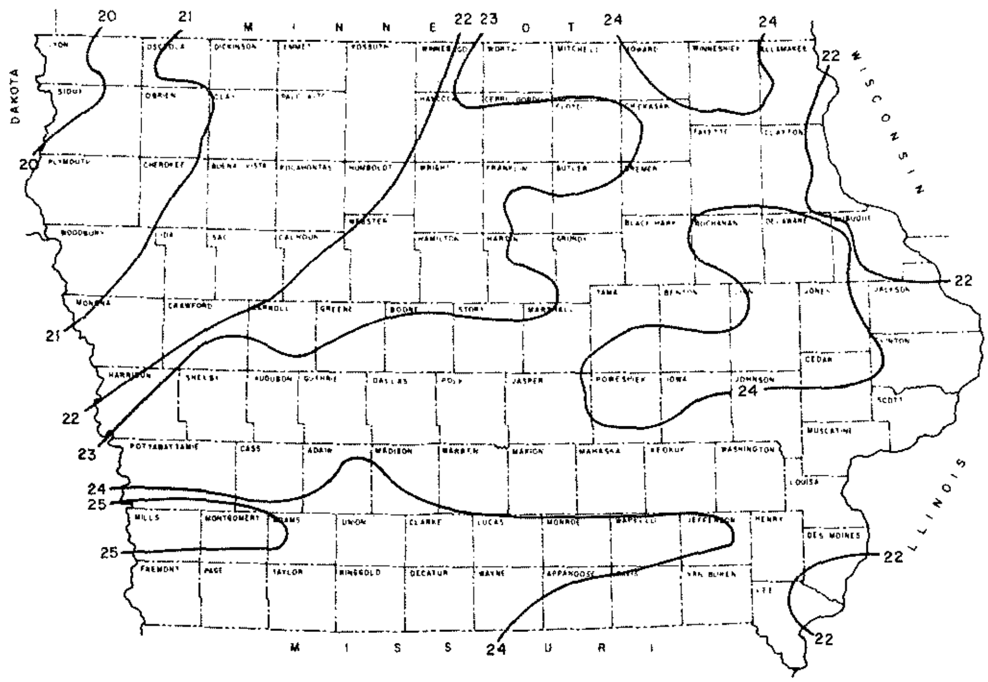


Figure 6. Average Annual Crop Season Precipitation (April-September) in Iowa (Inches). Source: Iowa Department of Agriculture.

Iowa loses approximately 25 inches of moisture annually to evapotranspiration. This compares to a statewide average precipitation of 32 inches. Figure 7 indicates that this loss is highest in the southeast and lowest in the northeast.

Evapotranspiration is greatest during the summer, when it exceeds the amount of rainfall. This deficit occurs during the peak growing period. If this deficit is not compensated by soil moisture a decrease in crop yields may result. From late fall through spring, precipitation exceeds evapotranspiration, allowing water to collect in the soil or runoff. This seasonal surplus ranges up to seven inches in Iowa as indicated in Figure 8. However, during the period June through September, all areas of the state usually experience at least a short-term moisture deficiency when evapotranspiration exceeds rainfall (Figure 9).

Seasonal and regional water surplus and deficit patterns are reflected in streamflow. Lowest flows usually occur during the late summer or winter when precipitation is lowest. Flows are often highest in the spring and early summer. Regional variations are illustrated by generally dependable late summer streamflows in northeastern Iowa, and the often no-flow or low-flow conditions in western Iowa.

IOWA'S GEOLOGY AND LANDSCAPE

Iowa's landscape is due to the location and type of **bedrock** material deposited and later sculptured by physical processes. These same materials store and transmit water underground, and are a major factor in

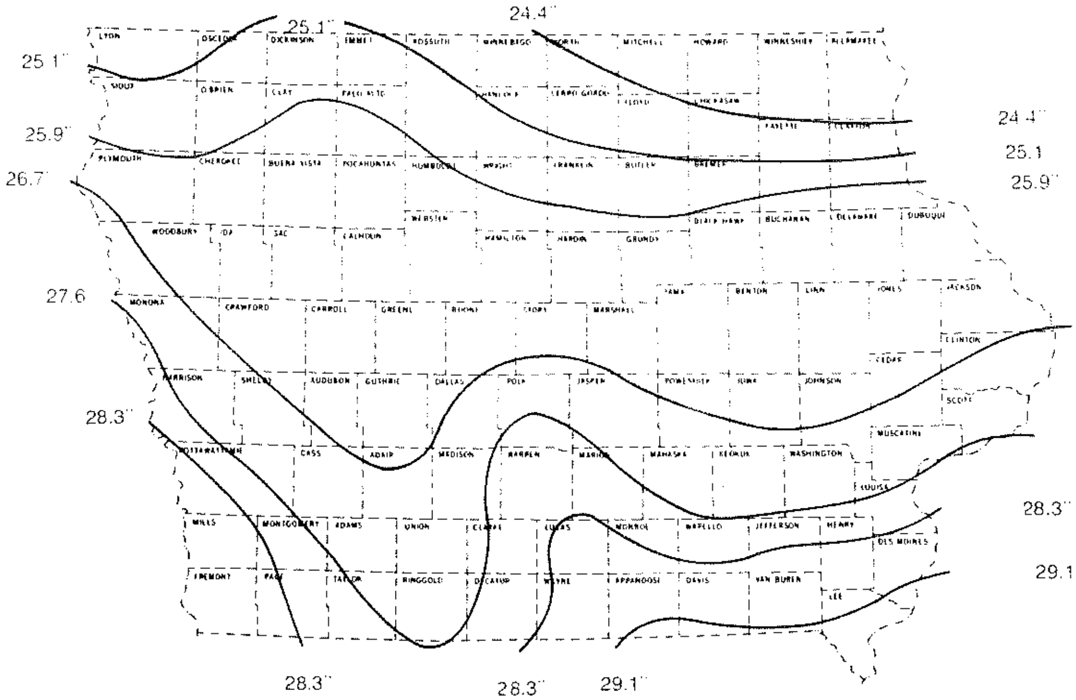


Figure 7. Average Annual Moisture Potentially Lost to Evapotranspiration in Iowa (Inches). Source: Matter.

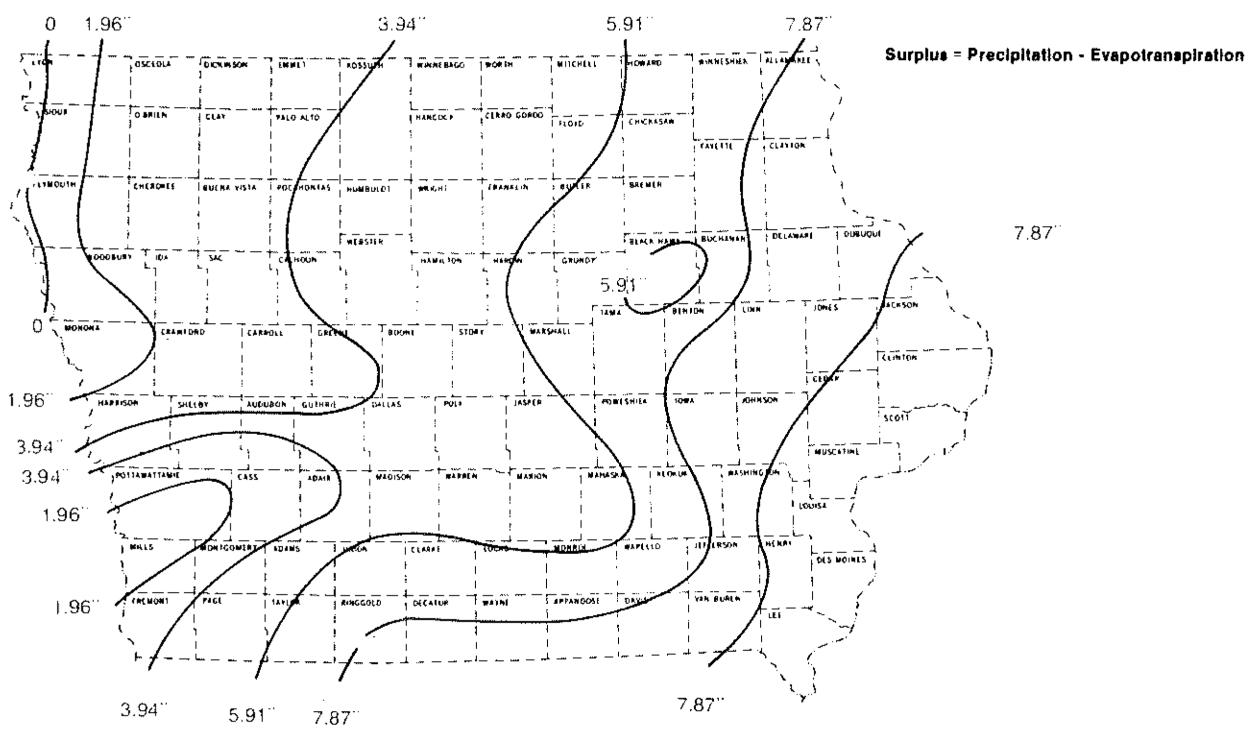


Figure 8. Average Precipitation Surplus in Iowa During March Through May (Inches). Source: Matter.

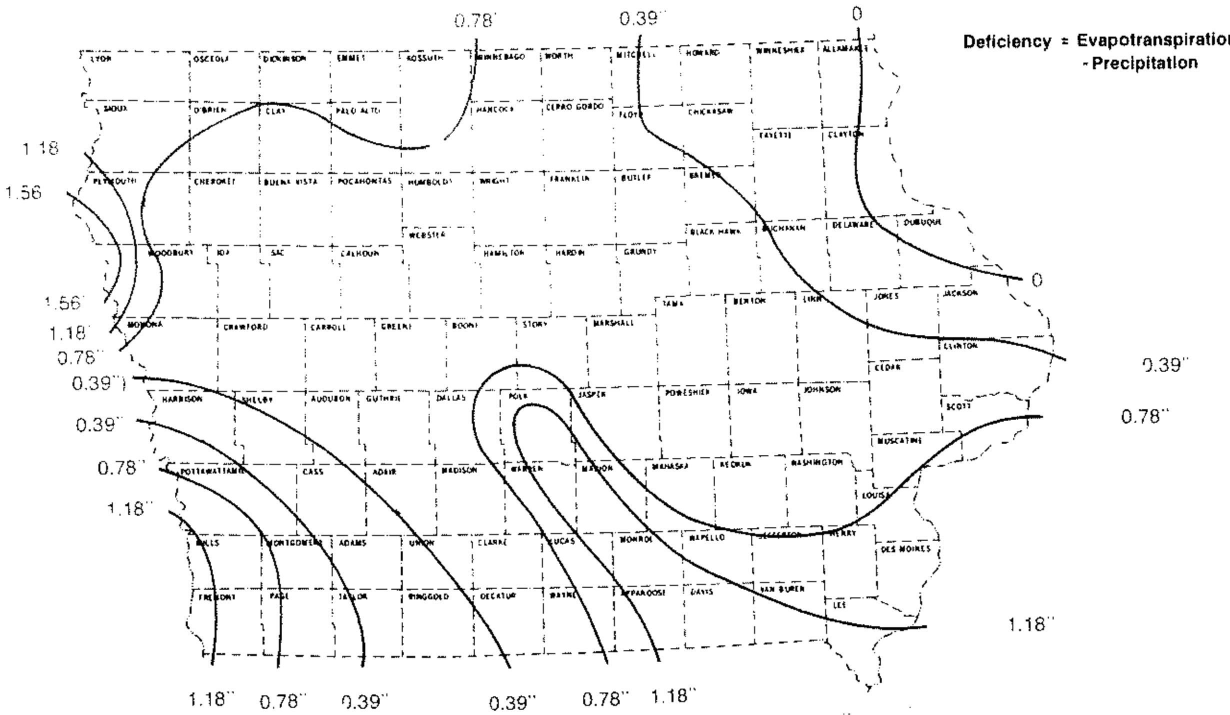


Figure 9. Average Water Deficiency in Iowa During the Primary Growing Season, June Through September (Inches). Source: Matter.

determining the availability of water.

The older the rock layer, the deeper it usually occurs. The oldest rock layers encountered in water resource investigations are nearly two billion years old. They are water-impermeable crystalline rocks that occur below the other formations. These rocks are considered to be the basement rock on which rest the water-bearing bedrock units. The youngest bedrock formations are shales and sandstones located in western and northwestern Iowa.

Each bedrock layer was formed by slow sedimentation during a series of inundations by warm seas early in geologic history (from about 200 to 600 million years ago). As a result the major bedrock units are formed by numerous distinct rock layers, each with varying capabilities to store and transmit water.

Bedrock layers are not perfectly flat or parallel to one another. Sculpturing by erosion, and bending of the material by shifts in the earth's crust, have formed the bedrock beneath Iowa into a shallow dish shape with a downward tilt to the southwest. A ball placed upon the top of a bedrock layer in northeast Iowa could hypothetically roll towards the opposite corner of the state. This layering and tilting of the bedrock is illustrated in Figure 10.

Differential layering of permeable and impermeable rock, combined with the tilt of the bedrock, affects the movement of groundwater. Water moves vertically between different water-bearing bedrock units, following the pull of gravity. There is also a slight horizontal movement, with water following the path of least resistance along pressure gradients between bedrock layers.

Bedrock has been modified by a combination of forces. Bending of the bedrock surface, glaciation, and water and wind erosion have modified the surface of Iowa to the way it appears today. Most of the original bedrock material has been covered by more recent deposits.

All of Iowa was once covered by glacial ice sheets, a relatively recent event in the geologic time scale (within the last million years). Some parts of Iowa, notably northeastern and southern parts of the state, were last covered longer ago than north-central Iowa. Except where bedrock is exposed, most parts of Iowa have deposits of this glacial material, or **glacial drift** (often called drift or till). Drift is a mixture of clay, silt, sand, gravel and boulders. Multiple drift layers occur in some areas of Iowa because several ice sheets advanced and receded across the state.

Water and wind have modified the glacial drift in Iowa, resulting in a variety of landforms as shown in Figure 11. North central Iowa, which was most recently covered by glaciers, has not had the same amount of time to weather and erode. Topography in this area is still level to gently rolling, with natural drainage often slow. Southern Iowa has not been glaciated as recently as the north-central region. Longer erosion of the drift material has created a more deeply cut, or **dissected drainage** pattern.

As a result of erosional processes, the uppermost covering in Iowa usually is one of the following.

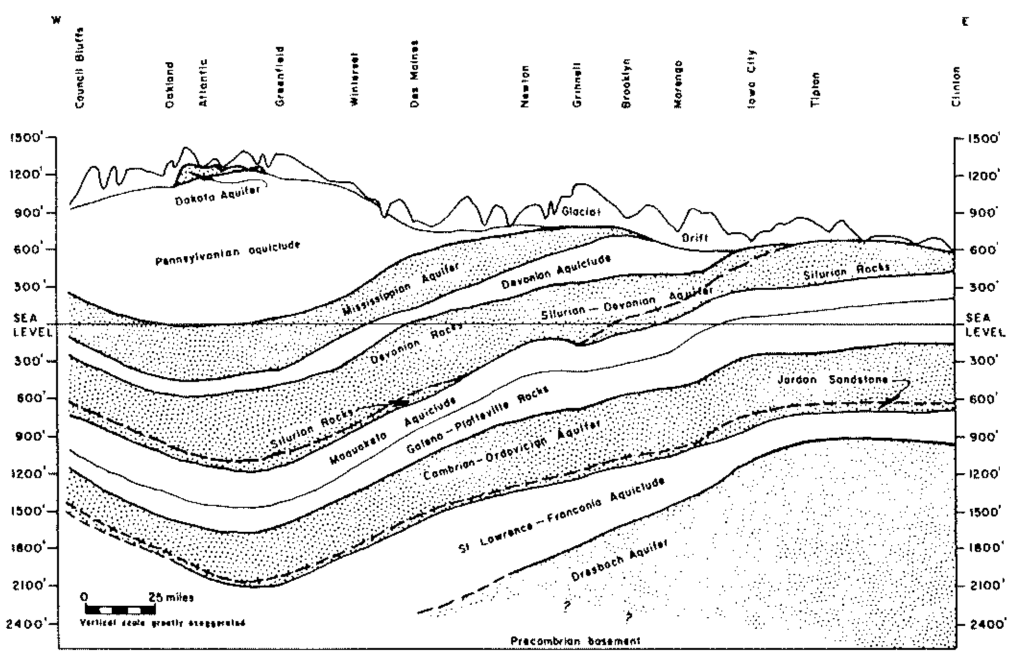


Figure 10. Generalized Cross-Section of Major Water-Bearing Bedrock Layers in Iowa. Source: Steinhilfer and Horick.

GLACIERS -- AND IOWA'S LANDSCAPE

The topsoil and gently rolling hills of Iowa are the result of glaciers, the most recent geologic events to occur in Iowa. As recently as 10,000 to 14,000 years ago, parts of Iowa were covered by glaciers, or ice sheets.

Much earlier in geologic history Iowa was covered by warm seas, during which time sedimentation slowly resulted in the formation of the deep bedrock layers underlying the state today. Then Iowa's climate changed, becoming cooler with increased snowfall. The first time occurred 1.5 to two million years ago and resulted in the Nebraskan glacial stage. Three subsequent glacial advances have covered all or part of the state since then, the last being the Wisconsin advance which covered much of northcentral Iowa.

Each glacier pushed and carried large amounts of material, slowly grinding and shaping the upper bedrock, and depositing finer sand, gravel, clay and silt material as it receded northward. This finer material deposited by the glaciers, referred to as glacial drift, formed the basis for most of Iowa's soil. The southern parts of the state which were not covered by the most recent glacial advances have had a longer time to weather and erode; thus, the glacial drift may be removed from some surfaces. This part of the state is also marked by more distinct drainage patterns than the northwestern and north central parts of Iowa where many lakes and marshes are found.

PHYSIOGRAPHIC UNITS IN IOWA

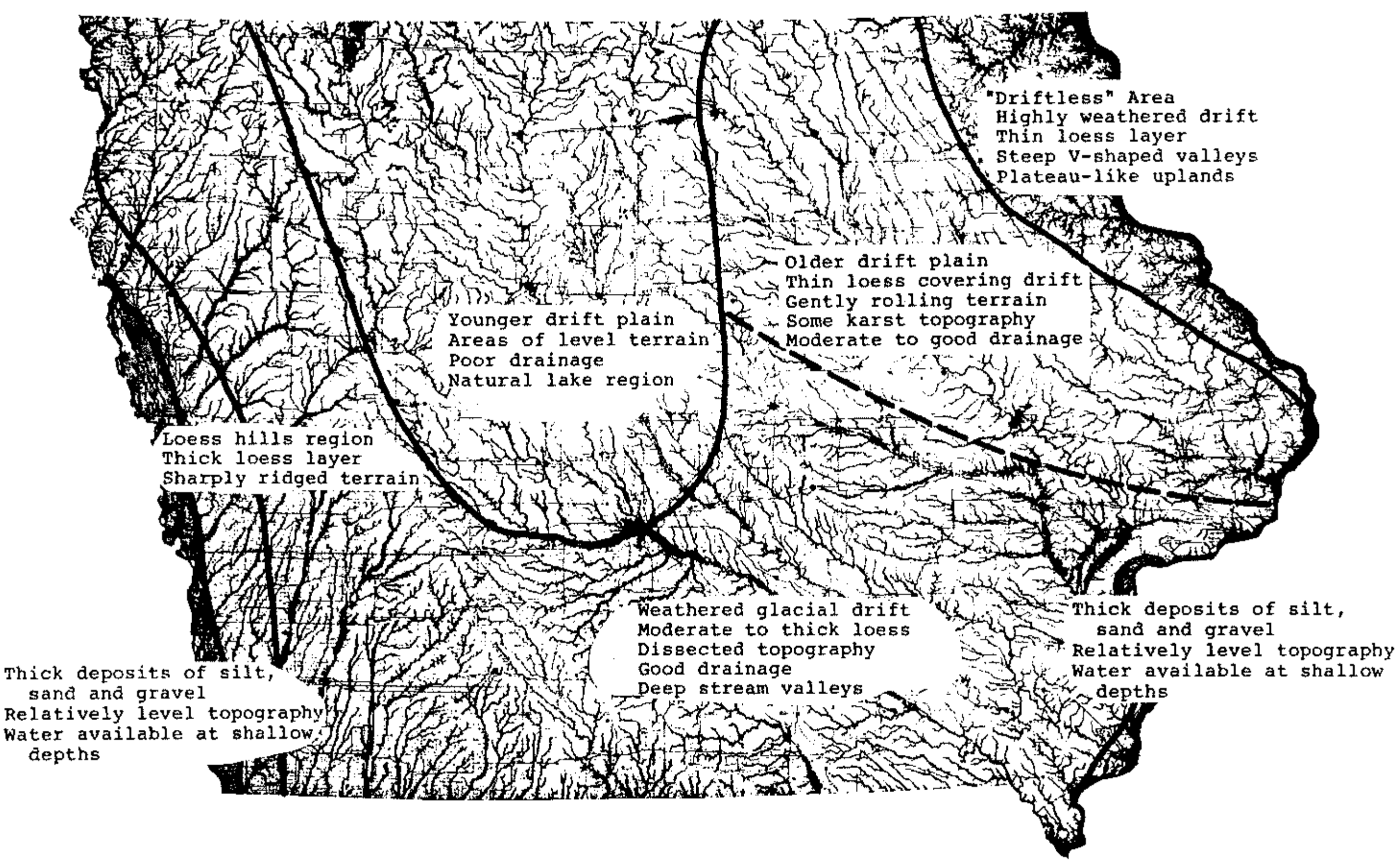


Figure 11. Major Physiographic, or Landform Regions of Iowa. Source: Prior.

1. Glacial drift, often altered by weathering, erosion and soil-forming processes.

2. **Loess**, wind blown clay soil material, often thinly covering the glacial deposits. Hills along the Missouri River valley are formed from loess deposits up to 200 feet thick.

3. **Alluvium**, water-deposited sands and gravels generally found along major rivers.

4. Bedrock is most frequently found exposed in northeastern Iowa where most of the glacial drift has been eroded.

IOWA'S SURFACE WATER RESOURCES

Iowa has approximately 18,000 miles of surface streams and 870,000 acres covered by natural lakes or man-made impoundments. The water leaving the state in surface streams as runoff is the second largest water loss after evapotranspiration. Natural lakes and impoundments provide temporary storage of that water.

Interior River Basins

Iowa's streams and rivers generally flow in a southerly direction into either the Mississippi or Missouri River. Approximately 75 percent of the state's runoff enters the Mississippi River, with the remainder entering the Missouri River. Iowa's streams are typically classified into six major basin regions.

1. Northeast Iowa Basin
2. Iowa-Cedar Basin
3. Skunk Basin
4. Des Moines Basin
5. Southern Iowa
6. Western Iowa.

These six basins are shown in Figure 12. The major characteristics of the six basins are listed in Table 1.

Drainage basins of Iowa streams that are tributary to the Mississippi River tend to be broader and have greater drainage areas than those that drain to the Missouri River.

Border Streams

Iowa is unique in being bordered by the Mississippi and Missouri Rivers. These are used for commercial navigation, recreation, and cooling water for power plants. The Big Sioux and Des Moines Rivers also are border streams in the northwest and southeast, respectively.

The Mississippi River's flow and elevation are controlled by a series of 27 locks and dams between Minneapolis and St. Louis. These were constructed to increase navigational use of the river. Eleven locks and dams are located along Iowa.

The Mississippi is a source of water for municipal and industrial users. Several users withdraw directly from the river and others have wells drawing from adjacent alluvial deposits. Major users are concentrated at Dubuque, Davenport, Bettendorf, Muscatine, Burlington and Keokuk.

The major use of the Mississippi River is for transportation. Commodities carried include agricultural products, fertilizer, petrochemicals and coal. Downstream movement of all commodities past Keokuk exceeded 20 million tons in 1983. There are presently over 60 barge terminals along the river in Iowa.

The Missouri River is also a major commercial resource, although the overall level of utilization is much less than the Mississippi. No lock and dam system exists on the Missouri River. Water discharge of the river along Iowa is partially controlled by six large impoundments in Montana and North and South Dakota. Constructed to control floodwaters and snowmelt

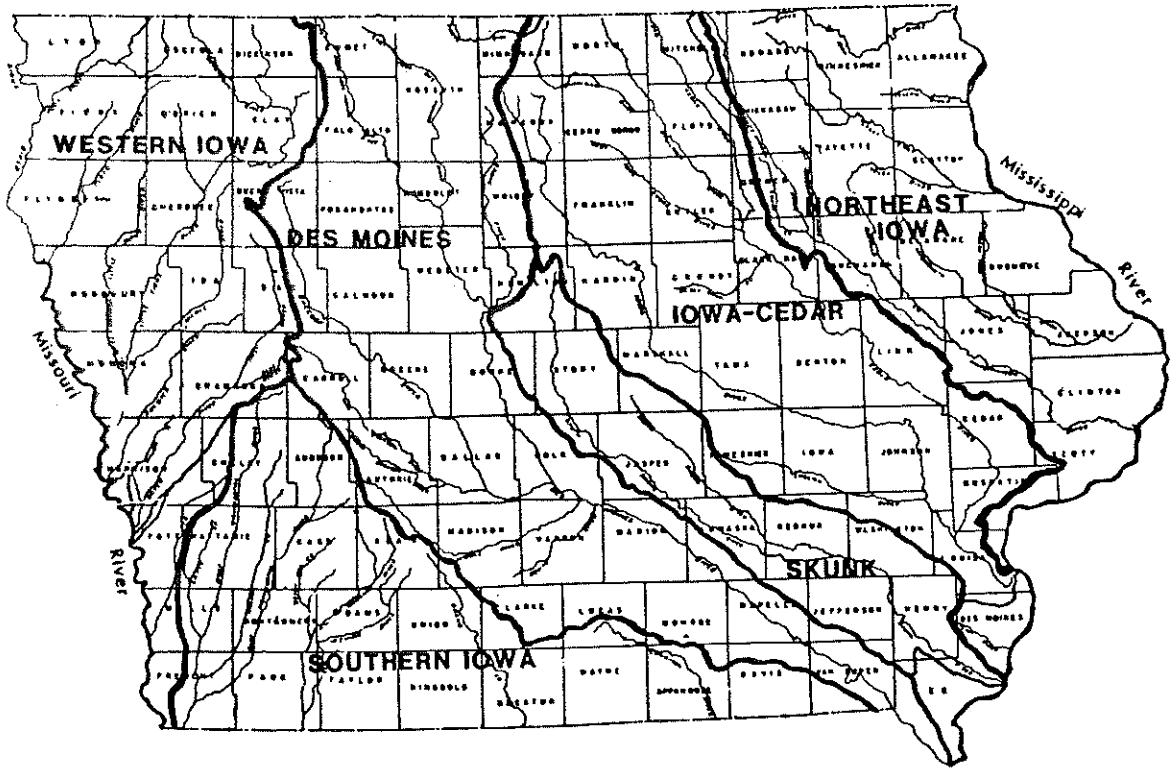


Figure 12. Major River Basin Regions of Iowa.

from the Rockies, they are also used for hydroelectric power generation, irrigation, and water supply. A principal downstream water requirement is adequate flow to support navigation below Sioux City.

Water utilization along the Missouri is lower than the Mississippi. Municipal and industrial use is primarily limited to Sioux City, Council Bluffs and two electric power generating facilities. However, several Iowa counties along the Missouri have experienced increased alluvial water withdrawals for irrigation during the last two decades.

Lakes and Impoundments

Four types of surface impoundments occur in Iowa.

1. Natural Lakes. Iowa's natural lakes generally are in north-central and northwest Iowa in regions that have been most recently covered by glaciers. Most lakes are generally shallow and small. The largest are Spirit, Clear, Storm and West Okoboji.

2. Man-Made Impoundments. This is the largest category of standing water in Iowa. The federal reservoirs at Saylorville, Red Rock, Coralville and Rathbun have the greatest storage capacity. In addition, there are thousands of small impoundments and farm ponds. The Department of Water, Air and Waste Management has issued permits for over 2,000 impoundments that have more than 18

Table 1. Characteristics of the Six Major Basin Regions in Iowa.

Basin Characteristic	Northeast Iowa	Iowa-Cedar	Skunk	Des Moines	Southern Iowa	Western Iowa
Basin Area (Square miles)	7,591	12,785	4,355	14,540	8,217	9,313
Percent of Iowa in Basin	13	23	8	26	14	16
Major Streams	Upper Iowa Yellow Turkey Maquoketa Wapsipincon	Iowa Cedar English Shell Rock	Skunk North Skunk Cedar Creek Crooked Creek	Des Moines Raccoon Boone Middle North	Nishnabotna Nodaway Thompson Chariton Grand	Big Sioux Little Sioux Rock Floyd Boyer
Major Lakes and Impoundments	Odessa Harwick Green Island	Coralville Clear	Little Wall Geode	Saylorville Red Rock Storm	Rathbun Centerville Green Valley	Big Spirit West Okoboji East Okoboji
Average Annual Runoff (Million acre-feet)	3.4	4.3	1.7	4.1	1.8	2.7
Average Annual Potential Yield[a] (Million acre-feet)	2.0	3.2	1.5	3.4	1.7	2.1

[a]Water considered available for off-stream use.

acre-feet of storage. Southern Iowa is dotted with thousands of smaller farm ponds. The statewide total exceeds 47,000.

3. Gravel and Quarry Pits. These partially-filled basins are common in many areas of Iowa and usually serve as a recreational resource. Several have been purchased by the state for fish and wildlife management.

4. **Oxbow Lakes.** These lakes are caused by the natural shifting of rivers when two bends in a river meet and join. Most oxbow lakes are found along the Missouri River, with only one located along the Mississippi River.

What Determines Surface Water Availability?

Most surface water available in Iowa is associated with larger streams and impoundments designed and managed for flood control or water supply. The largest portion of the state's surface water is discharged by streams, and equals approximately 18 million acre-feet of runoff per year. The average discharge of the major rivers is shown in Figure 13. Approximately five percent of the state's surface water is stored in natural lakes and reservoirs. Many natural lakes and smaller impoundments can not sustain withdrawals without possible depletion that would impact other uses (i.e., recreation, fish and wildlife). The total surface water budget is shown in Table 2.

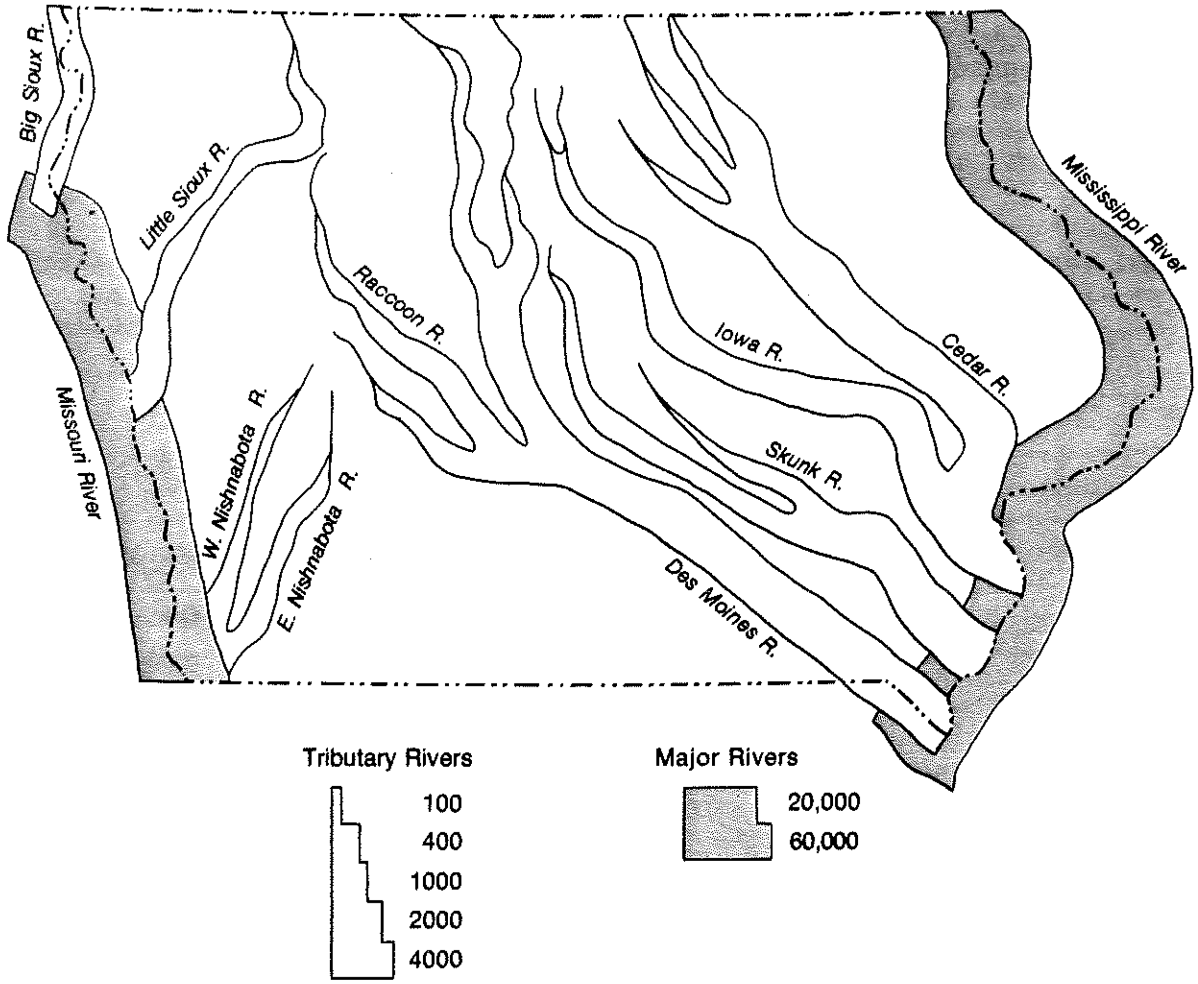
There is significant variability in the quantity of surface water available in Iowa. Major factors which determine surface water availability are described below.

1. Precipitation. Because the primary source of water is precipitation, natural streams have low and peak flows reflecting seasonal and annual precipitation patterns. The total flow rate in Iowa streams roughly parallels the distribution of rainfall.

STORING SURFACE WATER

Iowa has thousands of small farm ponds and a lesser number of larger reservoirs. The four largest are the federal reservoirs at Saylorville, Red Rock, Coralville and Rathbun.

While one of the purposes of Iowa's impoundments is to store water, not all of the water (or space) in the reservoir is necessarily available for withdrawal for other use. The largest storage volume and highest water elevation is associated with the maximum pool level. For impoundments designed for flood control, this is also called the flood pool elevation. The minimum pool elevation is generally the lowest elevation to which the pool is designed to be drawn under typical conditions. Larger regulated reservoirs, such as Saylorville, often have a conservation pool, or an intermediate level allowing for temporary adjustments in water storage. The conservation pool is also referred to as the normal pool level. The useful storage is that volume between the minimum and maximum (or in some cases the conservation) pool level. This volume of water may be used for water supply, low flow augmentation for downstream, or recreation.



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

Figure 13. Average Discharges of the Major Interior and Border Rivers of Iowa. Source: U.S.G.S.

Consequently, over 70 percent of the annual stream discharge occurs in the April through September growing season.

2. Topography. The north-central part of Iowa, covered with the youngest glacial drift, is relatively flat and poorly drained. Water is temporarily stored and slow to run off the land. In contrast, southern Iowa have well defined valleys and stream channels. In this area runoff to the streams is faster and more direct.

3. Geology. In the northern and eastern sections of Iowa the bedrock and alluvial deposits have a higher potential to store water. Seepage maintains streamflow even during droughts. However, in southern and western Iowa there is not the same underground storage capacity. Consequently, the streams' **base flow**, or that contributed by the groundwater, is relatively small. Consequently, drought periods are often characterized by low-flow or no-flow conditions.

Table 2. Average Annual Water Budget for Water Stored and Leaving Iowa.

Source	Acre-Feet of Water
Streamflow (or runoff)	18,230,000
Storage	1,250,000
Natural Lakes	300,000
State-Owned Reservoirs	50,000
Permitted Impoundments	348,000
Farm Ponds	119,000
Federal Reservoirs	433,000
TOTAL	19,480,000

4. Storage. Temporary storage of precipitation and runoff in lakes and reservoirs can provide a more reliable surface water resource than streams. Water can be withdrawn directly or discharged to maintain, or augment, downstream flows. Approximately one-half of Iowa's surface storage is provided by the four federal reservoirs. Smaller impoundments and farm ponds provide water on a more local basis. Many of the larger reservoirs were originally planned for flood control, with water supply storage a secondary benefit.

Most water resource management decisions are based on either flood flows or drought (low) flows. To date most actions have pertained to controlling floods. Low flow regulation, the most important aspect in determining water supply reliability, has received less attention.

Low flow levels in surface streams are critical not only from a water supply viewpoint, but also with regard to **assimilative** (or pollution absorption) **capacity.** The statistical 7-day, 1-in-10 year low flow level is the state's management criterion for water quality. State water quality standards must be met whenever streamflow equals or exceeds this level.

Flow is also reserved in many streams for fish and wildlife, recreation and other beneficial uses. This is the **protected flow** level established by state law. When streamflow drops to this point further withdrawal of water for **consumptive use** is prohibited.

What Determines Surface Water Quality?

Iowa's surface waters have variable water quality and are affected by several factors.

1. Soil Type and Land Use. The basic character of the soil, including its nutrient and erosive qualities, affects the quality of water passing over (and through) the soil column. Land use also affects the rate of runoff, and the amount and type of material washed from the soil. Cultivated row crop land has a higher potential for erosion and nutrient loss than does grass or forest land. Diffuse contamination from land areas is referred to as **non-point source pollution.**

2. Wastewater Discharges. Most municipal and industrial wastewaters are eventually discharged to surface waters. These are concentrated sources of nutrients and other contaminants to the streams, and are called **point source** discharges.

WHO USES IOWA'S WATER?

Water use by Iowan's varies according to type of use, location and source. Water users can be separated into several groups, including:

* Municipal
* Rural domestic
* Industrial
* Agricultural (livestock)
* Irrigation
* Power generation.

Water use estimates indicate that a large portion of municipal, rural domestic, industrial, agricultural, and irrigation water is withdrawn from groundwater sources. Generally, groundwater is the preferred water source when it is available. Water for power generation is usually pumped from surface waters, with most of the water returned to the original source after being used for cooling. The largest withdrawals by this latter group occur along the Mississippi and Missouri Rivers where there is higher dependability.

Irrigation water withdrawals are highest from the alluvial aquifers along the Missouri and Mississippi Rivers. This is a seasonal withdrawal, with most irrigation occurring during the summer months. Industrial and muncipal water use is centered around the major population centers, with a higher concentration of withdrawals in the eastern one half of Iowa. Rural domestic and agricultural water use, primarily for livestock, is rather even across the state, refecting the local rural population and livestock density.

The Department updated water use estimates for the state by user group and area. Water use projections were also prepared for the period 1985 to 2005.

3. Stream Discharge. Periods of high precipitation and stream discharge are usually associated with increased amounts of sediments and other suspended material washed from the soil. At these times the actual concentration of **dissolved solids** may be low. During low flow conditions the amount of runoff-introduced suspended material is low. However, low discharges are often characterized by high dissolved contaminant levels associated with point source discharges. The pollution tolerance of streams is also decreased during low flows. For these reasons, low flow conditions often produce water quality problems resulting in fish kills and other degradation.

The most recent review of water quality in Iowa by the Department has indicated that surface waters are degraded by several factors. The most serious of these are outlined below.

1. Nonpoint Pollution. Most of Iowa's streams and lakes are being impacted by nonpoint source pollution. The single largest source is agricultural runoff carrying sediment, nutrients and pesticides.

2. Sedimentation. Fine materials washed from agricultural land, urban and construction areas clog

stream channels and reduce the water storage capacity of impoundments. These sediments also carry nutrients and pesticides from cultivated cropland, contaminating surface waters and decreasing soil fertility.

3. Nutrients. Both point and nonpoint pollution sources contribute nutrients to surface waters. These stimulate aquatic plant growth, and hasten the aging process of lakes and impoundments. Recent concern has been centered on nitrogen, widely applied to agricultural lands. This converts to the **nitrate nitrogen** form in water. Increasing nitrate levels in some public and private water supplies have been measured in the last two decades.

4. Toxic Contaminants. Complex organic compounds and metals used by industrial processes and agriculture have been found in many surface waters. Pesticides (herbicides, insecticides and fungicides) have been detected in surface waters, lake sediments and fish flesh. Toxic compounds have also entered surface waters as point source discharges and from landfill disposal sites.

The continuing municipal treatment improvement program is decreasing the impact of point source wastewaters on surface waters. Few of the state's 18,000 miles of streams and essentially none of the lakes are impacted by such sources. While agricultural nonpoint source pollution affects most surface waters in Iowa, recent tillage practices may reduce the impact. Conservation and no-till farming practices reduce runoff and consequent loss of soil, nutrients and pesticides.

IOWA'S GROUNDWATER RESOURCES

Groundwater is a basic source of water for many Iowans. Less is generally known about the location, movement and quantity of groundwater than about surface waters. In the past, many misconceptions surrounded groundwater, and some still persist today. Earlier opinions had the groundwater moving in underground rivers, often flowing for hundreds of miles. Some early Iowa groundwater law was based on such misconceptions, allowing a landowner almost unlimited

IOWA'S WATER QUALITY CLASSES

Rules established by the Iowa Department of Water, Air and Waste Management allow surface waters of the state to be designated into three distinct use classes, "A", "B" or "C". All waters designated into these three classes are to be maintained to "protect livestock and wildlife watering, aquatic life, noncontact recreation, crop irrigation, and industrial, domestic, agricultural and other... uses". Additionally, each use class has specific targets for protection, generally outlined by the following:

Class A - Waters to be protected for primary whole body contact use with a minimum level of bacterial contamination;

Class B - Waters to be protected for wildlife, fish, aquatic and secondary contact (non-whole body contact) use; and,

Class C - Waters with the most stringest criteria to be protected as a raw water source for potable water supplies.

use of "percolated water", but limiting withdrawals from "underground rivers".

Basic Groundwater Principles

Precipitation not lost to runoff and evapotranspiration percolates downward to the water table. The **water table** is the upper surface of the saturated zone in the ground. The uppermost soil layer, not usually saturated with water (except temporarily after a rainfall), is the **zone of aeration.** In this top layer many of the pore spaces, microscopic voids between soil and rock particles, are not surrounded by water. Beneath the **water table** these spaces are filled with water.

Water is stored and slowly moves through the saturated zone below the water table. Saturated deposits capable of yielding water are called **aquifers.** These are permeable geologic formations capable of producing significant quantities of water to a well or spring. Aquifers are usually composed of less tightly packed material with a greater amount of pore space than aquitards. Unconsolidated sands and gravels, porous sandstone and limestone are the most common aquifer layers. Less permeable layers that cannot produce large quantities of water to a well or restrict underground water movement are **aquitards.** Aquitards are usually composed of more densely packed material such as clay or shale with less space for water. The layering of these two types of strata underground is a major factor determining water availability.

Aquifers are recharged by water entering from another source. For the uppermost glacial drift aquifers this **recharge** occurs with precipitation. The recharge area is where water initially enters the aquifer. For many of the bedrock aquifers the principal **recharge areas** coincide with outcrop areas where the aquifer is closest to the surface. For example, the Mississippian bedrock aquifer occurs throughout 60 percent of the state, although its primary recharge area is along a line in eastern Iowa. Contamination at or near the ground surface from spills or improperly constructed disposal areas can enter aquifers in these recharge areas.

In **discharge areas**, water emerges from the aquifer. This may be as water flowing from a spring, base flow to a stream, or as a lake or wetland.

Aquifers may exist under either confined or unconfined conditions. **Unconfined,** or water table, aquifers are near the earth's surface and are recharged by water infiltrating from the soil surface. **Confined** aquifers are under pressure, being located between two aquitards, or confining layers. This pressure is often illustrated by a flowing artesian well or spring where water naturally emerges from the ground. An artesian effect also occurs in wells tapping confined aquifers, as the water in the well rises above the top layer of the aquifer being tapped.

Major Groundwater Sources in Iowa

Groundwater aquifers in Iowa can be separated into two major types, consolidated and unconsolidated.

Unconsolidated aquifers are composed of deposits of gravel and sand resulting from glacial, wind or aluvial deposition. These are shallow deposits overlying the bedrock. These deposits are not as extensive and tend to be more localized than bedrock aquifers.

Three types of unconsolidated aquifers occur in Iowa.

1. Glacial Drift Aquifers. These were deposited by glacial advances. Local pockets of sand and gravel provide low to moderate amounts of water. Wells into drift aquifers are shallow, averaging less than 100 feet. Because of their proximity to the surface, water level changes in these aquifers are closely linked to precipitation.

2. **Alluvial Aquifers**. Deposits of sand and gravel by streams within the floodplain comprise the alluvial aquifers. Although areal coverage of alluvial aquifers in Iowa is low, total water availability and utilization is high. Large amounts of water are stored in the alluvium, often recharged by the adjacent stream, especially at pumping centers and during high streamflows. This linkage assures a more dependable supply of water. Alluvial aquifers slowly discharge water back into the stream during low runoff periods. Large industrial and irrigation withdrawals occur from the alluvial deposits along the Mississippi and Missouri Rivers.

   Major alluvial aquifers are shown in Figure 14.

3. Buried Channel Aquifers. Valleys in the upper surface of the bedrock have been filled with glacial drift, and subsequently covered with more layers of drift, loess or alluvium. These buried bedrock channels, or buried channel aquifers, are often directly connected with an overlying alluvial aquifer system. The distribution of these channels is sporadic, although more common in the eastern two-thirds of Iowa. Yields from these aquifers can be high, particularly when connected with alluvial systems.

   Figure 15 shows the generalized location of the major buried-channel aquifers in Iowa.

Consolidated, or **bedrock aquifers**, are rock material comprised of the sedimentary layers deposted early in geologic history. The more permeable layers of sandstone, fractured limestone and dolomites are the major bedrock aquifers. Less permeable shales, unfractured carbonate rocks and siltstone comprise the major aquitards between aquifers.

Four major consolidated aquifer systems are present in Iowa. While several different bedrock layers are included in these systems, these four major aquifers are commnly called the Dakota, Mississippian, Silurian-Devonian, and Cambrian-Ordovician aquifer systems.

As shown in Figure 16, the location and relative depths of each bedrock aquifer vary across Iowa. Generally, each bedrock layer is highest in the eastern and north-eastern part of the state with a tilt towards the southwest. These units form a shallow basin with its lowest point in the southwestern corner of the state.

Not all of the bedrock aquifers occur across the entire state. The Dakota system is primarily present in the northwest quarter of Iowa. The Mississippian and Silurian-Devonian aquifers are found in a large part of the state, although they are utilized in a more limited area.

A description of each major bedrock aquifer unit follows.

1. Dakota Aquifer. The Dakota sandstone formations occur throughout parts of northwestern and western Iowa. This is the uppermost bedrock aquifer in this region and a source for many municipal, industrial and livestock wells. High-

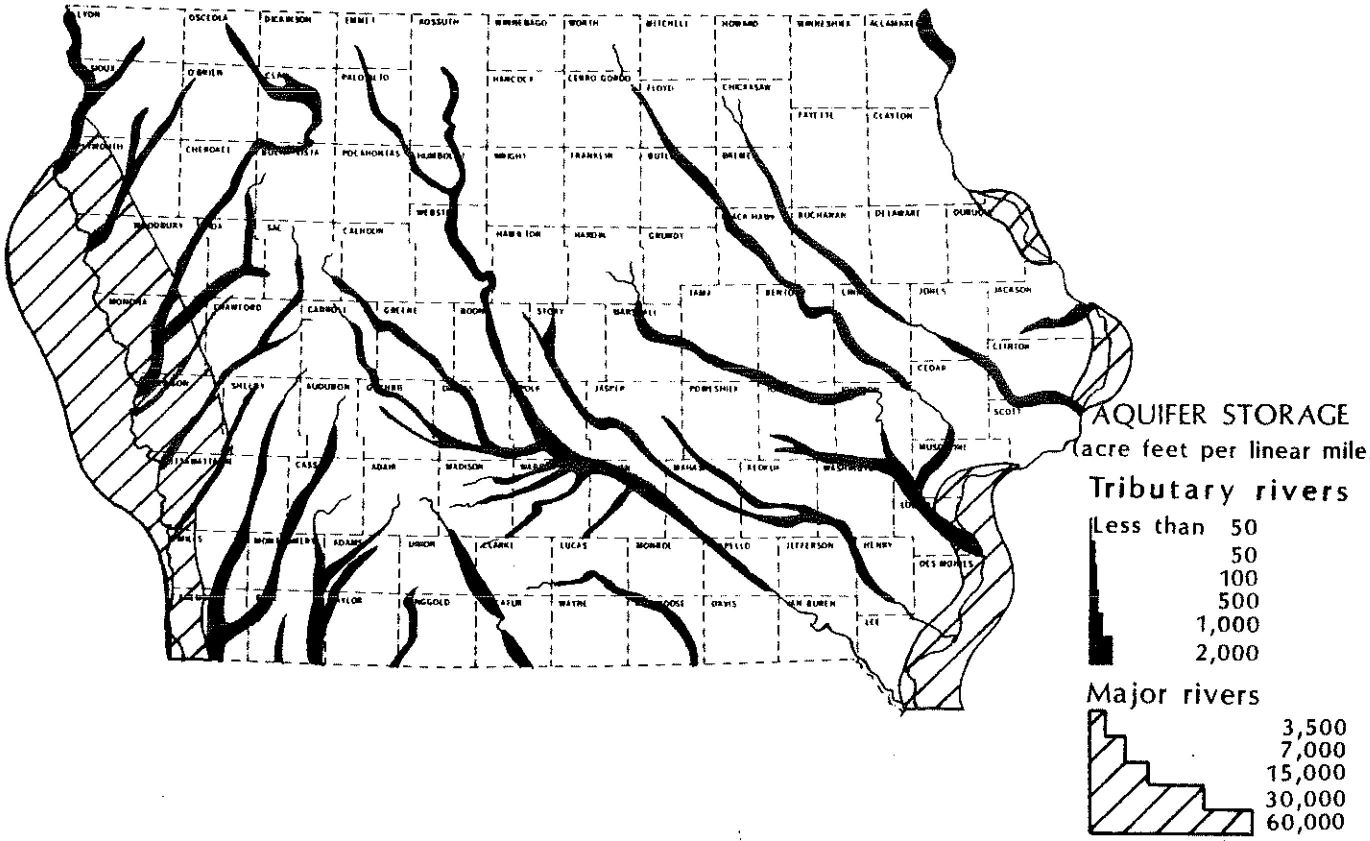


Figure 14. General Location and Capacity of Major Alluvial Aquifers in Iowa.
Source: INRC.

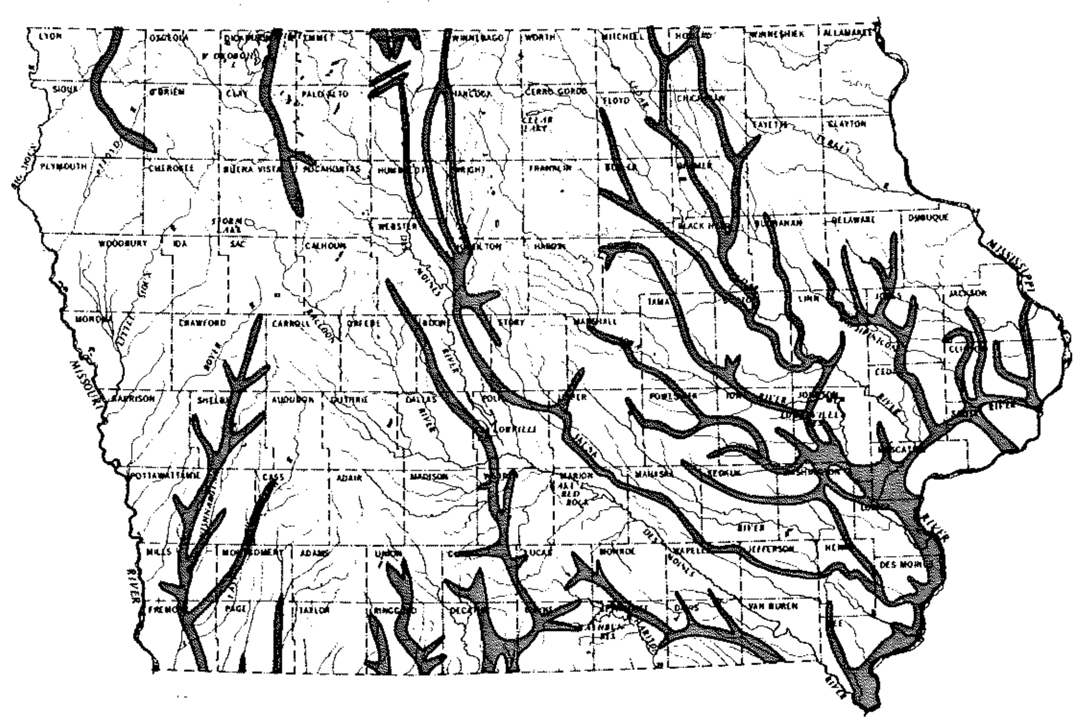


Figure 15. General Location of Major Buried-Channel Aquifers in Iowa.
Source: INRC.

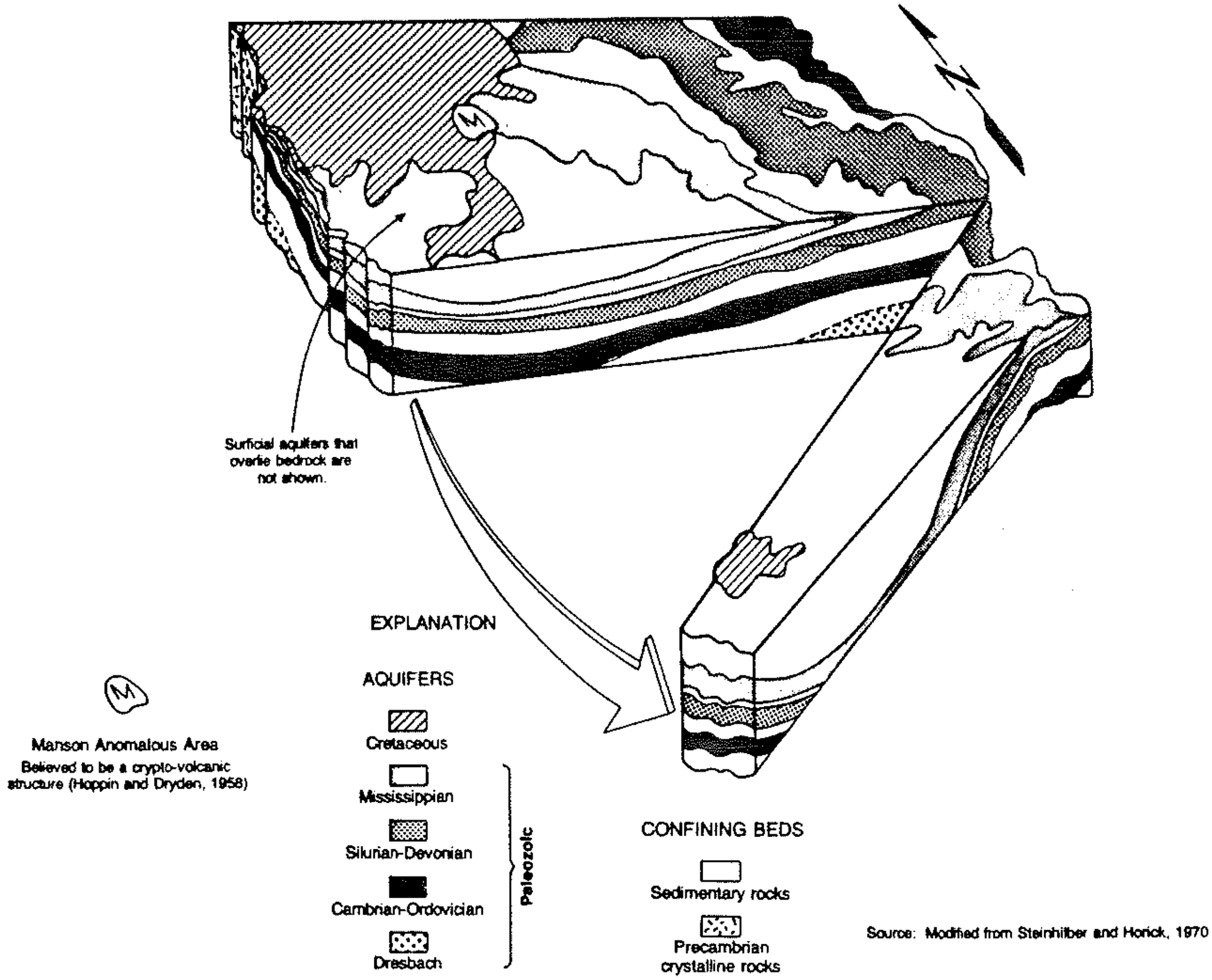


Figure 16. Generalized Geologic Cross-Section of the State of Iowa Illustrating the Major Bedrock Aquifers Utilized in the State.

er yields and quality occur in the northern sections of the aquifer and decline towards the south. The local influence of buried channel and alluvial aquifers also affects water availability in the Dakota.

Until recently the Dakota has primarily been utilized for rural and municipal water needs. In the 1970's withdrawal increased due to irrigation, creating some concern regarding the long-term stability of water levels in the formation.

2. Mississippian Aquifer. This aquifer is found underneath about 60 percent of Iowa. It is located near the surface in an area from the north-central to southeastern part of the state. This is the principle recharge area. Because of this recharge zone and proximity to the surface, there is a higher than normal potential for contamination of the aquifer to occur in this area. Utilization of the aquifer for private, municipal and industrial supplies is high in the area of recharge. Both quality and quantity decline towards the southwest.

3. Silurian-Devonian. This aquifer is composed of dense limestones and dolomites which do not store

or transmit large quantities of water. However, fractures and solution cavities in the rock allow for water storage. This characteristic is variable, and local water availability from this aquifer is dependent on the quality of the bedrock.

Overall water availability and use is highest in eastern Iowa where the aquifer outcrops, or is near the surface. The most productive area is along the Cedar River valley from Waterloo to Charles City. Water quality is generally acceptable in this region, but deteriorates to the south and west.

Water quality in the northeastern sections of the aquifer may be threatened by karst topography and a thin layer of glacial drift. Sinkholes present in the karst provide direct entry of contaminants into the aquifer. Even in the absence of sinkholes, the thin mantle of glacial drift in this part of the state is frequently insufficient to prevent leaching of contaminants into the aquifer.

4. Cambrian-Ordovician Aquifer. This aquifer is present throughout the state with the exception of the extreme northeast and northwest. It is commonly referred to as the Jordan aquifer, the principal water-bearing unit in the system. The Cambrian-Ordovician aquifer is one of the most dependable sources of groundwater in Iowa and is utilized by a large number of municipalities and industries.

   The porosity of the aquifer, and hence its water-bearing capacity, decreases towards the southwest. Depth to the aquifer also increases in this direction. Water quality is highest in the northeast, declining towards the west and south.

   Because of the artesian pressure of the aquifer, wells drilled into this system show a water level in the well casing above the top of the aquifer. This occurs in all confined aquifers. Since the 1880's this level in the Cambrian-Ordovician has dropped 150 to 200 feet in some sections of central and eastern Iowa. This decline is greatest near major withdrawal points. The present rate of decline is four to six feet per year at major pumping centers. The long-term effect of this change may require the deepening of wells.

What Determines Groundwater Availability?

Groundwater-bearing strata constantly have water moving through them. This rate of movement is relatively slow, ranging from several feet per day to only a few feet per year. Movement is caused by water entering the aquifer in recharge zones and leaving it in discharge zones.

The availability of water from a well is dependent on several factors.

1. Type of Deposit. There is considerable variation in water yield between different aquifers, as well as between different locations within an aquifer. However, where large volumes of water are required, wells often are constructed into either deep bedrock or alluvial aquifers. Glacial drift aquifers generally do not yield large volumes of water for sustained withdrawals. Wells tapping glacial drift aquifers usually supply smaller users such as farms and single family households. Wells constructed for large industrial or municipal withdrawals are usually

located in the alluvial deposits of rivers or in the higher yielding bedrock aquifers.

2. Size of Deposit. Many glacial drift and smaller alluvial aquifers have a limited recharge area, and thus limited capacity to produce water in a well.

3. Rate of Recharge. The upper glacial drift and alluvial aquifers are dependent on precipitation and streamflow for recharge, respectively. If either one of these factors declines over an extended period, water availability to the aquifer is decreased. Rate of recharge in bedrock aquifers, and thus long-term availability, is limited by the size of the recharge zone. The rate of recharge can be increased, and usually is increased, by withdrawal of water from an aquifer. This **induced recharge** occurs as groundwater systems try to reach equilibrium. For example, as water is withdrawn from an alluvial aquifer more water moves into the aquifer from the adjacent stream.

4. Rate of Withdrawal. The total withdrawal from an aquifer, from either one or several wells, can affect water availability. When water is withdrawn from a well the water level in and around the well is lowered. This lowering decreases with distance away from the well, and the resulting configuration in the groundwater level is called a **cone of depression** (Figure 17). Withdrawal above the recharge rate will increase the size of this cone. Continued withdrawals beyond the rate water flows towards a well can eventually result in the water level declining to the bottom of the well. This cone of depression effect and subsequent lowering of water levels in wells is also called **drawdown. Well interference** occurs when the cone of depression from one well intersects with that of another well. The result is cumulative effect, lowering the water level over a larger area than each individual well effect (Figure 18).

Groundwater Availability Issues

There is much discussion and a variety of opinions regarding the long-term availability (and thus utilization) of groundwater. Several terms have been introduced into such discussions, often clouding the basic facts regarding availability. These include "safe yield", "overdraft" and "groundwater mining".

Safe yield refers to pumpage that can be sustained at equilibrium with no long-term decline in water levels. In other words, withdrawal would not exceed recharge.

Withdrawals in excess of this **safe yield**, or recharge rate, is often referred to as **groundwater mining**, or **overdraft**. This is the depletion of water in the aquifer (usually in reference to bedrock aquifers), and resulting decline in water levels.

Two problems associated with changes in groundwater levels are, a) water levels in wells, and b) total water available in the aquifer. Decreased water levels may require wells to be deepened or a new water source sought. Total water in an aquifer is associated with long-term availability and is often related to economic issues. Limiting withdrawals to a supposed "safe yield" rate may not be economically feasible to existing users.

Where is Groundwater Available?

Unconsolidated glacial drift aquifers are present in most areas of Iowa,

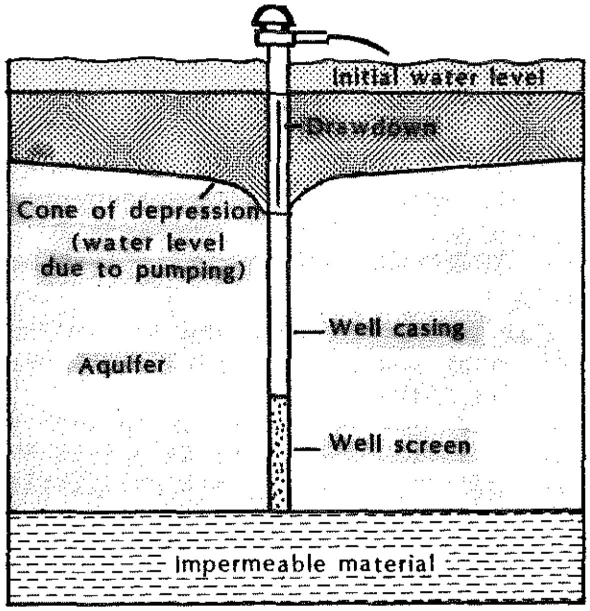
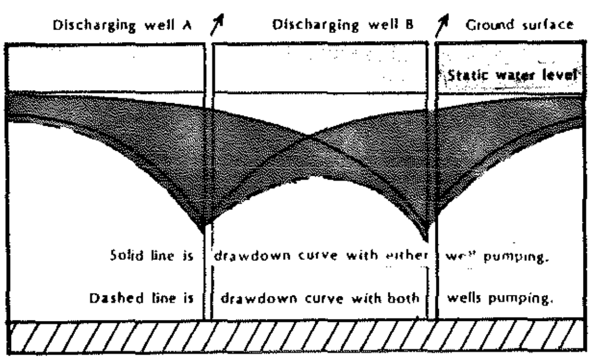


Figure 17. The Effect of Pumping on Water Levels in an Aquifer.

Figure 18. Well Interference Effect When Two Wells Drawing From the Same Source.



with the best yielding wells found in the north central region. This is the area last covered by glaciers. Alluvial and buried-channel aquifers are more limited in area, but can usually supply moderately large withdrawals. Some of the largest industrial and municipal withdrawals occur from the alluvium along the Mississippi and Missouri Rivers.

The most productive areas for the major bedrock aquifers are located in eastern Iowa. In this area the aquifers are located near the surface and the principal recharge areas. Yields and utilization for each of the major aquifers are highest in those areas at or near the recharge area. To the south and west the bedrock aquifers are located deeper, yields are lower, and quality declines. Table 3 briefly outlines water availability from each aquifer.

<u>What Determines Groundwater Quality?</u>

Several factors affect groundwater quality.

Table 3. Location and Yield of Major Aquifer Groups in Iowa.

Aquifer Type	General Location	Average Yield Range (gal./min.)
Glacial Drift	Small, shallow deposits scattered throughout the state	5-10 in north 1-5 in south and west
Alluvium	Along floodplains of streams, larger aquifers and high yields along larger streams	20-500 interior streams 1000+ along border rivers
Buried Channels	Scattered locations, more in eastern two-thirds of state	100-500
Dakota	Northwest and west central	100-500
Mississippian	In a line from Keokuk to north central part of state, best yields in north central region	10-500
Silurian-Devonian	Northeastern one-third of state has best yields, absent in small parts of northeast and northwest	100-500
Cambrian-Ordovician	Most productive wells in northeast and central sections of Iowa, absent in extreme northeast and northwest	300-1000

1. Surface Activity. Even in the absence of human action, material is dissolved and moved into the groundwater system. Changes in use can affect the type and rate of material moving into the groundwater. Septic tanks, landfills, spills and accepted agricultural practices can influence what moves into aquifers (Figures 19 and 20).

2. Soil Type. Soil and natural bacteria are effective in removing or changing the character of materials deposited at the land surface. Differences in this filtering ability occur, with clay soils being a better barrier to infiltration than sandy or more coarse grained soils.

3. Depth to Aquifer. Generally the deeper the aquifer, the more protection is afforded from surface contamination. Glacial and alluvial aquifers are the least protected. Some of the bedrock aquifers, however, are susceptible to contamination near their recharge areas.

4. Rate of Water Movement. Where water is slow to enter or move within an aquifer, the potential for serious widespread contamination is reduced. Increased water withdrawal from an aquifer can hasten contaminant movement, as water moves towards a well to replace that water withdrawn. This can increase the rate of recharge, and thus the movement of water and contaminants from the surface or other recharge source.

Iowa's groundwaters have the potential of being affected by several types of activities. Among the more common threats to groundwater quality are the following.

1. Uncontrolled dumps
2. Spills
3. Landfills
4. Wastewater impoundments
5. Drainage wells
6. Improperly abandoned wells
7. Agricultural fertilizers and chemicals
8. Animal wastes
9. Leaking underground storage tanks
10. Septic tanks.

What is the Quality of Groundwater?

A recent survey of Iowa's water quality indicated that several specific contaminants of concern are present in the state's groundwaters. These include materials naturally occurring in groundwater and those introduced by human activity. These are outlined in Table 4.

The same report also evaluated water quality within five major regions of Iowa. These regional summaries are provided below.

1. Northeast Iowa. The Iowa Geological Survey has conducted an intensive three-year survey of water quality and land use in this region. The results show that nitrates and pesticides are moving into the shallow groundwater systems and appear directly related to land use. Areas with less than 50 feet of soil overburden or without a confining layer of shale are the most vulnerable to contamination. Over time there has been a steady decline in shallow water quality.

2. East-Central and Southeast Iowa. Quality of water from the bedrock aquifers is fair, with most severe problems in the southeast due to high levels of dissolved minerals. Highest quality waters are from shallow alluvial systems and surface waters.

KARST TOPOGRAPHY AND SINKHOLES

Water, even rainwater, readily combines with carbon dioxide (a major component of the air) to form a weak carbonic acid. Within the ground this slightly acidic water is capable of dissolving limestone and dolomite bedrock material. This slow solutioning has produced cavities and channels in the bedrock. A landscape which reflects the irregularities caused by solutioning is called karst topography, and is common in parts of the Ordovician and Silurian strata of northeastern Iowa. Sinkholes form where such solution cavities cause the top of the bedrock to collapse, thus no longer supporting the mantle of glacial till or loess.

Although not presenting the only route for contamination to a groundwater aquifer, sinkholes do increase this potential. Direct drainage from the surrounding landscape may enter the aquifer at such points. The greater concern is that sinkholes are symptomatic of a thin glacial drift and loess layer, which over a large area provides minimal protection of the groundwater aquifer.

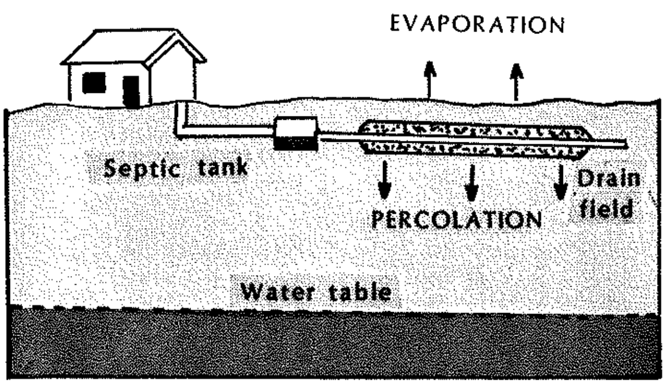


Figure 19. Septic Sytems Can Affect Groundwater if Inadequate Distance Does Not Allow Bacterial Action and Absorption to Remove Contaminants.

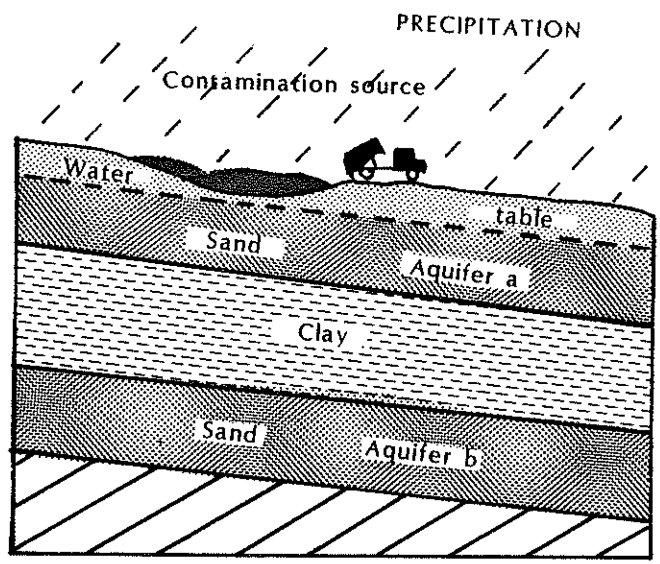


Figure 20. Soil Type and Depth to Aquifer Can Affect the Potential for Aquifer Contamination From Landfills. Aquifer B is Better Protected Than A.

3. North-Central Iowa. Bedrock aquifers produce good quality water. Nitrates and pesticides are beginning to enter shallow groundwater systems via infil tration and agricultural drainage wells. Water from some Cambrian-Ordovician wells contains radium above standards.

4. Northwest Iowa. Water from the Dakota aquifer is of fair to poor quality, with water from the deeper bedrock generally poor. Shallow groundwater systems may be impacted by agricultural activities.

5. Southwest and South-Central Iowa. Natural bedrock water quality is fair to poor, with many sources providing water unsuitable for human consumption. Highest water quality is from alluvial and surface systems.

WATER QUALITY AND USE

Water quality has a direct effect on the potential value of water for specific uses. Treatment may not always be possible, practical or economically feasible. Thus, water quality is often as much a consideration as quantity for a user developing a new water source. Characteristics of particular concern for three types of users are listed.

Domestic Water Supply	Agriculture	Industry
Taste	Dissolved Solids	Dissolved Solids
Odor	Sodium:Calcium Ratio	Hardness
Hardness	Alkalinity	pH
Nitrate	Nitrate	Alkalinity
Iron	Sulfate	Acidity
Fluoride		Sediment
Toxic Contaminants		

Table 4. Contaminants of Major Concern in Groundwater Aquifer Systems in Iowa.

Contaminant	Description and Significance of Problem	Source
Bacteria	Pathogenic bacteria usually eliminated by soil; presence in groundwater indicative of contamination; can cause water-borne disease	Improperly constructed or abandoned wells, sinkholes or drainage wells
Nitrates	Highly soluble in water; levels increasing in shallow aquifers; high concentrations can affect health of infants; general indicator of groundwater contamination	Low level natural concentrations; plus septic tanks and fertilizers, agricultural fertilizers suspected as principle cause for increasing concentrations
Fluoride	Beneficial in low concentrations; excessive levels can cause fluorosis, including mottling of teeth in children	Natural constituent; concentration above standards in some bedrock aquifers especially to the south and east
Sodium	High levels may be detrimental to individuals on sodium-restricted diets; sodium combined with potassium may cause foaming in boilers	Natural concentrations; high in some bedrock aquifers in southeast and southcentral Iowa
Radioactivity	Natural levels of Radium 226 and 228 are above water quality standards; effect and significance not fully known; potential health hazard	Radioactive compounds naturally occur in some deeper bedrock formations, especially in the south
Dissolved Solids	High dissolved solids can affect taste, aesthetics and economic value of water	Deeper bedrock formations have natural high levels of soluble salts that are leached by groundwater