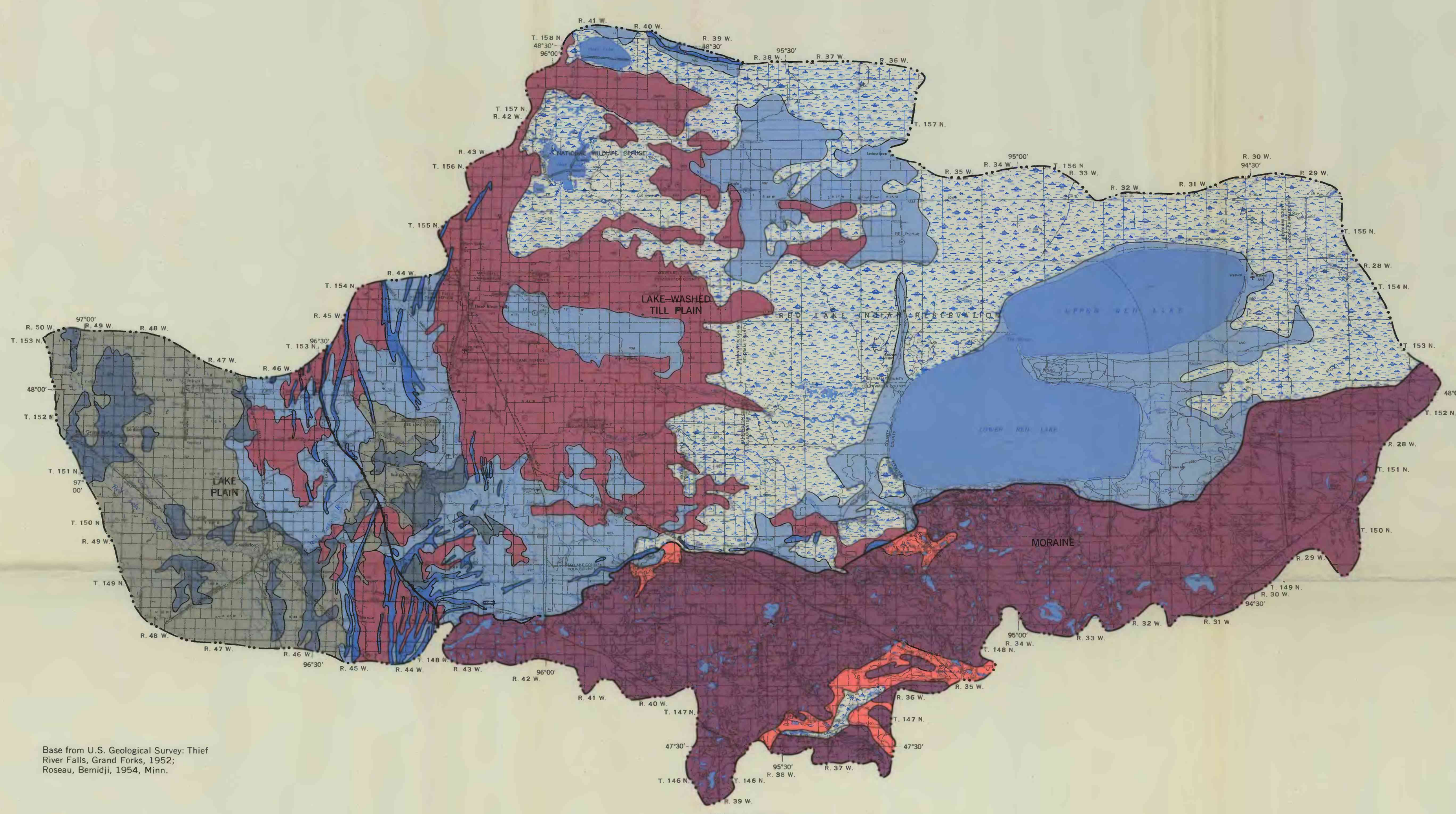
PHYSICAL SETTING AND SUMMARY



EXPLANATION

Clay
Dense, uniform, impermeable glacial lake clay. Thickness ranges from only a few feet in the eastern part to more than 120 feet in the western part. The nearly level land surface and heavy texture of the soil cause poor natural drainage. Ditching has been extensive to remove storm runoff. Nearly all the area is cultivated

Silt
Uniform, fairly permeable glacial lake silt generally less than 20 feet thick. The silt is underlain by clay or glacial till and represents a more shoreward phase of the Glacial Lake Agassiz sediments than the area of clay. The land surface is nearly level and natural drainage is poor. Ditching is extensive. Nearly all the area is cultivated

Sand and gravel (Beach deposits)
Fine sand to medium gravel formed as beach ridges by Glacial Lake Agassiz. The beach deposits range from only a few feet to more than 30 feet in thickness, and are underlain by till at most places. Drainage from the beach ridges is good but many of the inter-ridge areas are poorly drained and ditched extensively. Cultivation is common because of the poor water-holding capacity of the soil

Lake-washed till
Sandy, clay-silt loam containing fine to medium gravel and scattered boulders. The land surface is very gently rolling and the till is overlain in many local low areas by thin deposits of clay, silt, sand, and peat. The area is generally not well drained naturally, and ditching is extensive. Cultivation is common except in the more local areas of peat

Peat
Generally only a few feet thick. Poorly drained. The peat is the result of extreme wetness caused by the water table being at or very near the land surface. Peat also occurs locally in many closed depressions within the moraine

Sand
Very fine to fine-grained, uniform glacial lake sand generally less than 20 feet thick. The sand is underlain by till at most places. The land surface is nearly level but has a slightly greater slope than the areas of clay and silt. Drainage is better than in the areas of clay and silt but ditching is still necessary to remove storm runoff. Much of the area is cultivated but wind erosion is a common problem

Sand and gravel (Outwash deposits)
Fine sand to medium gravel formed as glacial outwash or ice-contact features. Thickness of the sand and gravel ranges from a few feet to nearly 100 feet. The topography is hilly except in the stream valleys which are quite flat. The water table is high in the stream valleys and areas of peat are common. Where the soil is better drained on the hillsides, it tends to be droughty. A few areas are farmed but the land is better suited to forestry

Glacial till
Sandy, clay-silt loam containing fine to medium gravel and scattered boulders. The land surface is gently rolling in the western part of the area to very hilly in the central and eastern parts. Slopes are well drained but there are numerous closed depressions, often containing a marsh or lake. Water erosion is moderate at most places, but deep gullies occur on steep slopes where the natural tree cover has been removed and the land is cultivated

Soils boundary

Physiographic boundary

Watershed boundary

THE RED LAKE RIVER WATERSHED INCLUDES THREE GENERAL PHYSIOGRAPHIC AREAS—THE GLACIAL MORAINE, GLACIAL LAKE-WASHED TILL PLAIN, AND GLACIAL LAKE PLAIN.

The moraine is an area of hills and depressions that has local relief up to 150 feet. The lake-washed till plain is a flat to very gently rolling area that has local relief up to 15 feet. The lake plain is extremely flat in the western part, sloping only a few feet per mile, but in the eastern part the slope increases and is traversed by north-south trending, long, narrow beach ridges up to 20 feet high. Altitude of the land surface ranges from about 800 feet above mean sea level where the Red River flows north out of the area to over 1,600 feet in the south-central part of the watershed.

The area of the watershed is approximately 5,990 square miles and includes all of Red Lake County and parts of Polk, Pennington, Beltrami, Clearwater, Marshall, Mahnomen, Koochiching, and Itasca Counties.

Population of the watershed is about 68,000, approximately 70 percent being rural.

The economy of the area is largely agricultural. The area of lake clay and silt is used mostly for raising sugar beets and wheat. Potatoes are grown on the sandier soils. In the lake-washed till plain west of the peatlands and in the western part of the moraine, farming includes growing small grains, dairying, and cattle raising. Lumbering is the principal occupation east of the Red Lakes and in the eastern part of the morainal area. The Red Lakes are fished commercially by the Indians on the Red Lake Indian Reservation. Industries in the area are small and are based on agricultural processing and service.

Drainage is one of the major water problems in the Red Lake River watershed. Drainage ditch construction, beginning about 1900, resulted in modification of runoff and an increase in agriculture. The most effective system of ditches occurs within the lake plain; many of the ditches in the lake-washed till plain are overgrown with vegetation and are ineffective.

EVALUATION OF WATER RESOURCES

Purpose	Considerations	Surface water: Red River of the North	Surface water: Red Lake River, Upper and Lower Red Lakes and minor tributaries	Surface water: Clearwater River and tributaries	Surface water: Thief River and tributaries	Ground water: Sand lenses within till	Ground water: Beach ridges	Ground water: Outwash and ice-contact sand and gravel
Municipal and industrial supply	For a moderate supply, principal needs are: Quantity 1) Minimum sustained supply of 2 cubic feet per second (cfs) or 900 gallons per minute (gpm). Quality 1) Total dissolved-solids content less than 500 milligrams per liter (mg/l). 2) Hardness less than 180 mg/l.	Adequate flow. Flow partly regulated by reservoirs on upstream tributaries. Additional storage possible. Total dissolved solids less than 500 mg/l at East Grand Forks. ——— Except at high flows hardness is generally more than 180 mg/l at East Grand Forks. Purification necessary.	Adequate flow and supply. Flow in river regulated by outlet dam at Lower Red Lake. Additional storage possible in the Red Lakes. Total dissolved solids mostly less than 500 mg/l. Hardness in lakes mostly less than 180 mg/l. During high discharge from Red Lake hardness in upper reaches of river mostly less than 180 mg/l. ——— At low flow and little lake outflow hardness in river is greater than 180 mg/l. Purification necessary. High evaporation loss in the Red Lakes. Small tributaries dry up during droughts.	Adequate flow in main stem. Storage possible in headwaters. Total dissolved solids mostly less than 500 mg/l. ——— Inadequate flow in minor tributaries. At low flow hardness is generally greater than 180 mg/l. Purification necessary.	Some additional storage possible. Total dissolved solids mostly less than 500 mg/l. ——— Many years no flow in fall and winter. At low flow hardness is greater than 180 mg/l. High evaporation loss in Thief and Mud Lakes (Agassiz Refuge pools).	Some sand lenses within till are adequate sources of water supply for small municipalities and industries. Suitable quality at most places. ——— Test drilling is usually necessary to locate aquifers adequate to supply amounts needed. Aquifer may be located at considerable distance from the place of water use. Hardness is generally greater than 180 mg/l.	——— Generally not an adequate supply. Limited areal extent.	Potential yield to individual wells is several hundred gpm at many places. Suitable quality. Fairly large areal extent. ——— Hardness is generally greater than 180 mg/l. Iron content might be high.
Rural domestic and stock supply	For an adequate farm supply, needs are: Quantity 1) About 5 gpm or more. Quality 1) Total dissolved-solids content less than 1,000 mg/l.	Adequate flow. Flow partly regulated by reservoirs on upstream tributaries. Additional storage possible. ——— Available only to riparian lands. Treatment necessary for domestic use.	Adequate flow and supply. Flow in river regulated by outlet dam of Lower Red Lake. Additional storage possible in the Red Lakes. Suitable water quality. ——— Available only to riparian lands. Treatment necessary for domestic use. High evaporation loss in the Red Lakes. Small tributaries dry up during droughts.	Adequate flow in main stem and most large tributaries. Suitable quality. ——— Available only to riparian lands. Treatment necessary for domestic use.	Adequate for small supply if storage facilities are developed. Suitable water quality. ——— Available only to riparian lands. Many years no flow in fall and winter. Treatment necessary for domestic use.	Sand lenses that yield 5 gpm or more to individual wells can be found at most places in the area. Suitable quality at most places. ——— Hardness is generally greater than 180 mg/l.	Most beach ridges contain sufficient water for yields of 5 gpm or more to individual wells. Suitable quality. ——— Lower beach ridges are unreliable sources of water. Hardness is generally greater than 180 mg/l.	Adequate yields. Suitable quality. ——— Hardness and iron content might be high.
Irrigation supply	For an average farm, needs are: Quantity 1) Minimum flow of 2 cfs during growing season or wells yielding 250 gpm or more. Quality 1) Total dissolved-solids content less than 2,000 mg/l. 2) Suitability of water quality for irrigation as indicated by classification of U.S. Dept. of Agriculture.	Adequate flow. Flow partly regulated by reservoirs on upstream tributaries. Additional storage possible. Suitable quality. ——— Restricted to riparian lands.	Adequate flow and supply. Flow in river regulated by outlet dam of Lower Red Lake. Additional storage possible in the Red Lakes. Suitable water quality. ——— Restricted to riparian lands. High evaporation loss in the Red Lakes. Small tributaries dry up during droughts.	Adequate flow in main stem during years of normal wetness. Additional storage possible in headwaters. Suitable quality. ——— Restricted to riparian lands.	Adequate for small acreage during years of normal wetness with development of storage facilities. Suitable water quality. ——— Restricted to riparian lands. Low or no base flow during years of less than normal wetness. High evaporation loss in Thief and Mud Lakes (Agassiz Refuge pools).	Quality of water is generally suitable outside of lake plain. ——— Test drilling is usually required to locate sand lenses that will yield 250 gpm to individual wells. Quality of water may not be suitable for irrigation at some places in the lake plain.	Suitable quality. ——— Generally not an adequate supply. Limited areal extent.	Potential yield to individual wells is more than 250 gpm at many places. Fairly large areal extent. Suitable quality. ——— Part of area might not be available for agriculture because of swamplands.
Hunting, fishing, and other recreation	Adequate cover for wildlife habitat is provided by: 1) Wetlands—potholes or lakes surrounded by marsh areas. 2) 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: 1) Absence of odors. 2) Sightliness. 3) Attractive physical setting. 4) Absence of pollution.	Some waterfowl loafing and feeding areas along river. Fair to poor fishing conditions. Public access at some sites. Good habitat along banks. Favorable location with respect to population. ——— Occasional high water. Aesthetic considerations generally poor to fair. Severe pollution by wastes from industries and municipalities; remedial measures have been investigated.	Some waterfowl nesting, loafing, and feeding areas. Many wetland game management and hunting areas. Large marsh area flooded in Indian Reservation for waterfowl, furbearers, and wild rice production. Good habitat along river banks. Public access at some sites. Commercial fishing in part of the Red Lakes in Indian Reservation. Suitable water quality above Crookston. Good sport fishing open to public in eastern part of Upper Red Lake out of Reservation. Aesthetic considerations generally good above Crookston. Mouth of Tamarack River source of walleye spawn. ——— Occasional high water. Red Lakes stage fluctuates because of operation of control dam. Aesthetic conditions generally poor below Crookston. Severe pollution downstream from Crookston. Small tributaries dry up during droughts. High evaporation loss in the Red Lakes.	Some waterfowl loafing and feeding areas along river. Large marsh area flooded in Indian Reservation from water diverted from Clearwater River for waterfowl production and hunting. Fair fishing in streams; good fishing in lakes. Public access at some sites. Good habitat along banks. Favorable location with respect to population. Suitable water quality. Aesthetic considerations generally fair to good. ——— Occasional high water. Some pollution by industry and municipalities.	Excellent migratory waterfowl nesting, loafing, and feeding areas in wildlife refuges. Many wetland game management and hunting areas. Public access at some sites. Good habitat along banks. Favorable location with respect to population. Suitable water quality. Aesthetic considerations generally fair to good. ——— Occasional high water. High evaporation loss in Thief and Mud Lakes (Agassiz Refuge pools).			

EXPLANATION

Advantages
Potential yield to individual wells is more than 250 gpm at many places.
Fairly large areal extent.
Suitable quality.

Disadvantages
Part of area might not be available for agriculture because of swamplands.

Overall evaluation for purposes and considerations indicated

Good | Fair | Poor

SUMMARY

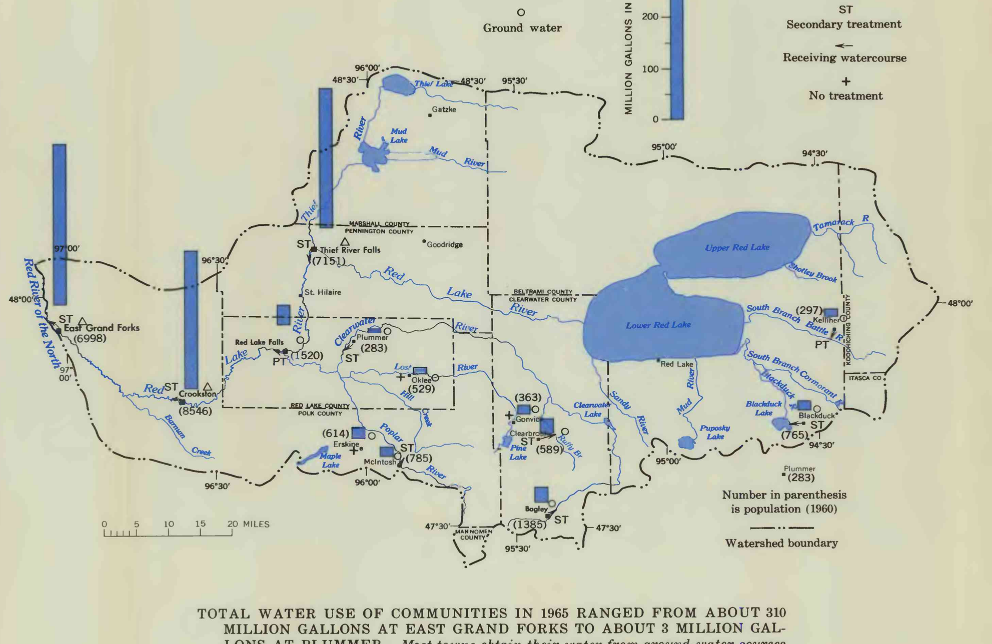
1. The annual mean runoff of the Red Lake River watershed above Crookston is about 2.6 inches or 730,000 acre-feet. Runoff is not equally distributed throughout the watershed—ranging from about 1 1/2 inches near the western border to more than 4 inches in the moraine in the southeastern part of the watershed.
2. Runoff is greatest during the spring when snowmelt occurs and the soils are generally saturated. High runoff may occur during the summer following thunderstorms rainfall although this generally occurs on small areas. Runoff recedes during late summer and fall to lowest values during late winter. The smallest range in daily discharge in unregulated streams occurs in late winter just prior to spring breakup.
3. Flooding along the streams in the lake plain and lake-washed till plain is caused by flat land surface and small capacity and low gradient of the channels. Moderately steep channel gradients and faster runoff in the eastern part of the watershed contribute to the severity of the flooding in the flat areas.
4. The natural streamflow of the Red River of the North and the Red Lake River is inadequate for pollution abatement and a dependable water supply. Streamflow is supplemented by release of stored water from Red Lakes within the watershed and from Orwell Reservoir and Lake Ashtabula, which are outside the watershed.
5. Annual evaporation of about 1.8 cubic feet per second per square mile of lake or reservoir surface (25 inches) must be considered in design of storage reservoirs.
6. The small tributaries in the lake plain and Thief River in the lake-washed till plain go dry during the fall and winter in many years and also during the summer during extreme droughts because they have little natural storage and little ground-water contribution.
7. Increase in baseflow of the Clearwater River occurs mainly in its headwaters in the morainal area and in the flat upland area near Red Lake Falls where the channel is deeply incised. For the 40 percent on the flow duration curve the baseflow increase in the morainal area was 40 cubic feet per second or 1.1 cubic feet per second per river mile and in the western part of the lake-washed till plain 48 cubic feet per second or 1.7 cubic feet per second per river mile. Part of this increase was due to inflow of tributaries. This compares with an increase of only 0.4 cubic feet per second per river mile in the reach in the lake-washed till plain between the moraine and the measuring site north of Okle.
8. Chemical quality of surface and most ground water is suitable for domestic and agricultural purposes. Surface water is the calcium magnesium type whereas ground water ranges from the calcium magnesium type at depth generally less than 50 feet to highly mineralized water of the sodium chloride type at greater depth in the western edge of the watershed. The sodium chloride water is not suitable for domestic or agricultural purposes.
9. Regional movement of ground water in the glacial drift is northward from the moraine toward the lake-washed till plain where it moves upward. Within the lake-washed plain regional movement is slowly westward toward the Red River Lowland.
10. Yields of wells tapping sand and gravel lenses in till are generally less than 25 gallons per minute; however, most communities have located aquifers by exploratory test drilling that will yield up to several hundred gallons per minute. Potentially the most productive aquifers in the watershed occur in the outwash and ice-contact deposits within the morainal area. These aquifers are undeveloped.

E X P L A N A T I O N

WATER SOURCE
Δ Surface water
O Ground water

WATER USE
MILLION GALLONS IN 1965
300
200
100
0

SEWAGE TREATMENT
PT Primary treatment
ST Secondary treatment
Receiving watercourse
No treatment



TOTAL WATER USE OF COMMUNITIES IN 1965 RANGED FROM ABOUT 310 MILLION GALLONS AT EAST GRAND FORKS TO ABOUT 3 MILLION GALLONS AT PLUMMER.—*Most towns obtain their water from ground-water sources which are generally available at relatively low development cost compared to surface water sources. The large municipal supplies are obtained from the Red Lake River. Most communities have sewage treatment facilities and discharge the effluent into watercourses. Crookston and East Grand Forks are planning improvement in their waste treatment facilities. No large amounts of water are used for agricultural purposes within the watershed.*

CONCLUSIONS

The hydrologic system within the Red Lake River basin is described and analyzed from a regional viewpoint. It is concluded that any large scale development of water supply within the basin would require additional structural measures to store water either on the land surface or within the ground-water reservoir by using the natural storage capacity of aquifers. The latter alternative would require much more information on the storage capacity of the ground-water reservoir in the particular place of development. Flooding is a major problem within the flat areas of the watershed but measures for considerable control have been completed. In its natural condition the watershed is ideally suited for wildlife propagation throughout much of its eastern part. Potential for water-based recreation is large in the morainal and Upper and Lower Red Lake area. Water supply is a particular problem in the western, highly developed agricultural area of the watershed.

ACKNOWLEDGEMENTS

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

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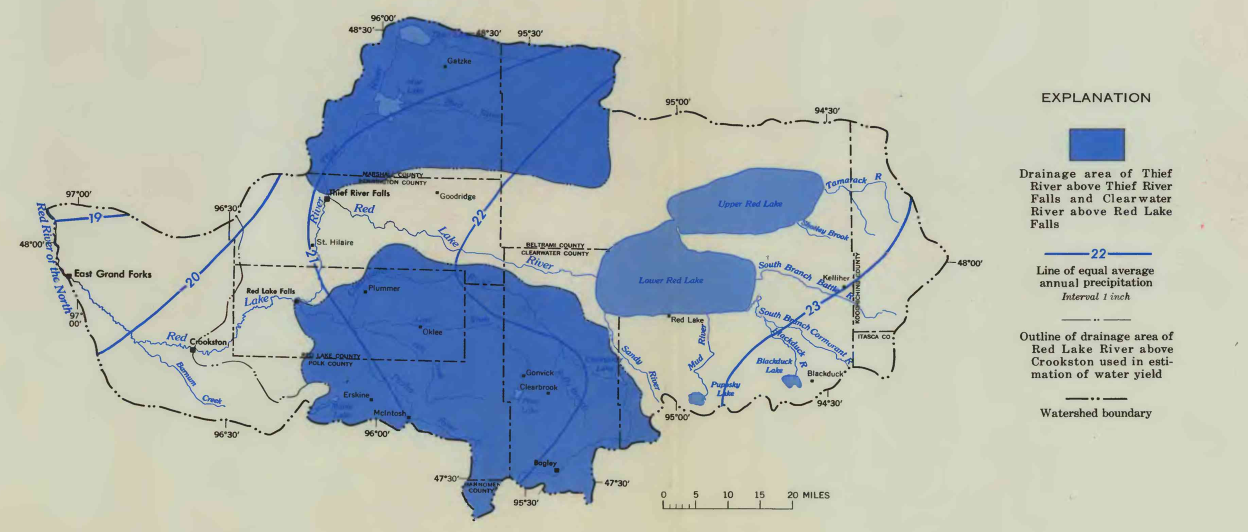
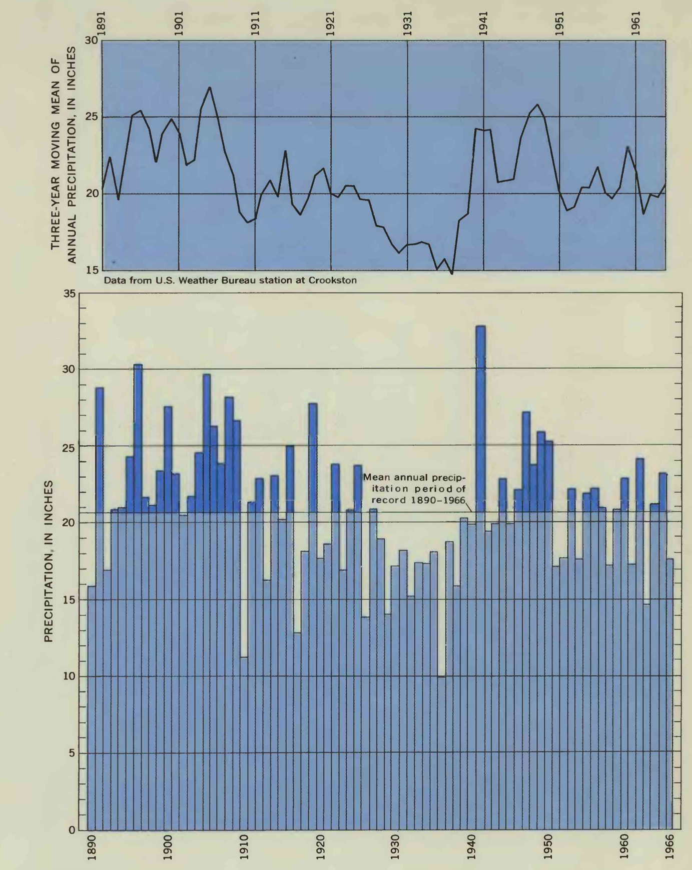
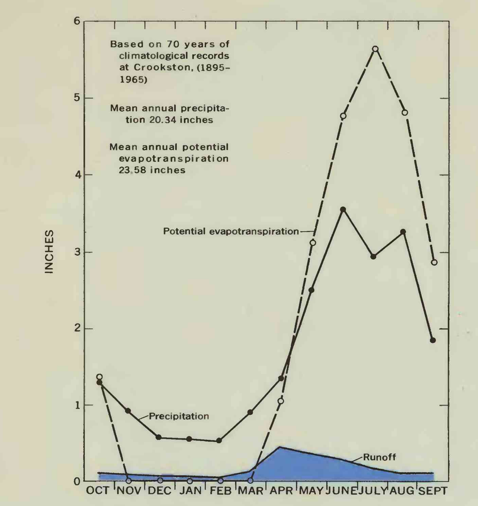
CLIMATE AND WATER YIELD



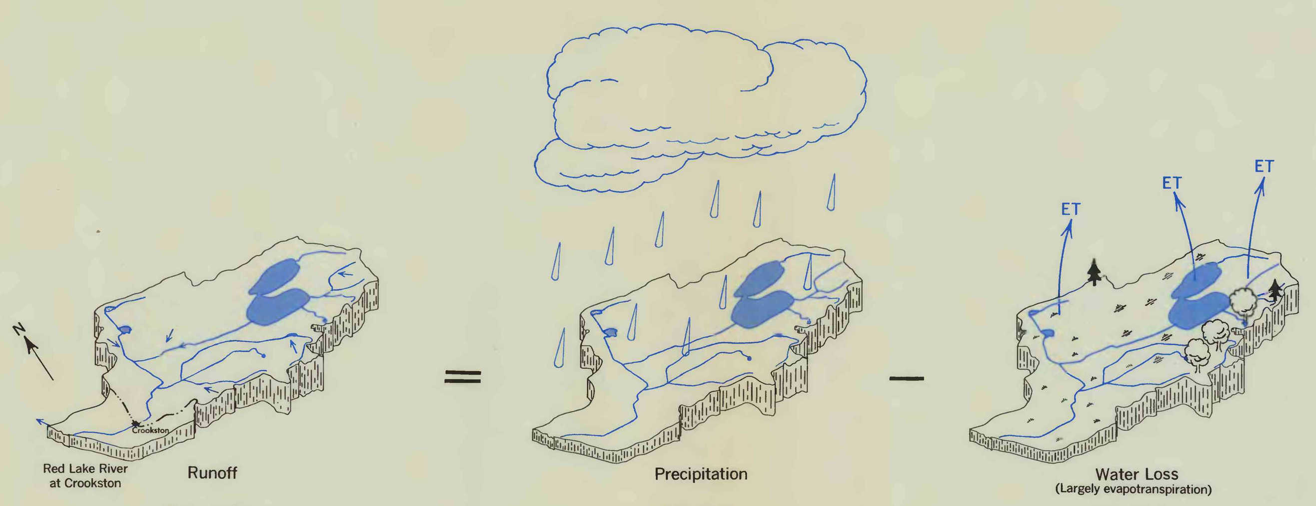
AVERAGE ANNUAL PRECIPITATION INCREASES FROM LESS THAN 19 INCHES IN THE LAKE PLAIN TO MORE THAN 23 INCHES IN THE MORAINAL AREA SOUTH OF LOWER RED LAKE.—*The Red Lake River basin above Crookston, used in the estimation of water yield (see analysis below), includes the morainal area and the lake-washed till plain. To show the runoff characteristics of the two dissimilar physiographic areas of the Red Lake River basin above Crookston hydrographs of streams draining them are included in the discussion of water yield. About half the average flow of the upper three-quarters of the basin is from the main stem regulated by storage in the Red Lakes.*



ANNUAL PRECIPITATION RANGES WIDELY FROM YEAR TO YEAR; HOWEVER, WET AND DRY PERIODS TEND TO OCCUR IN GROUPS.—*The greatest deficiency of precipitation occurred in the middle 1930's when the lowest 3-year mean was less than 15 inches. Rural and municipal water shortages were common during the drought of the 1930's but during the 1940's water shortages were not serious and some plans for water-supply augmentation were temporarily abandoned.*

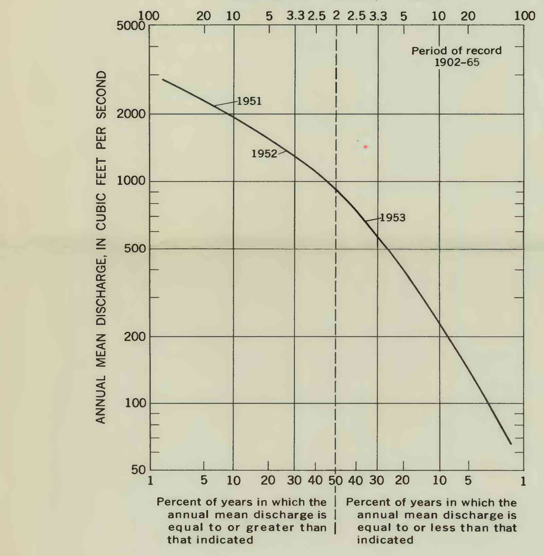


MOISTURE IS ADEQUATE FOR OPTIMUM PLANT GROWTH IN SPRING AND EARLY SUMMER DURING A NORMAL YEAR BUT A MOISTURE DEFICIENCY DURING AUGUST AND SEPTEMBER RESULTS IN LESS THAN OPTIMUM GROWTH.—*Moisture that accumulates in the soil and on the ground surface during winter and early spring is used later by plants up through July or is discharged as surface runoff. The estimation of potential evapotranspiration, computed by the method described by Thornthwaite and Mather (1957), is based on monthly precipitation and mean temperature for the month.*



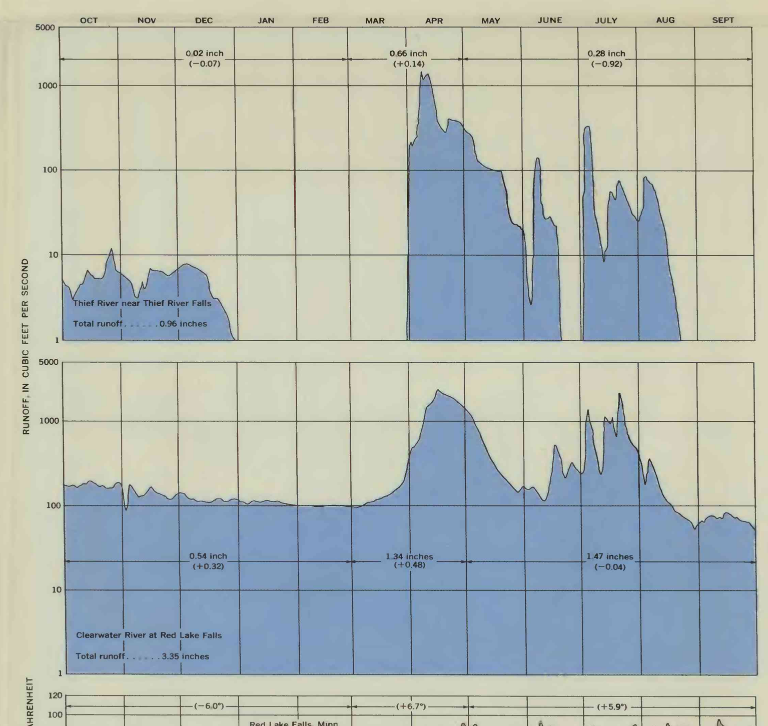
WATER YIELD OR ANNUAL MEAN RUNOFF FOR THE RED LAKE RIVER WATERSHED IS 2.6 INCHES FOR THE DRAINAGE AREA OF 5,280 SQUARE MILES UPSTREAM FROM THE STATION ON THE RED LAKE RIVER AT CROOKSTON.

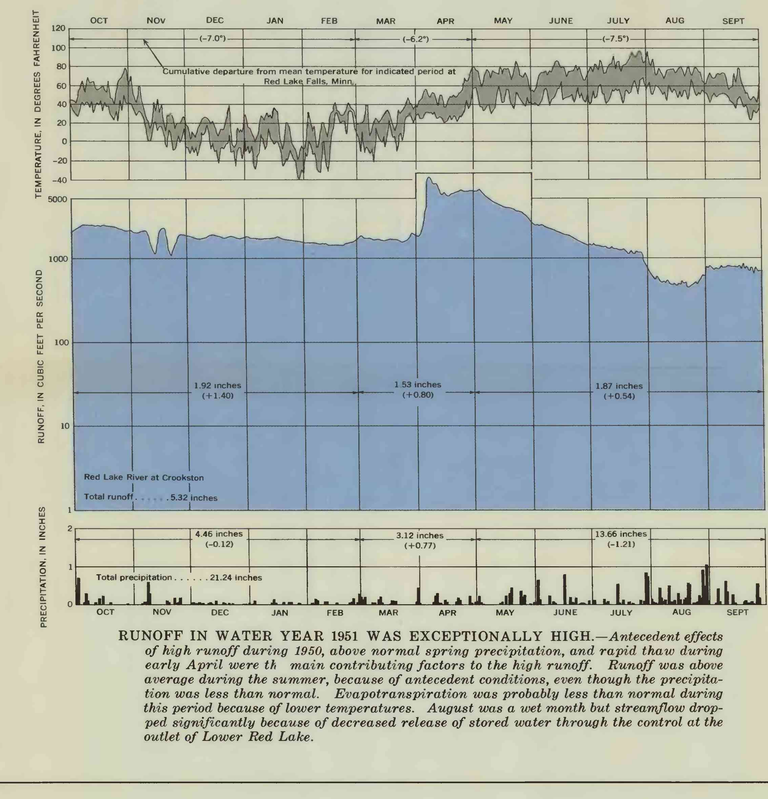
On a long term basis the water yield represents the amount available to man for management; however, only a small fraction of this water is available for man's use without storage. Water may be reused several times for nonconsumptive purposes but consumptive use, such as irrigation, is largely a net water loss to evapotranspiration. Evapotranspiration losses can be controlled partially by man through selection of land and water-management practices.



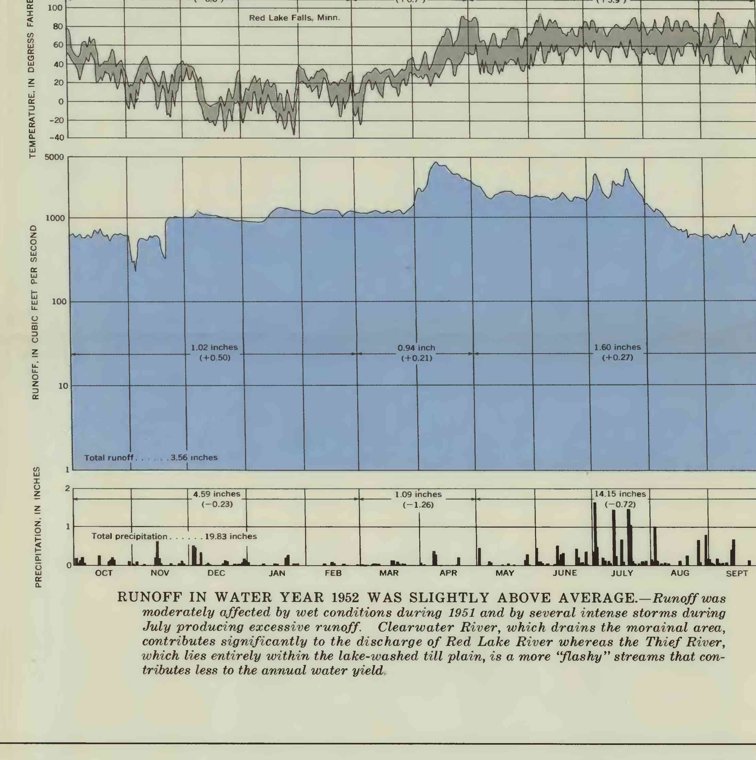
FREQUENCY DISTRIBUTION OF ANNUAL MEAN DISCHARGE OF THE RED LAKE RIVER AT CROOKSTON SHOWS THAT AN ANNUAL MEAN DISCHARGE OF 900 CUBIC FEET PER SECOND CAN BE EXPECTED TO OCCUR ON THE AVERAGE OF ONCE IN 2 YEARS.—*A high annual mean discharge of about 1,900 cubic feet per second or more and a low annual mean discharge of about 210 cubic feet per second or less can be expected to occur on an average of once in 10 years. These values are generally indicative of annual variations in discharge due to natural causes; however, over the years storage controlled by man in the Upper and Lower Red Lakes modifies the extremes.*

A period of 3 consecutive years that had available records were selected to analyze water yield for a wide range in yearly discharge.

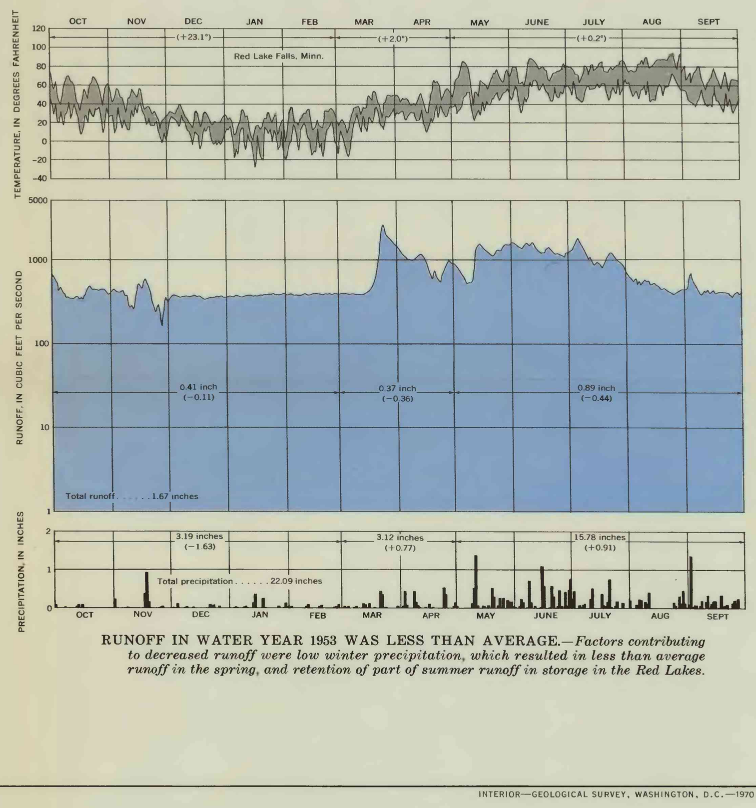




RUNOFF IN WATER YEAR 1951 WAS EXCEPTIONALLY HIGH.—*Antecedent effects of high runoff during 1950, above normal spring precipitation, and rapid thaw during early April were the main contributing factors to the high runoff. Runoff was above average during the summer, because of antecedent conditions, even though the precipitation was less than normal. Evapotranspiration was probably less than normal during this period because of lower temperatures. August was a wet month but streamflow dropped significantly because of decreased release of stored water through the control at the outlet of Lower Red Lake.*



RUNOFF IN WATER YEAR 1952 WAS SLIGHTLY ABOVE AVERAGE.—*Runoff was moderately affected by wet conditions during 1951 and by several intense storms during July producing excessive runoff. Clearwater River, which drains the morainal area, contributes significantly to the discharge of Red Lake River whereas the Thief River, which lies entirely within the lake-washed till plain, is a more "flashy" streams that contributes less to the annual water yield.*



RUNOFF IN WATER YEAR 1953 WAS LESS THAN AVERAGE.—*Factors contributing to decreased runoff were low winter precipitation, which resulted in less than average runoff in the spring, and retention of part of summer runoff in storage in the Red Lakes.*

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1970—W69211

WATER RESOURCES OF THE RED LAKE RIVER WATERSHED, NORTHWESTERN MINNESOTA

By
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1970