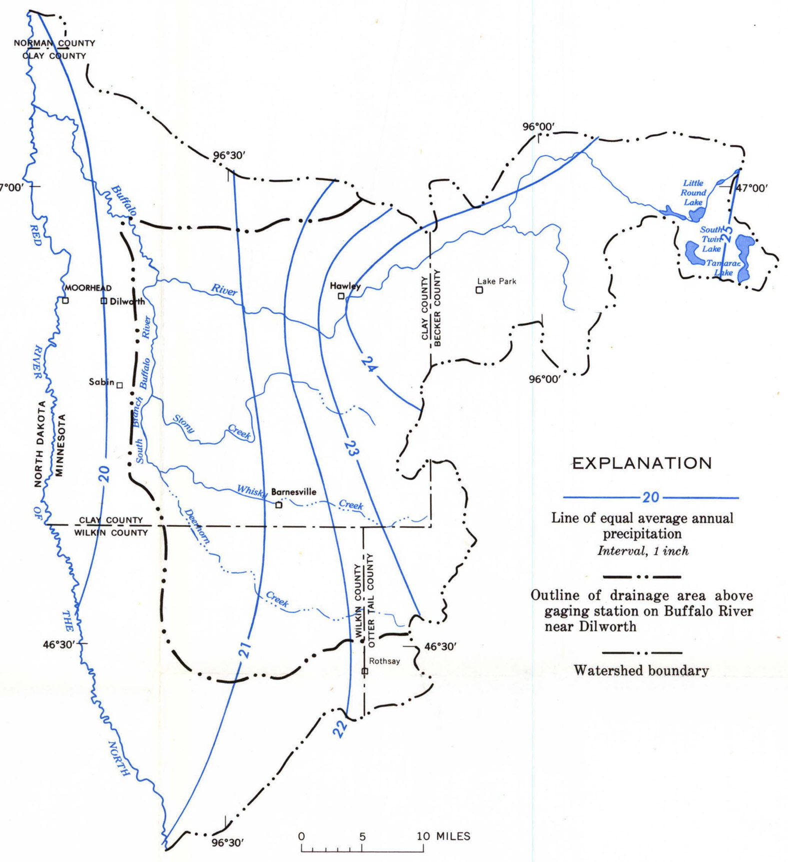
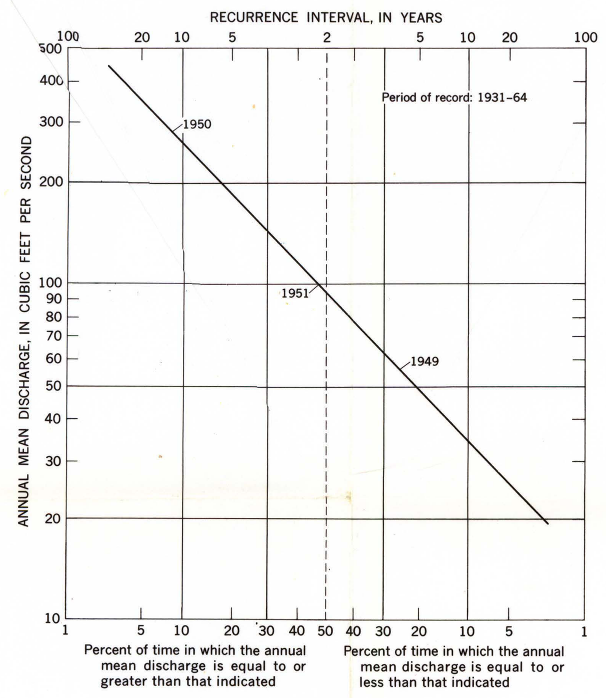
PREPARED IN COOPERATION WITH
THE MINNESOTA DEPARTMENT OF CONSERVATION
DIVISION OF WATERS, SOILS AND MINERALS

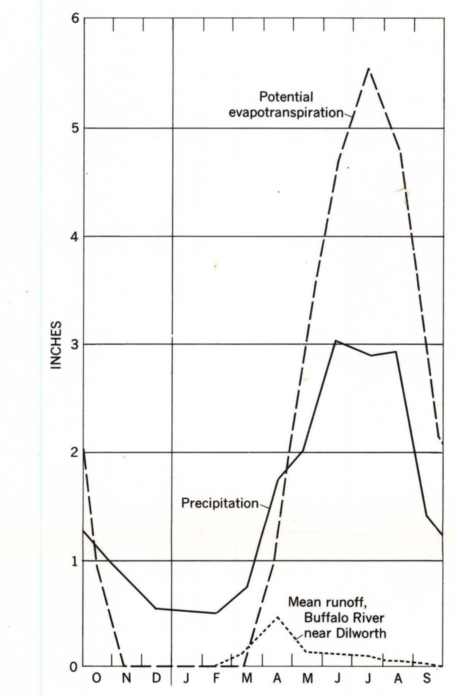
CLIMATE AND WATER YIELD



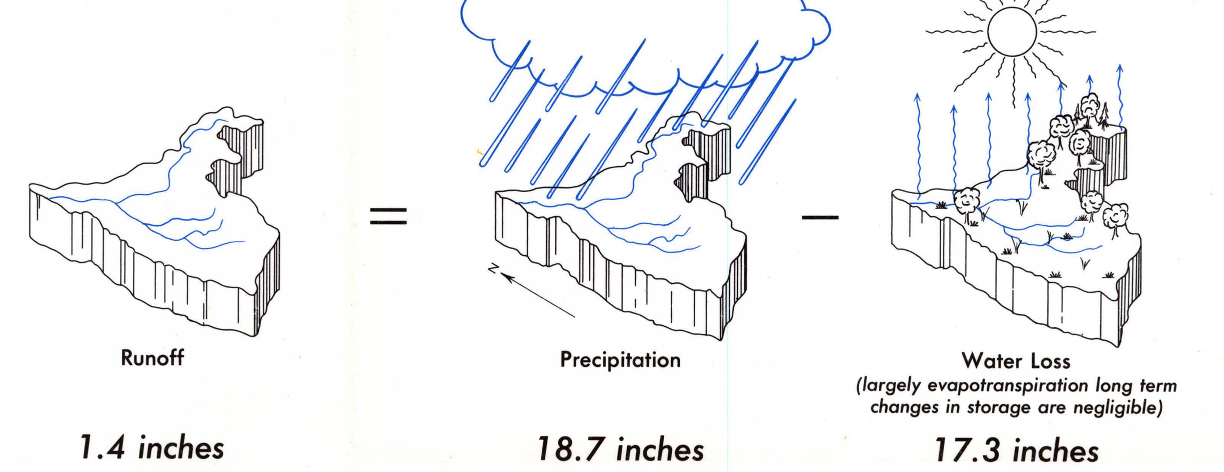
AVERAGE ANNUAL PRECIPITATION RANGES FROM ABOUT 20 INCHES NEAR THE RED RIVER OF THE NORTH TO 25 INCHES AT THE EASTERNMOST EXTREMITY OF THE WATERSHED.—*The climate of the watershed is characterized by cold winters and hot summers. Rainfall during the summer months is largely from thunderstorms, and generally is adequate for crops. Average seasonal snowfall is about 40 inches. The drainage basin of the Buffalo River near Dilworth was used in the estimation of water yield discussed below.*



FREQUENCY DISTRIBUTION OF ANNUAL MEAN DISCHARGE OF THE BUFFALO RIVER NEAR DILWORTH SHOWS THAT A YEARLY DISCHARGE OF ABOUT 90 CUBIC FEET PER SECOND CAN BE EXPECTED TO OCCUR ON AN AVERAGE OF ONCE EVERY 2 YEARS.—*The water yield was estimated for the 3 water years shown on the graph. They were selected because of the wide range of yearly discharge occurring for these 3 consecutive years.*

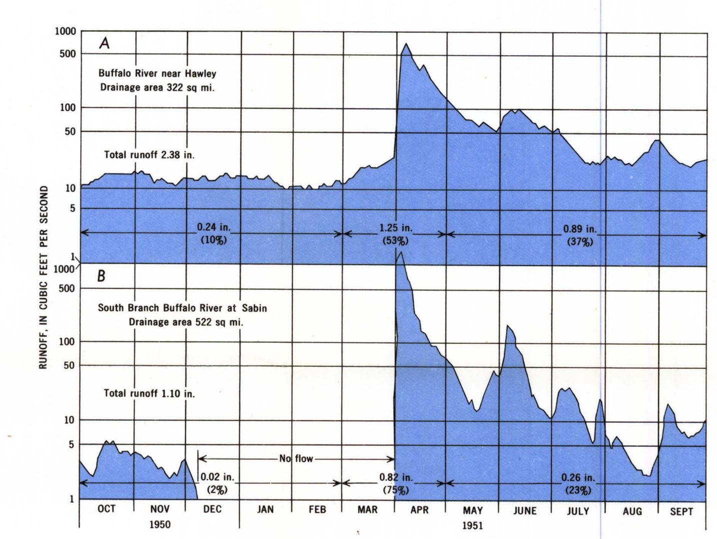


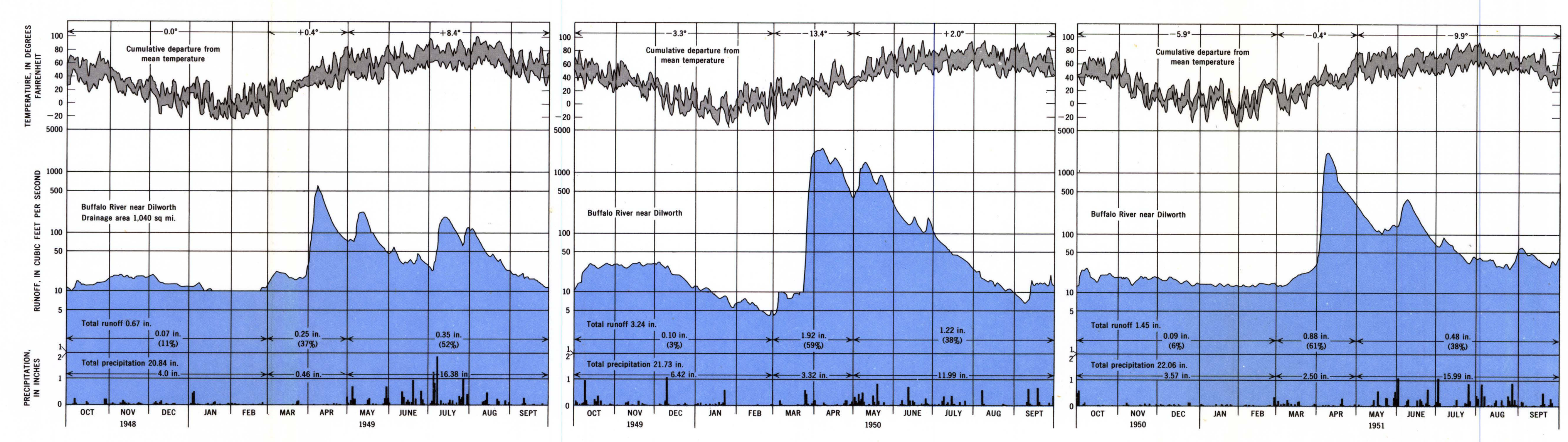
THE MONTHLY AND SEASONAL VARIATIONS AND RELATIONSHIPS BETWEEN PRECIPITATION, RUNOFF AND EVAPOTRANSPIRATION CAN BE DETERMINED FROM THE GRAPH.—*Average potential evapotranspiration is estimated to be more than 2 inches greater than the average precipitation for the month of July. Mean runoff is greatest for the month of April—being over twice as much as for any other individual month. The estimation of potential evapotranspiration was computed by the method described by Thornthwaite and Mather (1957). It is based on the monthly precipitation and mean temperature for the month.*



MOST OF THE ANNUAL PRECIPITATION IS RETURNED TO THE ATMOSPHERE BY EVAPOTRANSPIRATION DURING THE GROWING SEASON

The remainder of the precipitation is eventually discharged by streams from direct runoff or release from the ground-water reservoir. For the period from 1931 to 1965 the annual mean runoff for the Buffalo River near Dilworth was about 1.4 inches (78,000 acre-feet). The yearly runoff ranged from about 0.3 inch (18,550 acre-feet) in 1934 to 5 inches (277,000 acre-feet) in 1962—the ratio between the low and the high year being about 1 to 15. This variation is dependent largely upon weather conditions during the fall and spring. Evapotranspiration rate, which is dependent largely upon temperature, results in most precipitation being returned to the atmosphere during the summer.

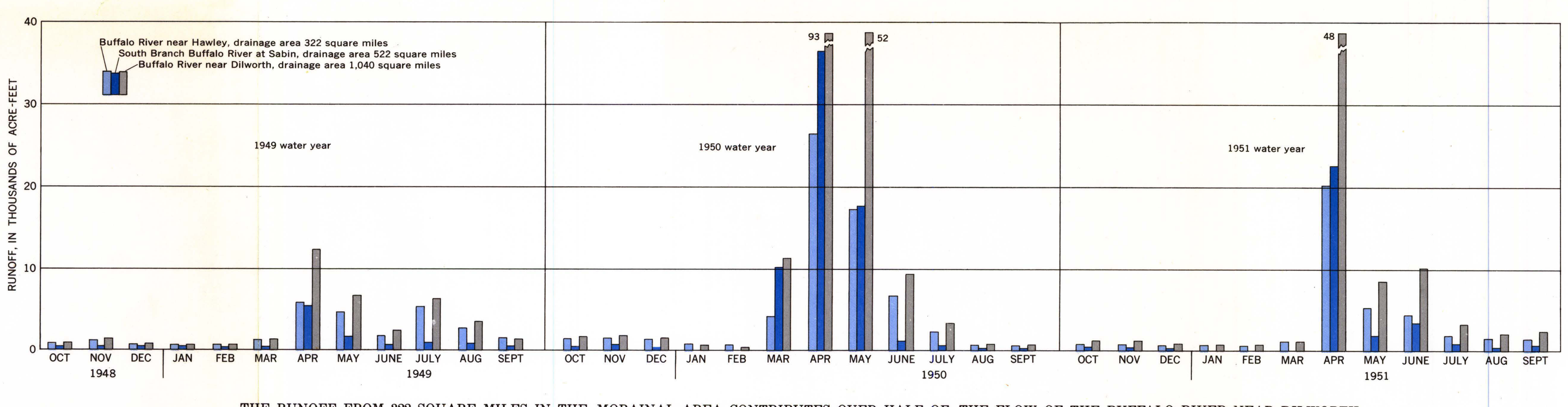




RUNOFF IN THE 1949 WATER YEAR WAS LOW BECAUSE THE PRECIPITATION WAS BELOW NORMAL DURING THE EARLY SPRING MONTHS.—*Although summer precipitation was greater than the average, runoff was less than normal for these months because of greater evapotranspiration losses resulting from higher temperatures.*

RUNOFF IN THE 1950 WATER YEAR WAS HIGH AS A RESULT OF GREATER AVAILABILITY OF WATER FOR RUNOFF DUE TO ABOVE NORMAL PRECIPITATION AND MOISTURE ACCUMULATION DURING THE FALL, AND ABOVE NORMAL PRECIPITATION DURING THE SPRING WHEN EVAPOTRANSPIRATION IS LOW.—*Precipitation during the summer resulted in little direct runoff to streams and nearly all the rain during July and August was lost to evapotranspiration.*

RUNOFF IN THE 1951 WATER YEAR WAS NEAR NORMAL BECAUSE OF ABOUT AVERAGE MOISTURE ACCUMULATION DURING THE FALL AND WINTER AND ABOUT NORMAL SPRING PRECIPITATION.—*Within the drainage area the runoff characteristics of the streams differ from a moderately variable discharge having a sustained base flow for the Buffalo River near Hawley (See hydrograph A) to a more variable discharge having periods without flow for the South Branch Buffalo River at Sabin (See hydrograph B). The difference in runoff characteristics results from differences in topography and geology between the two drainage areas. The Buffalo River near Hawley flows in a well defined valley and drains a lake-dotted, hummocky, morainal area underlain by silty till and scattered sand deposits. The South Branch Buffalo River flows in a shallow channel and drains a flat lake plain underlain by clay and silt.*

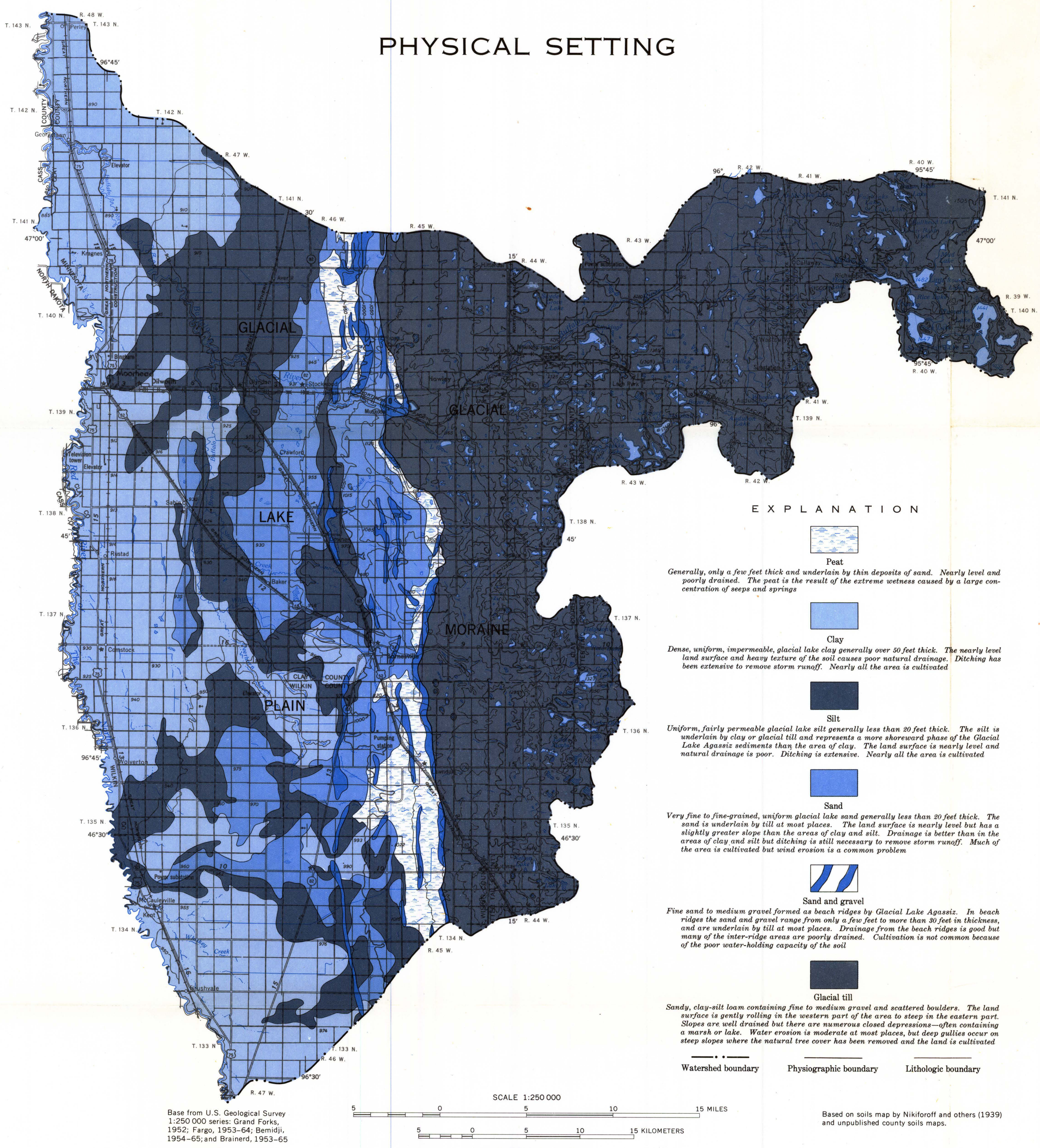


THE RUNOFF FROM 322 SQUARE MILES IN THE MORAINAL AREA CONTRIBUTES OVER HALF OF THE FLOW OF THE BUFFALO RIVER NEAR DILWORTH

However, during the early spring the runoff from the South Branch Buffalo River may considerably exceed that from the morainal area.

Management of runoff from the Buffalo River for large water supply and pollution alleviation would necessitate use of storage, either underground or on the surface. Surface-storage sites are available mostly in the morainal area and underground storage could be developed in the sandy channel deposits that border the South Branch Buffalo River north of Sabin. The Buffalo River has been suggested as a source for recharge of the channel aquifer in the vicinity of Dilworth near the Moorhead municipal wells.

PHYSICAL SETTING



THE BUFFALO RIVER WATERSHED INCLUDES TWO GENERAL PHYSIOGRAPHIC AREAS—A GLACIAL LAKE PLAIN AND A GLACIAL MORAINE

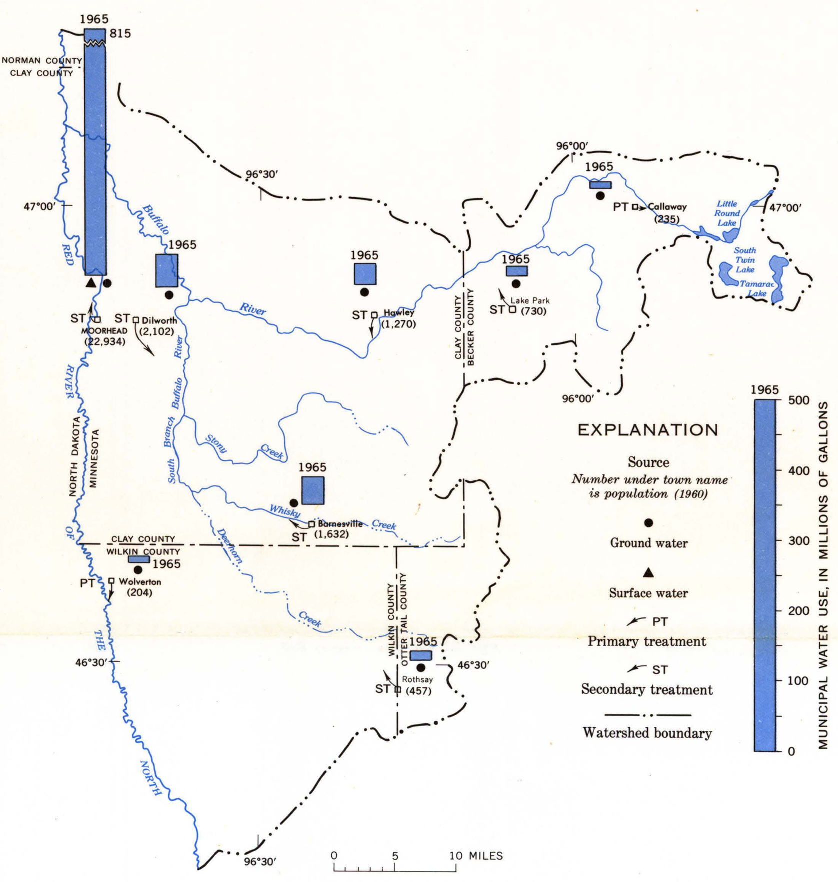
The lake plain, which was formed by Glacial Lake Agassiz more than 9,000 years ago, is extremely flat—sloping only a few feet per mile westward near the Red River of the North. The moraine is largely an area of gently rolling hills, but in the eastern "tail" of the watershed the relief locally is over two hundred feet.

The watershed has an area of about 1,690 square miles and includes most of Clay County and parts of Wilkin, Otter Tail, Becker, and Norman Counties. The population of the area is about 45,500—31,000 urban and 14,500 rural.

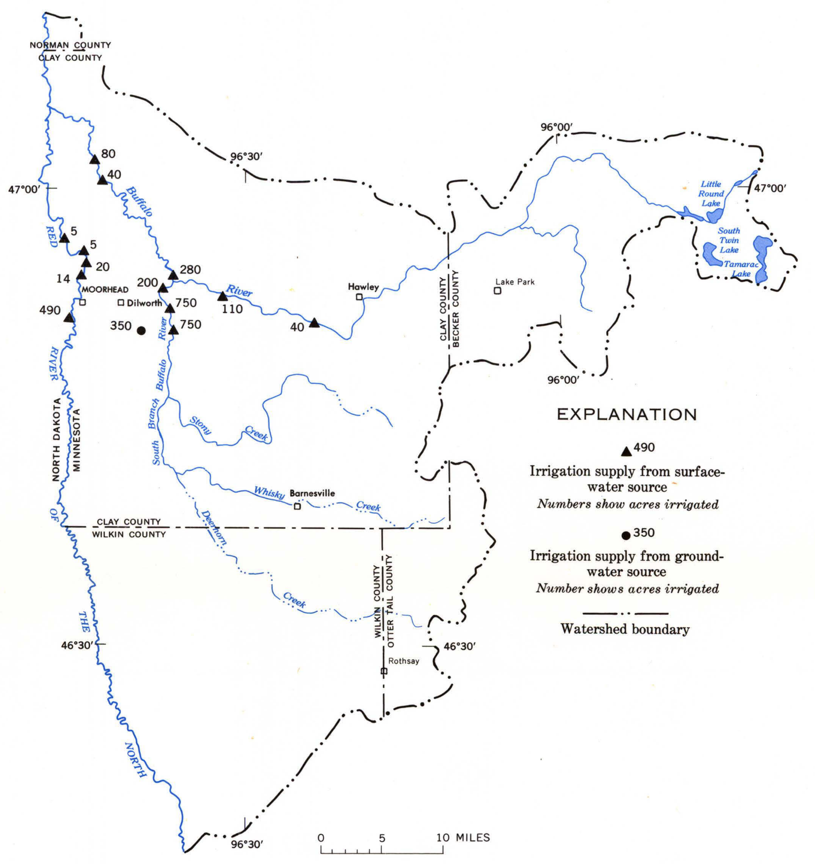
The economy is largely agricultural. Sugar beet and wheat farming are dominant in the areas of clay and silt; potato farming is confined mainly to the sandy areas. Dairying and stock raising is important in the morainal area. The larger industries are located in Moorhead and consist of sugar beet, potato, and dairy product processing.

Water-based recreation consists mostly of fishing in the larger lakes in the morainal area and water-fowl hunting in the area of prairie potholes—the western part of the morainal area.

WATER USE AND SUMMARY



ALL THE MUNICIPALITIES IN THE WATERSHED OBTAIN WATER FROM GROUND-WATER SOURCES.—*However, the principal supply for the largest water user, the city of Moorhead, is from the Red River of the North. All municipalities with sewage systems have sewage treatment facilities.*



WATER FOR IRRIGATION OF CROPS IN THE WATERSHED IS OBTAINED LARGELY FROM SURFACE WATER SOURCES.—*Irrigation is practiced mainly in the Moorhead-Dilworth area where the water is obtained from the Red River of the North, Buffalo River, and South Branch Buffalo River. The largest acreages of land irrigated are near the South Branch Buffalo River.*

SUMMARY OF WATER RESOURCES

Purpose	Considerations	Surface water: Red River of the North	Surface water: Buffalo River and major tributaries	Surface water: Lakes and potholes	Ground water: Glacial till	Ground water: Beach ridge aquifer	Ground water: Channel sand aquifer (mapped aquifer A)	Ground water: Buried sand and gravel aquifer (mapped aquifer B)	Ground water: Sand aquifer within till (mapped aquifer C)
Municipal and industrial supply	For a moderate supply, principal needs are: Quantity: Minimum sustained supply of 2 cfs or 900 gpm. Quality: Total dissolved-solids content less than 500 ppm. Hardness less than 180 ppm.	Adequate flow. Additional storage possible in Otter Tail River basin in headwaters. Favorable location—largest city and industries located near river. Total dissolved solids less than 500 ppm above Moorhead. ——— At low flow hardness is greater than 180 ppm. Purification necessary.	Adequate flow in main stem of Buffalo River except in extreme droughts. Storage possible in headwaters. Total dissolved solids less than 500 ppm in main stem, but may be higher in South Branch Buffalo River. ——— Inadequate flow in South Branch without storage. At low flow hardness is greater than 180 ppm. Purification necessary.	Large lakes adequate for limited use. Additional storage possible in lakes with adequate inflow. Total dissolved solids mostly less than 500 ppm. ——— Hardness is greater than 180 ppm. Purification necessary. High evaporation loss.	Till contains local aquifers which are adequate sources of water supply for small municipalities in the watershed. ——— To locate a source of supply, considerable test drilling may be necessary. An aquifer may be located at considerable distance from the place of water use. Hardness is generally greater than 180 ppm.	——— Generally not an adequate supply. Limited areal extent.	Adequate for small communities. Yields to individual wells would be greater than 100 gpm. Large storage capacity of aquifer is available for water management by artificial recharge from nearby streams. ——— Much additional information is needed on hydrologic characteristics of the aquifer to adequately determine its capacity for use as a large supply. Hardness is generally greater than 180 ppm.	Adequate for moderate supply. Yields to individual wells would probably be several hundred gpm. Aquifer is undeveloped. ——— Hardness is generally greater than 180 ppm. Water contains much sulfate. More information needed to determine maximum yields.	Potential yield to individual wells over 100 gpm in some places. ——— Water level decline in wells near Moorhead indicates that the local aquifers can be overdeveloped by continuous pumping at high rate. Overdevelopment is particularly possible where the till is covered by lake clay. Hardness is generally greater than 180 ppm.
Rural, domestic and stock supply	For an adequate farm supply, needs are: Quantity: About 5 gpm or more. Quality: Total dissolved-solids content less than 1,000 ppm.	Adequate flow. Suitable quality. ——— Available only to riparian lands. Treatment necessary for domestic use.	Adequate flow in main stem and many tributaries except South Branch Buffalo River (see disadvantage). Suitable quality. ——— Available only to riparian lands. No flow in South Branch Buffalo River most winters. Treatment necessary for domestic use.	Most are adequate for stock. Additional storage possible in lakes with adequate inflow. Suitable quality. ——— Available only to riparian lands. Many small lakes and potholes dry up during extreme droughts. Limited inflow in most small lakes and potholes. Treatment necessary for domestic use.	Sand lenses that yield more than 5 gpm to individual wells can be found at most places in the area. ——— Hardness is generally greater than 180 ppm.	Most ridges contain sufficient water for yields of 5 gpm or more to individual wells. ——— Lower beach ridges are unreliable sources of water. Hardness is generally greater than 180 ppm.	Yields in excess of 5 gpm from small diameter wells. ——— Hardness is generally greater than 180 ppm.	Yields in excess of 5 gpm from small diameter wells. ——— Hardness is generally greater than 180 ppm.	Yields in excess of 5 gpm from small diameter wells. ——— Hardness is generally greater than 180 ppm.
Irrigation supply	For an average farm, needs are: Quantity: Minimum flow of 2 cfs during growing seasons or wells yielding 250 gpm or more. Quality: Total dissolved-solids content less than 2,000 ppm. Suitability of water quality for irrigation as indicated by classification of U.S. Dept. of Agriculture.	Adequate flow using water released from storage. Additional storage possible in Otter Tail River basin in headwaters. Suitable quality. ——— Restricted to riparian lands.	Adequate for small acreage during years of normal wetness. Additional storage possible in headwaters. Suitable quality. ——— Restricted to riparian lands.	A few large lakes in headwaters are a source for small acreage during years of normal wetness. Additional storage possible in lakes with adequate inflow. Suitable quality. ——— Restricted to riparian lands. Limited inflow in most small lakes and potholes. High evaporation loss.	Quality of water is generally suitable outside of Lake Plain. ——— Test drilling is usually required to find lenses that would yield 250 gpm to individual wells. Quality of water may not be suitable for irrigation at some places in the Lake Plain.	Suitable quality. ——— Many of the smaller and moderate size ridges will not yield sufficient water to wells for an irrigation supply. Limited areal extent.	Adequate for most irrigation supplies. Water for irrigation has been pumped from open pits. ——— Yields of different wells may range considerably owing to variations in permeabilities of materials within the aquifer.	Adequate for most irrigation supplies. Yields to individual wells would probably be several hundred gpm. ——— Aquifer underlies a poorly drained area for the most part. Quality of water indicates that a salinity hazard is possible on wetlands.	Potential yield to individual wells over 100 gpm in some places. ——— Test drilling would be required to find parts of the aquifer that would yield several hundred gpm to individual wells. Quality of water may not be suitable for irrigation.
Hunting, fishing and other recreation	Adequate cover for wildlife habitat is provided by: Wetlands—potholes or lakes surrounded by marsh areas. Streams which have woodland marsh areas along banks. Adequate depth and quality of water for fish in lakes and streams. Adequate availability and access to areas suitable for hunting, fishing and other water sports. Available resorts and lake cottages. Aesthetic considerations: Absence of odors. Sightliness. Attractive physical setting. Absence of pollution.	Some waterfowl resting and feeding areas along river. Fair fishing conditions. Public access at some sites. Good habitat along banks. Boating in pool above Moorhead. Favorable location with respect to population. Suitable water quality. ——— Occasional high water. Aesthetic considerations generally fair although poor below Moorhead.	Some waterfowl resting and feeding areas along streams. Fair fishing conditions. Public access at some sites. Good habitat along banks. Favorable location with respect to population. Suitable water quality. ——— Aesthetic considerations generally poor to fair.	Excellent migratory waterfowl nesting, resting and feeding areas. Many wetland game management and hunting areas. Large lakes good for fishing and water sports. Favorable location with respect to population. Lakeshore resorts and cottages on large lakes. Suitable water quality. Aesthetic considerations generally good for large lakes. ——— Some potholes dry up during droughts. Occasional high stages. High evaporation loss.					

EXPLANATION

Good — Fair — Poor

Overall evaluation for purposes and considerations indicated.

Most ridges contain sufficient water for yields of 5 gpm or more to individual wells. — Advantages

Lower beach ridges are unreliable sources of water. Hardness is generally greater than 180 ppm. — Disadvantages

CONCLUSIONS

1. The annual surface runoff of the drainage basin ranges from less than 0.7 inch to more than 3.2 inches and is normally about 1.4 inches. Most of the annual runoff occurs in spring and early summer when evapotranspiration losses are low and soil conditions, such as frozen or saturated soil, are favorable for runoff.
2. All communities in the watershed except Moorhead obtain all their municipal water supply from ground water and their individual usage in 1965 was less than 200 million gallons. Moorhead used about 890 million gallons of water in 1965.
3. Water from the Red River of the North, supplemented by ground water, is used for municipal water supply by Moorhead. The natural flow of the river is inadequate as a dependable source for water supply and pollution abatement in the Fargo, N. Dak.—Moorhead, Minn. area and is increased during low flow by release of stored water in Orwell Reservoir on the Otter Tail River, headwater of the Red River of the North. A plan has been suggested for additional augmentation of low flow in the Fargo—Moorhead area by diversion of water from the Sheyenne River in North Dakota into the Red River of the North above Moorhead.
4. The Red River of the North, Buffalo River, and South Branch Buffalo River are sources of water for irrigation of small acreages. Larger irrigation supplies could be obtained from streams with development of storage reservoirs in the headwaters.
5. The streamflow of the main stem of the Buffalo River is sustained by lake storage in the upper morainal area and by flow from springs in the river valley in the western part of the moraine. Although the tributaries of the South Branch Buffalo River head in the spring discharge area at the western base of the moraine the South Branch Buffalo River has low base flow (no flow most winters), because of poorly defined surface drainage, flat slopes in the lake plain, high evaporation losses and winter freezeup.
6. Flat land surface, small capacity channels and low gradient of channels contribute to flooding along the Buffalo and South Branch Buffalo Rivers in the lake plain. Most of the floods on the major streams occur as the result of snowmelt and spring rains.
7. The frequency of recurrence of the long periods of low flow during the severe drought of the 1930's cannot be adequately defined by the short length of streamflow records in the watershed.
8. The 18 state wetland wildlife management areas and 18 federal waterfowl production areas provide wetlands for maximum wildlife production and excellent hunting opportunities in the lake and pothole area in the watershed. There are some hunting areas along the river banks.
9. Annual evaporation of about 2.2 cubic feet per second per square mile of lake or reservoir surface must be considered in design of storage reservoirs.
10. The moraine is the recharge area for the aquifers within the till below the lake plain. Local discharge areas occur within depressions and valleys within the moraine. Regionally the water moves westward from the moraine toward the lake plain where it is discharged mostly in the area adjacent to the moraine, although some ground water is discharged near the Red River of the North. The regional flow system within the basin is known only generally. To define the complexity of the flow system more data are needed on the extent and permeabilities of the geologic units within the ground-water reservoir.
11. Adequate supplies of ground water for rural and domestic purposes are available throughout the watershed. Large supplies are known to be generally available only from the mapped aquifers. Test drilling is necessary to locate sand and gravel lenses in till capable of yielding large quantities of water.
12. The quality of surface and ground water is generally suitable for most municipal, industrial and agricultural purposes. Ground water is moderately mineralized—dissolved-solids concentration ranges from less than 400 to more than 1,000 parts per million. The water is hard to very hard.
13. Pumpage of ground water in the Moorhead area from 1910 to 1947 lowered water levels in wells tapping sand lenses within the till causing a substantial decrease in well yields. Concern with declining water levels from 1949 to 1960 in the channel sand aquifer resulted in the decision by the city water managers to obtain additional supplies from the Red River of the North. More hydrologic and geologic information is needed to determine the maximum sustained yields of heavily developed aquifers and the feasibility of artificial recharge.

ACKNOWLEDGMENTS

We express our appreciation to the well owners and well drillers in the area for their cooperation in providing data for this study.

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WATER RESOURCES OF THE BUFFALO RIVER WATERSHED, WEST-CENTRAL MINNESOTA

By
R. W. Maclay, L. E. Bidwell, and T. C. Winter

1969