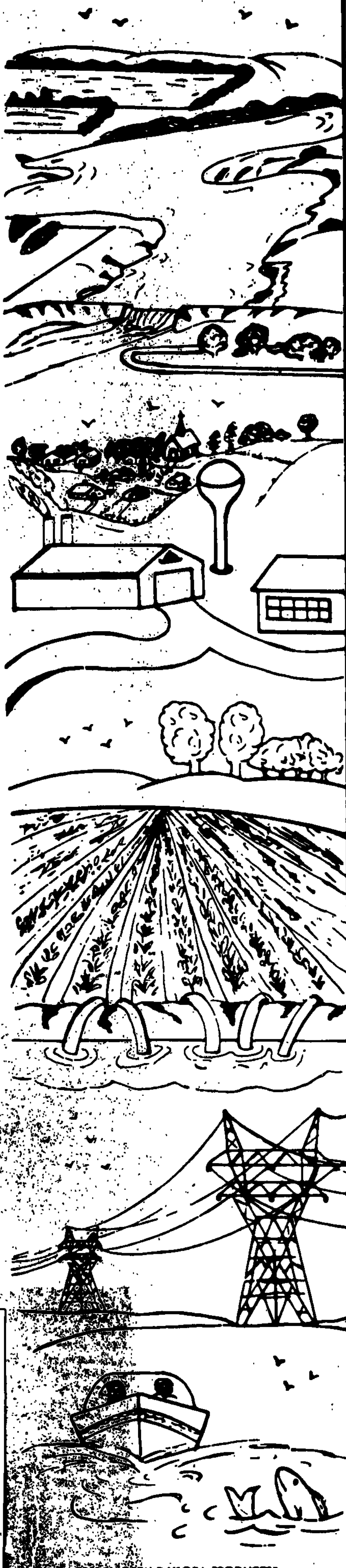


REPORT OF

NORTH DAKOTA STATE WATER COMMISSION

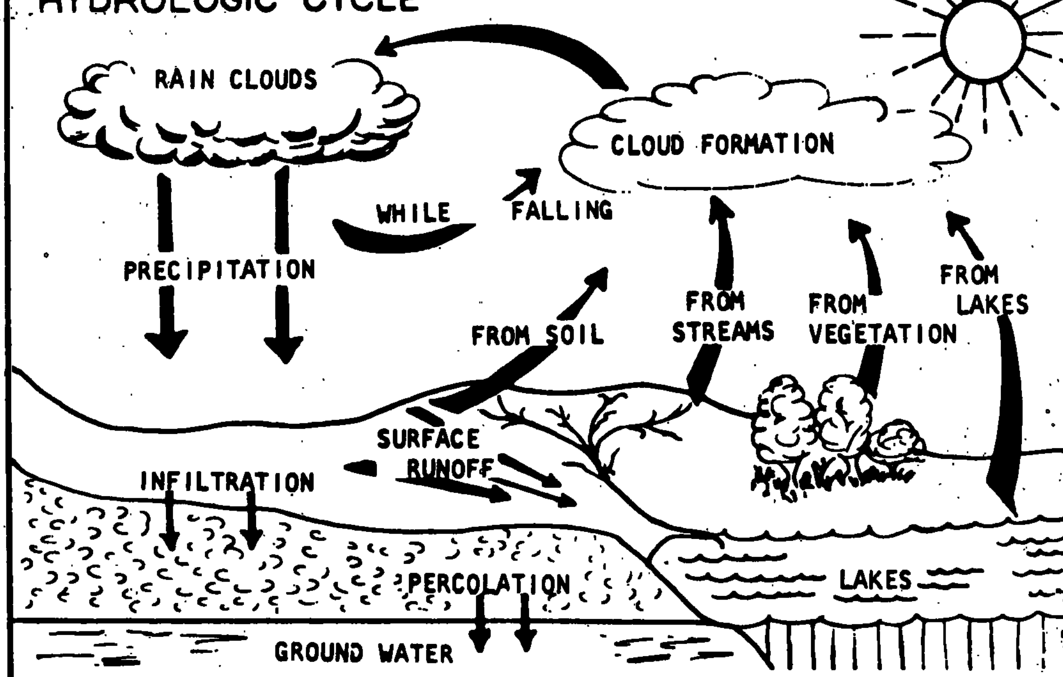
STATE OFFICE BUILDING
900 BOULEVARD
BISMARCK, NORTH DAKOTA 58501

NORTH DAKOTA INTERIM
STATE WATER RESOURCES DEVELOPMENT PLAN

SWC PROJECT No. 322

Information Series No. 8 1968

HYDROLOGIC CYCLE



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Financial assistance for the preparation of this Plan, in the form of matching funds, was received from the Water Resources Council under the provisions of Title III, Public Law 89-80, "The Water Resources Planning Act," July, 1965.

North Dakota State Water Commission

1301 State Capitol 223-8000 Ext. 251

Bismarck, North Dakota 58501

Letter of Transmittal

November, 1968

Governor William L. Guy
State Capitol
Bismarck, North Dakota 58501

RE: State Water Plan, SWC Project #322

Dear Governor Guy:

The Interim State Water Resources Development Plan with its related Appendices was prepared by the Commission staff and some consulting services. Work was initiated in 1966 with financial assistance from the Water Resources Council through the Water Resources Planning Act, P.L. 89-80.

Intended as a comprehensive framework study, the Interim Plan is to be utilized in the formulation of detailed subbasin water resources development plans as time and funding permit.

Many state and federal agencies and others provided information and reviewed the data utilized in the planning process. We are grateful for their cooperation.

Sincerely yours,

Milo W. Hoisveen

Milo W. Hoisveen
Engineer-Secretary

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Chapter One

Introduction

CHAPTER I

PREFACE — INTRODUCTION

Of all the natural resources with which North Dakota has been endowed, none is more vital to the social and economic well-being of the people than its water resources. Up to now, research has failed to provide the means for manufacturing water. Neither has an acceptable substitute been found. The amount of water available for our use today is unchanged from the days of the pioneer, from the time of our forefathers. The amount of water available to man is constant, never changing; yet water uses and demands have multiplied over the years.

Since little can be done to increase nature's water allotment to our State, North Dakotans must learn to use their existing supplies more judiciously. This means redoubling of our efforts to achieve the most efficient level of water management possible. Our world is changing rapidly; society is becoming increasingly more complex, and providing solutions to the host of water management problems which will likely develop within the framework of such a changing world could become North Dakota's greatest challenge of the future.

To meet that challenge, North Dakota must carefully assess the present and begin planning now for the future. Future agricultural, urban, and industrial growth hinges on a most important decision; a decision which is well within the power of North Dakotans to make. North Dakota can move forward with a thriving economy by pursuing a vigorous and progressive water planning and construction program; or it can allow the economy to stagnate, even retrogress, by adopting a complacent attitude and by leaving each district, community, agency, or other entity to secure its own water supply as best it can with small regard given to the needs of others.

It is apparent to most that the continued growth and prosperity of North Dakota is dependent upon prompt and substantial efforts by the responsible local governmental agencies, the State and Federal government to insure that the planning and construction of water development projects keeps pace with the growing needs for water utilization and control.

Basis and Authority for State-Wide Water Development Planning

Expressions of State policy regarding water supply development are found in Section 210 of the Constitution of North Dakota and in Section 61-01-26, North Dakota Century Code.

Section 210 of the Constitution reads: "All flowing streams and natural water courses shall forever remain the property of the state for mining, irrigating and manufacturing purposes."

Section 61-01-26, North Dakota Century Code, states the following:

"**Declaration of state water resources policy.** — In view of legislative findings and determination of the ever-increasing demand and anticipated future need for water in North Dakota for every beneficial purpose and use, it is hereby declared to be the water resources policy of the state that:

1. The public health, safety and general welfare, including without limitation, enhancement of opportunities for social and economic growth and expansion, of all of the people of the state, depend in large measure upon the optimum protection, management and wise utilization of all of the water and related land resources of the state;
2. Well-being of all of the people of the state shall be the overriding determinant in considering the best use, or combination of uses, of water and related land resources.
3. Storage of the maximum water supplies shall be provided wherever and whenever deemed feasible and practicable;
4. Accruing benefits from these resources can best be achieved for the people of the state through the development, execution and periodic updating of comprehensive, coordinated and well-balanced short- and long-term plans and programs for the conservation and development of such resources by the departments and agencies of the state having responsibilities.
5. Adequate implementation of such plans and programs shall be provided by the state through cost-sharing and cooperative participation with the appropriate federal and state departments and agencies and political subdivisions within the limitation of budgetary requirements and administrative capabilities;
6. Required assurances of state cooperation and for meeting nonfederal repayment obligations of the state in connection with federal-assisted state projects shall be provided by the appropriate state department or agency;
7. Required assurances of local cooperation and for meeting nonfederal repayment obligations of local interests in connection with federal-assisted local projects may, at the request of political subdivisions or other local interests be provided by the appropriate state department or agency, provided, if for any reason it is deemed necessary by any department or agency of the state to expend state funds in

order to fulfill any obligation of a political subdivision or other local interests in connection with the construction, operation or maintenance of any such project, the state shall have and may enforce a claim against the political subdivision or other local interests for such expenditures. . . ."

The State Water Commission is charged, by statute, with the responsibility for implementing state water policy. Created by legislative enactment in 1937, the Commission is endowed with broad powers to initiate and conduct investigations of the water resources of the state. Section 61-02-14, North Dakota Century Code, authorizes the Commission to engage in the preparation of a comprehensive state water development plan. Section 61-02-14 provides that "The (state water) commission shall have full and complete power, authority, and general jurisdiction:

"7. To cooperate with the United States and any department, agency or officer thereof in the planning, establishment, operation, and maintenance of dams, reservoirs, diversion and distributing systems, for the utilization of the waters of the state for domestic, municipal and industrial needs, irrigation, flood control, water conservation, generation of electric power and for mining, agricultural and manufacturing purposes, and in this connection the state water conservation commission is hereby authorized, within the limitations prescribed by law, to acquire, convey, contribute or grant to the United States moneys, real and personal property, including land or easements for dams and reservoir sites and rights of way and easements for diversion and distribution systems or participate in the cost of any project."

Previous State-Wide Planning

The concept of planning for the development of North Dakota's water resources on a state-wide basis is not new. Such planning has long been recognized as a State responsibility. In 1937, the State Planning Board completed and submitted to the Governor its "Plan of Water Conservation for North Dakota." This report analyzed existing water problems within the framework of the State's five major drainage basins and contained recommendations for the solution of those problems.

Budgetary limitations brought on by a serious economic depression can be singled out now as the greatest impediment to developing the State's water resources in accordance with the recommendations made by the State Planning Board. When the severe drought conditions that had persisted throughout most of the 1930's were relieved and when the State began to recover economically, interest in and demands for water resources development subsided. Yet, in spite of the indifference to water resources advances which developed during the 1940's when North Dakotans and the Nation were preoccupied with fighting a second world war, progress continued. Many of the projects recommended in the 1937 Plan are now a reality. Much has been done over the years to solve North Dakota's water problems; much remains to be done.

A 30-Year Plan for the development of North Dakota's water and land resources was completed by the State Water Commission in 1962. This plan superseded the 1937 Plan which, by 1962, was outdated and badly in need of rennovation. In a manner similar to its 1937 forerunner, the 1962 Plan analyzed the status of existing developments and proposed measures to alleviate current problems and problems anticipated for the near-future. Then, going a step beyond suggesting alternative solutions to existing and near-future problems, the 1962 Plan anticipated water supply needs on a long term basis and recommended measures for meeting those needs. Incorporated into the 30-Year Plan were provisions for the construction of structures with a storage capacity in excess of 2.5 million acre-feet, including 1,071,650 acre-feet for Irrigation (not including the Garrison Diversion Unit); 778,950 acre-feet for Municipal Supply; 143,000 acre-feet for Wildlife; 247,000 acre-feet for Flood Control; and 324,000 acre-feet for Outdoor Recreation. A number of specific projects recomended for construction in the 1962 Plan have already been built.

How This Plan Differs From Those of the Past

The State Water Resources Development Plan differs from those of the past in many respects. Primarily, it is different because, for the first time, the entire State has been examined within the context of water availability and requirements projected to the next century. It is different because these projections are predicated upon carefully acquired data which has been collected by improved research techniques. For the first time, ground water is treated extensively and water requirements for quality control and outdoor recreation are considered adequately.

The Planning Scope

Broader in scope than that of earlier investigations, the State Water Plan has as its primary objective the formulation of a long-range plan for the comprehensive development of North Dakota's water resources. It envisions the control, conservation, protection and utilization of North Dakota's surface and underground water resources to meet all beneficial uses throughout the State, within the bounds of practicability.

Use has been made of all available basic data and information pertinent to water supply, water requirements, flood control, fish and wildlife, recreation, municipal and industrial supply, drainage, water quality, and the physical characteristics of ground-water basins.

The North Dakota Water Plan is conceived as a long-range and continuing plan, one that will meet the requirements for water up to the year 2000, but not a plan that anticipates full development of the State's water and related land resources prior to the beginning of the next century.

The Plan is a flexible pattern or framework into which future definite projects may be integrated. As conditions change, as additional data and experience are acquired, as technology increases, and as future conditions change in patterns that cannot be foreseen today, the Plan will be substantially altered and improved.

The Plan includes all known and envisioned water development projects in the State. Continued investigation may point up alternative projects which are more feasible than those discussed herein and which would accomplish the same ends.

The Plan is, of course, primarily concerned with water resource development. It recognizes too that the wasteful or improper utilization of other resources can have a profound effect upon all segments of the State's development, including its water development. No single resource need be sacrificed for the use of another. Sound planning techniques combined with good judgment can maintain a proper balance in resources development.

Chapter Two

Methodology and Goals

CHAPTER II

METHODOLOGY AND GOALS

METHODOLOGY

Utilization of Staff Services

The Commission's Comprehensive Planning Division, within the Assistant Secretary's scope of responsibility, includes two resources planners and a planning engineer.

Their primary function is the assimilation of data required in the preparation of a comprehensive state water and related land resources plan. Technical assistance is provided the planners by the Engineering Division within the Assistant State Engineer's scope of responsibility.

The State Water Commission "Organization Chart" found at the end of this section indicates the various technical disciplines available for consultation in the specialized water resources development fields.

Over-all supervision is provided by the Commission Secretary and Chief Engineer with policy decisions promulgated by the seven Commission members.

Utilization of Consultative Services

Initially Consulting Engineer Harvey O. Banks was employed to assist in outlining procedures and guidelines for developing the Plan. North Dakota State University Agricultural Economics Department and Water Resources Research Institute prepared a linear programming model to provide information on shifting agricultural production, irrigation water requirements, and economics of various irrigation farming practices. (Appendix D)

The Stanford Research Institute conducted a study of conflicting land uses for wildlife and agriculture in order to develop criteria for policies required in considering water and related land resources for these conflicting uses. (Appendix E)

Consulting Hydrologist Hugh McCreery developed the information concerning available ground and surface water based on stream gaging records and ground-water survey reports.

North Dakota State University Soils Department prepared an analysis of irrigable lands in each major basin determined by soil classifications (Appendix B)

Inter-Agency Coordination

Data and advice on a variety of items were obtained from various Federal and State agencies through informal conferences and publications provided by the agencies. Principal agencies and subjects include:

AGENCY	SUBJECT
University of North Dakota	Industrial water.
North Dakota State University	Municipal water. (In addition to consultative services)
State Game & Fish Department and U. S. Fish and Wildlife Service	Fish and wildlife resources.
North Dakota Geological Survey	Minerals and mining.
U. S. Geological Survey	Stream flow, ground water and topographic mapping.
North Dakota State Health Department, State Laboratories Department, and Federal Water Pollution Control Agency	Water quality.
North Dakota State Outdoor Recreation Agency, State Forester, State Highway Department and Bureau of Outdoor Recreation	Outdoor recreation.
State Planning Agency and Economic Development Commission	Population and economic statistics.
Environmental Science Services Administration	Climate and weather.
North Dakota State Tax Department	Revenue sources and well inventories.
Garrison Diversion Conservancy District and Bureau of Reclamation	Garrison Diversion Project and irrigation.
U. S. Soil Conservation Service and U. S. Army Corps of Engineers	Flood prevention and control.
Soil Conservation Districts and State Soil Conservation Committee	Land treatment practices.
State Civil Defense	Emergency planning.

AGENCY	SUBJECT
Legislative Research Committee and Attorney General	Legal.
International Souris River Board of Control, International Joint Commission, Souris-Red-Rainy River Basins Commission and Missouri Basin Inter-Agency Committee	Interstate and international waters.
Water Resources Council	Financing and guidelines.

Local Government Participation

The initial planning is concentrated on utilization of existing data applicable on a comprehensive basis. It is anticipated that as the Plan is updated and becomes more detailed, local political sub-divisions such as counties, cities, water management districts, soil conservation districts, irrigation districts, and park districts will become more intimately involved in the planning process.

Through participation by staff members in local government associations, information is obtained relative to specific area needs and problems.

Private Organization Participation

Staff members maintain liaison with private organizations through their publications and participation in their area meetings.

Planning Approach

All Commission and staff members outlined the known problems which require consideration and solution. These problems were summarized by the planners and used to determine needed developments in the planning process.

Basic data required to determine existing water and related land resources as well as projected requirements for these resources were summarized by the staff and consultants.

As the economic, land, water, financial, and problems data became available, experienced staff members recommended developments necessary to meet foreseeable water utilization and control requirements to the year 2000.

Development Goals

The goal of the State Water Resources Development Plan is to study existing information and to prepare reports on the current and projected requirements for water and related resources development, use, and planning in the State, including, but not limited to:

A. Water needs for domestic, municipal, agricultural, industrial and recreational purposes, fish and wildlife propagation and enhancement; and water quality control.

B. Interbasin and transbasin diversion and transportation of waters within the State. (Under Subsection 1.d. of Section 61-02-14 of the North Dakota Century Code, the North Dakota State Water Commission has the power and authority to "conserve and develop the waters within the natural watershed areas of the state and, subject to vested rights, to divert the waters within a watershed to another watershed area and the waters of any river, lake or stream into another river, lake or stream.")

C. Watershed and flood control for the protection of life and property; the conservation, development and use of all the water resources of the State; and estimation of present and future needs for flood and pollution control measures.

D. Reuse and reclamation of water; in order to minimize water losses from all consumptive uses.

E. Reservoir evaporation and control and transpiration losses. (Average annual evaporation from a free water surface is now about 36 inches.)

F. Thermal pollution, which may become a problem, particularly in the Missouri River. (Two 200,000 k.w. thermal electric generating plants are now in operation, and a third plant of even greater capacity is under construction. All of them are or will be along the Missouri River in the same limited area, using river water for cooling and discharging into the river. The effect of such thermal discharge and pollution upon operation of the affected plants and upon aquatic life presents problems.)

G. Underground storage of municipal and industrial water supplies, now practiced by a number of municipalities and being considered by several others. (Much additional study in this field is needed; e.g., cities such as: Edmore, Glenburn, Hunter, Minot, Portland, Tioga and Valley City.)

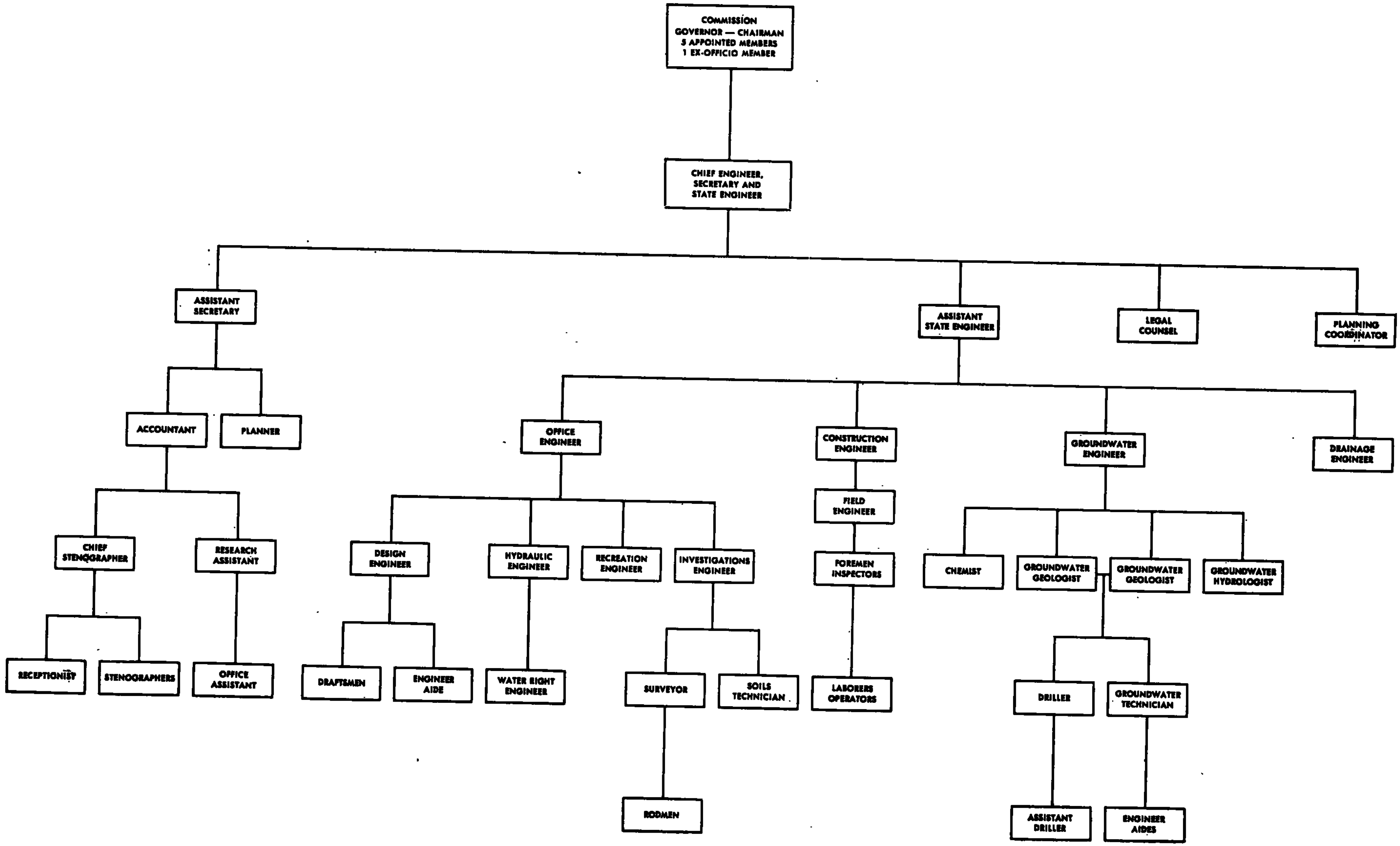
H. Control of river flows, which in some areas have changed due to construction projects and are causing severe erosion and interference with water intake works. (Remedial measures must be found and provided.)

I. Riverbank stabilization and protective works which are becoming increasingly necessary. (Farm, urban and recreational areas are threatened and damaged at a number of points in the State.)

J. Ground-water surveys to locate subterranean water supplies (Case in point: some years back, a fairly large utility plant proposed locating in a certain area if an adequate supply of water could be assured. The ground-water potential in that area was not then known and the plant was lost to another state. Subsequently, but too late, a ground-water survey discovered an aquifer at the site of first choice capable of providing many times the quantity of water required.)

NORTH DAKOTA STATE WATER COMMISSION

ORGANIZATION CHART



Chapter Three

History and Legislation

CHAPTER III

HISTORY AND LEGISLATION

HISTORY OF WATER RESOURCE DEVELOPMENT IN NORTH DAKOTA

To relate the history of water resources development in North Dakota with the degree of thoroughness it merits would require the expenditure of a substantially greater amount of time and concentration of effort than was possible in the preparation of this interim report. Consequently, the History of Water Resource Development Chapter is a simple chronology of events — one which accounts for the more significant elements of a total development, one that doubtless overlooks or excludes some important occurrence, project or legislative enactment.

Yet, in spite of the brevity with which it is treated herein, the history of water resources development in North Dakota seems to indicate that (1) North Dakotans have long been conscious of the necessity to protect and develop the waters of the State; (2) engineering feats once considered physically and economically unfeasible, if not impossible, are now being performed with matter-of-fact regularity; (3) the impetus of future water resources development must be greater than that of the past if North Dakota is to keep pace with other sections of the Nation; (4) the State and not the Federal Government will play an increasingly greater role in the course of future water developments; and (5) with an accelerated water resources development program, North Dakota can acquire as new citizens a greater percentage of those Americans now moving from overcrowded areas along the Atlantic Seaboard and the Pacific Coast to the more spacious Midwest.

1889 - (August 5th) Appearing before delegates to the Constitutional Convention, Major J. W. Powell, Director of the U. S. Geological Survey, urged framers of the Constitution to prevent corporations, bodies of men and capital from acquiring control of waters of the State. Acting upon the suggestion and advice of Major Powell, the convention adopted the following constitutional provision: Section 210: **All flowing streams and natural water courses shall forever remain the property of the state for mining, irrigating and manufacturing purposes.**

1890 - In 1890, two field parties under the direction of Morris Bien (U. S. Reclamation Service) investigated the possibilities for diverting water from the Missouri River across the divide separating the Missouri Valley from the valleys of the Mouse, the Sheyenne, and the James. Working from Minot during the late summer and fall, the reconnaissance/survey party ran 730 miles of levels without finding a suitable pass through the divide. The lowest point found in that divide was about 200 feet above the low water level of the Missouri River at Buford, where the Missouri enters the State, so the project was abandoned.

1903 - (October 20th) First State Irrigation Congress, Bismarck, North Dakota.

1904 - State Engineer recommends early examination of a proposed project involving the diversion of the Mouse River to Devils Lake.

1904 - Discussion of a high dam on the Missouri River — deemed impractical due to lack of proper foundations as reported by riverboat pilots. **"We therefore look askance,"** the 1st Biennial Report of the State Engineer states, **"at so dangerous an undertaking, and are likely to decide that, unless some unexpectedly advantageous site be found, such a project is impossible."**

1905 - (March 1st) Office of the State Engineer officially created by the Legislature. Prior to this time, there existed no comprehensive law regarding irrigation in the State. After the passage of the U. S. Reclamation Act of June 17, 1902, new interest was felt in the subject and in the year 1904, a fund was raised by leading citizens of the State, and Professor E. F. Chandler of the University of North Dakota was appointed State Engineer to assist in compiling an irrigation code in laying the foundations for systematic control of irrigation matters.

1905 - North Dakota State Legislature enacted Section 61-01-03 of the North Dakota Century Code. Section 61-01-03 sets forth the policy governing claims to the use of water which were initiated prior to and after March 1, 1905. Section 61-01-03 reads: **In all cases of claims to the use of water initiated prior to March 1, 1905, the right shall relate back to the initiation of the claim, upon the diligent prosecution to completion of the necessary surveys and construction for the application of the water to a beneficial use. All claims to the use of water initiated after March 1, 1905, shall relate back to the date of receipt of an application therefor in the office of the state engineer, subject to compliance with the applicable provisions of law, and the rules and regulations established thereunder.**

1905 - Construction started on the 60,000 acre Lower

Yellowstone Irrigation Project, 19,500 acres of which are located in North Dakota.

1906 - In 1906, the U. S. Reclamation Service started construction of a steam power plant at Williston using lignite coal as fuel. The purpose of this plant was to supply power for pumping for irrigation of the Williston Project, as well as the Buford-Trenton Project. As this was a new departure in the field of reclamation, several new and untried problems presented themselves. Among these were the operation of the government owned coal mine, the use of barges anchored in the Missouri River for mounting the pumps used on the first lift, and the operation of both steam plant and coal mine during only three months of the year.

1909 - Oldest irrigation district in North Dakota, the Lower Yellowstone Irrigation District in McKenzie County, established.

1909 - On January 11, the United States and Great Britain entered into a treaty relating to boundary waters and questions arising between these two countries. This treaty provided that an International Joint Commission be created to have jurisdiction of boundary waters. Consists of six members — three from each country.

1917 - North Dakota Irrigation District law passed.

1923 - North Dakota portion of the Lower Yellowstone Irrigation Project declared 99 percent complete.

1933 - Construction started on the Eaton Flood Irrigation Project on the Souris (Mouse) River in McHenry County.

1934 - Secretary of Agriculture notified the state engineer that pursuant to Section 8270 of the Compiled Laws of North Dakota for the year 1913, the United States intended to utilize certain specified unappropriated waters as of September 1, 1934, described as follows: **The Mouse River, also known as the Souris River, and all of its tributaries; the Des Lacs River, also known as the Des Lacs Lakes, and all of their tributaries; the James River, including its tributary the Pipestem River, and all tributaries of both such rivers in North Dakota; the Bois de Sioux River, the Sheyenne River, the Forest River, and all other tributaries of the Red River in North Dakota; all tributaries of the Missouri River in North Dakota.**

1936 - U. S. Congress passed the Flood Control Act of that year.

1937 - State Water Conservation Commission created by legislative enactment. To consist of the Governor, the Commissioner of Agriculture and Labor, and five other members appointed by the Governor.

1938 - (January 15th) Sioux County Water Management District organized making it the oldest active district in the State. (Originally established as Sioux County Water Conservation District No. 1).

1938 - (April 2nd) U. S. Congress gave its approval to the formation of the Tri-State Water Commission which included Minnesota and the two Dakotas.

1939 - Construction began on the 5,000 acre Lewis and Clark Irrigation Project in McKenzie County, six miles southwest of Williston in the Missouri River Valley.

1940 - (January 15th) Under the provisions of Article 9 of the Boundary Water Treaty, 1909, the Governments of the United States and Canada referred to the International Joint Commission the following questions with respect to the waters of the Souris (Mouse) River and its tributaries which cross the International Boundary from the Province of Saskatchewan to the State of North Dakota and from the State of North Dakota to the Province of Manitoba:

Question 1 - In order to secure the interests of the inhabitants of Canada and the United States in the Souris (Mouse) River drainage basin, what apportionment should be made of the Souris (Mouse) River and its tributaries, the waters of which cross the International Boundary, to the Province of Saskatchewan, the State of North Dakota, and the Province of Manitoba?

Question 2 - What methods of control and operation would be feasible and desirable in order to regulate the use and flow of the waters of the Souris (Mouse) River and of the tributaries, the waters of which cross the International Boundary, in accordance with the apportionment recommended in the answer to Question 1?

Question 3 - Pending a final answer to Questions 1 and 2, what interim measures of regime should be adopted to secure the foregoing objects?

The United States State Department, on March 28, 1940, and the Department of External Affairs of Canada, on April 12, 1940, agreed that no new work would be undertaken which might affect the flow of the Mouse River and that the present (1940) arrangement would be continued until the Commission had submitted its final report.

The final agreement, entered into in 1942, allows the Province of Manitoba a flow of 20 cfs from stored waters in North Dakota and allows Saskatchewan to retain 50 percent of the water rising in that Province.

1940 - (June 13th) Congress authorized Wyoming, South Dakota, Montana and North Dakota to enter into compact negotiations for the allocation of the waters of the Little Missouri River. Preliminary surveys were undertaken but no agreement was reached prior to the expiration date of January 1, 1943. Renewed interest was generated in 1954 when North Dakota ranchers owning land adjacent to the stream complained that little or no water was available for irrigation purposes. As a result of action taken in the North Dakota State Legislature, the North Dakota Congressional delegation introduced Federal legislation authorizing compact negotiations among the affected states in 1957. In 1962 the period for compact negotiations was extended by Congress until 1965. Subsequent authorization by Congress for extension of compact negotiations beyond 1965 has not been made.

1940 - (June 15th) North Dakota, by Act of Congress, was authorized to participate in Yellowstone River Compact negotiations.

1941 - Missouri River States Committee created in December for the purpose of securing flood control, irrigation, navigation, power development, and related improvements in the entire Missouri River Basin. The Governors of the ten Missouri Basin States in addition to representatives named by each Governor compose the Committee.

1943 - North Dakota State Legislature repealed Section 8270 of the 1913 Compiled Laws of North Dakota. Section 8270 is the authority under which the U. S. through the Secretary of Agriculture in 1934 declared its intent to utilize certain unappropriated waters in North Dakota (see 1934 reference in this section).

1944 - U. S. Congress passed the 1944 Flood Control Act. Authorized, among other things, the Missouri River Basin Studies.

1945 - Ground-water survey program initiated on a cooperative basis by the Ground-Water Branch of the U. S. Geological Survey and the State Water Commission. This program financed on a 50-50 basis. The State Geologist acts as the technical advisor for the State Water Commission in matters pertaining to ground water and otherwise assists in the program.

1945 - Missouri Basin Inter-Agency Committee organized in 1945 to provide an organization, composed of representatives from the states and Federal agencies concerned with the development of the Missouri River Basin.

1947 - (October 4th) Excavation was begun for the embankment of Garrison Dam at a site 72 miles north of Bismarck in McLean and Mercer Counties. A multi-purpose structure, Garrison Dam was designed to accomplish these objectives: (1) provide and stabilize municipal water supplies; (2) provide irrigation waters; (3) provide for flood control; (4) produce hydro-electric power; (5) permit diversion to Devils Lake and the James River basin regions; (6) provide facilities for recreation and wildlife; (7) maintain minimum low water flow on the lower Missouri in the interest of sanitation; and (8) improve navigation on the Missouri and Mississippi Rivers.

1948 - Construction started in April of the initial phase of the Bureau of Reclamation's Heart Butte Dam, located 18 miles south of Glen Ullin on the Heart River. Project deemed essentially complete by December of 1949. Currently provides water for irrigation, flood control, and recreation.

1949 - The North Dakota State Legislature created a conservation and reclamation district known as the Missouri-Souris Conservancy and Reclamation District to facilitate the construction of the Missouri-Souris irrigation and water diversion project and to (1) provide for the future economic welfare and prosperity of the people of this State, and particularly of the people residing in the area embraced within the boundaries of such conservancy and reclamation district; (2) provide for the irrigation of lands within the sections of such district periodically afflicted with drought, and to stabilize the production of crops on such lands; (3) replenish and restore the depleted waters of lakes, rivers and streams in said district, and to stabilize the flow of said streams; (4) replenish the waters of, and to restore the level of Devils Lake; and (5) make available within the district waters diverted from the Missouri River for irrigation, domestic, municipal and industrial needs and for hydro-electric power and other beneficial and public uses.

1950 - Bureau of Reclamation's Heart Butte Dam completed; estimated cost $3,500,000.
Bureau of Reclamation's Dickinson Dam (Patterson Lake) completed; estimated cost $1,400,000.

1950 - Homme Dam, Park River, completed; cost $1,340,000.

Baldhill Dam, Sheyenne River, all construction completed; estimated cost $2,700,000. Mandan flood control works and levees completed; estimated cost $645,000.

1951 - Yellowstone River Compact ratified by Congress and signed into law by the President.

1953 - (June 11th) Garrison Dam dedicated by President Dwight D. Eisenhower.

1954 - Congress passed Public Law 566, the Watershed Protection and Flood Prevention Act. Since then, the North Dakota State Soil Conservation Committee has received a total of forty-nine applications for watershed project action. More than a million dollars in federal funds have been expended by the Soil Conservation Service in planning of the various watershed projects throughout North Dakota that have been and must be accepted, approved and given priority for planning by the State Soil Conservation Committee. Nearly eleven million dollars in federal funds have been expended in construction of various dams and other improvements by the Soil Conservation Service. North Dakota's sixty-seven soil conservation districts encompass every acre of land within its borders.

1954 - Jamestown Reservoir completed north of Jamestown; built as an early portion of the Garrison Diversion Unit.

1955 - In 1955, the North Dakota Legislature established the Garrison Diversion Conservancy District consisting of 22 counties in the State that contained areas that would be benefited by the development of the Garrison Diversion Project. The Conservancy District was established to provide the overall legal entity through which this project could be constructed and operated. Headquarters for the District, which now encompasses 25 counties, are located in Carrington, North Dakota.

1955 - Construction started on the Tongue River Pilot Watershed Project in Cavalier and Pembina Counties.

1957 - The State Water Commission and boards of county commissioners were authorized to exercise control and supervision over any dam or water control device or flood control project constructed by or with the assistance of any Federal agency when no designation of responsibility for maintenance and operation of such works had been made and when the project was located outside the boundaries of a water management district. Included in this general category would be a majority of the small dams built throughout North Dakota by various Federal agencies during the 1930's.

1958 - The Swan-Buffalo Creeks Watershed, located in Cass County, became the first authorized Public Law 566 Watershed Protection and Flood Prevention project authorized in North Dakota.

1958 - Grand Forks flood protection levee and floodwall completed; estimated cost, $949,000.

1959 - The International Joint Commission established the International Souris River Board of Control composed of two members, one from the United States and one from Canada. This Board was charged with the responsibility of carrying out the provisions of an interim order on the Souris River recommended by the International Joint Commission in 1959.

1959 - The North Dakota Water Users Association was formed through a merger of the North Dakota Reclamation Association and the Missouri-Souris Projects Association. This organization is composed of individuals and organizations interested in furthering the water resources development program of the State and has been very active in conducting meetings relative to water questions and in supporting water law legislation and appropriations.

1962 - Fargo flood protection levee completed; estimated cost, $1,640,000.

1962 - (April 3rd) The Governments of the United States and Canada requested the International Joint Commission to investigate and report on measures to develop the water resources of the Pembina River Basin in Manitoba and North Dakota and determine what plan or plans of cooperative development would be practical, economically feasible, and to the mutual advantage of both countries, having in mind domestic water supply and sanitation, control of floods, irrigation and other beneficial uses. The Commission was asked specifically to recommend what plan or plans would best meet the above purposes and requirements, to estimate the costs, benefits and any adverse effects of carrying out such plans, to recommend how the available water should be apportioned in order to achieve the above benefits, and to recommend how the cost of carrying out such plan or plans might be apportioned between Canada and the United States.

1963 - (July 1st) The "prior appropriation" doctrine became the only doctrine recognized as a basis for granting water permits. Prior to July 1, 1963, both the "riparian" and the "prior appropriation" doctrines were recognized. Under the "riparian" doctrine the owner of land adjacent to a stream has certain rights, in common with other similarly situated owners, in the flow of the water by virtue of such land ownership. Under the "prior appropriation" doctrine, the first user of water acquires a priority to continue the use of that water and the nearness of the land he owns to the water course is not a factor in his right. The "prior appropriation" doctrine requires the filing of an application to appropriate water with a designated State agency (the State Water Commission) in order to establish the water right holder's priority date as to the use of the water.

1963 - (July 1st) Beginning this date, **Any person, firm, corporation or municipality which used or attempted to appropriate water from any watercourse, stream, body of water or from an underground source for mining, irrigating, manufacturing, or other beneficial use over a period of twenty years prior to July 1, 1963, shall be deemed to have acquired a right to the use of such water without having filed or prosecuted an application to acquire a right to the beneficial use of such waters if such user shall, within two years from July 1, 1963, file with the state engineer an application for a water permit in the form required by the rules and regulations of the state engineer . . .** (Section 61-04-22, North Dakota Century Code).

1963 - (August) Construction started on Pheasant Lake Dam west of Ellendale in Dickey County. In completing this project, a portion of Highway 11 was used as embankment for the dam.

1964 - As a result of cooperative efforts of Federal, State and local agencies, two reservoirs were created in North Dakota, west of the Cities of Bismarck and Mandan, by utilizing the embankment of Interstate Highway 94 as a dam. These two dams, one named Sweetbriar and the other Crown Butte, were the first highway dam combination projects to be constructed as a part of the Interstate system.

1965 - (March 2nd) Thirty-eighth Legislative Assembly passed Section 61-01-26, North Dakota Century Code, which declared a state water resources policy. This is a most significant step as it permits legal entities to cooperate with each other across county and other legal boundaries.

1965 - (August 5th) President Lyndon B. Johnson signed Public Law 89-108, thus authorizing the initial 250,000 acre Garrison Diversion Unit Irrigation Project.

1965 - (August) Construction started on the Bowman-Haley Dam located about 25 miles southeast of Bowman, North Dakota. A flood control, recreation and water supply development.

1965 - (October 30th) Governor William L. Guy of North Dakota and Governor Karl F. Rolvaag of Minnesota, petitioned for the establishment of a river basin commission in accordance with Title II of Public Law 89-80, The Water Resources Planning Act. Governor Nils A. Boe of South Dakota subsequently gave his concurrence. In December of 1966, the Water Resources Council adopted a resolution recommending and requesting the establishment of the Souris-Red-Rainy River Basins Commission.

1966 - Largely as a result of efforts made by the North Dakota State Outdoor Recreation Agency, the Federal Bureau of Outdoor Recreation began accepting and approving project proposals which envisioned the construction of dams whose principal function was to provide water-based recreational opportunities in the out-of-doors.

1967 - North Dakota received initial grant from the Federal Water Resources Council under the provisions of Title III of Public Law 89-80, for assistance in preparing a comprehensive State Water Resources Development Plan. Federal funds matched by State funds.

1967 - The 1967 Legislatures of North Dakota and Minnesota each appropriated $95,000 for the 1967-69 biennium to participate in the operation of the Souris-Red-Rainy River Basins Commission; appropriations to be matched by the Federal Government.

1967 - (May 16th) "Water Quality Standards for Surface Waters of North Dakota" adopted by the North Dakota State Water Commission.

1967 - (May 16th) North Dakota State Water Commission granted the U. S. Bureau of Reclamation a permit to divert and appropriate 3,145,000 acre-feet of water annually for use in operating the Garrison Diversion Unit. Believed to be the largest single water permit ever granted.

1967 - (June 20th) President Lyndon B. Johnson issued Executive Order No. 11359 establishing the Souris-Red-Rainy River Basins Commission. Created under the provisions of Title II of Public Law 89-80, dated July, 1965, Commission offices are located in Moorhead, Minnesota. The area of the basins and jurisdiction of the Souris-Red-Rainy River Basins Commission extend to those portions of the States of Minnesota, North Dakota, and South Dakota drained by the Souris, Red and Rainy Rivers system. These areas comprise about

60,000 square miles, of which approximately 29,110 are in Minnesota, 29,932 square miles are in North Dakota, 930 square miles are in South Dakota, and 30 square miles are in Montana.

Responsibilities of the Souris-Red-Rainy River Basins Commission include: (1) serve as the principal agency for the coordination of Federal, State, inter-state, local and non-governmental plans for the development of water and related land resources within its area of jurisdiction; (2) prepare and keep up to date, to the extent practicable, a comprehensive, coordinated, joint plan; (3) recommend long-range schedules of priorities for the collection and analysis of basic data and for investigation, planning, and construction of projects; (4) foster and undertake such studies of water and related land resources problems . . . as are necessary for comprehensive river basin planning; (5) develop framework studies which will project, for 1980, 2000 and 2020, land use patterns to the extent necessary to appraise in general terms the needs for water resource development, and the effects of land use on projected water resources availability, management, and development; and (6) conduct framework studies which will reach conclusions as to the urgency of water and related land problems in the subregions, and recommend priorities for more detailed studies in the near future (10 to 15 years) leading to the authorization of an action program for the development of the water and related land resources.

1967 - (October) The International Joint Commission recommended in its report of October, 1967, that the Governments of Canada and the United States enter into an agreement, as soon as practicable, to implement all features of the plan agreed upon by engineering representatives of the two countries for the cooperative development of the water resources of the Pembina River Basin. Plan 2, the Plan adopted by members of the International Joint Commission and recommended to the two countries, calls for the construction of two dams, a main supply canal, and a precast concrete supply conduit extending from the Pembilier Dam outlet works to the main supply canal. Pembilier Dam, to be built in the North Dakota portion of the river basin, would create a reservoir 22 miles long with a usable storage capacity of 110,000 acre-feet which would be used primarily for flood control. Approximately, 45,000 acre-feet would be used for water storage during the period between the recession of the spring flood and the late winter months. The conservation pool would provide a capacity of 20,000 acre-feet for accumulated sediment. The flooded area at maximum water level, elevation 1096.5, would be 4,000 acres. Total estimated cost of the joint project is $33,000,000.

1968 - A 1968 landmark decision handed down by the North Dakota Supreme Court in Baeth vs. Hoisveen upholds the constitutionality of State legislation which requires that a water permit be obtained from the State Engineer prior to appropriating water for other than domestic or livestock purposes or for fish, wildlife or other recreational uses.

1968 - (July) Garrison Diversion Unit pumping plant at Snake Creek embankment was site of ground-breaking ceremonies.

CONSTITUTIONAL PROVISIONS

Section 210 of the North Dakota Constitution provides:

> **All flowing streams and natural water courses shall forever remain the property of the state for mining, irrigating and manufacturing purposes.**

Although this is the only constitutional section relating to water, and a very simple and general one at that, it is for the purposes of a State Water Resources Development Plan, very comprehensive. Its very simplicity and generality are its strength.

STATUTORY PROVISIONS

North Dakota's statutory law provides for a number of entities and offices whose primary purposes are the development, utilization and/or control of the State's water resources. Among these are the North Dakota State Water Commission, the State Engineer, irrigation districts, drainage districts, soil conservation districts, the Garrison Diversion Conservancy District and water management districts. Irrigation districts and the Garrison Diversion Conservancy District are entities with a single purpose — irrigation. It is safe to assume that very few, if any, drainage districts will be established in the future as the board of commissioners of a water management district has the identical authority of a board of drainage commissioners plus so much more. In fact, it is recommended that all existing drainage districts be urged to dissolve as quickly as possible and allow the county water management district to assume their areas of responsibility or establish water management districts in those counties where none presently exist. The duties and areas of responsibility of the State Water Commission, the State Engineer and water management districts are extremely broad and flexible and the responsibility of carrying out the State Water Resources Development Plan should depend primarily upon them.

Irrigation Districts and the Garrison Diversion Conservancy District

Chapters 61-05 through 61-11 of the North Dakota Century Code dealing with irrigation districts and Chapter 61-24 dealing with the Garrison Diversion Conservancy District appear to be adequate insofar as the development of a comprehensive state water plan is concerned. There are sections within some of the chapters, of course, which should be amended in order to assist the administrators of these entities, but such sections whether amended or not will not affect the plan's development.

Drainage Districts

As previously stated, a water management district has all the authority of a drainage district and then some. When this authority was first given to water management districts by the 1963 Session of the Legislative Assembly, it was intended that eventually all drainage districts would gradually phase out and their duties would be assumed by a water management district.

General Water Law Provisions

Chapters 61-01 and 61-15 of the North Dakota Century Code provide sufficiently flexible guidelines within which the State Water Commission may comfortably operate in order to reach most forseeable and predictable goals.

State Engineer

The authority of the State Engineer is quite comprehensive. Some of his many powers and the authorizing section of the Century Code are:

61-03-13 - State Engineer may adopt rules and regulations.

61-03-16 - He may request Attorney General to begin legal action to adjudicate rights to any stream system in North Dakota.

61-03-21 - He is able to control releases of reservoirs capable of impounding more than 1,000 acre-feet of water.

State Water Commission

The State Water Commission, like the State Engineer, has very general and broad authority. Some of the many areas of jurisdiction of the Commission and the authorizing section of the Code are:

61-02-03 - May apportion or allocate water rights between projects.

61-02-11 - May adopt rules and regulations.

61-02-14 - This section of the Code contains some of the specific powers and duties of the Commission and it employs very broad, and comprehensive language.

61-02-24 - Commission may cooperate, contract or make compacts with the Federal Government, or any of its departments or agencies, with any state of the United States, the Dominion of Canada or any of its provinces.

61-02-28 - Authorized to make plans, investigations and surveys in or out of the state for establishing, maintaining, operating, controlling and regulating systems of irrigation, municipal, industrial, recreational and fish and wildlife projects.

61-02-29 - Possesses full control over all unappropriated public water.

61-02-30 - May secure water rights merely by making a written declaration to store, divert or control the unappropriated waters of a particular body of water.

61-02-39 - May adjust plans and operation of any project.

61-02-40 - Commission's authority extends to any right to the natural flow of all waters of the state.

61-02-41 - May enter all premises of water appropriators for purposes of making surveys.

61-02-43 and 44 - May hold hearings relative to water rights, make determinations of such rights and police and distribute waters to respective owners (this coupled with the Commission's authority to adopt rules and regulations could be very effective if we had the necessary funds to proceed); decision of commission is subject to landowners right of appeal to court of law.

61-02-46 through 02-63 & 02-67 & 02-68 - Commission may issue revenue bonds to finance cost of any project it is authorized to construct or in which it may participate.

NOTE: IT IS NOT INTENDED TO LIST EACH AND EVERY POWER AND DUTY OF EITHER THE STATE WATER COMMISSION OR THE STATE ENGINEER. IT IS MERELY INTENDED TO ILLUSTRATE THE EXTREME BROAD NATURE OF THEIR AUTHORITY.

Water Management Districts

Water management districts are very flexible. With this entity North Dakota law has provided an instrumentality with which any State or Federal office or agency interested in the development, utilization or control of the State's water resources may work.

INTERSTATE AND INTERNATIONAL COMPACTS

North Dakota is party to one international and two interstate compacts, the primary objectives of which are the preparation and adoption of long-range plans and development, utilization and control of certain flowing streams.

In 1909, a treaty between the United States and Great Britain, resulted in the establishment of the International Joint Commission. The Commission is charged with the determination of the rights of Canada and the United States, and their provinces and states, to the waters in which both countries have an interest. Each common body of water, and its drainage area, is a "reference." North Dakota, Saskatchewan, and Manitoba are concerned with the Souris River Reference and the Souris-Red River Reference.

The Souris River Reference, dated January, 1940, is concerned solely with the Souris (Mouse) River and its tributaries, while the Souris-Red River Reference, dated January, 1948, is concerned with the Souris River and the Red River of the North, including the Pembina River and its tributaries.

Only two interstate compacts are actually incorporated into North Dakota law. The Tri-State Water Compact is Chapter 61-17 and the Yellowstone River Compact is Chapter 61-23 of the North Dakota Century Code.

In addition to North Dakota, the Tri-State Compact includes South Dakota and Minnesota. Its purpose is to administer and supervise the drainage area for the Red River of the North with the exception of the Ottertail River and its tributaries. For years, this compact has been inactive due to the fact that not all states involved had representatives present at Commission meetings and because the Ottertail River and its tributaries were excluded from the Commission's jurisdiction. All that need be done to reactivate the Tri-State Compact is for North Dakota, South Dakota and Minnesota to each designate a representative.

The Yellowstone River Compact includes the States of North Dakota, Montana and Wyoming and provides for the division of the waters of the Yellowstone River and its tributaries. The Little Missouri Compact, which has been authorized but has been inactive for many years because a Federal referee has not been reappointed, provides for the division of the waters of the Little Missouri River and its tributaries.

Future compacts have, at one time or another, been proposed for the James River and the North Fork of the Grand River, both compacts involving North and South Dakota.

Chapter Four

Regional Setting

CHAPTER IV

REGIONAL SETTING

NORTH DAKOTA'S RELATIONSHIP TO THE NATION AND CANADA

North Dakota is located in the center of the North American Continent, bordered on the north by Canada, and on the west, south and east by other states of the United States of America. A panoptic view of the regional setting includes North Dakota, South Dakota, Minnesota, northwestern Iowa, northern Nebraska, eastern Montana, northeastern Wyoming, southern Saskatchewan, southern Manitoba, and a portion of southwestern Ontario.

A comparison made between these states and provinces shows that North Dakota ranks first in per capita agricultural economy, fourth in per capita mining economy, fifth in inland water area, third in the number of miles of hard surfaced highways, and fourth in population density.

General Description of States and Provinces in the Region[1]

NORTH DAKOTA

AREA:

70,665 square miles, including 1,208 square miles of water.

ELEVATION:

750 feet to 3,506 feet above mean sea level.

POULATION:

632,446 according to the 1960 Census.

CHIEF PRODUCTS:

Agricultural — barley, cattle and calves, flaxseed, oats, potatoes, rye, soybeans and wheat.

Mining — clay, lignite, natural gas, petroleum, salt, sand and gravel.

Manufacturing — dairy products, flour, feed, sugar, equipment for industry and agriculture.

North Dakota is a midwestern state in the center of the North American continent. The geographic center of North America is near the town of Rugby. North Dakota is the nation's most agricultural state. Its economy is based more heavily on farming than that of any other state. North Dakota has a larger percentage of workers in agriculture than any other state. About 65 out of every 100 North Dakotans live on farms or in farming areas — the highest proportion in the nation.

Farms and ranches cover nearly all of North Dakota. They stretch from the flat Red River Valley in the east, across rolling plains to the rugged Badlands in the west. North Dakota's chief crop is wheat, which is grown in every county. Only Kansas raises more wheat. North Dakota harvests more than half of the country's flaxseed. It is also the top producer of barley and rye.

Soil and water are North Dakota's most precious resources. Together they are the base of the state's great agricultural wealth and growing recreation industry. North Dakota also has enormous mineral resources. The Nation's largest coal reserves — about 350,000,000,000 tons of lignite coal — are in North Dakota. The state's oil reserves are also among the largest in the United States. Petroleum was not discovered in North Dakota until 1951, but it quickly became one of the state's most valuable minerals.

Few settlers came to North Dakota region before the 1870's. Transportation was poor and newcomers feared attacks by Indians. During the 1870's the Northern Pacific Railroad began to push across the Dakota Territory. Large-scale farming also began during the 1870's. Eastern corporations and some families established huge wheat farms covering thousands of acres in the Red River Valley. The farms made such enormous profits that they were called bonanza farms. In 1870, North Dakota had 2,405 persons. By 1890, only 20 years later, its population had grown to 190,983. Farming became firmly established as North Dakota's major industry.

North Dakota was named for the Sioux Indians who once roamed the territory. The Sioux called themselves Dakota or Lakota, meaning allies or friends. One of North Dakota's nicknames is the Sioux State, but it is more often called the Flickertail State because of the many Flickertail ground squirrels that live in central North Dakota.

Bismarck is the capital of North Dakota, and Fargo is the largest city.

SOUTH DAKOTA

AREA:

77,047 square miles, including inland waters.

ELEVATION:

962′ to 7,242′ above sea level.

POPULATION:

680,514

CHIEF PRODUCTS:

Agriculture — alfalfa seed and grass seed, beef and dairy cattle, barley, corn, flaxseed, hay, hogs, oats, rye, sheep, spring wheat.

Manufacturing — clay products, dairy products, flour and feed, lumber and wood products, meat products, printed materials.

Mining — clay, gold, sand and gravel, stone.

[1] K. L. Simenson, J. E. Walterson. *The Regional Setting: North Dakota State Outdoor Recreation Plan,* North Dakota State Outdoor Recreation Agency, pp. 1-32, adptd or repr from *The World Book Encyclopedia* with permission.

South Dakota is a midwestern state of many startling and beautiful contrasts. The wide Missouri River flows southward through the middle of the state. Low hills, lakes formed by ancient glaciers and vast stretches of fertile cropland lie east of the river. West of the river are deep canyons and rolling plains. The enchanting Black Hills rise abruptly in the southwest. Southeast of the Black Hills are the weirdly beautiful Badlands. South Dakota is often called the Land of Infinite Variety because of the many great differences in its landscape.

South Dakota is mainly a farm state. Farms and ranches cover about nine tenths of the state, and more South Dakotan's are employed in farming than in any other occupation. Sheep and cattle graze on the sprawling ranches of the western plains and on smaller farms in the east. Crops are grown on the rich soil of eastern South Dakota. The state is a top producer of beef cattle, hogs and sheep. It also ranks high in growing corn, flaxseed, rye, spring wheat and other crops.

Millions of tourists visit South Dakota every year. The tourist trade ranks second only to agriculture in importance. The Black Hills are one of the nation's most popular vacationlands. Attractions there include Mount Rushmore National Memorial, also called the Shrine of Democracy. Sixty foot high heads of George Washington, Thomas Jefferson, Theodore Roosevelt and Abraham Lincoln have been carved out of a granite mountain. The memorial is the world's largest sculpture. Nearby an even larger statue of the great Sioux Chief Crazy Horse is being blasted out of a mountain.

Most of South Dakota's mineral wealth lies in the Black Hills. Gold was discovered there in 1874. Two years later the rich Homestake lode was discovered. The Homestake mine is still the greatest gold producer of the western hemisphere.

The history of South Dakota reads like an adventure story. It is a tale of daring fur traders, battles between Indians and white settlers and stampedes to gold. Included in the story are such colorful names as Calamity Jane, George Custer, Sitting Bull and Wild Bill Hickock, but the most important figure in the state's history has been the farmer. The courageous South Dakota farmer has clung to his land through droughts and depressions and blizzards. He has made South Dakota one of the nation's greatest agricultural states.

South Dakota was named for the Sioux Indians who once roamed the region. The Sioux called themselves Dakota or Lakota meaning allies or friends. South Dakota's sunny climate earned it the nickname of the Sunshine State. The many coyotes that once lived in South Dakota gave it another nickname — the Coyote State.

The population center of the United States is in South Dakota, 17 miles west of Castle Rock. Pierre is the capital of South Dakota and Sioux Falls is the largest city.

MINNESOTA

AREA:

84,068 square miles, including 4,059 square miles water and 2,212 square miles of Lake Superior.

ELEVATION:

602′ to 2,301′ above sea level.

POPULATION:

3,413,864

CHIEF PRODUCTS:

- Agriculture — cattle and calves, corn, dairy products, flaxseed, hogs, oats, poultry and eggs, rye, soybeans, wheat.
- Manufacturing — breakfast cereals, canned fruits and vegetables, chemicals and related products, flour, food mixes, machinery and metal goods, meat packing products, medical and surgical instruments, paper and paperboard products, printing and publishing.
- Mining — clay, granite, iron ore, limestone.
- Fishing Industry — burbot, herring, perch, smelt, tullibee, walleyes, whitefish.

Minnesota is one of the chief food producing states in the United States. The state's wheat crops, flour mills and dairy products give Minnesota one of its nicknames — the Bread and Butter State, but Minnesota is usually called the Gopher State because many gophers live on its southern prairies.

More than a million cows graze on the rich pastures of Minnesota's dairy farms. The farmers of this midwestern state also raise great numbers of beef cattle, calves and hogs. Minnesota is a leading producer of corn, flaxseed, hay, potatoes, soybeans and sugar beets. All these farm products bring in an enormous income, but manufacturing is even more important to Minnesota's economy than agriculture.

Minnesota's chief manufacturing activity is processing the products of its farms. Minnesota makes more butter than any other state and is a leading producer of milk and cheese. It is one of the top meat packing states and flour producers and ranks high in canning vegetables.

About two-thirds of all the iron ore mined in the United States comes from Minnesota. The known deposits of the state's richest iron ore have been exhausted, but the Minnesota earth still contains billions of tons of valuable low-grade ore. Minnesota also has millions of acres of trees, although lumber companies have logged its forests heavily. These woodlands furnish raw materials for making pulp, paper and other products.

Minnesota's scenic beauty, thousands of sparkling lakes and deep pine woods make the state a vacation wonderland. It is a favorite state of hunters and fisherman because of its plentiful game animals and fish. In northern Minnesota, campers, canoeists and hikers can explore thousands of square miles of unbroken wilderness.

The state's history is much the story of the development of its great natural resources. The fur-bearing animals of Minnesota's forests first attracted fur traders. Next the fertile soil brought farmers who poured into the region from the eastern states and from Europe. The thick forests of tall pines attracted lumberjacks from Maine, Michigan and Wisconsin. Finally miners came to dig the vast deposits of rich iron ore.

MONTANA

AREA:

147,138 square miles, including 1,402 square miles of inland water.

ELEVATION:

1,800′ to 12,799′ above sea level.

POPULATION:

674,767

CHIEF PRODUCTS:

Agriculture — barley, beef cattle, dairy products, flaxseed, hay, sheep, sugar beets, wheat, wool.

Mining — copper, gold, fluorspar, lead, manganese, petroleum, phosphate rock, rare-earth metals, sand and gravel, silver vermiculite, zinc.

Manufacturing and Processing — dairy, flour and meat products, lumber products, metal products, petroleum products, sugar.

Montana is the fourth largest state. Only Alaska, Texas and California have larger areas. Western Montana is a land of tall rugged mountains. There, men dig deep into the earth to tap the state's vast deposits of copper, gold, manganese and silver. Eastern Montana is a land of broad plains. There, vast herds of cattle graze on the prairie grasses, wheat grows in the fertile soil, and wells bring oil up from deep under the ground.

The name Montana comes from a Spanish word meaning mountainous. Early travelers, who saw the sun glistening on the lofty snow capped peaks, called the area the Land of Shining Mountains. These mountains contained a wealth of gold and silver which gave the state another nickname, the Treasure State. Glacier National Park has mountain peaks so steep and remote that they have never been climbed.

Early Montana was Indian country, but gold was discovered there in 1862 and great numbers of eager prospectors rushed to the area. Mining camps sprang up overnight and wealth came to the territory, but the gold also brought problems. Outlaws spread terror in the mining camps until groups of citizens called vigilantes took the law into their own hands. The vigilantes hanged many of the outlaws and drove others away.

Montana was also the scene of another struggle. The efforts of the Indians to keep their land reached a climax in the state. The last stand of General George Custer and the final battle of the Nez Perce War were fought in Montana.

The mountains, the battlefields, the old gold camps and the vast lonely distances still make a visitor feel close to the American frontier. In the capital, Helena, the main street is called Last Chance Gulch. The name comes from the gold camp that stood on that site. Even today when a basement is dug for a building in Helena, the digging often produces enough gold to help pay for the building.

SASKATCHEWAN

AREA:

251,700 square miles, including 31,518 square miles of inland water.

ELEVATION:

697′ to 4,546′ above sea level.

POPULATION:

925,181

CHIEF PRODUCTS:

Agriculture — barley, beef cattle, flaxseed, oats, rapeseed, rye, wheat.

Mining — coal, copper, natural gas, petroleum, potash, sodium sulfate, uranium, zinc.

Manufacturing — dairy products, flour, meat, and meat products, petroleum products.

Forest Products — lumber, plywood, posts, pulpwood.

Fur Industry — beaver, mink, muskrat.

Fishing Industry — lake trout, pickerel, pike, tullibee, whitefish.

Saskatchewan, one of the prairie provinces of Canada is the greatest wheat growing region in North America. Saskatchewan farmers produce about three-fifths of Canada's wheat. The province's vast fields of golden wheat gave it the nickname of Canada's Breadbasket. Railroads carry huge loads of the grain to Canadian ports for shipment to all parts of the world. The Saskatchewan Wheat Pool is one of the world's largest marketing cooperatives. Its headquarters are in Regina, the Province's capital and largest city.

Saskatchewan has over a third of all the farmland in Canada — more than any other province. Saskatchewan's farms are on its flat southern prairies where most of the people live. Tall grain elevators rise in the hundreds of towns and villages that dot the fertile plains. More of the land is used to raise wheat than any other crop. In many areas, wheat fields extend to the horizon in all directions. Saskatchewan also ranks among the leading provinces and states in the production of barley, flaxseed and rye. The farmers of Saskatchewan raise large numbers of beef cattle as well as grain crops.

Southern Saskatchewan is much more than a rich farming region. Mapor oil fields were discovered there during the 1950's. These discoveries brought sudden changes to the prairies. Oil wells and drilling rigs became a common sight in the fields of golden wheat. Today, Saskatchewan produces more than a fourth of Canada's petroleum, and is a leading oil producer in North America. Petroleum refining has become Saskatchewan's chief manufacturing industry. Large scale mining of potash, used in fertilizers, began during the early 1960's. Saskatchewan's potash fields are the largest in the western world. Potash mining is the fastest growing mining industry in the province. By 1970, Saskatchewan is expected to provide more than a third of the world's supply of potash.

Northern Saskatchewan is rocky and covered with forests and lakes. It has the largest lakes in the province. Deposits of copper, gold, uranium and zinc in this portion of the province help make Saskatchewan a leading producer of these minerals. South of this region are forests of commercially valuable trees, including pines, poplars, and spruces. Caribou, elk and moose roam the rugged forests. Grayling, pickerel and trout swim in the sparkling streams and lakes. Many sportsmen from Canada and the United States fly to this rough wilderness to hunt and fish. Indians, metis and whites live in small scattered communities in northern Saskatchewan. They earn their living by fishing, mining, trapping and woodcutting.

The province took its name from the Saskatchewan River named by the Cree Indians. They called the winding river Kisiskadjewan which means fast flowing or river that turns around when it runs.

MANITOBA

AREA:

251,000 square miles, including 39,225 square miles of inland water.

ELEVATION:

Sea level to 2,727′ above sea level.

POPULATION:

921,686

CHIEF PRODUCTS:

Agriculture — barley, beef cattle, flaxseed, milk, oats, rye, sugar beets, wheat.

Manufacturing — cement, clothing, food products, lumber and wood products, petroleum products, transportation equipment.

Mining — copper, nickel, petroleum, zinc.

Fishing Industry — pickerel, pike, sauger, whitefish.

Manitoba is one of Canada's prairie provinces. It lies midway between the Atlantic and Pacific Oceans. Winnipeg, Manitoba's capital and largest city is the main transportation center linking eastern and western Canada.

About half the people of Manitoba live in Winnipeg and its suburbs. This area is the province's major industrial center. Busy food processing plants and other factories there help make manufacturing the chief source of income in Manitoba. St. Boniface, a suburb of Winnipeg, has the largest stockyards in Canada. The area also has clothing factories, petroleum refineries and railway equipment plants.

Winnipeg lies in rolling plains that cover the southern section of Manitoba. This fertile region has the province's richest farmlands. In summer, hundreds of square miles of wheat and other grains wave in the sun. Large numbers of beef cattle graze in fenced pastures. Other important farm products are flaxseed, milk, sugar beets and vegetables.

A vast rocky region lies across the northern two-thirds of Manitoba. This thinly populated region has great deposits of copper, gold, nickel and zinc. Thompson has the only facilities in the western world for all stages of nickel production from mining to processing. Manitoba ranks among the leading North American producers of nickel and zinc. Thick forests stretch across the southern half of the region. Balsam firs, spruces and other trees provide wood for Manitoba's factories and paper mills. Much of the northern half of the region is too cold for trees to grow.

Manitoba's many rivers and lakes cover almost a sixth of the province and help make it a popular vacationland. Tourists enjoy boating and swimming in the clear sparkling waters. Fisherman come from many parts of North America to cast for bass, pike and trout. In the rugged forests, hunters track caribou, elk, moose and smaller game. In the marshes and prairies, they shoot ducks, geese and partridges.

WYOMING

AREA:

97,914 square miles including 503 square miles of inland water.

ELEVATION:

3,100′ to 13,785′ above sea level.

POPULATION:

33,066

CHIEF PRODUCTS:

Agriculture — beans, cattle, hay, sheep, sugar beets, wheat, wool.

Mining — bentonite, coal, iron ore, natural gas, petroleum, trona, uranium.

Manufacturing — beet sugar, flour, lumber and wood products, petroleum products, processed meats, sulfur.

Wyoming is a state famous for the beauty of its mountains. The peaks of the Rocky Mountains tower over the landscape. They provide the setting for the nation's largest and oldest national park, Yellowstone. Wyoming has not only the first national park, but also the first national monument — Devils Tower — and the first national forest — Shoshone. Another famous scenic wonder, Grand Teton National Park, includes some of the west's most beautiful mountains. Millions of tourists visit Wyoming each year to enjoy its scenery and historic places.

Not all of Wyoming is mountainous. Between the mountain ranges lie broad flat treeless basins. Some of these basins are dotted with rugged lonely towers of rock called buttes. In the eastern part of the state a flat dry plain stretches westward towards the mountains.

Wyoming's wealth — cattle and oil — comes from its land. More than 80 percent of the state's land is used for grazing. Thousands of oil wells dot the prairies. Visitors may see a white face steer cropping the grass near a pumping oil well. Petroleum, natural gas and other minerals make Wyoming one of the leading states in mining. Wyoming also ranks as a leader in the production of bentonite, a special clay used in oil well drilling; trona, a mineral with wide use in the chemical industry; and uranium, the raw material of atomic power.

The federal government owns almost half the land in Wyoming. Since the state depends mostly on its land, this makes the government especially important in Wyoming economy. Federal agencies control grazing, logging and mining on the government land.

Wyoming has attracted travelers since the earliest days of white settlement. Three of the great pioneer trails of the American West cross Wyoming. The California, Mormon and Oregon trails all took the covered wagons through South Pass. This pass became famous as the easiest way for the pioneers to cross the mountains.

Millions of people have crossed Wyoming, but relatively few have stayed. Of the 50 states, only Alaska and Nevada have fewer people according to the 1960 census. Wyoming's capital and largest city, Cheyenne, has a population of less than 50,000.

The word Wyoming comes from a Delaware Indian word meaning **upon the great plain.** Wyoming is nicknamed the equality state because Wyoming women were the first in the nation to vote, hold public office and serve on juries. In 1870, Esther Morris became the nation's first woman justice of the peace. In 1924, Wyoming voters elected the first woman governor, Nellie Taylor Ross.

NEBRASKA

AREA:

77,227 square miles, including 615 square miles water.

ELEVATION:

840′ to 5,424′ above sea level.

POPULATION:

1,411,330

CHIEF PRODUCTS:

Agriculture — beef cattle, corn, grain sorghums, hay, hogs, soybeans, wheat.

Manufacturing — animal feed, canned vegetables, dairy products, farm implements, flour, meat products, refined beet sugar.

Mining — clay, limestone, natural gas, petroleum, sand.

Nebraska is one of the leading farming states in the United States, yet it was once considered part of the "Great American Desert." The people of Nebraska with their determined pioneer spirit made the Nebraska desert a land of productive ranches and farms. The hardy Nebraska farmers clung to their land despite dry periods, economic depression and grasshopper plagues. To grow crops in dry regions, they built irrigation systems and practiced scientific farming. Where crops could not be made to grow, Nebraskans used the land to graze cattle. They learned the value of joining together to sell their products cooperatively.

Today, the sound of busy tractors and other farm machinery is heard across Nebraska. In the west, waving fields of golden wheat stretch as far as the eye can see. In north central Nebraska, huge herds of beef cattle graze on enormous ranches. On the fertile farms of the east, farmers grow corn, grain sorghums and other crops. The farmers there also raise hogs and fatten cattle for market.

Nebraska's chief manufacturing activity is processing the huge quantities of food produced on its ranches and farms. Meat packing is the leading food processing activity, and Omaha is one of the world's largest meat-packing centers.

Much of the history of Nebraska is the story of the tough, strong-willed Nebraska farmer. Many of the first farm settlers built their homes out of the Nebraska sod, because they found few trees on this grassy land. In the 1860's, the first great wave of homesteaders poured into Nebraska to claim free land granted by the federal government. Hard times, insect pests and droughts discouraged many farmers and they returned to the East, but most of them refused to give up, and they built a rich, productive state.

The independent pioneer spirit of the people of Nebraska also led them to adopt a unicameral state legislature. Nebraska is the only state in the nation with a unicameral legislature. Lincoln is the capital of Nebraska and Omaha is the largest city.

The name Nebraska comes from the Oto Indian word "nebrathka." The word means flat water and was the Indian name for Nebraska's chief river, the Platte. Nebraska's official nickname is the Cornhusker State. This nickname comes from corn, the state's leading crop and from cornhusking contests that were once held each fall in many rural communities.

NORTHWESTERN IOWA

AREA:
: 56,290 square miles, including 258 square miles of water.

ELEVATION:
: 480′ to 1,657′ above sea level.

POPULATION:
: 2,757,537

CHIEF PRODUCTS:
: Agriculture — cattle and calves, corn, dairy products, hay, hogs, oats, poultry, eggs, soybeans.
: Manufacturing — cement, farm machinery, fountain pens, laundry equipment, processed meats and other food.
: Mining — clay, coal, gypsum, sand and gravel and stone.

Iowa is one of the greatest farming states in the United States. It ranks second only to California in the total value of crops and livestock. Iowa has about a fourth of the richest farmland in the United States. More corn — about a fifth of the nation's supply — grows in this fertile soil than in any other state. Iowa is sometimes called the Corn State and is known as the land where the tall corn grows.

The pioneers who first plowed the prairie sod of Iowa uncovered deep layers of rich black soil. They made the rolling grass-covered plains bloom with vast fields of thriving crops. Today, farms make up 94 percent of Iowa's total area. Only Kansas and Nebraska have greater percentages of farmland. About a fourth of the people of Iowa live on farms.

Iowa farmers provide seven percent of the nation's food supply. Corn, of course, is the chief crop. The farmers feed much of it to their hogs. More hogs are raised in Iowa than in any other state — about a fourth of the country's total. Iowa is also a leading producer of beef cattle, dairy products, oats and soybeans.

The manufacturing industries of Iowa largely serve the state's agriculture. The most important manufacturing activity is meat-packing and several Iowa cities have busy stockyards. Many factories process food products, especially from corn or manufacture farm machinery. Manufacturing has been expanding rapidly and attracting many rural residents to the cities and towns. In 1960, for the first time in Iowa's history, the U. S. Census reported that most Iowans lived in urban areas. Sioux City has the nation's largest popcorn processing plant and Cedar Rapids has the largest cereal mill. The country's biggest home-laundry appliance factory is in Newton. Des Moines, the capital and largest city, is a center of insurance companies.

Iowa leads the states in percentage of people who can read and write — more than 99 percent. It has held this leadership since 1910. Iowa's school system has produced many famous men — Herbert Hoover, the 31st President of the United States, was born in West Branch. Another Iowan — Henry A. Wallace, served as Vice President under President F. D. Roosevelt. In the arts, the scenes and people of rural Iowa painted by Grant Wood have won world-wide fame.

Iowa's most famous nickname is the Hawkeye State. This nickname probably honors Black Hawk, a famous Indian Chief. Black Hawk led the Sauk and Fox Tribes against the whites in the Black Hawk War of 1832. The Indians were defeated and gave up a strip of land along the Mississippi River. This land was known as the Black Hawk Purchase. In 1833, permanent settlement began there.

THE PEOPLE OF THE REGION
NORTH DAKOTA

The 1960 U. S. Census reported that North Dakota had 632,446 persons. The population had increased two percent over the 1950 figure, 619,636. The U. S. Bureau of the Census estimated that by 1965 the population had slipped to about 626,000 persons (World Book Encyclopedia data).

> Editor's Note: Series P-25, No. 333 U. S. Bureau of Census, March 10, 1966 estimates North Dakota population for July 1, 1965 at 650,000 persons, which is an increase of 18,000 persons.

Only about 35 percent of the people of North Dakota live in cities and towns. North Dakota has the lowest percentage of city dwellers of any state. North Dakota has one Standard Metropolitan Statistical Area as defined by the Bureau of the Budget. This is the Fargo-Moorhead metropolitan area. The area had 106,027 persons including 46,662 persons in Fargo.

North Dakota has no large manufacturing industries to encourage the growth of big cities. Only 15 cities in the State have more than 2,500 persons; only four have more than 25,000 persons. They are, in order of size, Fargo, Grand Forks, Minot and Bismarck. North Dakota's larger cities still serve their original function as centers of shipping, supply and trade for the surrounding agricultural region. Most of the factories in the cities are small. They manufacture, pack and process chiefly food and food products.

Settlers began to pour into North Dakota by the thousands in the late 1880's. They were attracted by reports of the large profits that had been made in wheat farming. Most of the settlers came from states to the east and south. The largest number from other nations came from Norway. They settled throughout the region. Germans and Russians settled in the south central area and Canadians moved into the Red River Valley. Today about 95 of every 100 North Dakotans were born in the United States. Most of the others came from Canada, Germany, Norway and Russia.

The majority of immigrants who arrived in the 1880's belonged to the Lutheran and Roman Catholic Churches. Today more than half the church members in North Dakota belong to these two churches. Other large religious groups in the state include Methodists and Presbyterians.

SOUTH DAKOTA

The 1960 U. S. Census reported that South Dakota had 680,514 persons. The population had increased four percent over the 1950 figure. The U. S. Bureau of Census estimated that by 1965 the population had reached about 682,000.

South Dakota's percentage of city dwellers ranks among the lowest in the nation. Only about two-fifths of the people live in cities and towns. The state has only one Standard Metropolitan Statistical Area which is the Sioux Falls metropolitan area, having 86,575 persons including 65,466 in Sioux Falls.

South Dakota has no great manufacturing industries to prompt the growth of large cities. Only eight cities in the state have populations of more than 10,000. Only two cities — Sioux Falls and Rapid City — have more than 25,000 persons. Most South Dakota towns were established to serve the surrounding agricultural regions. A majority of these towns lie east of the Missouri River, in the state's chief farming area. Many towns have also grown up in the Black Hills where mining and the tourist industry prosper.

About 97 out of every 100 South Dakotans were born in the United States. Most of those born in other countries came from Denmark, Germany, Norway, Russia and Sweden.

Lutherans make up the largest single religious group in South Dakota. Roman Catholics are second largest group, followed by Methodists, Presbyterians and members of the United Church of Christ.

MINNESOTA

The 1960 U. S. Census reported that Minnesota had 3,413,864 persons. The population had increased 15 percent over the 1950 figure, 2,982,483. The U. S. Bureau of the Census estimated that by 1965 the state's population had reached about 3,665,000.

Almost two thirds of the people of Minnesota live in cities. More than a third live in the Minneapolis-St. Paul metropolitan area. Minnesota has three Standard Metropolitan Statistical Areas as defined by the U. S. Bureau of the Budget.

Minneapolis is the largest city in Minnesota. It adjoins St. Paul, Minnesota's capital and second largest city. The Twin Cities, as they are called, serve as the state's leading cultural, financial and commercial center. Duluth, Minnesota's third largest city, is the western most port on the Great Lakes and an important industrial center.

About 96 out of every 100 Minnesotans were born in the United States. Most Minnesotans who were born in other countries came from Denmark, Finland, Norway and Sweden. Many also came from Canada, Czechoslovakia, Germany, Great Britain, Poland and Russia.

Lutherans and Roman Catholics are the largest religious groups in Minnesota. Other large religious groups include Baptists, Congregationalists, Episcopalians, Methodists and Presbyterians.

MONTANA

The 1960 U. S. Census reported that 674,767 persons lived in Montana. The population had increased 14 percent over the 1950 figure of 591,024. The U. S. Bureau of Census estimated that by 1965 the state's population had reached about 733,000. Montana's 21,200 Indians, most of whom live on reservations, make up three percent of the population.

About half of the people live in cities and towns and about half live in farm areas. The state has no cities of more than 60,000 population. Billings and Great Falls are the only Standard Metropolitan Statistical Areas as defined by the U. S. Bureau of the Budget.

Most of Montana's cities began as mining towns, or as centers of trade for farm and ranch areas. Butte, the third city in population, grew from a mining camp. So did Helena, the state capital.

The majority of Montanans are protestants, but Roman Catholics form the largest single religious group.

SASKATCHEWAN

The 1961 Canadian census reported that Saskatchewan had 925,181 persons. The population had increased 11 percent over the 1951 figure of 831,728. The Dominion Bureau of Statistics estimated that by 1965 the provincial population had expanded to approximately 946,000.

More than two fifths of the people of Saskatchewan live in cities and towns. Saskatchewan has no Census Metropolitan Areas as defined by the Dominion of Statistics. The province has six cities with populations of more than 10,000. They are, in order of size, Regina, Saskatoon, Moose Jaw, Prince

Albert, Swift Current and North Battleford. Almost a fourth of the province's people live in Regina and Saskatchewan.

About 85 percent of Saskatchewan's people were born in Canada. Most of those born in other countries came from Great Britain, the United States or Russia. About 40 percent of the people have English, Irish or Scottish ancestors. Other groups, in order of size, include those of German, Ukranian, Scandinavian or French descent. Saskatchewan has about 30,600 Indians. Most of the province's Indians live on reservations. Several thousand Metis live in the thinly populated northern part of the province.

More of Saskatchewan's people belong to the United Church of Canada than to any other religious body. Other large church groups, in order of size, include: Roman Catholics, Lutherans and members of the Anglican Church of Canada.

MANITOBA

The 1961 Canadian census reported that Manitoba had 921,686 persons. The population had increased 19 percent over the 1951 figure of 776,541. The Dominion Bureau of Statistics estimated that by 1965 the population had reached about 960,000.

About two thirds of the people of Manitoba live in cities and towns. About half — 475,989 persons — live in the metropolitan area of Winnipeg, the province's only Census Metropolitan Area.

Besides Winnipeg, Manitoba has eight cities and towns with populations of more than 10,000. They are St. Boniface, St. James, Brandon, East Kildonan, West Kildonan, Transcona, Portage LaPrairie and Flin Flon.

More than 80 of every 100 Manitobans were born in Canada. The province also has large numbers of persons born in Germany, Great Britain, Poland and Russia. About 40 percent of the people have English, Irish or Scottish ancestors. Some descendants of French settlers live in towns where French is still the chief language.

The United Church of Canada has the largest church membership. Other large religious groups are Roman Catholics, members of the Anglican Church of Canada and Lutherans.

WYOMING

The 1960 U. S. Census reported that Wyoming had 330,066 persons. This was an increase of 14 percent over the 1950 figure of 290,529. The U. S. Bureau of Census estimated that by 1965 the state's population had reached 357,000.

A little more than half of Wyoming's people live in cities. Most of the cities are small compared with those in other states. Cheyenne, the capital and largest city, and Casper, the second largest city, both have fewer than 50,000 persons. The next three cities, in order of size, are Laramie, Sheridan and Rock Springs. About a fourth of the state's people live in cities along a single major highway and rail line in southern Wyoming.

About 97 out of every 100 persons in Wyoming were born in the United States. Wyoming has about 4,000 Indians, most of whom live on the Wind River Reservation, near Riverton.

A majority of the people of Wyoming are protestants. The largest religious groups in Wyoming include: Baptists, Congregationalists, Episcopalians, Lutherans, Methodists, members of the Church of Jesus Christ of Latter Day Saints (Mormons), Presbyterians and Roman Catholics.

NEBRASKA

The 1960 U. S. Census reported that Nebraska had 1,411,330 persons. The population had increased seven percent over the 1950 figure, 1,325,510. The U. S. Bureau of Census estimated that by 1965, the state's population had reached 1,453,000.

About half the people live in cities. Nebraska has two Standard Metropolitan Statistical Areas as defined by the U. S. Bureau of the Budget. These are: Omaha, with a population of 457,873 and Lincoln with a population of 155,272.

Omaha, the state's largest city, serves as the industrial and trade center of eastern Nebraska and western Iowa. Omaha is one of the nation's chief rail centers. Lincoln, the second largest city, became Nebraska's capital in 1867. The first capitol stood on the open prairie. Pioneers planted trees that still shade much of Lincoln's streets. D Street is famous for its many huge pin oaks.

Lincoln is an educational, governmental and retail shopping center. Grand Island, Nebraska's third largest city, has a population of almost 26,000. It is an important shipping point for farm and manufactured products. Only eight other Nebraska cities have more than 10,000 persons.

Nearly 97 of every 100 Nebraskans were born in the United States. Persons of German descent make up about a third of the population and Germans are the largest group of Nebraskans born in other countries.

Protestants make up the chief religious group in Nebraska. The largest protestant bodies include: Baptists, Disciples of Christ, Episcopalians, Lutherans, Methodists, Presbyterians and members of the United Church of Christ. Lutherans make up the largest protestant group in the state. Many Roman Catholics live in Nebraska, especially in cities and towns.

IOWA

The 1960 U. S. Census reported that Iowa had 2,757,537 persons. The population had increased five percent over the 1950 figure of 2,621,073. The U. S. Bureau of the Census estimated that by 1965 the state's population had reached 2,819,000.

A little more than half the people of Iowa live in cities and towns. Most of these urban residents live in the state's metropolitan areas. Iowa has six Standard Metropolitan Statistical Areas as defined by the U. S. Bureau of the Budget.

Iowa has seven cities with populations of more than 50,000. The largest city is Des Moines, the capital. The next largest city in order of population are: Cedar Rapids, Sioux City, Davenport, Waterloo, Dubuque and Council Bluffs.

Almost half the people of Iowa live in rural areas, and most of these rural residents live on farms. Iowa is the only state in which the farm population makes up more than half the total rural population. This farm population consists of about 662,000 persons. Only two states — North Carolina and Texas — have larger farm populations.

About 80 percent of all Iowans were born in the state and 98 percent were born in the United States. Most Iowans are descendants of people from the Balkan Peninsula, Germany, Great Britain and Scandinavia. About a third of the Iowans born in other countries came from Germany.

Protestant churches have the largest membership in Iowa, although Roman Catholics form the largest single religious group. Large protestant groups in the state include: Baptists, Lutherans, Methodists, Presbyterians and members of the Christian Churches (Disciples of Christ) and the United Church of Christ.

DEMOGRAPHIC CHARACTERISTICS

State or Province	Population 1950	Population 1960	% Change	Census Estimate 1965	Density Per Sq. Mi.	% Rural	% Urban
North Dakota	619,636	632,446	3	650,000	9	65	35
South Dakota		680,514	4	682,000	8	61	39
Minnesota		3,413,864	15	3,665,000	41	38	62
Montana	591,024	674,767	14	733,000	5	50	50
Saskatchewan	831,728	925,181	11	946,000	4	57	43
Manitoba	776,541	921,686	19	960,000	4	36	64
Wyoming	290,529	330,066	14	357,000	3	43	57
Nebraska	1,325,510	1,411,330	7	1,453,000	18	46	54
Iowa	1,621,073	2,757,537	5	2,819,000	49	47	53
Average			10%		15.6	49.2	50.8

SUMMARY

Of nine states and provinces, North Dakota's 1960 population ranks No. 8.

Ranks 4th in density per square mile.

Ranks last in percent of urbanites.

Ranks 1st in percent of nonurban.

THE SETTING

A listing of cities having a population of 10,000 or greater located within the region circled on the attached maps. (1960)

North Dakota

Bismarck	30,584
Dickinson	10,800
Fargo	47,400
Grand Forks	36,000
Jamestown	16,300
Mandan	10,525
Minot	34,300
Williston	12,300

South Dakota

Aberdeen	23,073
Brookings	10,558
Huron	14,180
Mitchell	12,555
Pierre	10,088
Rapid City	42,399
Sioux Falls	65,466
Watertown	14,077
Yankton	9,279

Minnesota

Albert Lea	17,108
Anoka	10,562
Bemidji	9,958
Bloomington	50,498
Brainerd	12,898
Brooklyn Center	24,356
Brooklyn Park	10,197
Columbia Heights	17,533
Coon Rapids	14,931
Crystal	24,283
Duluth	106,884
Edina	28,501
Fairmont	9,745
Faribault	16,926
Fergus Falls	13,733
Fridley	15,173
Golden Valley	14,559
Hibbing	17,731
Hopkins	11,370
Mankato	23,797
Maplewood	18,519
Minneapolis	482,872
Minnetonka	25,037
Moorhead	22,934
New Ulm	11,114
Owatonna	13,409
Red Wing	10,528
Richfield	42,523
Robinsdale	16,381
Roseville	23,997
Saint Cloud	33,815

Minnesota (Continued)

St. Louis Park	43,310
St. Paul	313,411
South St. Paul	22,032
Virginia	14,034
White Bear Lake	12,849
Willmar	10,417

Eastern Montana

Billings	52,851
Havre	10,740
Miles City	9,665

Southeastern Saskatchewan

Moose Jaw	33,206
Regina	112,141
Saskatoon	95,526
Swift Current	12,186
Yorkton	9,995

Southern Manitoba

Brandon	28,166
East Kildonan	27,305
Portage LaPrairie	12,388
St. Boniface	37,600
St. James	33,977
Transcona	14,248
West Kildonan	20,077
Winnipeg	265,429

Northeastern Wyoming

Casper	38,930
Sheridan	11,651

Northern Nebraska

Columbus	12,476
Norfolk	13,640
North Platte	17,184
Scottsbluff	13,377

Northwestern Iowa

Sioux City	89,159

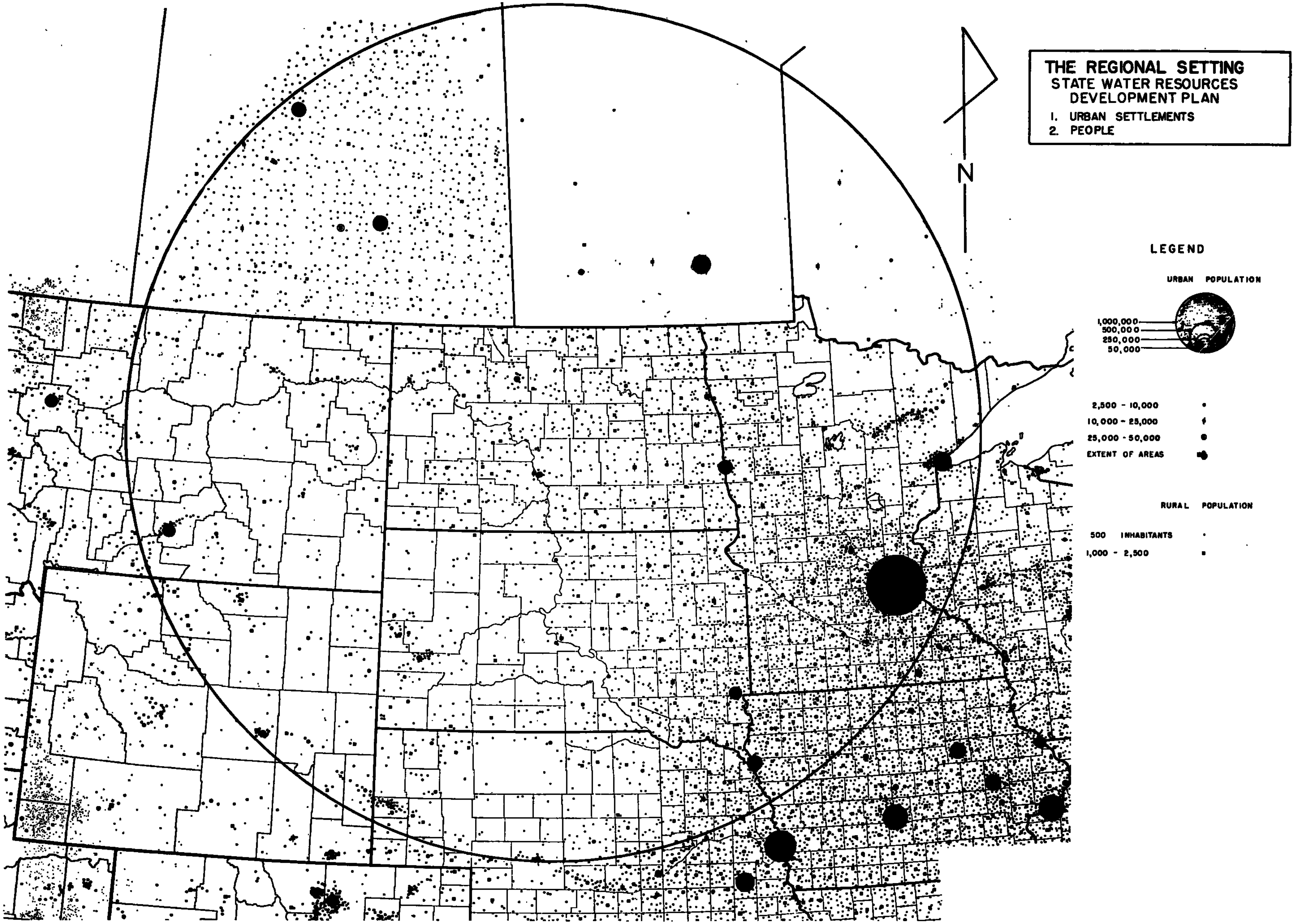
THE REGIONAL SETTING

STATE WATER RESOURCES
DEVELOPMENT PLAN

1. TRANSPORATION FACILITIES
2. MAJOR RECREATION RESOURCES & TOURIST ATTRACTIONS
3. INDIAN LANDS

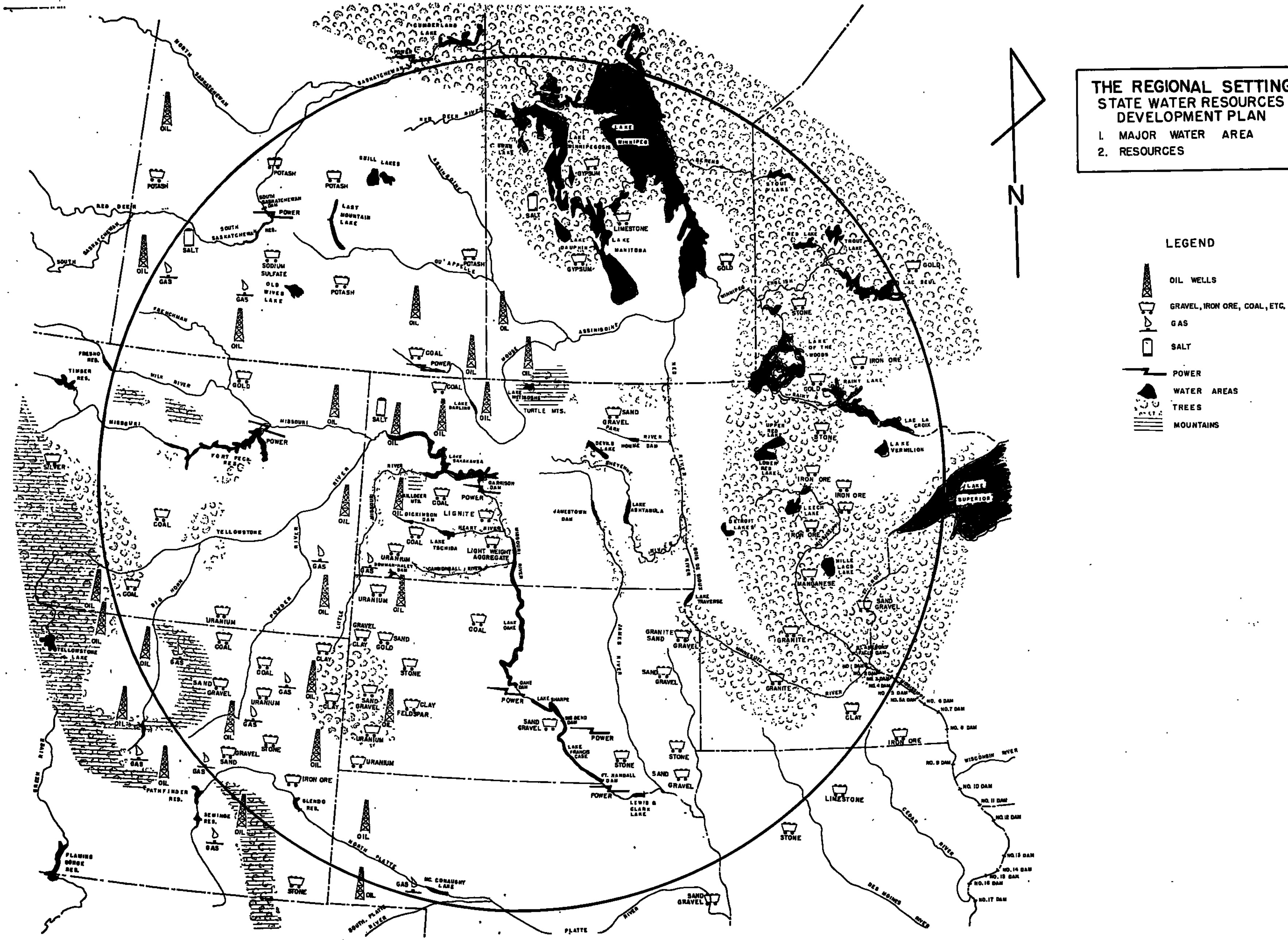
LEGEND

- LAKE
- INDIAN RESERVATION
- PARKS
- SCENIC ROUTE
- POINTS OF INTEREST
- COMMERCIAL AIRPORT
- NATIONAL MONUMENTS


THE REGIONAL SETTING
STATE WATER RESOURCES
DEVELOPMENT PLAN
1. URBAN SETTLEMENTS
2. PEOPLE
N
LEGEND
URBAN POPULATION
1,000,000
500,000
250,000
50,000
2,500 - 10,000
10,000 - 25,000
25,000 - 50,000
EXTENT OF AREAS
RURAL POPULATION
500 INHABITANTS
1,000 - 2,500

THE REGIONAL SETTING
STATE WATER RESOURCES DEVELOPMENT PLAN

1. MAJOR WATER AREA
2. RESOURCES



MAJOR PHYSIOGRAPHIC AND GEOGRAPHIC FEATURES

For planning purposes, the State of North Dakota has been subdivided into five major hydrologic basins, incuding the Missouri River Basin, the James River Basin, the Souris (Mouse) River Basin, the Devils Lake Basin, and the Red River of the North Basin.

MISSOURI RIVER BASIN

The Missouri River Basin, largest in the State, drains 33,902 square miles in Western and Central North Dakota, or approximately 48 percent of the State's total area of 70,665 square miles. It is made up of seven subbasins and a rather extensive area, north and east of the river, which is normally noncontributing. Two major reservoirs namely the Oahe Reservoir and Lake Sakakawea, occupy major portions of the mainstem Missouri River in North Dakota.

Yellowstone River Subbasin

The Yellowstone River rises in the northwestern corner of the State of Wyoming and flows in a generally northeastward direction for 871 miles to its confluence with the Missouri River near Buford, North Dakota. Only 16 miles of river channel lie within the State. The average channel slope for these 16 miles is less than one foot per mile compared to a river average of 13.3 feet per channel mile. Seven hundred forty-eight square miles or 478,720 acres are drained by the Yellowstone River in western McKenzie County and the northwestern corner of Golden Valley County.

North Dakota tributaries to the Yellowstone River are Bennie Pierre Creek, Horse Creek and Charbonneau Creek.

Initial irrigation development in the North Dakota portion of the Yellowstone subbasin dates back to 1906 when construction began on the Bureau of Reclamation's 60,000 acre Lower Yellowstone Project. Some 19,500 acres of the project are located in North Dakota. Irrigation water for the Lower Yellowstone Project is diverted from the Yellowstone River by a diversion dam at Intake, Montana.

Irrigation development using ground water dates from 1938 and is presently limited to individual operators and three 800 acre irrigation Districts. Of the three districts, only the Sioux draws a portion of its water directly from the river. Partially developed, the Cartwright District secures its water supply from wells drilled adjacent to the Yellowstone River, and the Yellowstone Pumping District will depend completely upon ground water for irrigation.

Additional ground-water irrigation development west of the Yellowstone in North Dakota is expected to be negligible, as a large percentage of land susceptible to irrigation is already included in the Lower Yellowstone Project.

Future ground-water irrigation development is expected to occur, as in the past, largely in areas east of and adjacent to the river itself. Of the approximately 8,600 acres located adjacent to the river, and therefore susceptible to the application of ground water, only 1,045 acres are currently being irrigated.

Municipal use of ground water in the North Dakota portion of the Yellowstone subbasin is limited to the city of Alexander. Ground water presently supplies Alexander's population of 269 (1960) adequately from the standpoint of quantity. Communities within the subbasin which do not have municipal supply systems, from either surface or groundwater storage, include Dore, Cartwright and Charbonneau. Water requirements for these communities are met through individually drilled, privately owned wells. The small size of these communities seems to preclude development of municipal systems at any time in the foreseeable future.

Ground water supplies 100 percent of current domestic needs in the North Dakota portion of the subbasin. There is presently no industrial demand for water. An estimated 1133 acre-feet or 310 surface acres of water are provided throughout the North Dakota portion of the subbasin by small dams and dugouts for stock watering purposes. The remainder of demands for stock water are met by pasture and on-farm ground-water wells.

Little Missouri River Subbasin

Rising in northeastern Wyoming, the Little Missouri River flows in a northerly direction, draining portions of northwestern South Dakota, southeastern Montana, and southwestern North Dakota. It enters North Dakota in the extreme southwest corner of the State and flows northward in a tortuous course to a point in northwestern Dunn County where it discharges into the Little Missouri Bay of Lake Sakakawea. The Little Missouri drains 4,746 square miles in North Dakota, including major parts of Slope, Golden Valley, and Billings Counties and lesser parts of Bowman, McKenzie, and Dunn Counties. A major portion of the area drained by the Little Missouri in North Dakota is of the so-called "Badlands" type. Topographical features associated with "Badlands" are created in part by the rapid runoff common to the region and in part by the characteristics of the soil. Although the headwaters of the tributary creeks rise and flow through a largely prairie region, the rapid fall to the main stream creates the numerous, deep, steep-walled gullies or ravines.

As spring runoff water travels through these gullies or ravines, it lifts large quantities of silt from the stream bed and transports it to the main stream where, because of a decrease in the velocity of flow, it is deposited. Except in the spring when most runoff occurs and during short periods immediately following violent storms during the summer months, most streams directly tributary to the mainstem of the Little Missouri are dry.

Irrigation development in the subbasin at present consists of slightly more than 5,100 acres. A majority of these acres are under water-spreading systems with lesser amounts being irrigated by both gravity and sprinkler systems. Future irrigation development within the subbasin must rely heavily upon surface storage for a dependable water supply as ground water is not available in sufficient quantities, particularly in the stream valley of the Little Missouri River itself. Extensive test hole drilling in 1956 demonstrated that the potential for groundwater irrigation of land located in the Little Missouri River Valley is severely limited.

Knife River Subbasin

The Knife River rises in the northeastern corner of Billings County and the southeastern corner of McKenzie County. From this point it flows in a tortuous course eastward and slightly southward to the Dunn-Mercer County line, crossing about 15 miles north of the southeast corner of Dunn County. From here it turns and flows eastward and slightly northward to the Missouri River which it enters at Stanton in Mercer County, about 65 miles above Bismarck. The total area of 2,507 square miles drained by the Knife River lies in North Dakota and includes major portions of Dunn and Mercer Counties and lesser portions of Oliver, Billings, Morton and Stark Counties.

A low divide on the west separates the Knife River Basin from the Little Missouri drainage basin. The basin is roughly oval in shape, the greater axis lying approximately east and west and being about 88 miles in length. The greatest width, north and south, is about 40 miles. The river has one important tributary, Spring Creek, which drains about 660 square miles in the northern portion of the basin.

The Knife River drainage basin lies in that portion of the Great Plains known as the Missouri Plateau. Its topography, for the most part, is rolling, and stream valleys are generally shallow. In the northwestern part of the basin, the steep-sided, mesa-like Killdeer Mountains, with elevations ranging about 3,600 feet above mean sea level, rise to a height of more than 700 feet above the surrounding prairie to form the most conspicuous topographic feature in the watershed.

The Knife River Valley is an alluvial valley varying in width from 1/4 to 2 miles which has been cut into numerous small tracts by the meandering of the stream. The stream channel is narrow and varies in depth from 20 to 35 feet. At many of the bends in the river there are cut banks 100 feet or more in height.

Natural drainage in the subbasin is generally good, with only a few small surface areas containing harmful amounts of alkali. Soils of the subbasin are fertile and well adapted to growing grains when sufficient moisture is available. Sheet and gully erosion affect relatively small areas and are not a serious problem.

Agriculture and livestock raising are the principal industries in the subbasin. There is also mining of lignite coal which is increasing as a result of several large thermal generating plants in the area. Some clay is also mined.

Hebron, Beulah, Hazen and Killdeer, with populations in 1960 of 1340, 1318, 1222, and 765 respectively, are the largest towns in the subbasin.

Within the Knife River subbasin, 47 state and locally constructed dams with a minimum individual capacity of 50 acre-feet collectively store 21,358 acre-feet of water, including 1,501 acre-feet for stock water, and 10,573 acre-feet for fish, wildlife and recreation. Small dams and dugouts store an additional 5,663 acre-feet for stock water and incidental fish and wildlife use.

The State Engineer has granted permits for the use of approximately 2,700 acre-feet of subbasin water for irrigation purposes. Except in unusual circumstances, one acre-foot is granted per acre of land to be irrigated.

Heart River Subbasin

The Heart River rises in Billings County near the northwestern corner of Stark County. It flows eastward in an erratic course to its confluence with the Missouri River near Mandan. At its most southerly point, where it crosses the Grant-Morton County line, it is approximately 20 miles south of a straight line drawn between the source and the mouth. The subbasin is approximately 120 miles long, east and west, and has an average width of approximately 28 miles. The total area drained by the Heart River, all of which is in North Dakota, is 3,343 square miles and includes most of Stark County and parts of Billings, Dunn, Hettinger, Grant, Morton, and Oliver Counties.

The elevation of the Heart River at its confluence with the Missouri River is approximately 1,615 feet above sea level, and at its headwaters, approximately 3,000 feet above sea level. The total valley length is 120 miles and has a drop of about 10 feet per mile. The length of the river channel is twice that of the valley. The Heart River meanders from side to side through a valley about 1½ miles wide.

Important "north-side" tributaries of the Heart River include: Green River, Heart Butte Creek, Big Muddy Creek, and Sweetbriar Creek. Antelope Creek of Stark County and Antelope Creek of Grant County are important "south-side" tributaries.

Natural drainage is good throughout the subbasin, with most soils generally free from excessive amounts of alkali. Soils in the upland areas of the subbasin consist of loam and silt loam, with patches of sandy loam, all of which are well suited for agricultural purposes. Bottomland soils usually range from sandy loam to clay loam. Clay to clay loam predominates in the "breaks" located adjacent to the river. Farmlands in the subbasin are fertile and are capable of producing good grain crops in years of adequate moisture.

Mandan and Dickinson, with 1960 populations of 10,525 and 9,971 respectively, are the two largest cities in the subbasin. Other important population centers include Glen Ullin (1,210), Belfield (1,064) and New Salem (986).

Seven communities in the subbasin have municipal water supply systems. The City of Dickinson purchases water stored in Patterson Lake from the U. S. Bureau of Reclamation. Water pumped from the Missouri River supplies the City of Mandan. Ground water is the source of supply for the remaining five communities. Six communities within the subbasin are without municipal water supply facilities.

Current programs in the subbasin adequately meet quantity demands for rural domestic and livestock water. Virtually all rural domestic requirements are met by ground-water developments. Stock water requirements are met by a combination of small dams, dugouts, and ground water. During periods of extreme and extended drought, occasional water shortages may develop. Since ground water is generally available, it may be necessary during such times to develop new and/or deeper wells.

Providing rural domestic water which meets minimum quality standards in the subbasin is a problem. State Health Department standards fix the maximum number of dissolved solids at 500 milligrams per liter for good quality water. Most of the rural domestic water in the subbasin has a higher concentration of dissolved solids. Reduction of high concentrations of sodium, chlorine and sulfates is economically infeasible at this time because of the limited populations which must assume the costs. Although much of the water does not meet minimum standards, it is safe for human consumption.

Within the Heart River subbasin, 51 dams with a minimum individual capacity of 50 acre-feet and a combined storage capacity of 8,859 acre-feet have been constructed through State and local cooperation. Of these 8,859 acre-feet, 1,969 acre-feet have been appropriated for stock water use and 6,890 acre-feet for a combined fish-wildlife-recreation use.

Two hundred thirty-two thousand three hundred (232,300) acre-feet of additional storage is made available through the Heart Butte Dam and Dickinson Dam.

Dickinson Dam, located in Stark County southwest of Dickinson, is owned by the U. S. Bureau of Reclamation and stores 6,800 acre-feet of water for municipal and industrial, irrigation and recreation use. Heart Butte Dam, also built by the U. S. Bureau of Reclamation, is located in Grant County. This structure has a total storage capacity of 225,500 acre-feet, including 150,500 acre-feet of flood control storage and 26,000 acre-feet for irrigation. Numerous small dams and dugouts store an additional 7,843 acre-feet for stock water and incidental fish and wildlife use throughout the subbasin. Total storage capacity within the subbasin is approximately 254,000 acre-feet with a water surface area of nearly 14.5 square miles.

Water permits have been granted by the State Engineer for the irrigation of 15,490 acres throughout the subbasin.

In addition to the 150,500 acre-feet of exclusive flood control storage allocated to the Heart Butte (Lake Tschida) Reservoir, flood control measures in the subbasin include the incidental flood control storage provided by Dickinson Dam and the levees and appurtenant works of the Mandan Lower Heart Project.

Cannonball River Subbasin

The Cannonball River rises in the northeastern corner of Slope County near Amidon, North Dakota, and flows in a southeasterly direction through Hettinger and Grant Counties to its confluence with Cedar Creek, its major tributary, on the Grant-Sioux County border. From this point, the Cannonball River flows in a northeasterly course, forming the north boundary of Sioux County, until it enters the Missouri River (Oahe Reservoir) at a point approximately 30 miles above the North Dakota-South Dakota state line. The total area drained by the Cannonball River in North Dakota is approximately 4,310 square miles.

The elevation of the Cannonball River at its confluence with the Missouri River is 1,592 feet above mean sea level. Elevations approaching 3,000 feet above mean sea level are common in headwater areas. The Cannonball River channel meanders through an irregular valley of from ¼ to 1½ miles in width. The river channel is approximately twice as long as the river valley.

Important tributaries in addition to Cedar Creek include Thirty Mile Creek in Hettinger County, Dog Tooth Creek and Louise Creek in Grant and Morton Counties.

Mott and New England, with 1960 populations of 1,463 and 1,095 respectively, are the two largest cities in the subbasin. Six communities in the subbasin have municipal water supply systems. Ground water is the source of supply for all of these communities. Nine communities within the subbasin are without municipal systems.

Except during periods of extreme and extended drought, when local water shortages may develop, current programs in the subbasin adequately meet quantity demands for rural domestic and livestock water. Virtually all rural domestic requirements are met by ground-water developments. Stock water requirements are met by a combination of small dams, dugouts and ground water.

Securing "quality" rural domestic and municipal water is a problem in the subbasin. State Health Department standards fix the maximum number of dissolved solids present for "good quality" water at

500 milligrams per liter. None of the six communities with municipal systems is able to meet these standards. Most rural domestic water in the subbasin has a higher concentration of dissolved solids. Treatment plants designed to reduce high concentrations of sodium, chlorine and sulfates are infeasible for most of the smaller communities at this time because of the limited populations which must assume the costs. Although much of the water does not meet minimum standards, it is safe for human consumption.

Within the Cannonball River subbasin, 63 dams with a minimum individual capacity of 50 acre-feet and a combined storage capacity of 23,603 acre-feet have been constructed through State and local cooperation. Of these 23,603 acre-feet, 4,752 acre-feet are allocated to a stock water use with the remainder allocated to a combined fish, wildlife and recreation use. Numerous small dams and dugouts store an additional 6,087 acre-feet for stock water and incidental fish and wildlife use throughout the subbasin.

The State Engineer has granted permits for the use of approximately 4,940 acre-feet of subbasin water for irrigation purposes, with approximately 4,000 acres being irrigated during the past growing season. Additional acreage is available for irrigation development in the Cannonball River Valley, but before such development can occur, it is necessary to construct water storage structures. Since a major portion of the subbasin's runoff occurs during the spring break-up period and since streams are virtually dry during summer months except during and immediately following violent storms, sufficient water is not presently available for this additional development. The necessary reservoir sites are still available.

Grand River Subbasin

Eight hundred ninety-four (894) square miles of the Grand River subbasin lie within the State. The North Fork of the Grand River rises near the North Dakota-South Dakota boundary in Bowman County and flows within 1, 2 or 3 miles of the state line for more than 40 miles before it leaves the State in the southwestern corner of Adams County. Its confluence with the Grand River is located near Shadehill, South Dakota.

The Grand River subbasin lies entirely outside the glaciated region. Uplands consist largely of flat to gently rolling terrain in which the water courses have quite thoroughly dissected the plateau surface. At the lower end of the main tributaries, the valleys are deeper and, in general, have a fairly small drop per mile. The Grand River flows in a meandering course through a valley averaging 1½ miles in width. The average slope of the valley floor is about 8 feet per mile.

Important tributaries located in North Dakota include South Fork, Spring, Lightning, Buffalo, and Hidden Wood Creeks.

The principal industry in the subbasin is agriculture. Farmlands in the subbasin are quite fertile and are capable of producing good grain crops in years of adequate moisture.

Hettinger and Bowman are the two largest cities in the North Dakota portion of the subbasin with 1960 populations of 1769 and 1730 respectively. Four communities in the subbasin have municipal water supply systems. Four do not. Existing systems are supplied 100 percent by ground-water sources.

Current programs in the Grand subbasin adequately meet quantity demands for rural domestic and livestock use. Virtually all rural domestic requirements are met by ground-water wells. Stock water requirements are met by a combination of small dams, dugouts and ground water. During periods of extreme drought, occasional water shortages for these purposes may develop. At such times, it may be necessary to develop new and/or deeper wells.

Providing municipal and rural domestic water which meets the minimum quality standards in the subbasin is a problem. While much of the rural domestic and municipal water does not meet minimum standards, it is safe for human consumption.

Located within the Grand River subbasin in North Dakota are ten (10) dams with a minimum individual storage capacity of 50 acre-feet, which have been constructed through the cooperative efforts of state and local governments. Collectively, the ten (10) dams store some 2,965 acre-feet of water for stock water and fish-wildlife-recreation use. An additional 939 acre-feet are available for stock water and incidental fish and wildlife use in the subbasin from numerous small dams and dugouts.

Bowman-Haley Dam, a U. S. Army Corps of Engineers' project located near the communities of Bowman and Haley, has a permanent conservation storage pool of 21,950 acre-feet. Completed in 1966, the dam provides 106,000 acre-feet of exclusive flood control storage. A total of 4,968 acre-feet of water has been appropriated for municipal and industrial use by the City of Bowman and the Bowman County Water Management District.

Irrigation in the Grand River subbasin is limited because of low stream flows during the summer when the need for water is greatest.

Water permits for 976 acre-feet have been granted for irrigators in the subbasin to date. Five hundred acres were irrigated during the past growing season. Considerably more land could profitably be irrigated were adequate water supplies available when needed.

DIRECT MINOR MISSOURI RIVER TRIBUTARIES

Excluding the James River Basin which, for planning purposes is considered a separate basin, the Missouri River Basin has a total drainage area within the State of 33,902 square miles. The Yellowstone, Little Missouri, Knife, Heart, Cannonball, and Grand River subbasins collectively drain 16,548 square miles west of the Missouri River in North Dakota. The remaining drainage area, 17,354 square miles, has been divided into two distinctive areas for planning purposes: Western Missouri Mainstem Tributaries, and the Eastern Missouri Direct Tributaries, a large portion of which is noncontributing.

Western Missouri Mainstem Tributaries

Approximately 2,801 square miles of land are drained by Missouri River tributaries which flow directly into the mainstem of the river from the west. This area consists of four disjointed, but topographically similar sections. The first of these sections begins at a point immediately downstream from the confluence of the Yellowstone and Missouri Rivers southwest of Williston in McKenzie County near the North Dakota-Montana border and ends at a point north of Stanton in eastern Mercer County near the confluence of the Knife and Missouri Rivers. The area is bounded on the north by Lake Sakakawea and on the south by the northern boundaries of the Yellowstone, Little Missouri, and Knife River subbasins.

Steep bluffs, 200 to 600 feet in height, are the common land form of the upper reaches of the Missouri River Valley. These bluffs are frequently dissected by numerous small streams and coulees to form the Missouri River "breaks." These "breaks" lead, in turn, to uplands considerably higher than uplands east of the river. By the same token, bluffs overlooking the river in this area are generally steeper and higher than those east of the river. Farmers and ranchers in areas such as this frequently integrate their operations to include the uplands, the "breaks" and the bottomlands.

Principal tributaries from west to east in the area include Timber, Tobacco Garden, Clear and Bear Den Creeks, all of which are located in northern McKenzie County.

The principal industry of this area is the raising of livestock. The area has no important population centers.

A second section of the Western Missouri Mainstem Tributaries begins near Stanton, North Dakota, just south of the confluence of the Knife and Missouri Rivers in Mercer County and ends at a point southeast of Mandan in Morton County immediately above the Heart River's confluence with the Missouri River. Center, North Dakota, located on Square Butte Creek, is the only sizeable community in the area. Its municipal water system served a 1960 population of 476. Source of supply for the system is ground water. The water is considered to be of good quality.

Area topography is similar to that found in upstream reaches of the river, except that bluffs overlooking the river are not as steep or as severely dissected by small stream valleys and coulees as those found in the extreme western portion of the State.

A third section of the Missouri River Mainstem Tributaries is made up of the Little Heart River Basin drainage area, located south of Mandan in Morton County, and several smaller streams directly tributary to the Missouri. Area topography is similar to that described above. Three small communities, St. Anthony, Huff and Fort Rice, are located within the area. Principal land uses are farming and grazing.

An extensive portion of Sioux County, drained by Battle Creek, Porcupine Creek, and Four Mile Creek, constitutes a fourth division of the Western Missouri Mainstem Tributaries. Oahe Reservoir serves as the eastern boundary of this area. It is bounded on the west and north by the southeastern boundary of the Cannonball River subbasin. The entire area is a part of the Standing Rock Indian Reservation. Major industries in the area are farming and raising livestock.

Fort Yates and Selfridge, with 1960 populations of 1,100 and 371 respectively, are the only two communities in the drainage area. Both communities are served by ground-water municipal supply systems.

Eastern Missouri Direct Tributaries

The Eastern Missouri Direct Tributaries subbasin consists of those lands located north and east of the Missouri River which are drained by mainstem tributaries. The subbasin's total area of 14,553 square miles is made up of major portions of Williams, Mountrail, McLean, Sheridan, Kidder, Logan and McIntosh Counties: lesser portions of Stutsman, Wells, Ward, Burke and Divide Counties, and all of Burleigh and Emmons. The northern portion of the subbasin abuts the southern boundary of the Souris River subbasin, while the eastern boundary of the subbasin adjoins the western border of the James River subbasin.

Approximately 4,927 square miles of the subbasin are normally noncontributing. Under normal conditions, runoff does not reach the Missouri River. Rather, it is trapped in the many small lakes and potholes which are characteristic of the noncontributing portion of the subbasin.

Principal tributaries in the Eastern Missouri Direct Tributaries subbasin include the following: Little Muddy River, Williams County; White Earth River, Mountrail, Williams, and Burke Counties; Little Knife River, Mountrail County; Deepwater Creek, Mountrail and McLean Counties; Painted Woods Creek, McLean and Burleigh Counties; Burnt and Apple Creeks, Burleigh County; and Beaver Creek, Emmons, Logan and McIntosh Counties.

Forty-seven (47) communities are located within the contributing portion of the subbasin. Eighteen (18) of these communities have municipal water systems. Twenty-nine (29) communities are currently without such systems. Of the 18 communities with municipal systems, 15 utilize ground water as a source of supply. Bismarck, Williston and Riverdale pump directly from the Missouri River.

Bismarck and Williston with 1960 populations of 27,670 and 11,866 respectively are the two largest cities in the subbasin. Other important population centers in the subbasin include Tioga (2,087), Linton (1,826), Stanley (1,795), Garrison (1,794), New Town (1,586), Wishek (1,290), Parshall (1,216), and Ray (1,049).

Within the Eastern Missouri Direct Tributaries subbasin, 182 dams capable of storing a *minimum* of 50 acre-feet of water each and with a combined storage capacity of approximately 98,010 acre-feet, have been constructed cooperatively by State agencies and local interests. Water stored by these structures serves Fish-Wildlife-Recreation, Flood Control, Stock Water, Municipal and Industrial, and Irrigation uses. Approximately 11,241 acre-feet of additional stock water are provided by numerous small dams and dugouts throughout the subbasin.

JAMES RIVER BASIN

The James River rises in Wells County in central North Dakota. It follows a tortuous course generally southeastward until it leaves the State in southeastern Dickey County. In North Dakota, the James River drains approximately 6,831 square miles, an area roughly 55 miles wide and 140 miles long. The valley through which the James River flows averages about 100 feet in depth and is from a few hundred feet to three miles wide. The river channel itself varies from 25 to 100 feet in width.

The James River Basin is located in the drift prairie of North Dakota, the eastern portion displaying a gently rolling topography with the western portion, which rises to a continental divide, characterized by a more hilly terrain. Elevations approaching 1,580 feet above mean sea level are characteristic of the basin's headwaters area. From the headwaters area, the topography slopes gradually to approximately 1,300 feet above sea level where the James leaves the State.

The most important tributary to the James River is Pipestem Creek, which enters the James on the west side near Jamestown and drains much of the northwestern portion of the basin. Other important west side tributaries include Beaver Creek, Bonehill Creek, Cottonwood Creek, and Maple River. Bear Creek, which rises in southwestern Barnes County and flows in a southerly direction to its confluence with the James River in northeastern Dickey County, is the only major east side tributary.

Jamestown, with a 1960 population of 15,163, is the largest city in the basin. Other important population centers include Carrington (2,438), New Rockford (2,177), Ellendale (1,800), Oakes (1,650), and LaMoure (1,068). Forty-two (42) of the basin's 56 communities have populations of 250 or less.

Nineteen (19) of the basin's 56 communities have municipal water supply systems. All are supplied from ground-water sources. Only the Jamestown and Carrington systems, with water treatment facilities, supply water which meets the State Health Department's minimum requirement for "good quality" water.

Virtually all rural domestic water supply requirements are met by ground-water developments. Stock water requirements are currently being met by a combination of small dams, dugouts and ground water. Small dams and dugouts alone provide 4,920 acre-feet of storage for stock water and incidental fish and wildlife uses.

Within the James River basin, 108 dams with a minimum individual capacity of 50 acre-feet and a combined storage capacity of approximately 58,209 acre-feet have been constructed cooperatively by State agencies and local interests. Of these 58,209 acre-feet, 43,118 acre-feet are currently being used for fish-wildlife-recreation, 14,362 acre-feet for stock water and 729 acre-feet for municipal and industrial water supply.

Jamestown Reservoir, located behind Jamestown Dam on the James River above Jamestown, was built by the U. S. Bureau of Reclamation as the first feature of the Garrison Diversion Unit. Ultimately, when water is available from the Missouri River, it will serve irrigation, a municipal supply for the City of Jamestown, pollution abatement, and flood control. Operation for these purposes will provide incidental fish, wildlife, and recreation benefits. The reservoir has 800 acre-feet of inactive and 28,000 acre-feet of conservation storage space and 190,000 acre-feet flood control storage. Until water becomes available from the Missouri River, the reservoir can serve only municipal water, pollution abatement and flood control. Total storage capacity in the basin, excluding flood control storage, is approximately 99,000 acre-feet.

The State Engineer has granted permits for the use of approximately 3,795 acre-feet of basin water for irrigation purposes, with approximately 2,368 acres being irrigated during the past growing season, almost completely through the use of sprinkler systems. With full development of the Garrison Diversion Unit, 171,500 acres of basin land will be placed under irrigation.

SOURIS RIVER BASIN

The Souris (Mouse) River rises in southeastern Saskatchewan and flows in a southeasterly direction across the International Boundary into North Dakota near the northwestern corner of Renville County. From this point, it continues to flow in the same southeasterly direction through the City of Minot in Ward County to Velva in McHenry County where the general direction of flow changes to the northeast until it reaches Towner. Here, the river curves gradually and flows in a northwesterly direction until it reenters Canada west of the Turtle Mountains in north central Bottineau County.

The Souris River drains portions of Saskatchewan, Montana, North Dakota, and Manitoba. In North Dakota the area drained by the Souris River is 9,112 square miles.

In North Dakota, above Minot, the Souris River Valley is comparatively straight with a fairly constant width of about one-half mile. Throughout this 64 mile reach of the river, valley walls rise sharply 100 feet or more to broad, comparatively level benches. Between Minot and Verendrye, the valley displays the same general characteristics, but it is wider in places and has benches which are somewhat lower and more broken. Below Verendrye the north side bench diminishes to a low ridge and lands toward Bantry and Upham tend to merge with the valley.

The channel of the Souris River follows a meandering course, averaging slightly less than 100 feet wide and 15 to 25 feet deep. The total length of the channel is about double the length of the valley through which it traverses. Principal tributaries above Minot are the Des Lacs River, which enters the Souris River about seven miles north of Minot near Burlington; Moose Creek, which receives runoff from the Moose Mountains in Canada; and Long Creek. Of these three streams, only the Des Lacs River, which rises just above the United States - Canada boundary, enters the Souris River in North Dakota.

Other important tributaries outside the Souris River "Loop" include the Wintering River, which flows largely in southern McHenry County, and Willow Creek, which rises in the Turtle Mountains and flows in a southwesterly direction to its confluence with the Souris River about eight miles east of Upham. The interior of the Souris River "Loop" is drained principally by a single stream system, the Deep River. Principal tributaries of the Deep River are the Cut Bank Creek (north), Little Deep Creek, and Cut Bank Creek (south).

The largest city in the basin is Minot with a 1960 population of 30,604. Minot Air Force Base, located north of Minot near Glenburn, houses an approximate military and civilian population of 15,000, the second largest population center in the Souris River basin. Other important population centers include Rugby (2,972), Bottineau (2,613), Crosby (1,759), Kenmare (1,696), Velva (1,330), Dunseith (1,017), Mohall (956), and Towner (948).

Thirty (30) of the 77 communities located within the basin operate municipal water supply systems. Only Minot and Westhope pump directly from the Souris River. Twenty-eight (28) systems rely completely upon ground water for their supply. The City of Minot also pumps water from the Souris River to recharge the aquifer from which city water is drawn. In addition to the city itself, the Minot municipal system also supplies Minot Air Force Base.

Water for both rural domestic and municipal use can generally be found in sufficient quantities throughout the basin to supply needs except for Minot. During periods of extreme and extended drought local water shortages have occurred. At such times, it may be necessary for an affected community to either deepen existing wells or to develop new wells.

While securing sufficient quantities of water is not a common problem, securing "good quality" water is. It should be noted that although much of the rural domestic and municipal water available for use within the basin does not meet minimum Health Department standards, it is safe for human consumption.

Within the drainage area of the Souris River, 214 dams have been constructed to store some 325,000 acre-feet of water for the following uses: Stock Water, Fish-Wildlife-Recreation, Municipal and Industrial, and Irrigation. Approximately 142 of these dams have individual storage capacities of less than 50 acre-feet, providing, in large measure, opportunities for stock water and incidental fish-wildlife-recreation use. Seventy-two (72) structures individually capable of storing 50 acre-feet or more provide a major percentage of total storage. Over 90 percent of the basin's storage capacity is dedicated to a fish and wildlife (Game Refuge) use.

In addition to the storage capacity cited above, approximately 13,000 acre-feet are provided throughout the basin by small dams and dugouts for stock water and identical fish and wildlife use.

The State Engineer has granted permits for the use of 1,346,000 acre-feet annually for irrigation purposes within the Souris River basin. Of this figure, approximately 1,320,000 acre-feet were granted for irrigation to occur under the Garrison Diversion plan.

Because it rises in Saskatchewan and returns to Canada in Manitoba, the regulation of the Souris River's flow has been placed under the jurisdiction of the International Joint Commission, which was created in 1909 by treaty between Great Britain and the United States. The Commission is composed of three members each from Canada and the United States. It is authorized to consider and determine the rights of the two nations or subdivisions to the use of waters of the rivers, streams and lakes in which both countries have an interest. Problems and disputes, called "references," arising from the use of such common waters are referred to the International Joint Commission.

The Souris River Reference is dated January, 1940. The final agreement, entered into in 1942, allows the Province of Manitoba a flow of 20 cfs from stored water in North Dakota, and allows Saskatchewan to retain 50 percent of the water rising in that Province.

In 1959, the International Joint Commission established the International Souris River Board of Control composed of two members, one from the United States and one from Canada. This Board is charged with the responsibility of carrying out the provisions of an interim order on the Souris River recommended by the Commission in 1959 to replace the initial interim order of 1940. Provisions of the 1959 interim order are set forth in the 12th Biennial Report of the State Water Commission.

As a result of the Board's actions, 38 stream flow gaging stations, 17 reservoir level measuring stations, and six evaporation stations are maintained within the Souris River Watershed.

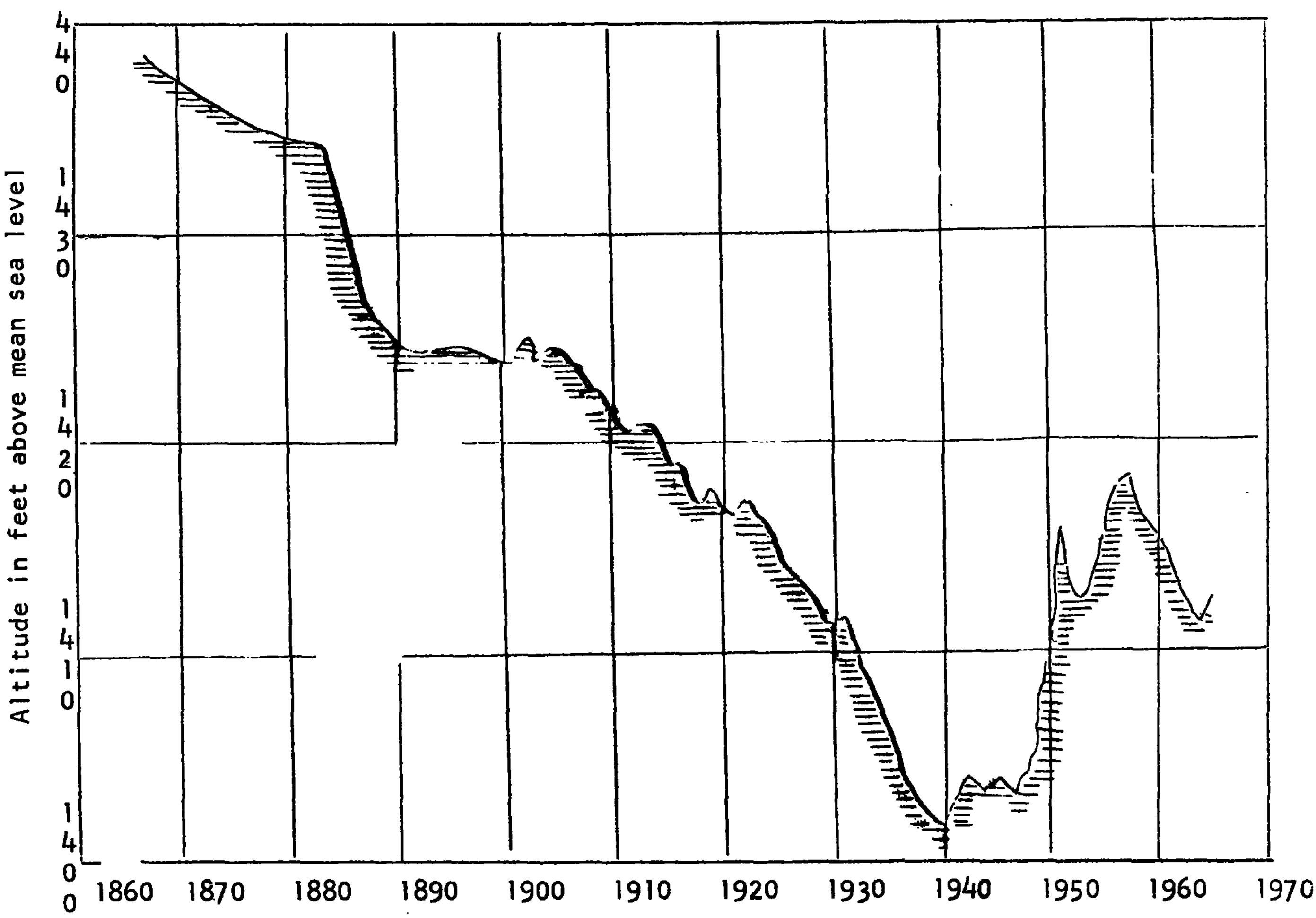
DEVILS LAKE BASIN

The Devils Lake Basin, located in northwestern North Dakota, is a closed or noncontributing basin. That is to say, runoff is trapped within the basin and prevented from leaving by the topography. Devils Lake serves as the ultimate collecting point for a majority of the basin's surface runoff.

Within this basin lies a chain of waterways which begins with the Sweetwater group and extends through Mauvais Coulee, Devils Lake, East Bay Devils Lake, and East Devils Lake to Stump Lake. At times, when lake levels are high, Mauvais Coulee drains the Sweetwater group, discharging considerable water in Devils Lake. Early records indicate that Devils Lake was a deep, fresh-water lake, providing excellent fishing, water fowling and other recreational uses.

Warren Upham's, **The Glacial Lake Agassiz: U. S. Geological Survey, 1895,** suggests that in 1830 the surface elevation of Devils Lake was 1,441 feet, mean sea level. This is 40 feet above the lowest known stage, which was reported in 1940. U. S. Geological Survey records indicate that the maximum elevation of Devils Lake stood at 1,438.3 in 1867. Since then the lake has shown a gradual downward trend until a low of 1,400.9 feet was reached in 1940. Since 1940 the trend has been reversed, and the lake has been rising. (The following graph illustrates the history of the changing levels of Devils Lake.)

FLUCTUATION IN LEVEL OF DEVILS LAKE*



* Lake level based on average of highest and lowest observations during a year.

The Sweetwater group of lakes which includes Sweetwater Lake, Dry Lake, Lac Aux Mortes, and Lake Irvine is the first link in the Devils Lake system. Unlike Devils Lake and other major lakes located in the lower portion of the basin, the Sweetwater group, as suggested by their name, consists of fresh-water lakes. Prior to the time of a general downward trend in the level of lakes in the basin, the Sweetwater lakes were connected by a series of small coulees that at times discharged significant volumes of water into Mauvais Coulee. This general decline in lake levels ended the flow between lakes, causing the Sweetwater group to become disconnected bodies of water, whose depth varied with climatological changes.

Under average runoff conditions, these lakes are shallow, often marshy or nearly dry. Portions of Sweetwater Lake, Lake Irvine and Dry Lake have a history of cropping during the 1960's. Sweetwater Lake was nearly dry during the drought years of the 1930's; yet it overflowed in 1951, 1965, 1966 and 1967. During such overflow periods, extensive sheet-water type flooding occurs in the Sweetwater-Dry Lake area. In earlier times, before the channels linking the Sweetwater group of lakes became partially filled with blow-dirt and choked with vegetation, normal runoff could escape without causing the damaging floods which occur periodically at the present time. Over the years the drainage system above Sweetwater Lake has been modified significantly by farm drainage and the construction and reconstruction of roads. This modification has accelerated the inflow into Sweetwater Lake and is partly responsible for the recurring flooding to adjacent farm lands in recent years.

Mauvais Coulee, principal tributary to Devils Lake, is the largest drainage channel in the Devils Lake system. It flows intermittently, largely in response to snow melt and excessive precipitation during the spring.

Devils Lake, with a 1960 population of 6,299, is the largest city in the basin. Other important population centers in the basin include: Cando (1,566), Rolla (1,398), Lakota (1,066), and Leeds (797). Of the 48 communities located within the boundaries of the basin, 11 have municipal water systems. All utilize ground water as a source of supply.

Located within the Devils Lake Basin are 30 dams capable of storing in excess of 50 acre-feet each. The combined storage of these structures is 31,793. An additional 1,791 acre-feet of storage is provided by small Soil Conservation Service type dams and dugouts.

The total drainage area of the Devils Lake Basin is 3,580 square miles.

RED RIVER OF THE NORTH

The Red River of the North is formed by the confluence of the Ottertail and Bois de Sioux Rivers at the twin cities of Wahpeton, North Dakota, and Breckenridge, Minnesota. It flows 400 miles in a tortuous northerly course, forming the boundary between North Dakota and Minnesota, to the international boundary between the United States and Canada. From the boundary, it flows generally northeast 155 miles in Canada to Lake Winnipeg. The drainage area of the Red River Basin in North Dakota is approximately 17,240 square miles.

North Dakota Tributaries of the Red River Of the North in the United States

STREAM	River Miles From L. Winnipeg	Approximate Length in Miles	Drainage Area in Sq. Miles
West Side Tributaries in North Dakota			
Wild Rice River	470.1	243	2,020
Sheyenne River	428.2	500	7,140
Elm River	387.3	69	510
Goose River	357.4	186	1,280
Turtle River	—	—	730
Forest River	243.0	147	1,030
Park River	222.2	110	1,010
Pembina River	157.8	275	1,960
Minot Tributaries	—	—	1,560

Principal Minnesota tributaries entering the Red River between the confluence of the Bois de Sioux and Ottertail Rivers and the international boundary are the Buffalo, Wild Rice, Red Lake, Snake, Tamarac, and Two Rivers. The Roseau River which drains a portion of the basin in Minnesota joins the Red River in Canada. Tributaries in North Dakota and Minnesota flow generally east or west into the northward flowing Red River. Near the river, North Dakota tributaries tend to turn northward, flowing in some instances, nearly parallel with the mainstem for many miles before finally entering it. Longer tributaries have relatively steep slopes, particularly where they flow from the bordering highlands to the valley floor. In the lowlands, however, many tributaries have very flat slopes with poorly defined watershed boundaries.

During the last glacial period, the entire watershed of the Red River of the North was covered by a continental glacier which altered topography and resulted in the formation of the soils of the basin. Prior to the glacial period, the surface was rough and the drainage clearly defined. When the glacier moved southward over the region, it wore down the divides and ridges and filled the valleys, thus producing the rolling surface of a portion of the watershed. As the glacier melted and receded northward, a heterogeneous mass of clay, sand, gravel and boulders, termed "drift" was deposited over the basin to depths of up to 400 feet. A series of recessional moraines were formed, roughly concentric with one another, each representing a halt in the general retreat of the ice sheet. These moraines, varying in size, give greater relief to the area bounding the Red River drainage basin than is characteristic of the drift plain in general.

After the ice front had retreated within the Red River drainage basin, water from the melting glacier was ponded between the surrounding highlands and the ice front that blocked the northern outlet, thus forming glacial Lake Agassiz. This lake at first, drained southward through the Lake Traverse-Bigstone Lake depression into the Minnesota River Valley, later by an eastern outlet into northern Minnesota, and finally northward through Lake Winnipeg into Hudson Bay. During the time Lake Agassiz was in existence, sediments transported by rivers were spread over the bottom to a depth of 20 to 50 feet, covering the drift in most places. In addition, deltas formed by the rivers flowing into the lake cover large areas of the old lake bed.

Several beach ridges were formed at successively lower elevations as the level of the lake dropped and as the outlet changed. These beaches tell the story of the lakes demise. As Lake Agassiz drained, it left a very level dry lake bed with a fall averaging two to three feet per mile towards the river and less than one foot per mile to the north.

The Pembina Escarpment forms the western edge of this plain in the north. The escarpment rises as much as 50 feet per mile for a distance of three or four miles where it meets the more gently sloping drift prairie. South of the escarpment, the boundary between the lake plain and the uplands becomes less pronounced until, in the Wild Rice subbasin, it is almost obliterated by a terminal moraine.

Most of the major tributaries of the Red River in North Dakota have their headwaters in the drift prairie or in the Pembina Escarpment. In the upper reaches of these tributary courses, valleys are narrow, steep sided and relatively deep. As the tributaries leave the drift prairie or escarpment and enter the lake plain, their valleys continue to be narrow. The depth of the valleys decreases generally, however, as the rivers become more winding.

The Wild Rice Subbasin

The Wild Rice River rises in the south central part of Sargent County. As it flows in an easterly direction across the county, it is joined by a number of tributaries whose own headwaters are located in the Sisseton Hills of South Dakota. Shortly after it enters Richland County, it falls into the Red River Valley and flows in a serpentine course to the eastern part of the county. Here, it turns northward and enters the Red River in extreme southeastern Cass County, south of Fargo. The total area drained by the Wild Rice River in North Dakota is 2,020 square miles.

Much of the subbasin comprises one of the best farming regions in the State, but some marginal land, particularly in the west, is also found. Within the subbasin, 50 legal drains with a total approximate length of 325 miles provide artificial drainage for some 730,000 acres of productive farmland.

Ground water serves as a source of supply for the ten (10) municipal water supply systems in operation in the subbasin. Water from the Ottertail River supplements Wahpeton's three wells. Major cities in the subbasin include Wahpeton, Hankinson, and Lidgerwood, with 1960 populations of 5,876, 1,285, and 1,081 respectively.

Within the Wild Rice subbasin, 41 dams with an individual minimum capacity of 50 acre-feet, collectively, store approximately 18,750 acre-feet of water. An additional 766 acre-feet of stock water and incidental fish and wildlife storage are provided by numerous Soil Conservation Service type small dams and dugouts.

Sheyenne River Subbasin

North Dakota's longest river, the Sheyenne River, rises in Sheridan County in central North Dakota. In its 506 mile course to the Red River, it flows through Wells, Benson, Eddy, Nelson, Griggs, Barnes, Ransom, Richland, and Cass Counties. Portions of Pierce, Foster, and Steele Counties are drained by the Sheyenne. The total area drained, all of which is in North Dakota, is 7,140 square miles.

The Sheyenne River subbasin is spread over three distinct areas: The Red River Valley; the delta and morainal area; and the drift prairie. It is within this latter area that the headwaters are located. Here, the coulees are two to five miles long, 30 to 60 feet deep, and ⅛ to ⅜ of a mile wide. The main valley is rather steep sided, and ranges from bluff to bluff, from ⅜ to ¾ of a mile wide in the lower reaches. The depth and width of the valley gradually decreases after it leaves the drift prairie. The uplands in the plain of the Red River are very level.

Soils within the subbasin vary from valley to alluvium, ranging from the lake silt of the Red River Valley proper to the glacial till intermixed with sand and gravel found in the glacial drift area. The Sheyenne Delta area has soils that are largely sandy loam.

The main tributary of the Sheyenne River is the Maple River which drains approximately 1,500 square miles in Steele, Barnes, Ransom, and Cass Counties. Other important tributaries are Baldhill Creek, north of Valley City, and Swan Creek and Rush River, both of which are tributaries to the Maple River in Cass County.

Agriculture and agricultural service businesses employ a majority of the subbasin's working force. To assist farmers in attaining the maximum economic benefit from their farming operations, 15 legal drains have been constructed within the subbasin. Fourteen (14) of these drains, varying in length from less than one (1) mile to 15 miles, are located in the lower portion of the subbasin where artificial drainage is more urgently needed and where benefits are more obvious. A single legal drain is located in the upper portion of the basin in

Pierce County. Collectively, legal drains within the basin have a total length of 112 miles and drain an approximate 391 square miles.

Within the Sheyenne subbasin, nearly 150 dams with a minimum individual capacity of 50 acre-feet and a combined storage capacity of 28,800 acre-feet, have been constructed. Numerous small Soil Conservation Service type dams and dugouts provide an additional 3,558 acre-feet of storage for stock water and incidental fish and wildlife uses.

Baldhill Dam and its reservoir, Lake Ashtabula, provide a total storage capacity of 70,700 acre-feet at full pool, including 1,200 acre-feet of dead storage. The active storage, 69,500 acre-feet provides multiple-purpose benefits for municipal and industrial water supply, water quality improvement, flood control, recreation and fish and wildlife enhancement. Normally, a program of winter releases is initiated about 1 October each year which draws down the reservoir about 3.5 feet below the normal pool level by 1 March to provide about 18,200 acre-feet of storage for controlling the spring runoff. Most years, the normal full pool level is recovered following spring runoff. Most of the active storage has been allocated by the State Water Commission to the five cities and six industries which shared in dam construction costs. Twenty-five (25) percent of the water was allocated on the basis of total cash contributions; 75 per cent on the basis of 1950 populations (in the case of municipalities). Under this formula the cities and industries noted below were allocated, on an annual basis, water in the amounts indicated:

Municipal or Industry	Amount (Acre-Feet)
Fargo	35,880
Grand Forks	20,023
Valley City	6,686
Southwest Fargo	959
Lisbon	1,780
Sugar Company	2,732
Union Stock Yard	159
Great Northern Railroad Co.	235
Northern Pacific Railroad Co.	235
Soo Line Railroad Company	76
Northern States Power Company	235

Twenty-four (24) of the subbasin's 67 communities have municipal water supply systems. With the exception of Casselton in Cass County, whose water supply is drawn from a reservoir on the Maple River, all municipal systems utilize groundwater wells as a source of supply. Kathryn, located in southern Barnes County, utilizes a local spring. Most of the rural domestic and municipal water supplies in the subbasin do not meet the State Health Department's minimum requirements for "good quality" water.

The State Engineer has granted permits for the use of approximately 6,900 acre-feet of subbasin water to irrigate slightly more than 4,300 acres. With full development of the Garrison Diversion Unit, an additional 235,900 acres will be placed under irrigation.

Elm River Subbasin

The Elm River rises in southeastern Steele and northwestern Cass Counties, flowing generally eastward to its confluence with the Red River in the extreme southeastern corner of Traill County. Total drainage area of the Elm River is approximately 510 square miles. Unlike most of the tributaries to the Red in North Dakota, which tend to turn sharply north before entering the mainstem, the Elm River turns slightly southeastward.

To assist farmers in realizing the maximum possible benefit from their farming operations, 13 legal drains ranging in length from 1½ to 8½ miles have been constructed within the Elm River subbasin. These drains collectively assist in the drainage of over 100,000 acres of the watershed.

In July of 1958, the United States Congress approved a Watershed Plan developed by local sponsors in cooperation with the Soil Conservation Service. Since then, local groups have worked with State and Federal officials to install dams, channels, and soil conservation practices needed to protect the land and reduce floods. The Elm River Watershed Project includes 50 miles of stream channel improvement for flood control in addition to three flood control dams which have a combined flood control storage capacity of over 7,000 acre-feet.

Eight communities are located in the Elm River subbasin. Four of them have municipal water supply systems. Hunter, Page and Arthur, with 1960 populations of 446, 432 and 325 respectively, are the largest communities in the subbasin.

Goose River Subbasin

The headwaters of the Goose River are located in central Nelson County. Flowing eastward through the glacial drift area and the Elk Valley Delta, it passes through the southwestern part of Grand Forks County, the northeastern part of Steele County, and into Traill County where, almost directly east of Caledonia, it enters the Red River of the North. At its widest point, east and west, the subbasin has an approximate width of 50 miles. North and south, the subbasin extends a distance of about 70 miles. Total area drained by the Goose River is an estimated 1,280 square miles. Important tributaries include Goose Creek, and the Goose River's north, middle, and south branches. Small grain and row crop farming coupled with a growing agricultural products processing industry constitute the primary source of employment within the subbasin.

Within the Goose River subbasin, 41 dams have been built to provide a total approximate storage capacity of 14,300 acre-feet for stock water, fish and wildlife, irrigation and recreation. An additional

525 acre-feet of water are provided for stock water and incidental fish and wildlife use by small dams and dugouts.

The State Water Commission, in cooperation with the State Outdoor Recreation Agency, the State Game and Fish Department, and local sponsors, has installed a diversion dam on Beaver Creek, creating a complex of three lakes. Known as the Golden Lake complex, these three lakes have a combined surface area of 921 acres and a combined impoundment capacity of 8,645 acre-feet. The complex consists of a diversion dam on Beaver Creek and all of the interconnecting diversion ditches and structures associated with the project. Rush Lake, which has a surface area of 278 acres and a capacity of 695 acre-feet of water, is maintained primarily for wildlife habitat. Golden Lake has a surface area of 339 acres and contains 5,000 acre-feet of water. It is utilized for fishing, boating and related activities as well as cottage development. North Golden Lake has a water surface area of 313 acres and contains 2,950 acre-feet of water.

Twelve (12) legal drains, ranging in length from one mile to 9.5 miles, have been constructed in the subbasin to assist farmers in realizing the maximum economic benefit from their land. Together, these drains assist in the removal of runoff from approximately 181 square miles or 115,840 acres of the subbasin.

Sixty (60) percent of the subbasin's communities boast municipal water supply systems. Five (5) communities utilize ground-water wells as a source of supply, while a single community, Mayville, uses a surface water supply. The Cities of Hatton and Northwood are having considerable difficulty in locating and developing a dependable ground-water supply. Both are considering the installation of dams and reservoirs on the Goose River to supplement their present ground-water supplies. Mayville, with a 1960 population of 2,168, is the subbasin's largest city. Other important population centers include Hillsboro (1,278), Northwood (1,195), and Portland (606).

The State Engineer has granted permits for the use of 221 acre-feet of subbasin water for the irrigation of 150 acres of land.

Turtle River Subbasin

The Turtle River has its source in the vicinity of Petersburg in east central Nelson County. From the headwaters area, it flows eastward and slightly to the south through the Elk Valley Delta and reaches the Red River Valley near Arvilla in Grand Forks County. From this point, it flows northeastward to its confluence with the Red River in the northeast corner of the County. The subbasin can be described as being slightly less than 50 miles long and approximately 20 miles wide. Its total drainage area is an estimated 730 square miles. Its major tributary is the Salt Water Coulee.

Within the subbasin, 11 dams have been constructed with a total estimated storage capacity of 3,075 acre-feet for stock water, recreation, and fish and wildlife uses. Numerous small dams provide storage for an additional 287 acre-feet of water for stock and incidental fish and wildlife use. Twenty-six (26) miles of legal drains help carry away runoff from about 50 square miles of fertile and productive farmland in the subbasin.

To be found within the boundaries of the subbasin are ten (10) communities. Larimore, with a 1960 population of 1,714, is the largest. Other population centers include Emerado (328), Manvel (313), and Petersburg (272). Only Larimore and Emerado have municipal water supply systems. Both use ground-water wells as a source of supply. Larimore, Emerado, and Manvel have experienced an accelerated population growth rate because of their proximity to Grand Forks Air Force Base. The need for a supplemental source of supply is growing steadily, as a consequence.

The State Engineer has granted permits for the use of 293 acre-feet of water for the irrigation of approximately 190 acres of land throughout the subbasin.

Forest River Subbasin

The Forest River rises in the western part of Walsh County, and in eastern Nelson County. It flows southeastward across the Pembina Delta to the vicinity of Inkster in Grand Forks County where it descends to the floor of the Red River Valley and continues to flow in a northeasterly course to its mouth at a point about 11 miles north of the Walsh-Grand Forks County line. The subbasin may be generally described as being approximately 55 miles long and 20 miles wide. It is bounded on the north by the Park River, on the south by the Turtle River, and on the west by the Devils Lake subbasin. The total estimated area drained by the Forest River is 1,030 square miles or 659,000 acres.

Within the Forest River drainage basin, eight dams with a minimum individual storage capacity of 50 acre-feet have been built by cooperating State and local governmental agencies. These eight dams have an approximate combined storage capacity of 4,280 acre-feet. Lake Ardoch, which alone stores 3,450 acre-feet, is the largest single structure. The principal use of water stored within the river basin is that of fish and wildlife. A number of small dams store an additional 366 acre-feet for stock water and incidental fish and wildlife uses.

About 11 percent of the land area of the subbasin is artificially drained by eight legal drains. The area drained is principally that located near the Red River. A total of 37 miles of such drains assist in the removal of runoff from about 99 square miles of valuable farmland.

Of the 14 communities located within the boundaries of the subbasin, only Minto and Adams have municipal water systems. Both are supplied by ground water. Minto, with a 1960 population of 642, is the largest community in the subbasin. Other communities include Fordville (1960 population — 367), Adams (360), and Lankin (303).

Within the subbasin, a number of Soil Conservation Districts, the State Game and Fish Department, and the Walsh, Grand Forks, Nelson and Cavalier County Water Management Districts, are cooperating with the Soil Conservation Service of the U. S. Department of Agriculture to plan and develop the Forest River Watershed Project.

Five dams have been completed with a combined storage capacity of 20,000 acre-feet, of which 5,000 acre-feet is permanent storage and 15,000 acre-feet is flood storage. The permanent storage provides nearly 350 surface acres for recreation, fish and wildlife purposes. The completion of two planned dams in this subbasin will provide an additional 8,000 acre-feet of flood storage and 2,200 acre-feet of permanent storage with 200 surface acres. Of the 150 miles of planned channel improvements, 64 miles have been completed.

The principal industry of the area is farming. The State Engineer has granted water permits for the use of 197 acre-feet of water to irrigate approximately 150 acres of farmland.

Park River Subbasin

The Park River has its source in the southeastern part of Cavalier County. It flows southeastward from its headwaters through the Pembina Delta and descends to the floor of the Red River Valley near the City of Park River in central Walsh County. From this point, it flows generally eastward, but slightly northward in a winding course to its confluence with the Red River five miles south of the Walsh-Pembina County line. The subbasin may be described as a rich agricultural area approximately 60 miles long, east and west, and 25 miles wide at its widest point, north and south. It is bounded on the north by the Pembina River subbasin, on the west by the Devils Lake basin, and on the south by the Forest River subbasin. The total estimated area drained by the Park River is 1,010 square miles or 646,440 acres.

Within the subbasin, 22 dams with a minimum individual storage capacity of 50 acre-feet have been constructed by cooperating State agencies and local governments. These 22 dams have an estimated, combined storage capacity of 8,560 acre-feet. Water stored behind these structures is used to provide fish and wildlife habitat, municipal and industrial water, and outdoor recreation opportunities. Homme Dam, constructed by the U. S. Army Corps of Engineers, immediately west of Park River, North Dakota, impounds 6,700 acre-feet of water, 3,000 acre-feet of which is for flood control purposes. The dam's reservoir offers a variety of outdoor recreation opportunities for area residents and visitors. More important perhaps, the dam has become an important segment in the municipal water supply systems of Grafton and Park River. The latter taps Homme Dam while Grafton, located 37 miles from the dam, obtains its water supply from releases made from the dam. The City of Grafton has filed for a water permit on the Red River in anticipation that it may not be possible to meet water demands through either the development of ground-water or surface water resources in the subbasin. A number of smaller dams, such as those constructed by the Civilian Conservation Corps during the 1930's and those being constructed currently by the Soil Conservation Service, store an additional 824 acre-feet of water for stock water and incidental fish and wildlife use.

Seventeen (17) legal drains, totaling 72 miles in length, have been built in the subbasin to date. Collectively, these drains assist in the removal of excess runoff, made up of spring rains and snow melt and of midsummer thunder storms, from about 940 square miles.

Thirteen (13) communities, ranging in population from nearly 6,000 to less than 100, are located within the boundaries of the Park River watershed. Six of these have municipal water supply systems, and of the six, three utilize ground water and three surface water. Grafton, with a 1960 population of 5,885, is the largest city in the drainage basin. The City of Park River (1960 population 1,813) is the second largest city in the subbasin.

Agriculture and agricultural products processing plants constitute the primary source of employment in the subbasin. Continued expansion of agri-business type ventures is expected to place increasingly heavier demands upon the existing water supply.

To date, the State Engineer has granted water permits to farmers in the subbasin for 165 acre-feet of water for the irrigation of about 89 acres.

Pembina River Subbasin

The Pembina River has its source and a large portion of its drainage area of Canada. It enters North Dakota near Elkwood in Cavalier County and flows in a southeasterly course to the Cavalier-Pembina County line. Here it turns to flow in a northeasterly direction to Neche near the International boundary. Leaving Neche, it follows a slightly southeasterly route until it reaches its confluence with the Red River at the City of Pembina. In North Dakota, the Pembina River, along with its major tributary, the Tongue, drains an estimated 1,960 square miles. Portions of Rolette, Towner, Cavalier and Pembina Counties make up the land area of the basin. From its extreme western end in Rolette County to the Minnesota border, the area drained by the Pembina River extends a distance of approximately 135 miles. At its widest point, in central Cavalier County, the subbasin is about 25 miles wide. Topography of the subbasin ranges from that of the eastern Turtle Mountains, to the Pembina Escarpment, to the Red River Valley.

Within the subbasin, 38 dams have been constructed with a total estimated storage capacity of

30,450 acre-feet for stock water, recreation, fish and wildlife, municipal water supply, and flood control. Flood control projects constructed by the Soil Conservation Service, under authority of Public Law 566, have combined permanent and flood control storage capacity of nearly 20,000 acre-feet. Numerous small dams — those which normally store less than 50 acre-feet — and dugouts provide an additional 706 acre-feet of storage for stock water and incidental fish and wildlife use.

Twenty-one (21) legal drains, totaling 116 miles in length, have been built in the subbasin to date. As a system, these drains assist in the removal of excess runoff from approximately 659 square miles.

Langdon, with a 1960 population of 2,151, is the largest of the subbasin's 20 communities. Other important population centers include Walhalla (1,432), Cavalier (1,423), and Neche (545). Four of the five communities with municipal water supply systems secure their water from either the Pembina or Tongue Rivers. The City of Neche in the extreme northeastern part of Pembina County supplies water to the municipalities of Gretna and Altona in Manitoba, Canada.

Agriculture remains the principal industry of the subbasin. The State Engineer has granted water permits to farmers in the subbasin for 100 acre-feet of water for the irrigation of approximately 46 acres of land.

MINOR RED RIVER OF THE NORTH TRIBUTARIES

An estimated 1,560 square miles are drained by direct minor tributaries of the Red River including the Bois-de-Sioux River. The area is composed of six minor watersheds lying adjacent to the Red River and between the various subbasins noted in the foregoing description of the Red River Basin. The area is important because it supports the heaviest concentration of population in the State and because of the amount and kinds of water resources development which have occurred to date.

Fargo, the State's largest city, is located adjacent to the Red River in an area where drainage is directly to the mainstem. Located downstream from Fargo, is Grand Forks, whose 1960 population of 34,451, is second only to Fargo's 1960 population of 46,662. Of the ten (10) communities found within the six minor watersheds, three have municipal water supply systems. All three secure their supply from the Red River.

Twenty-three (23) dams capable of storing a minimum of 50 acre-feet each, have been built to date within the subbasin and store water for stock water, recreation, fish and wildlife, and municipal use. The combined capacity of these structures for all uses is estimated to be 6,240 acre-feet. An additional 481 acre-feet are stored by small dams and dugouts. These latter dams have been constructed primarily to meet stock water requirements, but they do receive an incidental fish and wildlife use.

An extensive network of legal drains has been constructed in the watersheds draining directly into the Red River. Seventy-seven (77) such drains, ranging in length from less than one mile to 13.5 miles, assist in the removal of excess runoff from an estimated 1,142 square miles.

Irrigation being carried on within the area referred to here is negligible.

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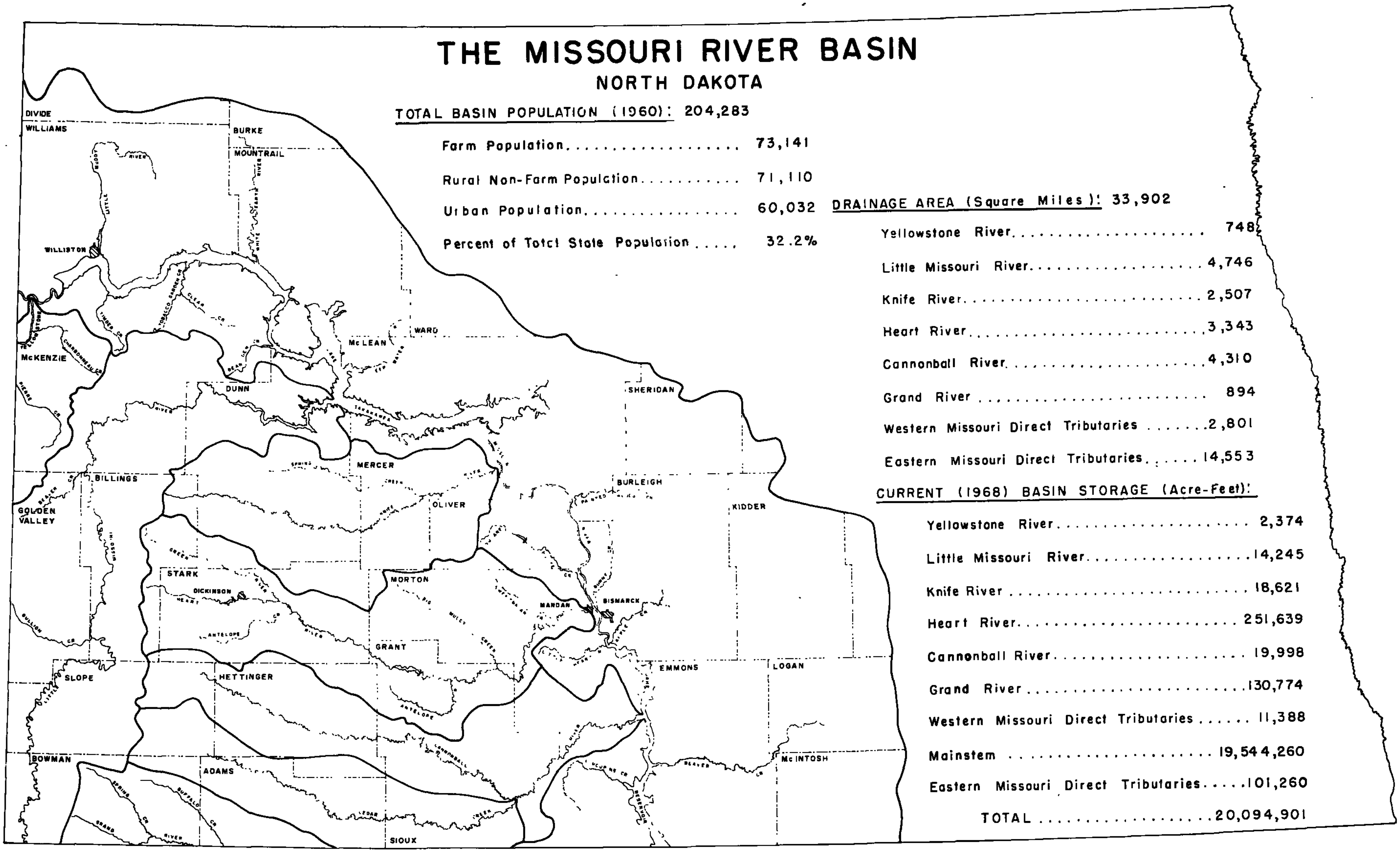
DRAINAGE AREAS BY BASIN AND SUBBASIN IN SQUARE MILES

STREAM (Basin)		DRAINAGE AREA IN SQUARE MILES
Missouri River		
Yellowstone River	748	
Little Missouri River	4,746	
Knife River	2,507	
Heart River	3,343	
Cannonball River	4,310	
Grand River	894	
Western Missouri Mainstem Tributaries	2,801	
Eastern Missouri Direct Tributaries	9,626	
Eastern Missouri Direct Tributaries (Noncontributing)	4,927	
TOTAL MISSOURI RIVER (excluding James)		33,902
James River		6,831
Souris River		9,112
Red River		
Pembina River	1,960	
Park River	1,010	
Forest River	1,030	
Turtle River	730	
Goose River	1,280	
Elm River	510	
Wild Rice River	2,020	
Sheyenne River	7,140	
Bois de Sioux River	195	
Red River (Direct Tributaries)	1,365	
TOTAL RED RIVER		17,240
Devils Lake Basin		3,580
TOTAL AREA OF NORTH DAKOTA		70,665

THE MISSOURI RIVER BASIN

NORTH DAKOTA



TOTAL BASIN POPULATION (1960): 204,283

Farm Population	73,141
Rural Non-Farm Population	71,110
Urban Population	60,032
Percent of Total State Population	32.2%

DRAINAGE AREA (Square Miles): 33,902

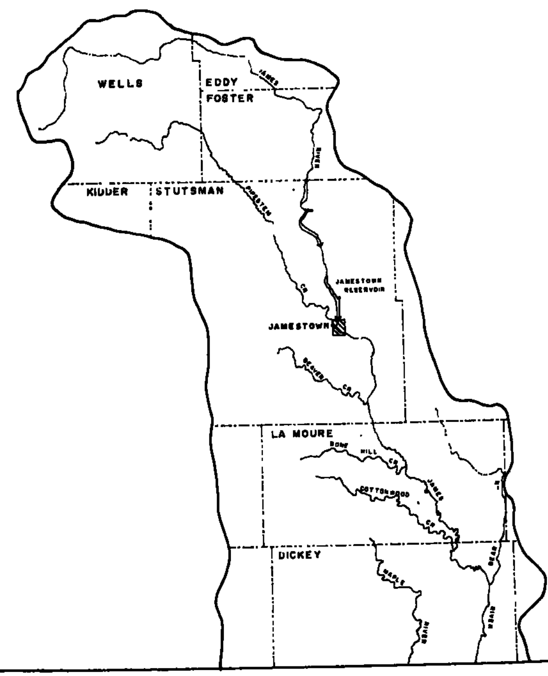
Yellowstone River	748
Little Missouri River	4,746
Knife River	2,507
Heart River	3,343
Cannonball River	4,310
Grand River	894
Western Missouri Direct Tributaries	2,801
Eastern Missouri Direct Tributaries	14,553

CURRENT (1968) BASIN STORAGE (Acre-Feet):

Yellowstone River	2,374
Little Missouri River	14,245
Knife River	18,621
Heart River	251,639
Cannonball River	19,998
Grand River	130,774
Western Missouri Direct Tributaries	11,388
Mainstem	19,544,260
Eastern Missouri Direct Tributaries	101,260
TOTAL	20,094,901

THE JAMES RIVER BASIN

NORTH DAKOTA

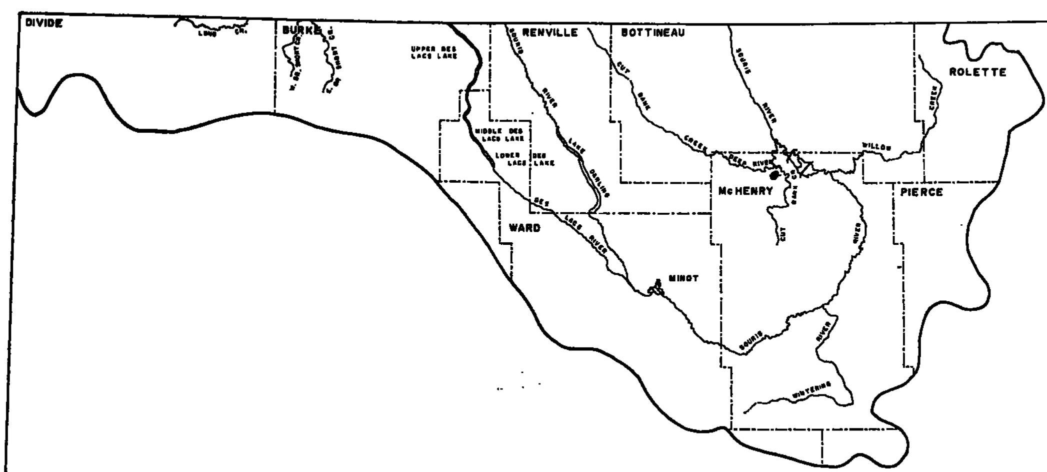


TOTAL BASIN POPULATION (1960): 61,523

Farm Population	23,263
Rural Non-Farm Population	23,097
Urban Population	15,163
Percent of Total State Population	9.7%

DRAINAGE AREA (Square Miles): 6,831

CURRENT (1968) BASIN STORAGE (Acre-Feet): 288,686



THE SOURIS RIVER BASIN

NORTH DAKOTA

TOTAL BASIN POPULATION (1960): 103,671

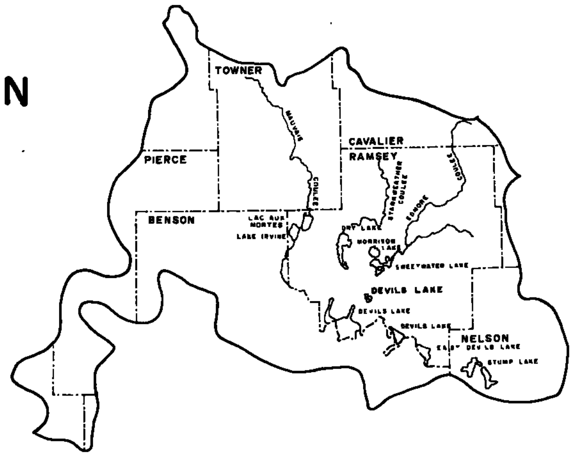
Farm Population....................	30,570
Rural Non-Farm Population...........	36,912
Urban Population.................	36,189
Percent of Total State Population.....	16.4%

DRAINAGE AREA (Square Miles): 9,112

CURRENT (1968) BASIN STORAGE (Acre-Feet): 256,745

THE DEVILS LAKE DRAINAGE BASIN

NORTH DAKOTA



<u>TOTAL BASIN POPULATION (1960):</u> 35,536

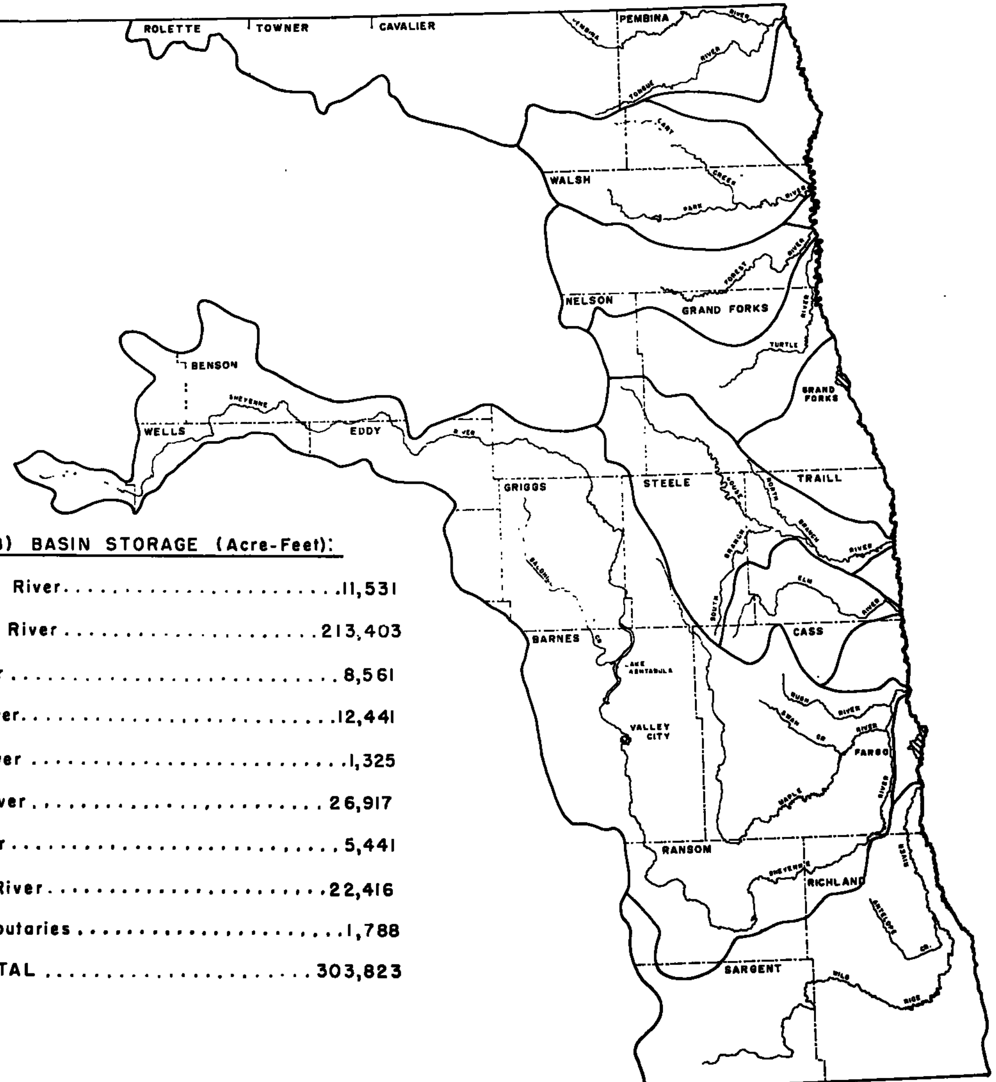
Farm Population..................	14,702
Rural Non-Farm Population...........	14,536
Urban Population.................	6,298
Percent of Total State Population.....	5.6%

<u>DRAINAGE AREA (Square Miles):</u> 3,580

<u>CURRENT (1968) BASIN STORAGE (Acre-Feet):</u> 29,703

THE RED RIVER BASIN

NORTH DAKOTA



TOTAL BASIN POPULATION (1960): 227,433

Farm Population	63,227
Rural Non-Farm Population	60,195
Urban Population	104,011
Percent of Total State Population	36.0%

DRAINAGE AREA (Square Miles): 17,240

Wild Rice River	2,020
Sheyenne River	7,140
Elm River	510
Goose River	1,280
Turtle River	730
Forest River	1,030
Park River	1,010
Pembina River	1,960
Minor Tributaries	1,560

CURRENT (1968) BASIN STORAGE (Acre-Feet):

Wild Rice River	11,531
Sheyenne River	213,403
Elm River	8,561
Goose River	12,441
Turtle River	1,325
Forest River	26,917
Park River	5,441
Pembina River	22,416
Minor Tributaries	1,788
TOTAL	303,823

Chapter Five

Current and Projected Economic Data for North Dakota

CHAPTER V

CURRENT (1967) AND PROJECTED ECONOMIC DATA FOR NORTH DAKOTA

The primary purpose of this chapter is to present the results of a study undertaken by the State Water Commission to evaluate the present economic structure of North Dakota and to provide economic projections necessary for the appraisal of future water resource needs for 1980 and 2000. With the exception of population projections, all other economic projections were made on a State-wide basis only rather than on a river basin basis. Population projections were made on an economic region basis, whose boundaries follow county lines as shown on the map on the following page. The boundaries of these economic regions, however, closely approximate the actual river basin boundaries as is shown by the comparison between the river basin area and the area of each corresponding economic region in the first section of Table 1. Counties included in each of these economic regions are given below:

MISSOURI (23)	JAMES (6)	SOURIS (8)	DEVILS LAKE (4)	RED (12)
Adams	Dickey	Bottineau	Benson	Barnes
Billings	Eddy	Burke	Nelson	Cass
Bowman	Foster	Divide	Ramsey	Cavalier
Burleigh	LaMoure	McHenry	Towner	Grand Forks
Dunn	Stutsman	Pierce		Griggs
Emmons	Wells	Renville		Pembina
Golden Valley		Rolette		Ransom
Grant				Richland
Hettinger				Sargent
Kidder				Steele
Logan				Traill
McIntosh				Walsh
McKenzie				
McLean				
Mercer				
Morton				
Mountrail				
Oliver				
Sheridan				
Sioux				
Slope				
Stark				
Williams				

POPULATION-ECONOMIC REGIONS

Population projections used in developing the State Water Plan were developed by means of the following formulas:

(1) $\frac{\text{Projected Population}}{\text{1960 Population}} = (1+r)^X \text{ or } 1+r = \sqrt[X]{\frac{\text{Projected Population}}{\text{1960 Population}}}$

AND

(2) 1960 Population $(1+r)^X$ = Projected Population

The symbol r in each of the above formula represents the average rate of change in the State's population between 1960 and the year to which population was projected and X represents the number of years between 1960 and the projected year.

These formulas were extracted from "The Projection of Population Characteristics in North Dakota" published by the Bureau of Business and Economic Research, College of Business and Public Administration, University of North Dakota, Grand Forks.

The first step in making these projections was to determine the average rate of change in the State population between the years 2000 and 1960 by using formula one. The estimated population for the State of North Dakota by the year 2000 is 1,120,100. This figure was given in the Senate Select Committee Report No. 5.

This average rate of change is then used in formula two to determine the projected population for the year 2000 in each of the five major river basins.

The following work shows the computation of the average rate of change in the total State population between the years 2000 and 1960.

$$\frac{\text{2000 population}}{\text{1960 population}} = (1+r)^{40} \text{ or } 1+r = \sqrt[40]{\frac{\text{2000 population}}{\text{1960 population}}}$$

State population in 2000 = 1,120,100
State population in 1960 = 632,446

$$1+r = \sqrt[40]{\frac{1{,}120{,}100}{632{,}446}}$$

$$1+r = \sqrt[40]{1.772}$$

$$1+r = \frac{\log 1.772}{40}$$

$$1+r = \frac{0.24846}{40}$$

$$1+r = 0.00621$$

Now taking the antilog of both sides we have:

$$1+r = 1.014$$
$$r = 0.014$$

Then taking formula two, we can determine a multiplier which when multiplied by the 1960 population, will give us the projected population for the year 2000.

$$\text{1960 population } (1+r)^{40} = \text{2000 population}$$
$$(1.+0.014)^{40} = \text{2000 population}$$
$$(0.014)^{40} = \text{2000 population}$$
$$40 \log 1.014 = \text{2000 population}$$
$$40\ (0.00604) = \text{2000 population}$$
$$0.2416 = \text{2000 population}$$

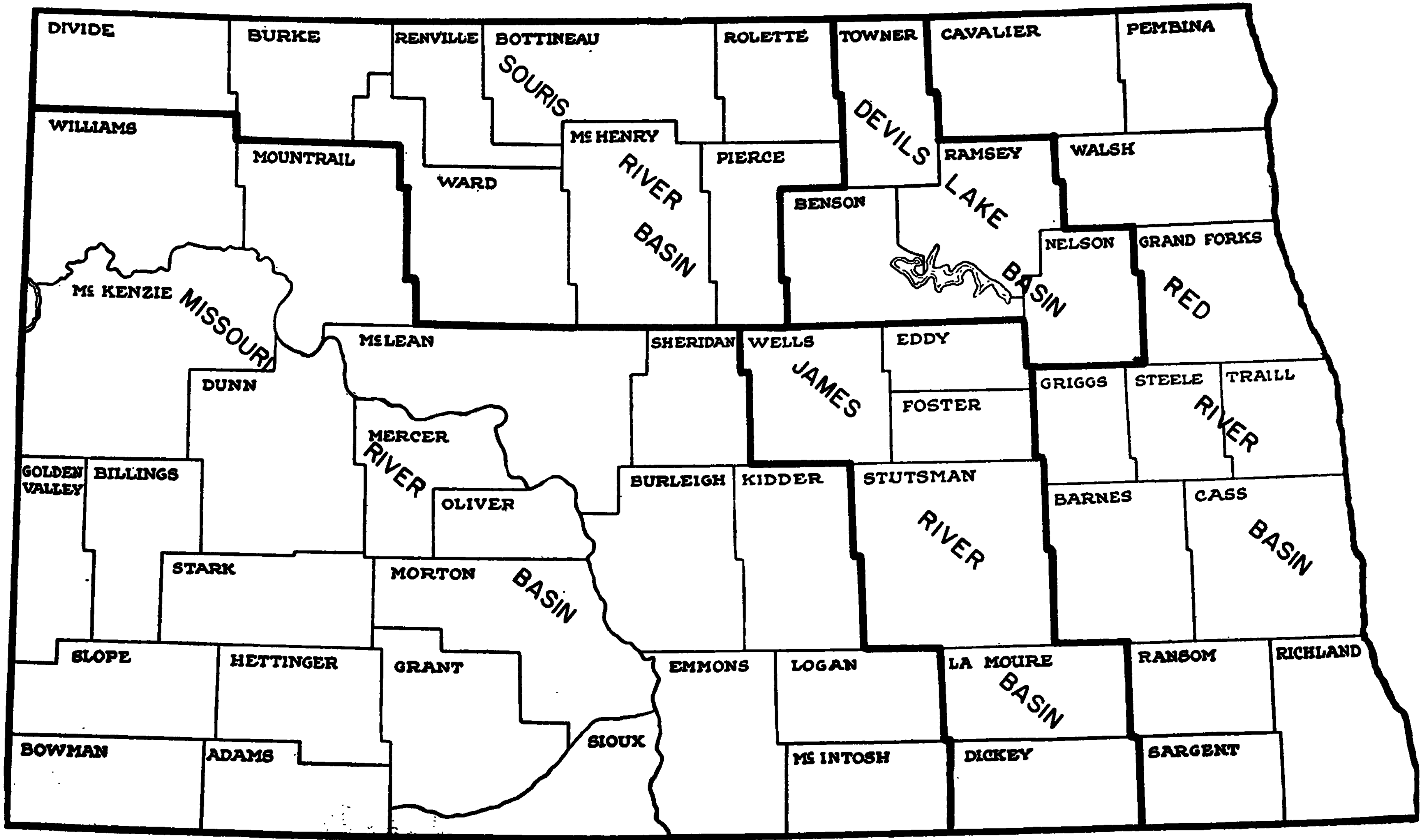
Taking the antilogarithem of this we have

1.744

as the multiplier for each of the 1960 populations of the five major river basins within the State. Using this multiplier, the population by 2000 is estimated to be:

Missouri River Basin	364,500
James River Basin	109,100
Souris River Basin	183,000
Devils Lake Basin	63,200
Red River Basin	400,300

NORTH DAKOTA STATE WATER PLAN
S.W.C. PROJ. NO. 322
ECONOMIC REGIONS FOR MAJOR RIVER BASINS



TOTAL WORK FORCE

In December 1967, North Dakota's work force numbered 226,430. This work force included all persons who were employed or were capable of holding a job. A first step in securing work force projections for 1980 and 2000 was to determine what percentage of the State's 1967 population actually participated in the 1967 work force. The resulting participation rate was then multiplied by the State's projected 1980 and 2000 populations to determine the anticipated State work force for those periods. In the foregoing process, it was assumed that participation by the State's population in the State's work force will remain relatively constant over time. It seems likely that while increased technology will result in a loss of some jobs, increased manufacturing and other economic development will create new jobs resulting in a fairly constant participation rate in the State's work force.

Total Unemployment

North Dakota's unemployment in December of 1967 was 10,400 people. This was approximately 4.6 percent of the State's total work force of 226,430. It is assumed that increased technology and manufacturing will decrease, rather than increase the percent of the State's work force which is unemployed. In order to make some projection of future unemployment for 1980 and 2000, it was assumed that the percent of the State's work force being unemployed for each time period would decrease at a rate of one percent per 10-year period from the 1967 percentage. Hence, the projected percent of the State's work force unemployed for 1980 and 2000 respectively is 3.6 and 1.6 percent.

Total Agricultural Employment

Agricultural employment in North Dakota in December 1967 was 40,000. This was approximately 18.5 percent of the State's total employment at that time. Due to the anticipated development of the Garrison Diversion Unit and increased irrigation from other sources in other areas, as well as an increased need for the production of food products to meet national and world demands for food, it is assumed that agricultural employment will increase. However, due to increased technology, mechanization, and improved farming methods, it is likely that the overall percentage of the State's total employment involved in agricultural employment will remain fairly constant over time. Thus, it is assumed that projected agricultural employment for 1980 and 2000 will be about 18.5 percent of the total employment for those time periods.

Self-Employed, Unpaid Family Workers, and Domestic Service

In December 1967, 22,430 of the State's total nonagricultural employment were self-employed or employed in family businesses with no pay or as domestic servants. This was 12.7 percent of the nonagricultural employment at the time. For the purpose of this report, it was assumed that projected employment of this type for 1980 and 2000 would continue at about the same percent of the total State nonagricultural employment for each of these time periods.

Wage and Salary Employment

Total wage and salary employment in North Dakota during December 1967 was 153,600. This type of employment is broken down into four major categories:

(1) Mining, construction, and manufacturing (19,270)

(2) Transportation, communications, and public utilities (11,960)

(3) Trade (44,350)

(4) Finance, insurance, real estate, service, and government (78,020)

The percentage distribution among the four categories of the total wage and salary employment for 1967 is 12.6, 7.8, 28.6 and 51.0 percent respectively. Future wage and salary employment in each of these four categories is expected to continue at about the same percentage rate of the total employment.

Total Personal Income

"Personal income is the current income received by persons from all sources, net of personal contributions for social insurance. Not only individuals (including owners of unincorporated enterprises), but nonprofit institutions, private trust funds, and private health and welfare funds are classed as 'persons'. Personal income includes transfers (payments not resulting from current production) from government and business such as social security benefits, military pensions, etc., but excludes transfers among persons. Although most of the income is in monetary form, there are important nonmonetary inclusions — chiefly, estimated net rental value to owner-occupants of their homes, the value of services furnished without payment by financial intermediaries, and the value of food consumed on farms."[1]

North Dakota's total personal income in 1966 was $1.6 billion according to the **1967 Statistical Abstract of the United States.** Figures shown in this abstract reflect an average annual increase of approximately $75 million in the State's total personal income from 1955 to 1966. During the time period from 1964 to 1966, the increase in total annual personal income was $300 million or an average annual increase for this two-year period of $150 million. This indicates that the average annual increase in total personal income from 1964 to 1966 as compared to the increase from 1955 to 1966 has doubled. While it would be extremely hazardous to say that this increase in total personal income for North Dakotans will continue to double, it is very likely that due to increased manufacturing and agricultural develop-

[1]"Income, Expenditures, and Wealth," *Statistical Abstract of the United States*, U. S. Department of Commerce, Washington, D. C., 1967, p. 367.

ment in the State, personal income will continue to increase. For the purpose of this report, it was assumed that the total personal income for North Dakota will continue to increase at approximately $100 million per year until the year 1980. Beyond 1980, due to the development of the Garrison Diversion Unit and other irrigation as well as increased manufacturing and power development, it is assumed the total annual personal income will increase about $150 million per year up to the year 2000.

Median Annual Income Per Family

The median annual income per family in North Dakota in 1960 was $4,530 and the average number of persons per family was 3.55. In 1950, the median annual income was $3,580 and the average number of persons per family was 3.70. It may be anticipated that the trend will continue resulting in increasing median annual incomes and fewer persons per family. Since the average family size from 1950 to 1960 has decreased by 0.15 persons per family, it was assumed that this decrease in family size would continue at approximately the same rate for each 10-year period. Therefore, the average family size is assumed to be 3.4 persons per family by 1980 and 3.1 persons per family by 2000. These figures were then used to determine the average number of families for each time period in North Dakota. The average number of families was divided into the total personal income for the State to determine the median annual family income.

Per Capita Tax

During fiscal year 1966, the total estimated Federal, State and local taxes paid in North Dakota amounted to approximately $317.9 million. This figure divided by the total State population gives a per capita tax figure for North Dakota residents of about $490, which was approximately 20.4 percent of the State's per capita income of $2400 in 1966. Due to anticipated increases in defense costs, welfare and social security payments, educational costs, etc., it is likely that the per capita tax will increase over time. In order to make per capita tax projections for 1980 and 2000, it was assumed that the per capita tax would be about 25 and 30 percent respectively of the per capita income for each time period.

The tables on the following pages contain the economic data gathered for North Dakota in this study. Table 1 is a compilation of data on area and population figures for the State. Table 2 consists of all other current (1967) and projected economic data, such as total work force, employment, unemployment, earnings, per capita income, etc., utilized in developing the State Water Plan.

TABLE 1. Area in Square Miles and Population Figures by Hydrologic Basin and Economic Region in North Dakota.

Type of Data	Missouri	James	Souris	Devils Lake	Red	State Total
Area (Square Miles):						
Hydrologic Basin	33,902	6,910	9,321	4,710	15,822	70,665
Economic Region[2]	33,408	7,133	11,102	4,829	14,193	70,665
Population-Economic Regions:						
1960 Census	204,283	61,523	103,671	35,536	227,433	632,446
1980 Projected[3]	212,100	64,100	124,400	33,900	264,500	699,000
2000 Projected[4]	364,500	109,100	183,000	63,200	400,300	1,120,000

[2]Basin boundaries based on county lines.
[3]Elmer C. Vangsness. *The People Study; North Dakota State Outdoor Recreation Plan,* North Dakota State Outdoor Recreation Agency, 1966.
[4]Source for State total population projection: *Senate Select Committee Report No. 5,* 86th Congress, March, 1960.

TABLE 2. Current (1967) and Projected Economic Data for North Dakota.

TYPE OF DATA	1967	1980	2000
Total State Population	644,400[5]	699,000	1,120,000
Total Work Force	226,430[6]	245,350	393,120
Total Unemployment	10,400[7]	8,830	6,290
Unemployment as a Percent of the Work Force	4.6%	3.6%	1.6%
Total Employment	216,030[8]	236,520	386,830
Employment as a Percent of the Population	33.5%	29.6%	29.0%
Employment as a Percent of the Work Force	95.4%	96.4%	98.4%
Total Agricultural Employment	40,000[9]	43,760	71,560
Total Nonagricultural Employment	176,030	192,760	315,270
Self-Employed, Unpaid Family Workers, and Domestic Service	22,430[10]	24,480	40,040
Wage and Salary Employment	153,600[11]	168,280	275,230
Mining, Construction and Manufacturing	19,270[12]	21,200	34,680
Transportation, Communications and Public Utilities	11,960[13]	13,130	21,470
Trade	44,350[14]	48,130	78,720
Finance, Insurance, Real Estate, Service and Government	78,020[15]	85,820	140,360
Total Personal Income in 1966 (Billion Dollars)	1.6[16]	3.0	6.0
Median Annual Income Per Family in 1960 (Dollars)	4,530[17]	14,590	16,610
Per Capita Income in 1966 (Dollars)	2,400[18]	4,290	5,360
Per Capita Tax in 1966 (Dollars)	490[19]	1,070	1,610
Per Worker Earnings in 1966 (Dollars)	7,410[20]	12,660	15,500
Average Work Week (Hours Worked)[21]	38.7	35.6	30.9
Average Paid Vacation (Weeks)[22]	1.8	2.6	3.5

[5]"North Dakota Population," *North Dakota Growth Indicators 1968-69*, North Dakota Economic Development Commission, August 1967, Page 22.
[6]Estimated Work Force in North Dakota, North Dakota State Employment Service, December, 1967.
[7]Same as 6.
[8]Same as 6.
[9]Agricultural employment estimate prepared by the North Dakota Crop and Livestock Reporting Service, United States Department of Agriculture.
[10]Prepared in cooperation with the United States Department of Labor; figues are rounded to the nearest 10.
[11]Same as 6.
[12]Same as 6.
[13]Same as 6.
[14]Same as 6.
[15]Same as 6.
[16]"Income, Expenditures, and Wealth", Section 11, *Statistical Abstract of the United States*, U. S. Department of Commerce, Washington, D. C., 1967, p. 327.
[17]*Demographic Data for North Dakota: North Dakota State Outdoor Recreation Plan*, North Dakota State Outdoor Recreation, Appendix 1, Volume 3, 1965.
[18]Same as 16.
[19]The total estimated Federal, State, and local taxes paid in North Dakota during the fiscal year ending June 30, 1966, was approximately $317.9 million according to figures compiled by Kenneth M. Jakes, Director of Research and Development, in the *Twenty-Eighth Biennial Report of the Tax Commissioner of the State of North Dakota to the Governor and Legislature for the Biennial Period July 1, 1964 to June 30, 1966.*
[20]Per worker earnings were determined by dividing the total personal income by the total employment.
[21]Vangsness.
[22]Vangsness.

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Chapter Six

Problems

CHAPTER VI

PROBLEMS

A first step in the formulation of any type of plan is to select a "planning approach" and, regardless of the type of approach ultimately chosen, it must be consistent with both goals and capabilities. With this in view, it was determined early in the planning process that a "problem approach" was the most practicable approach available to Commission planners in their efforts to develop a State Water Resources Development Plan. This approach involves two initial steps: (1) the identification of known problems, and (2) the collection of data pertinent to the solution of these problems.

It is intended that this chapter do no more than cite known problems, relate the history of their development, and suggest possible alternative solutions. The selection of specific solutions and the assignment of priorities, if any, is the function of Chapter 12, RECOMMENDATIONS.

RIVER BANK STABILIZATION

Description of Problem — The loss or destruction of valuable agricultural lands and wildlife habitat brought about by the erosion of a river's banks.

History of Problem Development — Prior to the construction of Garrison Dam, the waters of the Missouri River were heavily laden with silt and sediment. Though bank erosion did occur under these conditions, it was minimal, and usually, for each loss of land there was a corresponding accretion or gain in the area. Since the construction of Garrison Dam, however, the silt and sediment transported by the river are now deposited in the reservoir. As a consequence, water currently being released from the dam is virtually silt free. This clear water has a high silt-carrying capacity and immediately upon release, endeavors to attain its full bedload. In doing so, it causes an erosion of the river bank and the eventual sloughing of huge chunks of valuable river-bottom land into the river.

Compounding the erosion caused by the releases of silt-free water from Garrison Dam are the erratic flows brought about by irregular demands made upon the dam's power plant and the excessively high wintertime releases under the ice. The surging, churning effect of erratic streamflow accelerates the erosion process. High releases made under the ice during the winter also place severe stress upon river banks and upon works designed to protect those banks. In the spring, when the ice goes out, some of the banks and sections of the protective works weakened by excessively high wintertime releases slough into the river.

In 1963, the Congress of the United States authorized $3,000,000 for bank stabilization works between Garrison Dam and Oahe Reservoir in North Dakota. Following appropriations, the State Water Commission, the Corps of Engineers and local water management districts all cooperated in the selection of the bank eroded areas to receive priorities in regard to the initial project. The number one priority was given to the Square Butte segment of the project because of the impending danger to approximately 5,000 to 6,000 acres of valuable agricultural lands. The Missouri River had, at the time, concentrated its erosive capacity in an area approximately 2,000 or less feet from Square Butte Creek. Indications were that in a few years the Missouri River would shorten its course by cutting into the creek, and in so doing, destroy an immense acreage. The Morton County Water Management District and the State Water Commission cooperated in giving the assurances required for this project by the Federal Government.

The number two segment selected was the Lake Mandan area, located in Oliver County. At the time the priority was assigned, 325 acres of land in this section had already been severely eroded. Without immediate adequate protection, at the time, it was apparent that a considerable block of land would be severed by the action of the water.

Number three priority was given to an area referred to as the Fort Clark Irrigation Project. Here, the banks had been eroding at a rapid rate, threatening a considerable portion of the irrigation project as well as the intakes of the Basin Electric and United Power Association Power Plants.

The Painted Woods area, located in the left bank of the Missouri below Washburn, was assigned the number four priority. A distance of less than 2,000 feet separated Painted Woods Lake from the Missouri River. Had the river been allowed to cut across the lake, 4,000 to 5,000 acres of land would have been isolated and eventually eroded.

In 1967, revetment structures installed hardly more than a year earlier by the Corps of Engineers to protect the banks of the river, had deteriorated sufficiently to require extensive repairs. Partial failure of some of these structures has been attributed to the erratic releases from Garrison Dam, the excessively high wintertime releases, and to the manner in which they were installed. Instead of excavating through the sand bars to the more stable foundation below, project officials placed the rock materials directly upon the sand bars on the premise that the river would perform the excavation. This procedure, though a successful method where no maintenance is charged, should be a recognized construction procedure. The cost of repairs is borne by the State Water Commission and the local water management district in accordance with the assurances required by the Federal Government.

The State Water Commission has taken the position that the Missouri River between Oahe Reservoir and Garrison Dam is no longer a free-flowing river. Rather, it has become merely a canal for transporting water released through the operation of the mainstem reservoir system. As a consequence, the Commission contends that the Federal Government is responsible for preventing the bank erosion which is washing away great quantities of private land each year and for the operation and maintenance costs necessary to maintain the needed revetment structures.

The bank stabilization problem which exists in the North Dakota portion of the Yellowstone River sub-basin is similar to that of the Missouri River between Oahe Reservoir and Garrison Dam. Once again, a principal cause of the erosion which threatens large tracts of highly productive land as well as irrigation water intake stations is the irregular release of water from one of the mainstem dams, in this instance, Fort Peck Dam in eastern Montana. Fluctuations in the surface elevation of the Missouri River are followed by corresponding fluctuations in the level of the Yellowstone River near its confluence with the Missouri. As the Yellowstone River rises and falls, its banks are exposed to a saturation and drying out process which tends ot weaken them and render them more susceptible to erosion.

Besides destroying sizeable tracts of land, some of which have been, with great expense to the landowner, leveled for irrigation, erosion has limited the methods by which irrigation can be successfully practiced on lands lying adjacent to the Yellowstone. A review of aerial photographs taken of one reach of the river northeast of Fairview indicates that a farm which 20 years earlier had contained 114 acres, in 1958 had been reduced by bank erosion to 64 acres, or to nearly half its original size. The greater part of the destruction had occurred in the four-five year period preceding 1958.

Three 800-acre irrigation districts are located within the area subject to erosion. The Sioux Irrigation Project, located on the eastern bank of the Yellowstone River, has initiated a conversion program from an undependable river supply to ground water. The Cartwright and Yellowstone Pumping Irrigation Districts, also located adjacent to the reach of the river being eroded, have elected to use ground-water wells as a source of supply in view of the problems encountered by the Sioux Irrigation District in maintaining an adequate river pumping facility. Erosion alone cannot be blamed for the undependable supply problems. The Yellowstone River, particularly during periods of low flow, is extremely braided. Channels are capable of shifting almost overnight. At times, river intake systems may reach the channel with no difficulty; at other times, following a temporary channel change, the pumping facilities can be rendered inoperable very rapidly. This condition is quite obviously aggravated by the constant erosion of the river bank.

Bank stabilization problems, local in nature, occur on the majority of North Dakota's streams. Seldom does the severity of the problem in a given reach of a river reach such proportions as to render it eligible for study and correction by the Corps of Engineers.

Alternative Solutions — To solve the problem of bank stabilization on the Missouri River between Oahe Reservoir and Garrison Dam, it is imperative that:

1. The Federal Government recognize that the Missouri River between Oahe Reservoir and Garrison Dam is no longer a free-flowing river.
2. Congress pass legislation authorizing the Corps of Engineers to proceed immediately with the installation and future maintenance of any additional protective works required to stabilize the banks of the Missouri River.
3. The plan of operation of the mainstem reservoir system be revised in a manner which would stabilize releases from Garrison Dam and reduce what are now considered excessively high wintertime releases under the ice. (If the Missouri River's banks were **adequately** protected, fluctuating releases could be continued.)

Relief from the erosion problem currently being experienced in the Lower Yellowstone River subbasin must not be delayed if the valuable land being destroyed is to be reclaimed and/or saved. Consideration must be given to the installation of major bank stabilization works and to a re-examination of the operating plan of the Missouri River mainstem reservoir system.

Local, minor erosion problems, such as those found below Baldhill Dam on the Sheyenne, at Minot and Towner on the Souris, and in the Wild Rice and Park River subbasins, are likely to remain local and minor in nature. Corrective measures will, in most instances, be taken by local entities and individual landowners.

STATE AND LOCAL RELATIONSHIPS

Description of Problem — In many instances, water resource development interests on the local level lack the legal entity through which they can adequately provide for the planning, development and control of water resources in their area.

History of Problem Development — The State Water Commission is not prohibited by statute from cooperating in the planning, construction, and development of water resource projects with local groups who do not have status as legal entities. In numerous past instances this has, in fact, been done. Legal entities, however, have capacities which nonlegal entities lack, the principal ones being their capacity to assume operation and maintenance responsibilities and their authority to provide for special assessments. Water management districts, for example, have the power to levy special assessments or raise funds through a general mill levy, not exceeding three mills, to meet their costs of operation and in some instances the costs of the projects in which the district becomes involved. Local groups lacking such means for the raising of funds required for construction and planning are frequently thwarted in their efforts to investigate or build a desired project.

The need for local legal entities on a State-wide basis has long been apparent. The problem of not having legal entities with which to work is gradualley being overcome through the formation of soil conservation districts, irrigation districts, park districts, water management districts, and the Garrison Conservancy District. All have certain capabilities in the development of water resources below the State level, and all will play an important role in stimulating, developing, and maintaining water-based projects local in nature.

Because its capabilities are less limited than those of irrigation or park districts, the water management district emerges as the type of organizational arrangement best suited to overall water resources planning and development. Provision exists in North Dakota statutes for the organization and establishment of such districts. They provide the local people in a given area a legal base through which they can provide for water resource development and for the control of water resources in their area.

Water management districts have the power to investigate, to construct, or to arrange for the construction of water resources projects in their areas. These projects can be of many types and can serve many purposes. They can be facilities to provide conservation storage of water; to maintain water levels in lakes or to augment flows in streams; to regulate and control flood waters; to provide for removing surplus waters from agricultural lands, or they can be projects of a related nature that will provide benefits to the district through the conservation and regulation of the district's water resources.

Such districts also have the authority to enter into contracts with the United States, its agencies or with agencies of the State Government for the construction of projects that will benefit the district.

The procedure provided in State Law for the organization of water management districts is as follows: A petition is filed with the State Water Commission by the governing board of a municipality, county or other political subdivision or by 51 percent of the freeholders of the proposed district requesting that a water management district be established. The State Water Commission, upon receipt of this petition, determines whether or not it would be advisable to establish such a district, and, if it believes it would be advantageous to do so, calls a hearing (or hearings) on the petition. Following the hearing, if it appears that it is desirable to organize the district, the Commission issues its order declaring the district established. After the Commission's order is issued, the board of county commissioners of the county or counties in which the district is located is required to appoint a board of commissioners for the district.

The State Water Commission has cooperated extensively with many of the water management districts in planning, constructing and developing various types of water projects, administering the law under which the districts operate and advising them in matters dealing with their operation.

Solution — To facilitate and accelerate the orderly development of North Dakota's water resources, a continuing effort to organize water management districts over the entire State should be pursued. Local legal entities and State agencies are not as specialized in their water resource responsibilities as are the Federal agencies. As a consequence, coordination of their activities is not a significant problem. Any shortcomings in present coordination between the State and local levels can be resolved by conscientious efforts on the part of all concerned to adhere to the policy "That the well-being of all of the people of the state shall be the over-riding determinant in considering the best use, or combination of uses, of water and related land resources."

FEDERAL ASSURANCES REQUIREMENT ON PROJECTS WHOSE BENEFITS ACCRUE LARGELY TO DOWNSTREAM INTERESTS

Description of Problem — Federal law requires that the State of North Dakota and cooperating legal entities such as counties or water management districts provide certain assurances before Federal funds may be expended for construction purposes under provisions of the Flood Control Act of 1944, as amended. This assurances requirement places an unfair and inequitable economic burden upon the State of North Dakota and her citizens.

History of Problem — The Congress of the United States expressed its general policy on flood control in Section 3 of the Flood Control Act of 1936 (Public Law 738, 74th Congress), which contained the following requirements:

> "That hereafter no money appropriated under authority of this Act shall be expended on the construction of any project until States, political subdivisions thereof, or other responsible local agencies have given assurances satisfactory to the Secretary of War (Army) that they will (A) provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of the project, except as otherwise provided herein; (B) hold and save the United States

free from damages due to the construction works; (C) maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of War (Army)****."

Subsequent Flood Control Law enactments generally eliminated requirements for local cooperation for reservoir projects but retained requirements for local (A), (B), and (C) assurances for channel improvement and channel rectification projects.

The Missouri River Bank Stabilization Project below Garrison Dam in North Dakota was authorized as a flood control project by Public Law 88-253, approved December 30, 1963. This authorization required (A), (B), and (C) assurances by local interests as the project was one of channel improvement and rectification. Assurances by local interests for bank stabilization projects similar to that authorized between Oahe Reservoir and Garrison Dam in North Dakota are not required where commercial navigation is being practiced. To date, North Dakota is the only Missouri River Basin State required to provide such assurances.

The State Water Commission has argued consistently over the years that the invocation of assurance (C) — requiring local interests to maintain and operate all works on the Missouri River Bank Stabilization Project after their completion, in accordance with regulations prescribed by the Secretary of the Army — is inappropriate because derived benefits extend far beyond the limits of the local area in which the project is located and because the need for repairs is attributable directly to erratic summer and winter releases made from Garrison Dam as it functions as an integral element of the Federal Government's mainstem reservoir system.

Alternate Solutions — The solution to this problem is obvious. Federal legislative action is needed to amend the 1963 Flood Control Act authorizing additional appropriations for the completion of bank stabilization and rectification works, as needed, in the Missouri River between Garrison Dam and Oahe Reservoir, and to place the responsibility for their operation and maintenance in the hands of the Federal Government or its appropriate agencies.

On January 19, 1967, North Dakota Senators Young and Burdick jointly submitted Senate Bill 537 which, if approved, would authorize additional stabilization and rectification works as deemed necessary by the Chief of Engineers and would transfer to the Federal Government the responsibility for their maintenance. In the House of Representatives on January 23, 1967, Congressman Kleppe introduced House Resolution 3402, a companion Bill to Senate Bill 537. In both the Senate and the House of Representatives the Bills have been referred to the Committee on Public Works. No action was taken during the 1st Session of the 90th Congress.

POST-CONSTRUCTION OPERATION AND MAINTENANCE COSTS

Description of Problem — Federal and State agencies responsible for the operation and maintenance of a project after its completion are in some instances required to begin such operation and maintenance and to assume the costs thereof before the project has had sufficient time to prove itself structurally sound. In assuming the responsibility for operation and maintenance, an agency may find itself paying not only for legitimate, normal operation and maintenance costs but also those costs more correctly attributable to inadequate construction and/or inadequacies in design growing out of changing field conditions.

History of Problem — From an engineering standpoint, it is possible to design water resource projects in such a manner as to virtually preclude the responsibility of their failure at any time in the future except as a consequence of some natural disaster. To do so, however, it is necessary to include certain design features which, except in cases of actual natural disaster, are unnecessary and extremely costly. So costly would these structures be, in fact, that under current economic conditions, the construction of most projects would have to be declared economically infeasible. From an economic standpoint, it is unrealistic to design in a manner which protects a given structure from damage by forces whose frequency of occurrence is most accurately expressed not in terms of years or hundreds of years, but in thousands of years. Since the cost of providing structures designed to withstand any and all forces is prohibitive, it is the accepted engineering practice to design structures in such a manner as to protect against hazards which have occurred historically only once in every 100 or 50 or 25 years or less. Once the decision has been made as to the degree of flooding, for example, that a proposed flood control structure should protect against, the design develops accordingly. The proposed structure is neither under nor over designed. Rather, it is designed as precisely as technology permits on the basis of available data to meet the predetermined design standards.

The design of a water resource development structure is determined in part by the end result desired, in part by available data, and in part by the materials available for use in construction. The first year in the life of a dam is said to be the most critical. An unusually high flow may exert great pressure upon an earth embankment which has not had sufficient time to stabilize, thus weakening it structurally. Soils borrowed from a nearby area for use in the embankment may not maintain characteristics identical to those they possessed before being disturbed and transported. The heaving effect caused by alternating freezing and thawing may disturb the embankment or weaken joints in the spillway, training walls, etc. Another problem in design is related to the type of hydrographic data available for use. That which is available to design engineers is relatively new. This makes it necessary to take calculated risks — to interpolate our better records into assumptions — or to use runoff data based on topography and soil factors. Any one of the foregoing factors or a combination thereof or others could undermine the structural soundness of a dam. Experience has shown that any weakening of a structure resulting from either inadequate construction or inadequate design growing out of varying field conditions, is likely to manifest itself during the first three years of a project's life. With this in mind, local entities are not required to assume operation and maintenance responsibilities and costs for State Water Commission projects until three years after the completion of construction. The U. S. Bureau of Reclamation has adopted a similar policy. The Soil Conservation Service has also recently adopted a similar policy in regard to their watershed projects.

Alternative Solutions — Following the termination of construction activities by all Federal construction and before State agencies and local interests are required to assume any of the operation and maintenance costs growing out of that construction, a three year post-construction period should be provided by the constructing agency during which project works could demonstrate their structural adequacy.

THE STATE WATER COMMISSION AS THE FOCAL POINT OF ALL WATER RESOURCES DEVELOPMENT WITHIN THE STATE

Description of Problem — Federal agencies, other State agencies, local legal entities, organizations, associations, and individuals engaged in water resources development activities do not always honor the law making the State Water Commission the focal point of all such activities in North Dakota.

History of Problem Development — On different occasions, Federal, State and local agencies have planned and constructed — frequently in cooperation with each other — various types of water resources development structures in North Dakota without properly coordinating their activities with the Commission. Associations, organizations and individuals have, in a like manner, embarked upon worthwhile projects and have, in some instances without realizing it, placed in jeopardy significant investments in hard work, time and money. As the State's principal guardian of her waters, it is imperative that the Commission be cognizant of all proposed water resources development projects within the State regardless of their location or the identity of the constructing agency.

In its role as the principal overseer of water resources development programs within the State, the Commission has both the authority and the responsibility to coordinate and approve of all activities affecting the attainment of State-wide water resources development goals. The Commission cannot effectively discharge its responsibilities without the cooperation of all parties engaged in the many facets of development. Neither can it do so in the face of noncompliance with the law.

The uncoordinated efforts of numerous agencies and groups acting independently to solve local and regional water and water-related problems can prove to be detrimental to the welfare of the entire State in general and to groups and individuals in particular. To illustrate this point, a hypothetical case can be cited where a certain farmer went ahead with his plans to construct a combination fish and stock water dam on his property without proper regard for the availability of runoff or for his right to store that runoff.

It soon became apparent to the farmer that normal spring runoff would never fill his reservoir to a depth capable of supporting fish life. While it was true that the embankment, which he had hired an area contractor to build, impounded a considerable amount of water, it was equally true that at no place was the depth of that water greater than three and one-half feet. He realized, too late, that he had made a mistake, that he should have sought the advice of a professional engineer or a hydrologist, either of whom could have told him before he had spent many dollars and much time that he had overestimated the amount of runoff he could normally expect to collect in his reservoir, and that he had built a much larger embankment than necessary. Mr. Farmer could still claim some satisfaction from his venture. He had at least built a fine stock water pond; one which he could depend upon as a sure source of water for his cattle when the next dry spell occurred. Or so he thought!

Sometime later, when a downstream user's stock water dam failed to fill as usual, the farmer learned that he had committed yet another error. His neighbor complained to the authorities that the permit he held for waters drained by the stream crossing his land was being infringed upon by the builder of the new dam. Subsequent investigation of the complaint revealed that the farmer was clearly violating at least two State laws. In constructing a dam which stored in excess of 12½ acre-feet he had failed to comply with Section 61-02-20 of the North Dakota Century Code which states that "No dam capable of impounding more than twelve and one-half acre-feet of water, shall be constructed in this state, either in a watercourse or elsewhere, without the prior written approval of the commission. Before granting such approval, the commission may require the person or organization proposing to construct such dam to file plans and specifications satisfactory to its chief engineer. The commission may inspect such work during construction and may require any changes necessary to insure its safety and the safety of life and property."

Stated simply, Section 61-04-02 of the North Dakota Century Code requires that any department or agency of the federal government, or any person, association or corporation intending to acquire the right to the beneficial use of any waters must, regardless of intended use, make application to the state engineer for a permit whenever the structure to be built is capable of retaining more than twelve and one-half acre-feet of water.

Faced with the threat of a court case by his neighbor, the farmer reluctantly released the water he had temporarily stored in his new dam. Out of his pocket was the hard earned money he had needlessly paid to the bulldozer operator. But an even greater loss was that of his neighbor's friendship.

The foregoing is intended to illustrate the potentially disastrous results which could accrue from careless planning or noncompliance with the law. It illustrates less dramatically the impact which disconnected planning and construction activities can have upon the overall merit of a comprehensive State-wide water resources development program.

The State Water Commission has the responsibility and authority under the provisions of Section 61-02-27 of the North Dakota Century Code to require that "All persons, including corporations, voluntary organizations and associations when concerned with any agreement, contract, sale, or purchase, or the construction of any works or project which involves the use and disposition of any water or water rights under the jurisdiction of the commission, shall present to the commission all proposals with respect to the use or disposition of any such waters before making any agreement, contract, purchase, sale, or lease in respect thereof."

Section 61-03-21 of the North Dakota Century Code, which authorizes the State Engineer to require operators of water-storage reservoirs in North Dakota having a capacity of more than 1,000 acre-feet to file an annual operating plan, extends the Commission's authority and articulates the legislature's intention that the Commission be the central coordinating agency for all water resources development programs in the State.

It should be readily apparent to even the most disinterested and casual observer than an uncoordinated program for the development of North Dakota's water resources — the farmer and his dam being an example thereof — is not a satisfactory method of protecting, conserving and utilizing our most precious natural resource. Any such disjointed effort can hardly be expected to produce more than a similarly disjointed product.

Solution — Federal agencies and all individuals, including voluntary organizations and associations, should be apprized of their responsibilities, under the law, for coordinating their water-related planning and construction activities with the Commission. The State Water Commission shall continue making every effort to apprize others of its activities.

SEA LEVEL DATUM IN TOPOGRAPHIC MAPPING

Description of Problem — The variance in methods utilized by agencies of State government, by local political subdivisions and by private corporations or consulting firms in performing topographic mapping often results in the unnecessary duplication of survey activities.

History of Problem Development — Throughout the State of North Dakota, various State agencies, local political subdivisions, private corporations, and engineering firms are, for a variety of purposes, engaged in topographic mapping activities. Some of this topographic mapping is being performed on the basis of mean sea level datum. That is to say, land elevations are identified and recorded on the basis of their relationship to the mean level of the surface of the sea. Other topographic mapping is being performed on the basis of assumed datum only. This practice, as its name suggests, involves an assumption by the surveyor that a given point has a certain elevation, usually expressed as 100 feet. This latter method is adequate when those using the resulting maps are primarily concerned with a single project. In water resource development projects, where the relationship of many types of structures to one another is of the utmost importance, topographic mapping performed on the basis of assumed datum is inadequate.

Engineers responsible for the proper design of a proposed water storage structure must ascertain, before the commencement of construction, what effect the surface elevation of the proposed reservoir would have upon other developments in the area. They may learn from topographic maps which were prepared by others on the basis of assumed datum that the base of the structure located in the extreme upper-end of the proposed dam site has an assumed elevation of 125 feet. They may know this and may yet be unable to say with any degree of certainty how the proposed reservoir's surface elevation will affect that structure. They cannot relate mean sea level elevations to assumed elevations. They have little choice then but to initiate a new survey to determine at what mean sea level elevation the structure stands. This is unfortunate in view of the fact that such a resurvey would not be necessary had the State agency or other group responsible for the original survey performed its topographic mapping on the basis of mean sea level datum.

The need for a total conversion to the use of mean sea level datum by all government agencies and groups engaged in water resources development and planning is growing more and more apparent. Inherent in the concept of comprehensive water resources development and planning is the need to know the effects a development in one portion of a drainage basin will have upon another portion of that same basin or, for that matter, upon another basin. Securing the answers to this type of question is made difficult by the employment of two irreconcilable methods of performing topographic mapping.

Solution — There is a growing need for topographic mapping performed on the basis of mean sea level datum while at the same time, the usefulness of mapping performed on the basis of assumed datum only is becoming more and more suspect. The practice of using sea level datum in all topographic mapping should be adopted by anyone engaging in such activities. The State Water Commission continues to encourage and promote the use of sea level datum by all engineers whether they be State, Federal, County or representatives of engineering consulting firms. Once the practice of performing all topographic mapping on this basis has been established, much of the duplication which is now occurring will be curtailed. The ultimate result of such action will be not only a better overall plan for the development of our resources but a better plan at a significant savings in time and money.

MUNICIPAL WATER SUPPLY RESERVOIRS

Description of Problem — Deficiencies exist on a local basis throughout the State in the quantity and/or quality of ground water available for city water supply systems. Increasing urbanization is forcing some communities to convert partially or completely to surface water storage for a dependable water supply. Federal grants-in-aid programs for assistance in planning and constructing a growing number of these needed municipal water supply reservoirs are currently inadequate.

History of Problem Development — Federal grants-in-aid programs are available for use in connection with water-based game and fish projects, recreation and irrigation. The State Water Commission currently cooperates with various Federal agencies and local governments under several different grants-in-aid programs, believes them to be an excellent approach to the solution of a diversity of problems, and encourages their continuation as an effective method of solving problems whose funding requirements are often beyond the fiscal capacity of State and local governments.

Present opportunities for municipalities to participate in Federal cost sharing programs for the planning and construction of municipal water storage reservoirs are extremely limited.

A new Federal grants-in-aid program combined with the State grants presently being administered by the Water Commission would provide the additional assistance needed by a host of growing municipalities who are facing a critical need for more dependable water supplies — municipalities which, without significant assistance from both Federal and State programs, will be forced to content themselves with inadequate supplies or deteriorating quality or both. Impoundments constructed under the provisions of such grants could serve either as a direct source of supply or as the means by which aquifers, natural and artificial were recharged.

Solution — The solution to the problem of satisfying the growing need for construction of surface water storage reservoirs for municipal purposes hinges primarily upon the Federal government's initiation of a grants-in-aid program which will do for municipal water storage projects what has been done for game and fish projects, recreation and irrigation.

STATE-WIDE TOPOGRAPHIC MAPPING

Description of Problem — Topographic maps, prepared on the 7½ minute quadrangle basis, are useful in determining drainage area, in developing preliminary area capacity curves, in computing preliminary earth quantities, and in the selection of reservoir sites. Costly and time consuming field surveys are made necessary by the lack of adequate mapping of an area in which a proposed water resources project is to be located.

History of Problem — About 50 percent of the State of North Dakota had been mapped by the U. S. Geological Survey Topographic Branch at the end of 1967. Maps are published in various sizes. Over six hundred 7½ minute quadrangle sheets are available. Each sheet covers an area of approximately 49 square miles and is mapped at a scale of one inch equals 2,000 feet. Sixty-nine 15 minute quadrangle sheets at a scale of one inch equals two miles have been completed. Each of the 15 minute sheets shows an area of over 200 square miles, and the 30 minute sheets show an area of over 800 square miles. These maps accurately show elevation, slope, and other important features of the landscape in the area covered. They are utilized in planning dam sites, irrigation developments, ground-water surveys, outdoor recreation developments, road locations, utility locations and industrial development.

Alternative Solutions — Completion of a topographic mapping program for the entire State would greatly facilitate and expedite the planning and construction of potential or proposed water resources development projects in North Dakota. Steps should be taken to map the entire State using five foot contours on lands possessing elevation differences of less than 100 feet per square mile and on 10 foot intervals for areas having a greater change in elevation.

AGGRADATION

Description of Problem — The term "aggradation" is used to describe the gradual build-up of eroded material at the headwaters of a lake or reservoir. Aggradation carries the potential of being a most serious problem in portions of the State, particularly at the headwaters of Lake Sakakawea and the Oahe Reservoir. Evidence of the problem is asserting itself in the headwaters of Lake Sakakawea in the Williston area. Aggradation will occur in and above the Williston area at a more rapid rate than in the vicinity of Bismarck, because of the silt-laden waters of the Yellowstone River entering the Missouri River almost adjacent to the Buford-Trenton Irrigation Project immediately above Lake Sakakawea.

History of Problem Development — The aggradation now occurring below the confluence of the Missouri and the Yellowstone Rivers appears to be affecting the very existence of the Buford-Trenton Project. Project landowners are experiencing high water table conditions on this project. A considerable rise in the gauge reading at the Williston water intake has occurred. Since the pool elevation of Lake Sakakawea had attained or exceeded elevation 1840 MSL, signs of aggradation were apparent above the reservoir. The U. S. Geological Survey found it necessary to discontinue their gauging station at Williston in July, 1966 because of the backwater.

Aggradation often takes place when the rapid, silt-laden water of a stream comes in contact with the quiet waters of a reservoir. The water, when slowed by the current-free reservoir water, no longer has the ability to carry the silt and deposits it at the head of the reservoir. This process is repeated until a considerable backwater condition is created above the reservoir, causing a delta to be formed. The delta frequently becomes vegetated with willows and water-tolerant plant life. The water passing through the delta does so through numerous rivulets, as it no longer possesses a clear channel.

Solution —

Buford-Trenton Project: As aggradation becomes worse, possibly the only solution to avoid complete loss of the Buford-Trenton Project will be through the installation of batteries of pumps located on levees and put into use when the water table is high. As a further aid in alleviating this condition, irrigation pumps may be installed within the perimeter of the project, and ground water could be used to implement or replace, in part, the diverted water which is now pumped from the Missouri River.

Bismarck-Mandan Area: The aggradation problem in the Bismarck-Mandan area should be slow in developing, as the only sand and silt of significance will result from the bank erosion occurring below the Garrison Dam and resulting from its operation. The property loss resulting in the Bismarck-Mandan area could be exceedingly high if and when it takes place. The construction of bank rectification works along that reach of the Missouri River between Garrison Dam and the Oahe Reservoir could be most helpful in delaying the time of the detrimental effects of aggradation. This type of construction, if accomplished, would eliminate the bank erosion which now contributes most of the silt material being deposited in the Oahe Reservoir. It will also speed up the current of the river and cause it to carry the silt farther into the reservoir. It is possible, that as time progresses, batteries of pumps and protective levees may be required in many reaches of the river in the Bismarck-Mandan area adjacent to the reservoir. Here again, the pumps would be used in lowering the water table that will result from aggradation.

DISCLAIMING OF WATER RIGHTS BY THE U. S. CONGRESS

Description and History of Problem — The following Senate Concurrent Resolution, filed March 13, 1963, describes this problem, outlines the history of its development, and indicates the appropriate action needed for its resolution:

SENATE CONCURRENT RESOLUTION "C"
(Kee, Trenbeath, Morgan)
(From LRC Study)

DISCLAIMER OF WATER RIGHTS

A concurrent resolution requesting Congress to remove an apparent cloud upon and to disclaim any interest on the part of the United States to certain unused waters in North Dakota under a Declaration of Intent issued by the Secretary of Agriculture of the United States.

WHEREAS, the Honorable Henry A. Wallace, as Secretary of Agriculture of the United States, pursuant to section 8270 of the Compiled Laws of North Dakota for the year 1913 (repealed in 1943), notified the then state engineer of North Dakota by letter dated September 1, 1934, that the United States intended from an after that date to utilize certain specified unappropriated waters as of the date thereof, in the state of North Dakota, in said notice described as follows:

> "The Mouse River, also known as the Souris River, and all of its tributaries; the Des Lacs River, also known as the Des Lacs Lakes, and all of their tributaries; the James River, including its tributary the Pipestem River, and all tributaries of both such rivers in North Dakota; the Bois des (sic) Sioux River, the Sheyenne River, the Forest River, and all other tributaries of the Red River in North Dakota; all tributaries of the Missouri River in North Dakota;"

and

WHEREAS, in consequence thereof the then Bureau of Biological Survey, an agency in the Department of Agriculture, proceeded to and did acquire land in and adjacent to some of the waters named in said notice, and did establish, construct, and develop wildlife refuges and project works related thereto upon and in such lands and waters, and in connection therewith applied to the state for and was granted rights to appropriate and beneficially use specified quantities of water from several of the sources mentioned in said notice; and

WHEREAS, more than twenty years have elapsed since the expiration of the maximum period allowed under said section 8270 and other applicable state water laws within which project works commenced thereunder must be completed and the required notice of completion thereof should have been given the state engineer; and

WHEREAS, the hereinafter listed water rights granted the Bureau of Biological Survey or the Federal Fish and Wildlife Service for the appropriation and utilization of water in connection with such wildlife refuges and related project works, as shown by the records in the office of the state engineer, are the only water rights issued to and held by said agencies which are now in effect and recognized by the state as legal and valid; and

WHEREAS, the United States Department of Agriculture, the United States Department of the Interior, and the Federal Fish and Wildlife Service, after repeated requests by the state engineer therefore made, have failed, neglected, and refused to disclaim interest in or to, and thereby remove the seeming cloud upon, the unused waters of the lakes, rivers, and streams specified and described in the said notice of September 1, 1934, which have not attained the status of or ripened into legal and valid water rights for the appropriation and beneficial utilization of water in connection with the completed wildlife refuges and related project works hereinafter listed; and

WHEREAS, the insufficient rainfall and the growing dependence upon surface water for many beneficial purposes in connection with the State's dominant agricultural economy greatly emphasize the importance of erasing and removing the ostensible cloud upon the State's unappropriated public waters as a result of the said Declaration of Intent;

Now, Therefore, Be It Resolved by the Senate of the State of North Dakota, the House of Representatives Concurring Therein:

That the United States Congress be and it is hereby most respectfully petitioned and requested to remove the apparent cloud upon, by disclaiming any interest on the part of the United States in or to, the unused waters of the lakes, rivers and streams specified and described in the said Declaration of Intent, dated September 1, 1934, except as the same applies to the right to appropriate and beneficially utilize water, in approved quantities, for and in connection with the completed wildlife refuges and project works related thereto, for which specific water rights have been granted, are now in effect and are recognized as legal and valid by the state of North Dakota, and are identified and listed as follows, to wit:

TABLE 1. Water Appropriations in the Missouri River Basin.

File No.	Name of Refuge	Stream and Tributary to	County	Claim Date of
67	Appert Lake	Creek; Long Lake-Missouri	Emmons	8/30/37
1	Camp Lake	Strawberry Lake; Turtle-Missouri	McLean	8/30/37
73	Canfield Lake	Lake Canfield-Missouri	Burleigh	8/30/37
51	Chase Lake	Chase Lake; Missouri	Stutsman	5/25/38
75	Flickertail	Beaver Creek; Missouri	Emmons	8/30/37
4	Florence Lake	Florence Lake; Missouri	Burleigh	8/30/37
47	Lake George	Lake George; Missouri	Kidder	8/30/37
48	Halfway	Halfway Lake; Missouri	Stutsman	8/30/37
5	Hiddenwood	Hiddenwood Lake; Missouri	McLean-Ward	8/30/37
6	Hutchinson	Hutchinson Lake; Missouri	Kidder	8/30/37
19	Lake Ilo	Spring Creek; Knife-Missouri	Dunn	8/30/37
71	Long Lake	Long Lake Creek; Missouri	Burleigh-Kidder	2/17/37
72	Lost Lake	Painted Woods; Missouri	McLean	8/30/37
8	Lake Nettie	Turtle Lake; Turtle-Missouri	McLean	8/30/37
17	Pretty Rock	Creek; Cannonball-Missouri	Grant	8/30/37
11	McLean (Lake Susie)	Creek; Deep Water, Missouri	McLean	8/30/37
9	Shell Lake	Shell Creek; Missouri	Mountrail	8/30/37
74	Spring Water	Clear Creek; Beaver Creek-Missouri	Emmons	8/30/37
20	Stewart Lake	Deep Creek; Little Missouri-Missouri	Slope	8/30/37
10	Sunburst Lake	Creek; Missouri	Emmons	8/30/37
18	White Lake	Creek; Cannonball-Missouri	Slope	8/30/37
14	Lake Zahl	Little Muddy; Missouri	Williams	8/30/37

TABLE 2. Water Appropriations in the Mouse-Souris River Basin

File No.	Name of Refuge	Stream and Tributary to	County	Date of Claim
21	Cottonwood	Creek; Wintering-Souris	McHenry	8/30/37
28	Des Lacs	Souris; Red	Ward	8/28/37
22	Lords Lake	Lords Lake; Willow Creek-Souris	Bottineau-Rolette	8/30/37
29	Lower Souris	Souris; Red	Bottineau	8/28/37
24	Rabb Lake	Creek; Willow Creek-Souris	Rolette	8/30/37
25	School Section Lake	Creek; Willow Creek-Souris	Rolette	8/30/37
29	Upper Souris	Souris; Red	Ward-Renville	8/28/37
26	Willow Lake	Branch; Willow Creek-Souris	Rolette	8/30/37
27	Wintering Lake	Branch; Wintering-Souris	McHenry	8/30/37

TABLE 3. Water Appropriations in the Devils Lake Basin

File No.	Name of Refuge	Stream and Tributary to	County	Date of Claim
43	Brumba	Mauvais Coulee; Devils Lake	Towner	5/25/38
42	Lac Aux Mortes	Mauvais Coulee; Devils Lake	Ramsey-Towner	5/25/38
39	Rock Lake	Mauvais Coulee; Devils Lake	Towner	5/25/38
40	Silver Lake	Mauvais Coulee; Devils Lake	Benson	5/25/38
41	Snyder Lake	Mauvais Coulee; Devils Lake	Towner	5/25/38

TABLE 4. Water Appropriations in the James River Basin

File No.	Name of Refuge	Stream and Tributary to	County	Date of Claim
52	Arrowwood	James and Tributaries-James	Stutsman	8/28/37
54	Bone Hill	Bone Hill; James	LaMoure	8/30/37
53	Dakota Lake	James; James	Dickey	8/30/37
49	Maple River	Maple; James	Dickey	8/30/37
55	Ardoch Lake	Forest; Forest-Red	Walsh	8/30/37
60	Lamb's Lake	Creek; Goose-Red	Nelson	8/30/37
61	Little Goose	Little Goose; Goose Red	Grand Forks	8/30/37
62	Prairie Lake	Creek; Goose-Red	Nelson	8/30/37
30	Buffalo Lake	Creek; Sheyenne-Red	Pierce	8/30/37
31	Hobart Lake	Creek; Sheyenne-Red	Barnes	8/30/37
32	Johnson Lake	Creek; Sheyenne-Red	Eddy, Nelson, Foster	8/30/37
33	Pleasant Lake	Creek; Sheyenne-Red	Benson	8/30/37
34	Rose Lake	Creek; Stump Lake-Sheyenne-Red	Nelson	8/30/37
35	Sheyenne Lake	Sheyenne; Sheyenne-Red	Sheridan	8/30/37
50	Coal Mine Lake	Sheyenne; Sheyenne-Red	Sheridan	1/16/39
36	Sibley Lake	Creek Baldhead; Sheyenne-Red	Griggs	8/30/37
37	Stoney Slough	Stoney; Sheyenne-Red	Barnes	8/30/37
38	Tomahawk	Creek; Sheyenne-Red	Barnes	8/30/37
45	Wood Lake	Wood Lake; Sheyenne-Red	Benson	5/25/38
56	Billings Lake	Creek; Red	Cavalier	8/30/37
59	Kelly's Slough	Creek; Turtle-Red	Grand Forks	8/30/37
63	Storm Lake	Creek; Rice-Red	Sargent	8/30/37
58	Lake Elsie	Creek; Wild Rice-Red	Richland	8/30/37
57	Cloud Lake	Creek; Wild Rice-Red	Sargent	8/30/37
64	White Lake	Wild Rice Creek; Wild Rice-Red	Sargent	8/30/37
65	Wild Rice	Wild Rice; Wild Rice-Red	Sargent	8/30/37

Be It Further Resolved, that copies hereof be transmitted by the secretary of state to the members of the North Dakota delegation in Congress, who are hereby respectfully requested to take such action as may be deemed necessary or appropriate to give effect thereto; and

Be It Further Resolved, that the secretary of state transmit a copy hereof to the Secretary, and Assistant Secretary for Fish and Wildlife, of the United States Department of the Interior.

Filed March 13, 1963.

CONTROL OF INSECTS AND NOXIOUS WEEDS ADJACENT TO RECREATION LAKES

Description of Problem — Inadequate control of insects and noxious weeds in areas adjacent to recreation lakes tends to discourage their full utilization.

History of Problem Development — The presence of insects and noxious weeds adjacent to recreation lakes in North Dakota becomes a serious problem whenever the degree of infestation causes potential users to seek "more desirable" circumstances in which they can satisfy their needs for diversion and enjoyment in the out-of-doors. Unfortunately, examples of this problem can be cited for both natural and manmade recreation lakes in North Dakota.

The presence of weeds which are considered noxious because they are potentially injurious from a health standpoint or because they offend man's senses is not uncommon throughout the State. The incidence of such weeds is most pronounced, however, where natural vegetative cover has been agitated or removed. Noxious weeds are more apt to take root, for example, in a cultivated field than on the undisturbed prairie sod. Unless timely precautions are taken, noxious weeds often overrun canals, drainage ditches, roadway ditches, etc., before more desirable types of cover can take root. In constructing the embankment of a dam it is usually necessary to borrow materials from adjacent areas to provide for the embankment fill. When the borrow area is not resodded, noxious weeds flourish. Excavated areas of all kinds are subject to invasion by such weeds unless reseeding or resodding is accomplished soon after the excavation takes place.

Mosquitoes and other undesirable insects are sometimes found in abundance near and upon rivers, lakes and ponds. This is so in the case of mosquitoes, for example, because as a species, they utilize such watery areas for breeding and hatching purposes. The upper end of a reservoir often provides an almost ideal environment for mosquito reproduction. This is especially true when the upper end of a reservoir at normal pool level is characteristically shallow and marshy or when such conditions are created by periodic fluctuations in the surface level of the pool. When the surface of a reservoir rises above normal, water spreads out over areas which are usually quite level. In the process, surface soils become saturated, and quite frequently, small and shallow impoundments are created. The result is a potential mosquito producing area. Essentially the same problem is created when a reservoir drawdown occurs. Areas which are normally covered with depths of water not conductive to mosquito reproduction become swampy and potentially capable of producing mosquitoes in great numbers.

Solution — Besides a very real impediment to the full utilization of certain recreation lakes, noxious weeds and insects are undesirable from both a nuisance and health standpoint. Timely reseeding or resodding of excavated areas coupled with necessary chemical measures would go a long way in solving the noxious weed problem. Research indicates that prolific mosquito production is possible in extensive vegetated areas of a reservoir and in small coves and inlets which are flooded for periods long enough to permit development of the aquatic stages of the mosquitoes. Mosquito production in reservoirs is enhanced by either, or a combination of the following conditions: (a) rising water levels which result in intermittent flooding of the vegetated marginal areas for periods of a week or longer; and (b) pool levels which result in inundation of the vegetated marginal areas for periods of a week or more. It has been demonstrated on several occasions that **gradual** recession, or periodic fluctuation of the water level, alone, or in combination, minimizes mosquito production. It appears, therefore, that mosquito production in the reservoir can be greatly reduced during a major part of the season by water level management practices, where such management is possible. From the standpoint of mosquito control, it would be desirable to hold the reservoir level more or less constant near the upper limit of the normal pool level for as long as possible during early spring growth period in order to minimize the invasion of marginal vegetation. This would, at the same time, increase the effectiveness of subsequent recession and periodic fluctuation.

When unfavorable water level schedules occur for extended periods during the mosquito season, it may be necessary to utilize chemical measures in order to provide adequate control of mosquito production in certain areas of a reservoir.[1]

WETLANDS vs. AGRICULTURAL LAND USE

Description of Problem — In the Souris, Devils Lake and Red River Basins principally, numerous "potholes" or natural wetlands exist which are ideally suited for wildlife refuges and propagation.

[1] F. C. Harmston. *"Report of Mosquito Studies Lewis & Clark Reservoir, South Dakota — Nebraska."* U. S. Department of Health, Education & Welfare, 1962, pp. 16-17.

When insufficient precipitation leaves the land dry they are suitable for farming, as they are when properly drained. Some groups, public and private, feel these lands should be preserved for wildlife and others feel they should be developed for agricultural use. There are still others who feel that developments should be planned for total water management to render the lands useful for both wildlife and agricultural purposes.

History of Problem — Conflicts for managing lands topographically suited for both uses expand and contract with precipitation and governmental agency policy and finance modifications.

Principally involved are the landowners, hunters, wildlife federation, local water management districts, State Game and Fish Department, State Water Commission, U. S. Fish and Wildlife Service, Soil Conservation Service and Corps of Engineers. All have varying and divergent responsibilities, views and capabilities which require consideration.

Alternative Solutions —

A. An out-of-state consultant, Stanford Research Institute, conducted an extensive study and concluded that landowners were paying more than their fair share of costs to preserve wildlife; however, they reported that the general public alone could decide what economic value should be placed on wildlife and wildlife habitat.

   In employing the consultant, the objectives were to develop decision criteria, present an analytical approach to the problem, and develop a criteria applying plan. A financial analysis was to determine if drainage and development of the land for agriculture was economically feasible and if the monetary benefits from agriculture were greater than those from wildlife protection.

   These questions were not entirely answered in the Stanford Research Institute report of December, 1967.

B. The current procedure for Soil Conservation Service technical assistance should be modified so completed project plans rather than mitigation conditions may be presented to the project sponsor and affected landowners. It must be acknowledged here that while the Soil Conservation Service is sympathetic to this alternative, it is at the same time apprehensive over the cost of investigations. As a consequence, the Service feels it must continue to wait until the sponsors and affected landowners agree to the mitigation and preservation requirements before committing its funds.

C. A water management plan for individual watersheds should be provided to:

   Protect landowners from random sheet-water flooding;

   Stabilize water levels for existing wetland areas;

   Provide water for other uses, such as municipal, industrial, recreation and quality control; and

   Protect adjacent lands from flooding which might occur due to improvements for these purposes.

D. Wildlife beneficiaries would receive more dividends if investments were made in a total water management plan as envisioned in C above rather than attempting to preserve the status quo on existing wetland areas.

PRECIPITATION RUNOFF RIGHT-OF-WAY AND NATURAL CHANNELS

Description of Problem — The topography east and north of the Missouri Plateau region along with extensive urban, rural and transportation improvements preclude "natural channels" functioning as water courses prior to the extensive improvements.

Excess runoff, accelerated in many instances by man-made channels, causes destruction to lands and their inherent natural and developed works.

History of Problem — As man-made improvements continue to be made for various purposes in an affluent economic climate, changes inherently occur which affect the natural environment.

Such improvements have been made at an accelerating pace with the shift of population from rural to urban along with the compounded increase in living standards.

Alternative Solutions —

A. Determine the land area from which excess runoff accumulates and provide stable channels consistently designed to provide flood protection as needed to counteract changes in the natural drainage.

B. The total drainage area benefited by an improvement should assist in providing cost participation in the lands, channel, and related appurtenances required for the removal and control of excess runoff.

C. Sufficient right-of-way should be acquired by purchase or through easements to provide adequate area for future operation and maintenance of the channel improvements.

D. Grassed waterways.

FISCAL PROCEDURES AND LIMITATIONS

Description of Problem — State budgetary policy presently requires that budgets be submitted and appropriations allocated to State departments on the basis of "object" items; i.e., salaries, fees and services, supplies and materials, equipment, and contract work. The appropriations are also limited to two fiscal years, precluding any carry-over of funds into an ensuing biennial period.

These constraints are a problem to agencies which are project or program oriented due to their legislated duties and responsibilities requiring construction and investigational type activities.

Another problem in this regard is the requirement, in some instances, where project participation collections must be placed in the State general fund rather than to the credit of the fund from which the project costs were paid.

In addition, some projects require large sums of money which, if appropriated during a single biennial period, would cause a hardship on the State general fund.

History of Problem — From 1955 to 1965, the Legislature provided the State Water Commission with a "Multiple Purpose Fund" which could be utilized as an operating fund and the balance did not revert at the end of each biennium.

Project participation payments were credited directly to the fund and were used to pay the project costs from a central point — the Commission's.

Alternative Solutions —

A. Budgets could be submitted and appropriations allocated on a twofold basis — one for the strictly administrative functions and another for the project and program functions. The administrative budget could be on the basis of "object" items and the projects and programs budget could be on the basis of broad categories such as (for the State Water Commission) Comprehensive Planning; Engineering Investigations, Design and Research; Construction; and Operation and Maintenance.

B. A carry-over of funds for projects and programs should be allowed since such activities are subject to the vagaries of weather and numerous other unforeseen happenings which preclude their completion in a specific fiscal period from the start of planning.

C. Project participation payments should be credited to the fund from which the project costs are paid for more efficient operation.

D. Since relatively large capital expenditures are required for water resource developments projects, a procedure should be established for the accumulation of funds each biennium to create a reserve for major capital improvements. Such a proposal was submitted in HB724, 40th Legislative Assembly, but was not enacted into law.

IDENTIFICATION AND PRESERVATION OF RESERVOIR SITES

Description of Problem — Topography severely limits the number of natural reservoir sites available for development in the State of North Dakota. The future of the State's water resources development program hinges to a significant degree upon the availability of such sites. Incomplete knowledge of the location and characteristics of remaining potential reservoir sites acts as an impediment to the optimum development of the State's water resources.

History of Problem — Topography was an admitted limiting effect upon the number of potential dam and reservoir sites available for development in the State of North Dakota. But topographical limitations alone do not constitute the single factor limiting the number of such sites. In some instances, where topography is favorable, other limiting factors may be present. Foundation soils may be poor, drainage area and runoff may be inadequate, or borrow materials for use in building an earth embankment may be of unacceptable quality. Any number of limiting factors may be present to reduce the desirability of a particular site.

Inefficient utilization of present dam sites is another limiting factor. Small dams have been constructed to satisfy a known immediate need where maximum utilization of the site called for a much larger structure. In North Dakota today there are cities, industrial complexes, commercial developments, etc. occupying excellent dam and reservoir sites. While such sites are lost as far as water resources development is concerned, their presence can serve as a warning to development interests that now is the proper time to look toward the identification and preservation of remaining dam and reservoir sites.

Alternative Solutions — Sites should be catalogued and measures taken to discourage all development except agricultural within areas deemed suitable for reservoirs. The selection process should be based upon the use of 7½ minute topographic maps as prepared by the U. S. Geological Survey coupled with the necessary field surveys. Sites thus selected should be studied further for refinement of topographic data followed by the necessary foundation boring studies. Consideration should also be given to the purchase of lands destined eventually for inundation by reservoirs.

Land values are constantly increasing. Sites should be purchased now and be made available to the landowner or others on a rental basis until such time as the land is occupied by a reservoir.

ORGANIZATION OF HYDROLOGIC UNITS

Description of Problem — The inability of water management districts organized on a county-wide or partial county basis to adequately deal with water management and development problems which are local in nature, but whose effects extend far beyond county boundaries to other portions of a hydrologic unit.

History of Problem — Water management districts in North Dakota are organized principally along county or political boundaries rather than hydrologic boundaries. North Dakota presently has 43 organized water management districts within the State; 29 of these are organized on a county basis and 14 on a partial county basis. Under this arrangement many problems have arisen between water users living in different counties within the same hydrologic basin.

Water developments planned by water management districts to alleviate problems such as flooding and drainage are normally designed to solve problems which are local in nature and which occur within the boundaries of the district. Since the district's jurisdiction stops at the county or district boundary line, it is generally able to consider only a small portion of the entire problem area. Hence, developments planned in one water management district may result, for example, in increased flood damages or decreased water supplies to downstream users in neighboring counties. This often results in significant opposition from water users to the formation of water management districts and to any planning which they may attempt.

Alternative Solutions — The following are possible solutions to this problem:

1. Water management districts should be organized to encompass the entire State's area. Funds needed to finance water management districts based on hydrologic boundaries could be gained through the water management district special assessment feature and ad valorem levies or a combination of both taxing measures.
2. The formation of "hydrologic basin committees" composed of one or more members from each of the water management districts having a land area within a given hydrologic unit. The function of this committee would be to coordinate the activities of the various districts which are directed to the solving of problems basin-wide in scope.

IRRIGATION STANDARDS

Description of Problem — Present irrigation standards for both land and water as employed by certain Federal agencies in determining the feasibility of proposed projects are highly restrictive and tend to impede the development of private irrigation in North Dakota.

History of Problem — Irrigation in North Dakota has two dimensions, the private and semiprivate. In private development individual farmers develop their own water supply and distribution works, using as a source of supply, ground-water aquifers, rivers and reservoirs. Semiprivate development consists of private citizens organizing and contracting with the Federal Government for the construction of a diversion project such as the proposed diversion of waters from the Garrison Dam reservoir.

Private irrigation development in North Dakota is restricted due to irrigation standards for land and water developed by the Soil Conservation Service. Experience on the Columbia Basin Project has proved that it is possible and economically feasible to irrigate lands of much poorer soil quality and considerably steeper slope than the Service will consider irrigating in North Dakota. These standards will not have any effect on lands included in the Garrison Diversion Project; however, they do inhibit many farmers from irrigating lands of their own through private development. Production on much of this land could be increased considerably if irrigation were developed on a more realistic basis.

Increased development of private irrigation in North Dakota would result not only in greater economic benefits for the farmer, but also for the community where the farmer spends his money and for the State as a whole. Research indicates that each additional dollar the farmer earns generates from $2 to $6 in the community.

Solution — Various studies need to be initiated by the State Water Commission to review present irrigation standards for land and water in order to determine if these standards need to be revised and/or updated.

1. Investigation into the use of saline water for irrigation.
2. Research in the use of poor quality water in order to establish criteria for its use for irrigation and to determine or develop crops which are more tolerant of low quality water.
3. Field studies in areas where marginal or submarginal water is being used for irrigation in order to determine the effect of these waters on plant growth and land quality compared to that of better quality water.
4. State-wide studies to obtain detailed information in regard to soil topography, soil type, soil texture, soil depths, slope, drainage and water table. This information is vital to determine whether irrigation will be profitable, how the crops will respond when water is actually delivered and how the land should be prepared for irrigation.

FEDERAL ACREAGE LIMITATIONS

Description of Problem — The restriction of 160 irrigated acres per landowner in a Federal irrigation project retards the efficient utilization of modern equipment and diminishes the landowner's ability to operate competitively with other types of farming.

History of Problem — During the past 60 years the development of improved farming equipment and techniques has completely revolutionized the field of agriculture. Increased operating costs are forcing farmers to make the most of every dollar spent in the farm operation. Labor shortages necessitate the utilization of expensive machinery which is only economical and practical when the costs can be spread over large acreages.

In view of these increased operating costs the 66 year old 1902 Reclamation Law which established the 160 acre limitation concept on all Federal irrigation projects is unrealistic because the farmer cannot make efficient use of his equipment. This is particularly true in North Dakota where alfalfa, small grains, potatoes, and sugar beets are the major irrigated crops — crops whose production require specialized and expensive equipment. Under these conditions it is imperative that farmers be permitted to irrigate increased acreages to enable them to remain competitive with other types of farming.

Alternative Solutions — The following are possible solutions to this problem:

1. In light of increasing technology Federal reclamation laws should be modified to at least permit the irrigation of 640 acres of land by an individual owner on Federal irrigation projects.
2. Federal acreage limitations established by the United States Bureau of Reclamation should be reviewed and reappraised in light of differences in soils, climate and types of farming and crop production existing throughout the 17 reclamation states. The so-called Engle Formula may offer a solution to this long-time inequity.

FLOOD PLAIN ZONING

Description of Problem — The need for increased flood plain zoning to provide increased protection from flood damages for suburban areas and a number of cities in North Dakota.

History of Problem — Floods have been a natural and normal phenomena in North Dakota since settlement. This is particularly true in the Red River Basin. Major floods in 1948, 1950, 1952, 1965, and 1966 emphasize the need for increased flood control measures. A near record flood in 1966 resulted in approximately $14,700,000 damage in the Red River Basin.[2]

Flooding becomes a problem only when a man competes with rivers for the use of the flood plains. Flood plains are high water channels of rivers. The use of flood plains in North Dakota is both convenient and economically profitable. Primary uses of flood plains in our State are for agriculture and expanding urban development. The increased use of flood plains for these purposes, particularly urban development, has resulted in increased flood damages in spite of the State and Federal flood control projects which have been developed in our State. To discontinue the use of flood plains for these purposes is economically unfeasible, but the type and extent of use should be consistent with the risk involved and the degree of protection that is practical to provide.[3]

During the past few years North Dakota has given much consideration to flood plain zoning as a means of lessening flood losses and reducing the increased need for flood control. At the present time, however, none of North Dakota's cities have completed flood plain zoning. The Oak Park area in northwest Minot is one example of an urban area which is certain to incur large flood damages unless further encroachments onto the flood plains are prohibited.

Flood plain zoning is a legal tool that is used to control and direct the use and development of land and property within the flood plains of a river or stream.[4] This reduces flood damages by requiring that the flood plain be used for purposes not subject to flood damage, and by providing for an unobstructed floodway.

The development of reasonable and nonarbitrary flood plain zoning ordinances for a particular river or stream require a careful determination of the flood hazards along the river or stream. These ordinances must be based on sound and complete engineering data. In order to be reasonable the area, extent and elevation determinations of the land placed in the flood plain zone should be based on: historical evidence of flooding, frequency of floods, an engineering study of flood potential, an analysis of the degree of flood protection provided by other methods of regulation, the degree of flood protection offered by engineering structures and whether or not development in the immediate future will increase or decrease runoff. Land uses permitted on land which is subject to flooding should also take into consideration the anticipated growth of an area as well as the availability of nonflood lands to meet the needs of the community.[5]

Flood plain zoning insures the safekeeping of property for the public health and welfare and the best use of available land. The division of communities into various zones should be the result of a comprehensive planning program for an entire area. Pressures from housing developers frequently result in the development of areas which should have been zoned for other uses.

Solution — Flood plain studies need to be initiated in each of the five major river basins in North Dakota to delineate or recommend zones along the

[2]*Plan of Study*, Souris-Red-Rainy River Basins Commission, Moorhead, Minnesota, 1967, p. 10.

[3]Conrad D. Bue. "Flood Information for Flood Plain Zoning," *Geological Survey Circular 539*, U. S. Department of the Interior, 1967, p. 1.

[4]*1967 Guidelines for Reducing Flood Damages*, U. S. Corps of Engineers Bulletin, 1967, p. 3.

[5]Bue, p. 3.

State's streams and rivers to which specific regulations need to be applied. In addition legislation needs to be enacted requiring appropriate local government entities to formulate, adopt and enforce suitable floodplain management programs for each flood-prone urban area.

AQUIFER USE RULES AND REGULATIONS

Description of Problem — The increasing demands being placed upon ground-water aquifers — demands brought about by growing urbanization, increasing irrigation of farmlands, and increasing livestock consumption — emphasize the importance of carefully controlling and managing North Dakota's ground-water resources. A set of rules and regulations is needed to insure that these ground-water reserves are properly managed and to prevent their overdraft and subsequent pollution from intrusion by water of inferior quality.

History of Problem — North Dakota's ground-water resources are scattered throughout the State in aquifers of varying sizes. Aquifers are water saturated geologic formations sufficiently permeable to yield water to wells and springs. Water within these aquifers may move from one area to another within the aquifer as well as from one aquifer to another. In general, ground water moves from points of high elevation to points of low elevation — that is, from areas of recharge to areas of discharge.

The texture and sorting of the rock components control to a large degree the two major water-bearing properties of an aquifer—its porosity and permeability. Porosity of a rock is determined by the size and number of voids, or interstices, as compared to the total rock volume and is expressed as a percentage. Generally a porosity of more than 20 percent is considered to be high, and a porosity less than five percent low. The permeability of an aquifer is its capacity to transmit water. A permeable rock is also porous, but high porosity does not necessarily indicate high permeability.

Wise management of ground-water resources requires that yearly extractions from an aquifer do not exceed the so-called "safe annual yield" of that aquifer The safe yield of an aquifer is the quantity of water that can be extracted annually year after year without significantly impairing the continued usefulness of the water supply. But in proceeding from this broad generalization to a specific determination of safe yield for a given aquifer, difficult complications ensue. This is because such determination may depend upon many assumed criteria — hydrologic, water quality, type of diversion and its location, uses of the water, land subsidence,[6] and other physical and economic factors. Water pumped from an aquifer in excess of the safe annual yield is referred to as an "overdraft."

[6]Sinking of the land surface caused by withdrawals from aquifers.

Overdraft is not bad per se. In some areas unrestricted pumping has played an important part in the planned utilization of ground-water reserves. However, protracted overdraft conditions in many areas have had adverse effects. These include continued depletion of the aquifer, with increasing pumping costs and threatened destruction of the water supply; contamination of the water; salt water intrusion; and land sudsidence.

In view of changing physical and economic conditions, a determination of safe yield and of resulting overdraft, if any, must depend on conditions that exist or that are forecast at a specific time. Safe yield or overdraft determined on the basis of data available at one time may require substantial revision in the light of subsequent data and analysis.

Aquifer management is especially needed where a quality water aquifer lies above or below one possessing water of inferior quality. There is some indication in North Dakota that intrusions from inferior quality water aquifers are occurring when the quality water aquifers are being depleted at rates in excess of the safe annual yield.

Many of the buried glacial drift aquifers in the State may not support future water demands, resulting in overdrafts of these aquifers. Artificial recharge may be required in order to maintain a dependable water supply. Methods and techniques for the artificial recharge of buried glacial drift aquifers have not been developed.

Solution — The passage of legislation by the State Legislature or the adoption of administrative rules and regulations by the State Water Commission for proper management of aquifers and to prevent their overdraft. Other measures, as indicated below, should be initiated and/or continued as a means of providing additional technical and management knowledge. As new technical knowledge is acquired and as management practices become more sophisticated, the proposed Aquifer Use Rules and Regulations should be updated.

1. Carry on basic research for developing methods and techniques for artificially recharging buried glacial drift aquifers. This research should include a study of the most adaptable type of intake for removing silt and algae from streams and impoundments.
2. Continue the present cooperative ground-water investigation program on a county basis in order to identify aquifers with regard to location, water quality, and estimates as to potential yields to individual wells.
3. Continue to expand the water level monitoring program through the use of observation wells. Monitor the development of ground-water reservoirs and maintain records of well yields and withdrawals from various aquifers.

4. Construct analog models of aquifers in which problems occur to control and prevent aquifer overdrafts.

INDUSTRIAL WATER SUPPLY AND DEVELOPMENT

Description of Problem — The exact nature and extent of North Dakota's capacity to provide water, from both surface and ground-water sources, for potential industrial development is unknown.

History of Problem — It is an undeniable fact that our Nation's appetite for water is ever-increasing. Demands by municipalities, industry, recreation, agriculture, and other uses are mounting. North Dakota is beginning to feel the pressures of these demands. The State Water Commission, as the focal point of all types of water resource development activities within the State, is constantly working to meet these increasing demands for more and better water. If past developments are any indication of what the future holds, an increasing amount of water will be required to meet the needs of our principal industry — agriculture. And if our basic industry — now and in the future — is to remain on a competitive basis with the agriculture of other areas, we must make every possible effort to market finished products instead of the bulky, raw products we market today.

Momentum in the processing of our raw agricultural produce is growing. A sugar beet factory has been constructed in Drayton. Another will soon be built near Fargo, and yet another is in the "talking" stage for the Wahpeton-Breckenridge area. Near Mapleton, in Cass County, a corn sugar plant has commenced its operations. North Dakota can now boast of several potato flaking plants and a starch factory. Water, in considerable quantities, is a requirement for the operation of these industries.

Industries interested in these kinds of developments generally find their way to the office of the State Water Commission, asking for an evaluation of the current and potential water supply in respect to industrial plant requirements. The quantity and quality of water are appraised for both surface and ground-water sources. Too frequently, the ground-water potential has not yet been studied sufficiently to render a qualified answer. Industries dare not proceed when the dependability of their water supply is uncertain. A number of counties having some of the finest ground-water potential have not yet seen fit to initiate such studies. As a consequence, no satisfactory recommendation can be made to an inquiring industry, and the county has lost a fine opportunity to attract a desirable economic asset.

Questions regarding surface water supplies can be answered with comparative ease: Outside of the Missouri River, dams and impoundments are usually required to create a water supply. This was the case in Drayton where the State Water Commission constructed a $170,000 dam on the Red River in cooperation with the Pembina County Water Management District and the City of Drayton for the impounding of water for a sugar beet plant. The Commission, cooperating with Cass County or some other local legal entity, will construct a dam on the Sheyenne River for use in connection with the Holly Sugar Plant. A surface water structure may be needed on the Maple River for the Mapleton Corn Sugar Plant.

North Dakota continues to assert itself in the field of power generation. A power cooperative recently completed the construction of a dam in Oliver County for use as a cooling reservoir for a thermal generating plant. Two large generating plants are already located on the Missouri River in the Oliver-Mercer County area where the river provides a most reliable water supply. An investor-owned company has indicated a desire to locate in the Mercer County coal field if an impoundment of sufficient size can be established and maintained. It is apparent that the development of low-cost thermally generated power is having a most favorable effect upon our economy. But water is needed to further stimulate that economy.

Interest is now being manifested in North Dakota's barley potential for use in the barley malting industry. Recently our State Economic Development Commission requested information relative to areas where known quantities of ground water were available. Direct economic benefits, should such development actually occur, will not be known until the results of a study, currently underway at North Dakota State University, are published. Selection of potential sites will be made on the basis of the resources an area can offer toward plant requirements. In addition to new employment opportunities stemming from the installation of a malting barley plant — 46 persons per plant — the presence of these plants would tend to increase income levels for the community in which they are located and would, at the same time, generate needed secondary business activity in areas of declining population throughout the State. Besides payroll benefits, the potential malt plants would generate operating expenditures for electricity, fuel, taxes and transportation — all of which will increase income and employment levels in the local economy.

Solution — Since adequate local water supplies are prerequisite to industrial development, forward-looking communities should take whatever steps are necessary to have their water resources surveyed and studied. Comprehensive State water resources planning efforts should be focused upon the anticipated requirements for heavy water using industries and should encourage and assist responsible, fiscally capable entities in developing these anticipated water requirements.

"FOREVER" TYPE WATER PERMITS

Description of Problem — The present method of issuing water rights on a "forever" basis tends to impede the full development of ground-water resources in North Dakota.

History of Problem — Ground-water resources in North Dakota are scattered throughout the State in aquifers of various sizes. Aquifers are water saturated geologic formations of sufficient permeability to yield water to wells and springs. Water from within these aquifers is used for many purposes including municipal and rural domestic, livestock, irrigation and some industrial use.

Information pertaining to the annual yield capabilities of these aquifers is limited and water rights allowing withdrawals of ground water from various areas within the same aquifer may not be realistic at this time. After two or three years of yearly withdrawals, it may be revealed that some of these water rights may not be completely satisfied due to an overdraft from the aquifer in that area.

Further studies of specific aquifers in North Dakota may prove that it is necessary to do away with certain wells in order to space the existing wells for maximum development. Allocated water being supplied by those wells which are taken out of operation may then be supplied by pumping the water from a better positioned well resulting in more efficient and extensive use of our existing ground-water supplies.

Aquifers are reservoirs that receive recharge water and discharge excess water. Levels in these aquifers should be lowered enough to allow the highest possible recharge while permitting only minimal natural discharge. Recharge water for ground-water reservoirs is supplied primarily by precipitation and downward seepage from surface waters. Natural discharge from a ground-water aquifer occurs in the form of transpiration and/or seepage to surface waters. Such surface waters are, unlike ground water, subject to evaporation losses. Each year approximately three feet of water per surface acre are lost due to evaporation from free water surfaces. Reducing the natural discharge of ground-water aquifers by lowering the water table to a point where natural discharge and evaporation are minimal would result in an increased amount of ground water available to supply the needs of ground-water users.

Solution — The present method of issuing water rights on a "forever" basis needs to be reviewed and modified in order to bring about the full development of ground-water resources in North Dakota. In some areas, it may become desirable for landowners to cooperate in establishing a rotation system of pumping if the pumping of one landowner is adversely affecting the withdrawal being made by others. Irrigation districts, in establishing pumping criteria, may contribute to this solution.

SEDIMENTATION

Description of Problem — The continued deposition of sedimentary materials such as soil and other debris in North Dakota's lakes, streams, rivers and reservoirs contributes to downstream flood and drainage problems, increases pollution, and reduces the storage capacity of reservoirs.

History of Problem — Sedimentation resulting from wind and water has become a major problem in all hydrologic basins in North Dakota. Known problem areas include the Missouri River below Garrison Dam to the Oahe Reservoir, Missouri River at the Buford-Trenton Irrigation Project, Yellowstone River at the Yellowstone Pumping Irrigation Project, Souris River at Minot and Towner, Sheyenne River below Baldhill Reservoir, Wild Rice River, Park River, and Devils Lake Basin. Problems in these areas, as well as in other areas throughout the State, are particularly difficult since the streams intersect numerous political subdivisions and jurisdictions. Consequently, the problems have far-reaching effects.

Specific problems resulting from sedimentation in North Dakota include the following:[7]

1. Damage to the land from deposition of harmful material.
2. Damage to bottomlands by swamping or the impairment of surface or internal drainage.
3. Loss of storage in reservoirs.
4. Excessive water purification costs incidental to removing sediment from urban and industrial water supplies.
5. Silting of drainage ditches resulting in their inability to move water and excessive maintenance costs.
6. Maintenance of roads and highways necessitated by the silting of road ditches and blocking of culvert heads, causing overflow.
7. Deposition of sediment on crops.
8. Silting or irrigation canals and pumping areas.
9. Aggradation of stream channels.
10. Silting associated with flood damage to homes, industrial, and other properties. Silting also damages fish habitat in streams.

As a result of these problems, sedimentation must be given serious consideration in the planning, development, and use of the State's water resources. Failure to do this, may result in the State's water resource projects losing their usefulness.

Sedimentation consists of three basic processes: erosion, transportation, and deposition. Each of these processes is of major importance in the control, use and maintenance of our State's water resources.

[7]L. C. Gottschalk and Victor H. Jones, Valleys and Hills, Erosion and Sedimentation", *Water, The Yearbook of Agriculture, 1955*, Page 137.

Erosion is a natural process which has been changing the features of our landscape throughout geological history by wearing down our uplands and building up our lowlands. Water, ice, wind and gravity are the major forces of nature which contribute to erosion and the formation of sediment.

A drainage basin consists of two distinct erosion zones. These zones are (1) a zone of concentrated flow consisting of actual drainage channels, streams, and flood plains, in which stream erosion is the prime factor, and (2) a zone of unconcentrated flow, constituting the remainder of the drainage basin, in which rain wash and sheet erosion are the prime factors.[8] The rate of sheet erosion depends largely on the inherent erodibility of the soil, length and degree of slope, land use, and amount of runoff from all forms of precipitation. Channel or stream bed erosion depends to a large extent on stream-bed velocity and channel irregularities in addition to those factors mentioned for sheet ersosion.

The percentage of sheet or channel erosion of the total erosion in a watershed varies from place to place depending on local conditions. The bulk of sediment in humid agricultural areas is derived from sheet erosion, while in arid or semiarid areas, it comes largely from channel bank erosion or degradation of the bed of the channel. Both types of erosion are common to North Dakota with sheet erosion being more prevalent in the eastern half of the State.

The transportation of sediment produced by erosion occurs in two ways. As suspended load, it is distributed uniformly throughout the cross section of a stream's flow. As bed load, it slides, rolls, and and bounces along the stream bed.

In that portion of North Dakota where sheet erosion provides the main source of sediment, the sediment is fine in texture and is carried along as suspended load. This sediment is referred to as the wash load of a stream. Where channel erosion is the major source of sediment, the sediment is mostly coarser grained material and is transported mainly as bed load.

The wash load of a stream is related directly to the supply of sediment rather than the stream flow and its ability to transport this sediment. But the amount of bed load moving through a stream is directly related to the stream's rate of flow.

Wash load is very rarely present in quantities equal to the capacity of the stream's flow and travels with the same velocity as the flow. As a result, wash load is seldom deposited in a stream channel and has little effect on channel stability. The movement of bed load on the other hand is always in balance with flow conditions and plays a major part in channel stability. If the bed load becomes too great for the stream's flow, deposition occurs and if the load is less than the stream's flow can carry, the stream immediately begins eroding the channel walls and bottom in an attempt to achieve this balance.

Any conditions that change the sediment load or flow characteristics will have a corresponding effect on channel stability. The building of water resources development projects such as reservoirs or other control works often affect channel stability when these projects desilt the flow or change the flow characteristics by altering the discharge, the stream gradient, cross section of flow, or depth of flow.

Transportation of sediment from place to place results in this sediment being deposited somewhere. Deposition of this sediment is the counterpart of erosion. This occurs whenever the carrying capacity of the flow is reduced to the point where transport of the sediment is no longer possible.

As stream flow diminishes, the coarser sediments are deposited first followed by the more finely grained sediments. Thus, deposition, like erosion, is a selective process, which results in a gradation of deposits. Among the primary types of sediment deposits found in North Dakota's watersheds are colluvial deposits, alluvial fans, channel deposits, flood plain deposits, and lake and reservoir deposits.

Colluvial deposits usually form below sloping lands that have been cultivated without conservation controls. Deposits of this type are usually long, narrow, and sinuous, and originate primarily from sheet erosion. Damages associated with colluvial deposits are due primarily to changes in soil texture and fertility that affect productivity.

Alluvial fan deposits are usually formed below tributary streams of main valleys, where sudden changes occur in the stream transport capacity. The sedimentary materials making up these deposits generally originate from the stream channels. Damages resulting from alluvial fan deposits include: rapidity of deposition, which buries crops; coarse sediment, which lowers soil fertility in the areas of deposition; and topographic changes upon the alluvial plain.

The channels of the various river systems in North Dakota fall into two basic categories, degradational and aggradational. In the channels where degrading is predominant, the deposition of sediment is usually not a serious problem, except in local instances, because the streams have not developed alluvial flood plains. The majority of North Dakota's streams and rivers, however, have developed alluvial valleys and are either in a relatively stable condition or are actively building flood plains. Overloading streams with sedimentary debris, changes in runoff, and stream meandering are the main causes of deposition in stream channels of this type. Deposition of sediment in these stream channels is most conspicuous in the headwater areas. As a result, the consequent decline of channel capacity and increasing channel elevation has resulted in a

[8] J. W. Johnson, "The Transportation of Sediment by Flowing Water", United States Department of Agriculture, April 1940, Page 1-2.

number of types of damage including an increase in flood heights, elevation of ground-water level and a consequent spread of swampy areas, blocking of drainage outlets, impairment of flow in irrigation canals, and damage or destruction of recreational facilities such as fishing and swimming.

Deposition of sediment on the flood plains of North Dakota's streams and rivers is one of the major sedimentation damages found in our watersheds. This deposition takes place when sediment-bearing streams spill out of their channels and spread over the adjoining flood plain areas. These deposits bury crops, change soil character and fertility, and impair natural drainage.

Deposition of sediment in lakes and reservoirs in North Dakota is a serious problem resulting in lakes gradually being filled up with sediment and a loss of much needed storage capacity in reservoirs. All lakes, both natural and artificial, are subject to this deposition. As a stream or river enters the reservoir, its carrying capacity is reduced to almost nothing resulting in the deposition of the sediment in transport into the reservoir basin. Damages resulting from this deposition include depreciation of property values, cost of modification to power or water-supply plants, and damage to recreational facilities.

One of the State's major problems resulting from sedimentation is that of lake eutrophication. "Eutrophication is defined as the aging process of a lake."[9] Primary causes for eutrophication are increases in phosphorus and nitrogen, which bring about biological changes in the lake. These biological changes include an increase in the plant and animal life in the lake. Agricultural practices and domestic sewage from cities and lake-shore cottages are the primary contributors of nitrogen and phosphorus to our lakes. Agricultural pollution, including that from livestock feed lot operations, is probably the major source of nutrients and silt. As a lake or reservoir ages, its depth and volume are reduced due to the continued deposition of sediment. The end result of this aging process is that the lake or reservoir loses its ability to maintain the growth of fish and its esthetic appeal to those in search of suitable recreation areas. If this process is not stopped, eventually the lake will become filled up with sediment and turn into a bog which may, in time, dry up completely. Lake Metigoshe, located in Bottineau County in North Dakota, is an example of a lake in which eutrophication has become a rather serious problem.

Indicated Solution — The control of sediment production from any watershed in North Dakota involves, first of all, studies to determine how much sediment is being produced by erosion in the watershed and what percentage of this sediment is produced by each of the various erosional processes in the watershed. Once this basic information is available, the problem becomes one of developing a program of land management for the watershed compatible with multiple land ownerships in order to stabilize the sediment at its source and/or impound it before it can cause any damage. Usually a program of this type will involve not only single measures, but many combinations of measures. An adequate sediment control program in most of the State's watersheds will likely involve not only land management and treatment, but structural measures as well.[10]

Included among the various measures and practices which may be instituted in order to control sedimentation are the following:

1. Soil conservation and land management
2. Proper highway and railroad construction
3. Desilting works
4. Channel and revetment works
5. Bank stabilization
6. Special dam construction
7. Improved reservoir operation
8. Snagging and clearing of stream channels
9. Dredging operations
10. Channel changes

LOW FLOW AUGMENTATION

Description of Problem — Periodic low flows in many North Dakota streams is a factor which severely limits the beneficial use of the waters they carry. Dependent activities such as municipal water supply, irrigation, recreation, industrial and electric power development are adversely affected by the occurrence and duration of critical periods of flow. Increasing demands by these activities upon surface water supplies have emphasized the need to supplement the low flows of our rivers.

History of Problem — In years past, all North Dakota rivers have experienced periods of low flow during the dry seasons; however, since the construction of the Garrison Dam and the resulting regulation, the Missouri River no longer experiences such low flows. It is anticipated that periodic low flow problems on the Sheyenne and James River will be corrected when the Garrison Diversion project begins to function and the water supplies in these streams are augmented. Plans have been submitted for a dam on the Pembina River which would provide an adequate water supply for several beneficial uses. Many of the municipalities adjacent to smaller tributaries of the Red River are in need of river development to enhance their water supply. Water could be supplied for this enhancement by

[9]Robert G. Lipscomb, "Some Natural Aspects of Eutrophication", United States Geological Survey, Fort Wayne, Indiana, March 1968.

[10]Louis M. Glymph, Jr., "Control of Sediment Production", *Relation of Sedimentation to Accelerated Erosion in the Missouri River Basin*, Department of Agriculture, Soil Conservation Service, July 1951, Page 11.

such rivers as the Goose and Park were the necessary storage structures constructed on their upper reaches.

Missouri River tributaries entering the mainstem on the west are in need of development. The Dickinson Dam and the Heart Butte Dam on the Heart River are examples of what can be done to enhance the quality of water through low flow releases. The recently completed Bowman-Haley Dam will furnish an ample supply of municipal and industrial water for several Bowman County cities. Rivers in the western part of the State having the potential for development towards greater beneficial use are the Knife, Heart, Cannonball and Cedar Rivers. Studies have shown a great potential for irrigation if the water can be provided when needed. There is also a possibility of industrial development where these rivers pass through huge lignite resources.

Alternative Solutions — Other than a long-range plan for a diversion of waters from the Garrison Reservoir across western North Dakota to supply those rivers with water, the apparent solution is to build storage dams to regulate the flows so that most of the water could be put to use, thus eliminating excess runoff flows being lost to beneficial use in the State. Studies should be made to identify potential reservoir sites where ample water could be stored, and a plan developed for the use of this water.

DISBURSEMENT OF ORIGINAL FIELD NOTES

Description of Problem — Field notes on the original surveys of North Dakota lands made by the Bureau of Land Management are not readily available to county engineers and surveyors for their use in conducting county surveys.

History of Problem — The original survey of public lands in North Dakota made by the General Land Office, now known as the Bureau of Land Management, began about 1865 and ended about 1905. Field notes taken at the time of these original surveys by the surveyor have been stored on microfilm by the Bureau of Land Management and are available at the State Engineer's office in Bismarck, North Dakota.

Data included in these original field notes include the temperature and weather conditions at the time of the survey, date of survey, names of the surveyor and his crew members, index diagram of the township, description of the township and range lines as well as section and quarter corners, brief description of the land topography, general description of the township, and section, township and range numbers.

The information contained in these original field notes should be made available to every county in the State through a cooperative effort between State Water Commission personnel and the individual counties. This information could, if put into use, be of considerable value in preserving the original boundaries as established by the General Land Office as well as reducing the cost of county surveys. Copies of the original field notes should be filed with the county auditor and county engineer.

In the past, State Water Commission personnel have made efforts to encourage counties to obtain sets of the original field notes covering their respective counties from the Commission files. To date, however, the counties have indicated no real interest in obtaining these field notes, possibly due to a lack of finances. Requests for field note data vary; consequently, difficulty is encountered on the part of the staff to meet the immediate demand for this data.

The average cost to the county for obtaining these field notes would vary from $10 to $20 per township with the total cost per county being dependent on the county area, amount of detail gone into by the surveyor, and the terrain. New processing equipment now available in our office could assure the counties of having these records mounted on paper that would last indefinitely.

Solution — The most efficient and timely solution to this problem would be to pass legislation requiring original field notes to be on file in each county office.

STREAM CHANNEL MAINTENANCE

Description of Problem — As a result of legislation enacted by the 1959 Legislature, the State and local legal entities now share the responsibility for snagging, clearing, dredging, and otherwise maintaining rivers and streams throughout the state. On occasion, requests are made by individual counties for State Water Commission financial and technical assistance in maintaining a reach of a river or stream located within their county. Such maintenance, when it is performed, often affects several counties. Work completed in one county, though it benefits that county, can at the same time, adversely affect several downstream counties, in that velocities of runoff waters would be increased through the cleared reach, thus aggravating a potential or real downstream flood problem. In view of this, there is a pronounced need for a coordinated effort on the part of all counties affected.

History of Problem — Many of the streams in North Dakota which carry a large flow during spring runoff have long periods when there is little or no flow. During such periods of little or no flow, brush and tree growth flourishes in the channel. This in itself is good, when growth is restricted largely to the channel banks, as it affords considerable protection against bank erosion. However, when the growth invades the stream channel, it becomes a detriment. This growth, combined with debris that is either caught up in it or that is dumped into the channel, tends to block the flow of the rivers and streams during runoff periods, which, in turn, poses a flood problem.

When Dakota Territory was opened for settlement, the first settlers generally preferred to locate adjacent to streams or rivers because the trees that grew there provided many advantages. These sites provided a source of timber to build shelter for himself and his stock, a water supply, and a source of fuel. Now, modern heating fuel is readily available, and the growth of trees found in the channels of rivers and streams is no longer needed for fuel. As a result, tree and brush growth has built up considerably within stream channels, congesting them and reducing their capacity for carrying high flows.

Prior to 1959, State Law held that the landowner was responsible for the maintenance of the stream adjacent to his land. In 1959, the State Legislature regarded this statute as unfair to the landowner and repealed it. The landowner is, however, required to permit the entry of representatives of legal entities to accomplish the necessary snagging and clearing.

Alternative Solutions — In view of the fact that stream maintenance performed in one county often has a detrimental effect on downstream counties, it is essential that such maintenance be approached on a cooperative basis by the water management districts of the various counties affected. Perhaps it would be in order to establish a small river or drainage commission encompassing the affected counties. A committee, with membership chosen by drainage basin rather than county boundaries, could then be formed to formulate operation and maintenance plans and schedules. The committee could be selected from water management board members or, when no water management district exists, from the board of county commissioners.

POLLUTION

Description of Problem — It is generally acknowledged that pollution has not had the ravaging effects on North Dakota's rivers as it has had on rivers and streams in other parts of the Nation. As a result of the continued growth of our cities and towns and of the accelerated development of heavy water-using industry, sewage and wastes of many kinds have been released into our streams and rivers in increasing quantities. As a consequence, the quality of water has deteriorated until, in some instances, streams are approaching a state where they will be unfit for any use other than as a vehicle for the transport of effluents.

Clean water is one of the most important elements of a sanitary environment. A sanitary environment is the foundation upon which a sound public health structure must stand. Clean water is important to all aspects of human living — to health, sanitation, industrial and agricultural production, and to recreation. It is also important to the conservation of other natural resources, such as fish and wildlife in general.

History of Problem — Pollution in North Dakota is defined in Section 61-28-02 of the North Dakota Century Code as "such contamination, or other alteration of the physical, chemical or biological properties, of any waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or any other substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful, detrimental, or injurious to public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life."

As the cities and towns of North Dakota have grown in size, sewage effluents have polluted to varying degrees the rivers and streams. By 1951, the treatment by plants for removal of B.O.D. (Biochemical Oxygen Demand) was assumed to be 35 percent for primary treatment and 75 percent for secondary treatment.[11] Until quite recently, some cities have dumped raw sewage into the rivers which, when combined with a low percentage of treatment in other cities, became a source of pollution.

Industrial growth has accompanied the population growth in the State. Early factories discharged their effluents directly into rivers. Later, when lagoons came into use, the effluents were still a source of pollution because the lagoons were frequently drained into the rivers before proper treatment.

Other sources of pollution that have grown through the years of the State's development are:

— Siltation, which is the final stage of the "Sedimentation Process" where the soils and nutrients enter the rivers from land erosion.

— Agricultural pollution, which is the pollution resulting from barnyard and feed lot effluents which find their way into rivers.

— Pollution stemming from chemically fertilized croplands runoff and from the use of chemicals for weed and insect control.

— Waterfowl populations in the Lower Souris Wildlife Refuge have caused some pollution where the water is used for municipal supply.

Alternative Solutions — Continued enforcement of not allowing untreated domestic sewage and industrial wastes to be discharged into waters of the State.

Sedimentation of streams and lakes can best be cared for by correcting the source. Better farming practices, using maximum conservation meth-

[11] Missouri-Souris Development Area Water Pollution Investigation, November, 1951, p. 29.

ods to hold the topsoils in place, are recommended. Stream bank erosion prevention by bank rectification works constitutes another corrective measure. One of the most effective methods would be to accelerate the shelter belt program.

FLOOD CONTROL

Description of Problem — High runoff produced by excessive rainfall and/or sudden spring thaws after periods of heavy snowfall will cause a river or other bodies of water to overflow and inundate areas, causing or threatening damage. The loss of life and severe damages may result when flood waters strike cities, industries, and farms located in or near river valleys. Usually the damaged area is in a flood plain, which is a strip of relatively level land bordering a stream, built of sediment carried by the stream and dropped in the slack water beyond the influence of the faster moving water.

Floods can be classified in three categories:[12]

(1) Category A — All major floods, exclusive of relatively localized floods, in which extensive property damage occurs or serious danger to life or flood protective works prevails.

(2) Category B — Floods, including so-called "flash floods," as well as other relatively localized short duration floods that produce high property damage or hazard to life in local areas without creating or contributing substantially to dangerous flooding along larger rivers downstream.

(3) Category C — Flows approaching flood stage in relatively large drainage areas without having directly caused loss of life or significant property damage, but creating a condition especially favorable to a major flood in the event of further heavy rainfall or snow melt or both.

History of Problem — Before settlers came to North Dakota, there were few flood damages. Rivers and streams carved their valleys and the nomadic peoples who inhabited the territory moved to higher lands. Today, however, these valleys are populated with people and the developments needed to sustain them.

The Missouri and Red Rivers played an important role in the early development of North Dakota, in view of the navigation they supported, but after the development of railroads, rivers were used mainly for water supply and sanitation purposes. As the pioneer settlements grew into towns and cities, damages from floods increased in the form of destroyed bottom land crops, homes, businesses, bridges, roads, railroads and buildings. There appears to be a mistaken philosophy that the **flood frequency** has increased since the drouth of the Thirties. Stream flow records fail to substantiate this theory, as some of the worst floods in our history occurred prior to 1905.

North Dakota rivers generate destructive floods during the spring breakup of snow and ice. During such periods, flows may be increased considerably if rain occurs. Flooding also results from localized heavy rains. Additional flood threats may come from indiscriminate drainage performed without adequate hydrology studies.

The Red River of the North and its principal tributaries, the Wild Rice, Sheyenne, Goose, Turtle, Forest, Park and Pembina Rivers, serve as the drain ways for the eastern part of the State. They are generally characterized by flat slopes and low channel capacities, thus limiting their water carrying capacity during runoff periods. The James River, similarly, has flat slopes and inadequate capacity. The western part of the State is drained by the Missouri River and its principal tributaries which are generally characterized by steep slopes with swift runoff, making them all periodic flood producers.

Flood control development had its beginning with the Flood Control Act of 1936. This Act provided a basic plan and an authorized program for the control of water resources. In the early 1940's, the North Dakota State Water Commission cooperated with the Federal agencies to plan and engineer the overall program for North Dakota. The U. S. Army Corps of Engineers occupies one of the major roles in flood control planning and construction. Two reservoirs built by the U. S. Bureau of Reclamation also have flood control storage along with other multi-beneficial uses. The U. S. Soil Conservation Service has contributed materially to flood control by the construction of watershed projects in North Dakota. These watershed projects include channel work and flood retention structures. In such projects, the Soil Conservation District has the responsibility for assuring that 50 per cent of the farms above a structure are under a basic conservation plan.

Flood control projects completed in or affecting North Dakota are:

1948 - Lake Traverse, Bois de Sioux River — a reservoir at White Rock, South Dakota, and 24 miles downstream channel improvement extending into North Dakota to aid in partly controlling the Red River.

1949 - Heart Butte Dam (Lake Tschida) — multi-purpose reservoir south of Glen Ullin (Bureau of Reclamation).

1950 - Baldhill Dam (Lake Ashtabula) — multi-purpose reservoir near Valley City.

1951 - Homme Dam — multi-purpose reservoir near Park River.

1953 - Garrison Dam (Lake Sakakawea) — multi-purpose reservoir near Garrison.

1953 - Orwell Dam — multi-purpose reservoir near Fergus Falls, Minnesota — aids in flood control on the Red River.

[12]*Flood Emergency Manual*, U. S. Army Corps of Engineers, St. Paul District, 1956, pp. 5-6.

1954 - Jamestown Dam — multi-purpose reservoir near Jamestown (Bureau of Reclamation).

1958 - Rush River in Cass County — channel improvements.

1958 - Red River at Grand Forks — levee and flood wall.

1959 - Little Missouri River at Marmarth — levee.

1959 - Heart River at Mandan — levee and flood wall.

1963 - Red River at Fargo — levee, flood wall and channel improvements, control dam and rock weirs.

1963 - Heart River near Mandan — levee, flood wall, channel improvements.

1966 - Bowman-Haley Dam — multi-purpose reservoir near Bowman.

U. S. Corps of Engineers flood control projects under consideration:

Pipestem Dam — multi-purpose reservoir near Jamestown.

Sheyenne River — improvement for the lower 38.3 miles of the river.

Cannonball River — local protection for Mott.

Other U. S. Corps of Engineers projects, and studies:

Velva — levee and channel improvement (completed, 1966).

Scranton — levee and channel improvement (completed, 1959, on Buffalo Creek).

Linton — levee and channel improvement (not completed).

Cannonball River — complete study, water supply and flood control.

Watershed projects of the U. S. Soil Conservation Service, both completed and under construction, are listed below. The planned flood retarding structures were 66 percent completed, and the planned channel improvements were 40 percent completed as of November 1, 1967, according to information provided by that agency.

Tongue River	10 flood control structures	48.0 miles channel improvement
West Tributary Bois de Sioux River		9.8 miles channel improvement
Elm River	3 flood control structures	64.7 miles channel improvement
Swan-Buffalo Creeks	2 flood control structures	27.5 miles channel improvement
Wild Rice Creek	4 flood control structures	28.2 miles channel improvement
Tewaukon	4 flood control structures	11.7 miles channel improvement
North Branch Forest River	4 flood control structures	23.4 miles channel improvement
Middle-South Branch Forest River	3 flood control structures	3.7 miles channel improvement
Lower Forest River		120.0 miles channel improvement
Wild Rice Creek "B"	1 flood control structure	11.2 miles channel improvement
St. Thomas-Lodema		39.2 miles channel improvement
Willow Creek-Park River	1 flood control structure	56.1 miles channel improvement
Boundary Creek	2 flood control structures	65.4 miles channel improvement
Middle Branch Park River	5 flood control structures	37.6 miles channel improvement

In addition to 20 watershed project applications which have not been authorized for planning, the following projects are authorized and are being planned by the U. S. Soil Conservation Service:

Starkweather	Ramsey and Cavalier Counties
Mott	Hettinger County
North Branch Park River	Walsh, Pembina and Cavalier Counties
South Branch Park River	Walsh and Cavalier Counties
Square Butte Creek	Oliver and Morton Counties
Lower Turtle River	Grand Forks County
Upper Turtle River	Grand Forks and Nelson Counties
Buffalo Coulee	Traill and Grand Forks Counties
Midland-Drayton	Pembina County
Bathgate-Hamilton-Carlisle	Pembina County
Upper Maple River	Cass, Barnes and Steele Counties

Snagging and clearing operations have taken place on the following rivers: Park, Tongue, Sheyenne, Forest, Maple, and James. Investigations are underway for improvements near Amenia, Lisbon, Valley City, Fargo, Bowesmont, Pembina and for the seven mile reach of the Tongue River 11 miles above its mouth. Many flood control and related water resources projects are under survey at the present; the more notable being the bank stabilization on the Missouri River between the Garrison Dam and the Oahe Reservoir, the Pembina River development, Minot flood control and the lower Sheyenne River improvement.

Indicated Solution — Flood damage protection can only be achieved where a total program is completed which includes among others:

1. Soil and water conservation treatment on the uplands.
2. Retention structures on the tributaries.
3. Mainstem structures retaining large amounts of flood water.
4. Channel improvements.
5. Proper land use in flood hazard areas to reduce damages where other means of control are not utilized or sufficient.
6. Effective emergency action.
7. In the areas where agricultural drainage contributes to river flows, studies should be made utilizing runoff figures to determine if the amount of water added through drainage is offset by flood storage.

STREAM GAGING

Description of Problem — Practical and reliable development of water resource utilization and control works requires dependable data on the flow of streams upon which to base plans. It is essential to have adequate information reflecting how much water is or will be available and how it is distributed with respect to time. In North Dakota, where the stream flow fluctuates widely from season to season, it is extremely important that we have an understanding of these fluctuations.

History of Problem — Through September 30, 1960, the records of discharge and stage of streams, and contents and stages of lakes or reservoirs were published in an annual series of United States Geological Survey water-supply papers entitled "Surface Water Supply of the United States." Since 1951, 20 volumes have been published in the series; each volume covering an area whose boundaries coincided with those of certain natural drainage areas. The records of North Dakota are contained in Parts 5 and 6 of that Series.

Beginning with the 1961 water year, stream flow records and related data are released by the Geological Survey on a State-boundary basis. These records are prepared in cooperation with the North Dakota State Water Commission, North Dakota Highway Department, United States Army Corps of Engineers, United States Bureau of Reclamation, United States Department of State, United States Fish and Wildlife Service, and United States Soil Conservation Service.

Indicated Solution — Continue an accelerated investigation program with the United States Geological Survey and other interested agencies to provide more and better gaging stations along the streams, lakes and reservoirs in North Dakota.

GROUND-WATER DATA GATHERING

Description of Problem — As of 1950, the aggregate withdrawal of ground water in the United States averaged 30 to 35 billion gallons a day, or 17 to 20 percent of the total withdrawal of water from all sources for irrigation, industrial, municipal, and rural domestic use. The importance of ground water in the economy of North Dakota is only partly indicated by the quantity pumped from wells. Ground-water aquifers provide a natural regulation of water resources which is of extreme importance to the users of wells, springs, and diverters from the base flow of perennial streams, because it means dependability of supply.[13]

Without knowledge of the ground-water supply, proper management of this resource cannot be accomplished. Data gathering is needed in order to identify aquifers, with regard to location; to learn more of the recharge-discharge ratio of these aquifers; and to evaluate the chemical qualities of ground water and the changes in chemical qualities.

History of Problem — Exploratory investigations have been made in areas where there is little or no ground-water development. However, there are areas of North Dakota that have not yet been covered even by preliminary investigations. Ground-water studies have been completed for approximately 60 percent of the State's area by the State Water Commission, local entities, the North Dakota Geological Survey and the U. S. Geological Survey. An inventory of flowing artesian wells in the State is now underway. Many studies have been made of small ground-water areas in the State for municipal use. In a few instances where water quality has been questionable, periodic sampling of the water has been instituted.

North Dakota's use of ground water is rapidly increasing with the demands for irrigation waters and an increased per capita use. Perhaps 70 percent of irrigation water withdrawn from underground sources is consumed through evapo-transpiration. This increased use plus that needed for municipal and industrial uses in the State, points out the need for further ground-water studies.

[13]"Ground-Water Basin Management," *Manual of Engineering Practice No. 40*, American Society of Civil Engineers, 1961, p. 6.

Indicated Solution — Carry out detailed quantative investigations throughout the State and continue to inventory the quantity and quality of water in the aquifers. For such an inventory, it is necessary to know the physical characteristics of the aquifers, so that the quantity and rates of movement of water can be computed. The discharge from the aquifer by natural means and by wells should be determined as accurately as possible. A network of observation wells throughout the State will provide a monitoring system which will indicate the fluctuations of water levels in the various aquifers. It may also be necessary to construct analog models of aquifers where problems may arise. Ideally, the information should be gathered and the problem spotted before it occurs. In periods of extreme drouth, much pressure is exerted by the public to issue water permits without proper analysis of the aquifer in order to meet the emergency.

GROUND-WATER POLLUTION

Description of Problem — Ground-water pollution, although not considered critical at this time, does have several possibilities of becoming a problem. Pollution of underground waters is of a more permanent nature than that of surface waters, compounding the problem. Seriously polluted ground water may take years to purify while polluted surface water may be cleared up in a comparatively short time. The five principal sources of ground-water pollution in North Dakota are:

(1) Improper disposal of salt water in oil fields

(2) Improper construction of water wells

(3) Intrusion of highly mineralized water into fresh water aquifers

(4) Seepage from improperly located lagoons

(5) Possible pollution when excess irrigation water enters an aquifer

History of Problem — During the recovery of petroleum in the oil fields, salt water is produced. This salt water in the past has been stored in open pits and left to evaporate or has been disposed of by pumping it back into the ground to a depth where pollution is supposedly not a problem. Some of this salt or waste water has been handled carelessly, causing the pollution of domestic wells and livestock water supplies.

Water well construction has been a problem where some well drillers have not properly sealed around the casing of a well, allowing surface pollutants to enter the aquifer. Many times, and not always the fault of the driller, wells have been located where pollution could be a major problem. A problem of this type usually occurs when shallow wells are mislocated in relationship to barnyard or sewage disposal facilities.

Pollution from overdraft of an aquifer has not appeared too significantly in the State, though there has been some concern in this connection with the West Fargo Aquifer. Indications are that a highly mineralized water may be moving in laterally from another aquifer due to the loss of head in the West Fargo Aquifer.

Lagoon seepage or location problems in regard to ground-water pollution have not as yet been reported in North Dakota. The same is true of ground-water pollution from irrigation. Minor cases may have been encountered regarding these potential sources of pollution, but to date they have not been recognized as being significant.

Alternative Solutions — Since ground-water pollution is not viewed at this time as a serious problem in the State, no significant programs or studies have been undertaken to provide solutions. In the case of salt water extracted from petroleum in the oil fields, the oil industry's subsequent reuse of such water helps to minimize or even eliminate the problem. Produced water is used for secondary recovery operations by injecting it back into the oil producing zone. The State agency involved should probably police the oil well production to insure that all of the salt waters are stored in tanks instead of open pits when at the surface and that none of these waters are disposed of except to proper geologic formations.

Construction of water wells could be greatly improved by the upgrading of well drilling standards through legislation. The legislation should call for licensing only those drillers who meet certain qualifications. Here again the proper State agency should have the power to inspect this construction, if necessary.

Studies are now being made to determine whether or not one of the State's aquifers is being polluted by overdraft. Suggested solutions are not now definitely prescribed except for better control or better conservation of the waters in the aquifer. This field will require much more study; the construction of an analog model of an aquifer may aid in the solution.

In the matter of sewage or disposal lagoons, the proposed site of new lagoons could be investigated by both the Health Department and the Water Commission representatives. The problem could be eliminated if more facts were known prior to the construction of a lagoon. Items to be considered are subsoils, underground water, and the location of the proposed lagoon in respect to other water users. It may become quite important to know whether or not the lagoon location is over a potential source of ground water. If the subsoil or drainage is a problem, the design of the lagoon can minimize these problems.

Ground-water pollution from irrigation projects can possibly be determined by more intensive study of the effects of irrigation through the use of pilot projects. The canal problem can be improved by the use of canal liners or by using pipes wherever possible. Another improvement could be made by installing a drainage system where soils indicate pollution may become serious.

AGRICULTURAL DRAINAGE

Description of Problem — The lack of proper drainage of excess runoff from agricultural lands in North Dakota has a detrimental effect on the farmers ability to extract the maximum economic benefits from his farming operation.

History of Problem — Drainage is that part of water management related to excess runoff from our State's agricultural lands. The amount of excess runoff varies considerably from one part of the State to another depending on the lay of the land, as well as the amount of precipitation received. In eastern North Dakota, farmers are faced each year with recurrent and in some cases long lasting periods of rainfall which result in serious crop land flooding. The western two-thirds of the State, on the other hand, is faced with long and recurrent dry periods. Thus, drainage problems in that portion of the State, where occurring, are limited almost exclusively to spring runoff.

Drainage of excess waters from agricultural lands presents many problems to downstream municipalities and landowners. Included are increased flood damages, destruction of crops, inability of downstream landowners to seed and harvest low lying land, and detrimental effects on downstream soil fertility.

Drainage of North Dakota's agricultural lands locally is mainly aimed toward "land reclamation" rather than better management of the State's water resources. This drainage, due to its effects on surrounding land areas, has changed the pattern of runoff since the land's original settlement.

With conditions as primitive and unimproved by roads or cultivation as those which confronted the early settlers on the prairies of North Dakota, drainage was simply a function of the lay of the land, and flood damage was considered an act of God. Since the beginning of development of the State, which included 66 feet of right-of-way for vehicles at each section line, drainage of excess runoff from the land has been artificially influenced. Due to countless changes made in farms, fields, townsites, and roadways, natural drainage no longer follows the same patterns it did during the days of the pioneers. As a result of these changes, road ditches have replaced most of the State's shallow waterways which once existed in the flood plains. In some cases, rivers have been replaced by artificial ditches. Due to the many changes in the State's natural drainage pattern, there is a definite need in eastern North Dakota for improved water management of excess runoff.

There are three basic reasons leading to this need for improved management of excess runoff. First, because of extensive changes in farming methods and road improvements, the State's natural drainage pattern has been altered — and will continue to be altered — resulting in a change of location for water collection points and numerous problems related to excess runoff in our principal waterways. The waterways themselves are being degraded by the natural growth of trees and brush, choked by siltation from cultivated land, and by inadequate culverts or bridges.

Second, existing laws do not relate directly to the engineering problem of providing adequate right-of-way for carrying the excess runoff from a given contributing area to a "well defined channel," and are not specific in defining the channel in terms of the area it is required to drain, or how completely that area should be defined.

Third, total water management must include recognition of the destruction of wildlife habitat by the development of land for farming, roads for travel, and the needs of a more demanding land culture in general. The means for providing this recognition by countering the damaging effects of water management aimed at flood prevention and improvement of farming conditions are badly in need of clarification. Along with this, there is a definite need for programs to mitigate wildlife habitat damages, particularly wetlands, in a form which is understandable by and acceptable to the landowner.

Many of the problems which result from drainage of agricultural lands arise from the interpretation of existing laws related to land use. These problems, and also changes in the land area due to natural causes, have established, in the majority of cases, that riparian owners have land use rights to the center line of each channel, in practically all of the creeks, and most of the tributary rivers to the Missouri, Mouse, and Red Rivers. As a result of this, there is no measurable public right-of-way for water as there is for wheeled traffic.

There is a definite need to relate channel needs for excess runoff to waterways which are entitled to the protection of the law. This is especially true in the area of the eastern escarpment and flood plains, where all river channels tributary to the Red tend to follow a pattern in which the original channel, rising in a slough riddled upland, cuts a deep channel through the escarpment, has no channel at all below it, or no more than a series of shallow lows which are generally farmed during dry years, and ends up with an inadequate trench for outlet.

Attempts to define a "natural channel" entitled to the protection of the law, cannot be related to the natural or existing dimensions of the channel at any one point, because the original channel came into existence prior to land use modifications and because it varies greatly in depth, width, and gradient throughout its length.

The definition of a "natural channel" must include the determination that this channel is indeed the natural low through which water flows from an area contributing runoff. It must include an accurate determination of the area from which this runoff is contributed. In addition, the definition should consider the width of the right-of-way needed to convey excess runoff so that the land adjacent to the channel and any flood protective impoundment, natural slough, or lake area can be successfully farmed about eight years out of nine. This is regarded as the "happy medium" of flood protection, providing the best return on the investment.

By this approach, and with evidence which has been accumulated, it is quite obvious that there are no stream or river channels in existence in North Dakota which are adequate throughout their entire length to comply consistently with the above criteria for adjacent flood protection. In order for these channels to comply with the definition of a natural channel, it is necessary that all natural or artificial obstructions be removed and channel improvements be provided to raise inadequate portions of the channel to the same level as those portions of the channel which are adequate.

Basically, the problem of drainage centers around the fact that the public in general does not understand the basic principles of hydrology and does not generally accept the need for publicly owned waterways. As a result of public apathy and misunderstanding, a total water management program is not completed. It is also true that not all lands are necessarily suitable for drainage and might be more valuable to the State's economy as wetlands, provided the landowner were justly compensated for not draining.

Since agriculture and related industries provide the basic source of income for North Dakotans, it is important that steps be taken to reduce the flooding of valuable and productive lands which each year reduce significantly the income of the farmers in the area, and consequently impairs the economy of the State.

The State Water Commission drainage program is devoted primarily to the construction of floodways that serve large areas subject to water damage. This program was initiated in 1943 when the State Legislature appropriated funds for its implementation.

Funds appropriated to the Commission for drainage works are distributed to various drainage projects qualifying for assistance in accordance with Water Commission rules and regulations. State assistance is usually 40 percent of the construction costs. The Commission only cooperates in the construction of legal drains, which are constructed under the sponsorship of an acceptable legal entity, such as a board of drain commissioners; board of county commissioners; a township board; or a water management district. The local share of the project costs are paid by special assessments levied on the property benefited by the improvement.[14]

[14]*Fifteenth Biennial Report*, North Dakota State Water Commission, Bismarck, North Dakota, 1966, pp. 13-14.

Solution — The solution to the drainage problem in North Dakota consists of two basic parts:

(1) Education of the public and landowners in general on the subject of total water management with drainage being that part of water management concerned with excess runoff from precipitation after all potential retention sites, including sloughs, have been studied for feasibility as part of the total water management program.

(2) A concentrated community effort on the part of all interested parties is needed to establish public "roadways" for water, taking into consideration such things as depth, width, slope, and gradient.

PROJECT MAINTENANCE

Description of Problem — Local legal entities responsible for the operation and maintenance of projects completed by the State Water Commission and various Federal agencies often lack the ability and/or resources needed to discharge their responsibility properly.

History of Problem — Total responsibility for the operation and maintenance of a water resource development project completed by the State Water Commission is not transferred to the local legal entity until after the expiration of a three-year post-construction period. During this three-year period, the Commission participates with local interests in a joint operation and maintenance effort with the extent of Commission financial participation being determined largely by the number of other State agencies involved and by the local entity's financial capabilities.

Periodic inspection conducted during the post-construction period by the Commission reduce significantly the need for performing more than minor maintenance. Unfortunately, when the responsibility for operation and maintenance of a completed project is transferred to a local group, that group quite often is unsuccessful in discharging its responsibility. This failure frequently stems from the local group's lack of knowledge concerning maintenance practices and its lack of ready access to the type of equipment needed. At the same time, local entities often do not advise the Commission of a problem until after a minor maintenance problem has grown into a major problem; one which requires the expenditure of far greater sums of money than would have been necessary were the proper maintenance performed when its need became apparent.

Indicated Solution — The apparent solution to this problem involves the provision and utilization of equipment and crews from the State Water Commission to conduct periodic inspections and to perform maintenance on all water resource projects. While such a program would not relieve local entities of their present obligation to participate financially, it would relieve them of the need to procure equipment and of the need to perform the actual physical maintenance.

Equipment and crews should be sufficient to make inspections at intervals of no less than once each six months and to perform required maintenance immediately. The need for such an arrangement is underscored by the fact that the State Water Commission and boards of county commissioners are also responsible for the maintenance of the approximately 1,200 dams constructed in North Dakota by various Federal agencies during the 1930's. A total of approximately 2,000 dams were built during this period; 800 to 900 failing within the first two years of their existence, because of inadequate construction and/or maintenance. The State Water Commission and boards of county commissioners have endeavored to maintain many of the remaining dams within the limits of their respective budgets.

WEATHER MODIFICATION — CLOUD SEEDING[15]

Description of Problem:

The duality of science is never so apparent as it is in the weather modification field. A controversy exists between the accumulation of scientific knowledge of the mechanisms of cloud formation and precipitation and methods of modifying these mechanisms, and the practical application of this knowledge. In the final analysis the application rests on the accumulation of knowledge.

Cloud physics studies progress slowly, chiefly due to the inability of the scientist to duplicate atmospheric conditions within the laboratory. Other factors hamper the studies, such as the great scale of the cloud systems contrasted with the very small scale of the cloud elements, the great variability of the natural atmospheric conditions, the inadequacy of the experimental tools and the lack of control of the initial and final conditions of an experiment. Cloud seeding evaluations also require lengthy and expensive field projects with careful scientific controls and complicated statistical tests if they are to produce unquestionable results.

Direct application of present partial knowledge of cloud physics and cloud seeding in attempts to modify the weather is relatively simple and inexpensive. However, the lack of scientific controls common to most operations of this type makes the results open to question. Considerable controversy concerning the effectiveness of cloud seeding has been generated because of these differences in approach.

History of Problem:

Since early experiments in 1946 and 1947 there has been an increasing multiplicity of experiments connected with "rainmaking." The recognition of the economic import of rainfall control resulted in the early and rapid growth of many commercial enterprises in this field. Because of the nature and phenomenal potential of rainfall control, and the news appeal of "rainmaking," silver iodide cloud seeding has received a good deal of publicity. However, the conflicting views held by those active in the field have proved confusing to the general public and this has led to difficult public relations problems in many areas, notably those where field experiments are being conducted.

In many areas of the United States, legal procedures have resulted from the activities of cloud seeders — sometimes in the form of lawsuits claiming damages as a result of cloud seeding. Some states have enacted laws governing the operations of cloud seeders, while others have prohibited cloud seeding entirely.

The United States Bureau of Reclamation is now conducting a series of studies on the potential of cloud seeding. The development of cloud seeding in the mountains would eliminate or substantially reduce legal involvements as most of this area is public land.

Experiments have been under way for the past five years in Bowman County to facilitate "hail suppression" by cloud seeding. This county has shown the highest incidence of hail loss in the State the past 30-40 years. The experiments are conducted by North Dakota State University and the North Dakota State Aeronautics Commission under a grant by the National Science Foundation. Experimental work has been done by planes bombarding cloud formations with silver iodide to prevent hail. Radar has also been used to photograph cloud formations in order to determine what clouds are potentially hail producing. These experiments are showing favorable results but the information is not conclusive as yet.

Indicated Solution:

Although physical evaluations of cloud seeding experiments are extremely important, and may prove to be the final key in producing conclusive results, it is also generally recognized that modern statistical principles designed to cope with the natural variability of rainfall must play a major role in the conduct and evaluation of experiments in weather modification.

Statistical analysis requires a body of facts and data, and therefore, dictates that the experiment must be repeated until a significant result becomes evident. In order to keep the repetition to a reasonable economic level the statistical sensitivity must be maximized and the experiment very carefully designed. The results of many experiments have not proved acceptable because of poor design, mainly because of lack of control of the experiment, poor statistical technique, lack of randomization and failure to outline the specific experiment before applying the tests.

[15]Adopted from C. L. Crozier and J. D. Holland, *Cloud Seeding to Influence Rainfall — It's Importance and Present Status*, U. S. Department of Transportation, pp. 7-13.

Since there is some degree of success in weather modification efforts, the protection of the public requires some control of such experiments. Proper licensing of operators and control of their weather modification activities is needed to protect the public against being misled or bilked by novice operators whose activities may precipitate cloud bursts, hail or damaging winds, or may have **no** effect whatsoever upon precipitation levels.

PRESERVATION OF PROPERTY MARKERS

Description of Problem — Original markers or monuments for designating property limits were established by the United States Government during the original survey of public lands. Many of these original monuments and resurvey monuments are being needlessly destroyed each year by construction of roads, pipelines, etc., or in conducting farming practices. A licensed surveyor has the authority to determine the boundaries of private lands, but his determination of these boundaries cannot be accepted when it is evident that the properly established markers were not used, as the original survey carries priority over all resurveys. Large additional costs for re-establishing these corners must be borne by landowners where a dispute arises, in that additional effort is required to complete a survey when original monuments are absent.

History of Problem — The entire State of North Dakota was surveyed by the United States General Land Office, and all section corners and quarter section corners were established, marked, and monumented. Most of this work was originally done between 1870 and 1910. The monuments established then consisted of either chiseled rocks or charred oak posts buried and then mounded with earth for reference. A portion of the State was resurveyed during the 1940's, and at that time, the corners were re-established and marked with brass caps over a steel pipe.

In order to protect the monuments established by the Federal Government in surveying the public lands, Congress enacted legislation on March 4, 1909 which provided for a penalty for the unauthorized alteration or removal of such monuments. This Act, although its provisions are seldom invoked, nevertheless serves as a warning to the public and makes the public realize the importance of land boundaries. Likewise, Section 47-20-10 of the North Dakota Century Code renders the destruction of such monuments a misdemeanor.

Chapter 47-20 of the North Dakota Century Code contains the State Law relative to maintaining and establishing markers. The responsibility for re-establishing such markers is vested in the county surveyor. The State Engineer is the official repository for the original field notes and plats which were made at the time of the original survey.

Apparent Solution — A first step in solving this problem should involve a determined effort to inform the public of the importance of maintaining original property markers. An effort should be made to advise individuals and companies engaged in surveying activities that after title to a piece of land is granted by the United States, jurisdiction over the property passes to the State. The Federal Government retains its authority only with respect to the public lands in Federal ownership. Where lands are in private ownership, it is a function of the county or local surveyor to restore lost corners and to subdivide the sections.

Disputes concerning these questions must come before the local courts, unless settled by joint survey or agreement.

To keep within the intent of the law, where either road construction, farming, or the building of other improvements has disturbed a corner monument, the corner monument and accessories should be replaced and a complete record filed with the appropriate office. Durable material should be used, and there should be sufficient accessories to assure ready identification of the corner point. The utmost regard should be shown for the evidence of the original location; the monument will be carefully reconstructed by such additional means as may be appropriate, placing the original stake or stone in the ground at the base or along side the new monument, without destroying the evidence which served to identify that position.

Ties should be taken to references such as bearing trees, bearing objects, or permanent improvements, as available. A record, giving a complete description of the old and the new monuments with their accessories and references, should be filed with the county and in the appropriate land survey office of the Bureau of Land Management.

The Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., has on hand for sale to surveyors and the general public the following publication of the General Land Office.

Manual of Instructions for the Survey of Public Lands of the United States, edition of 1930.

FLOWING WELLS INVENTORY

Description of Problem — Section 61-20-06 of the North Dakota Century Code transferred the responsibility for maintaining an accurate and up-to-date record of all flowing wells in the State from the North Dakota Geological Survey to the North Dakota State Water Commission effective July 1, 1965. However, due to a lack of funds and personnel the Water Commission has not been able to develop and institute a program which adequately discharges this new responsibility.

History of Problem — Ground water represents one of the State's most valuable natural resources. The most economical means of recovering this water for man's use is through flowing wells or "artesian wells" as they are more commonly called. The term "artesian" is derived from Artesium, the Latin equivalent of Artios, the name of an ancient province of northern France where some of the most ancient flowing wells are found.

Water is under artesian conditions when it is confined in an aquifer by overlying impermeable material. The water level in a well drilled into such an aquifer will rise above the top of the aquifer. If the hydrostatic pressure is great enough, the water level will rise above the land surface and the well will flow.

Water from an artesian well always flows in the direction of least resistance. Thus, if a well taps an aquifer in such a position that the greatest portion of the aquifer is pressing down on the point where the well has tapped the aquifer, an artesian well is formed because the water immediately begins to rise in the well due to the greater pressure pushing down on the water adjacent to the well.

One of the first flowing wells in North Dakota was completed for the City of Ellendale in 1886. However, this probably was not the first flowing well to be developed in the State. Following the filing of the first North Dakota homestead entry by Joseph Rollette in 1868 for land in the northwestern part of the Red River Valley, that portion of the State was rapidly settled by immigrants. Since flowing wells can be obtained at relatively shallow depths even today in certain parts of the Red River Valley, it is not inconceivable that one or perhaps several industrious settlers in their search for underground water were fortunate enough to locate a source which flowed freely prior to 1886.

As of December 1, 1896, an estimated 500 to 600 artesian wells were located on the North Dakota side of the Red River Valley. The flow from these wells varied from a few gallons per minute to 600 gallons per minute per well with the total flow from these wells ranging between 5,000 to 8,000 gallons per minute. Water pressure in these wells varied from a few pounds to 53 pounds per square inch with a water temperature of about 46° F. The quality of this water varied considerably. Some of the water was fresh, some brackish, some salty, and some highly mineralized. The combined flow of all these wells was estimated at 10,000 acre-feet per year.[16]

Prior to 1896 relatively few artesian wells had been sunk outside of the Red River Valley, and these were located in the northern extension of the James River Valley as well as others at Rutland, Ransom, Tower City and Devils Lake. Unsuccessful attempts to locate artesian wells were made at Mandan, Bismarck, Dickinson, Sims and Medora.[17]

The first well to penetrate the Dakota Sandstone in North Dakota was located at Ellendale. This well was quite spectacular when completed on April 6, 1886, in that it was 1,087 feet deep with an original pressure of 197 pounds per square inch and flowed at approximately 700 gallons per minute. As a result of this well's success, the development of the Dakota Sandstone artesian system was continued with the drilling of a 1,476 foot public water supply well at Jamestown. In 1890, a 1,524 foot well was drilled at the State Hospital located south of Jamestown and a 977 foot public water supply well was completed at Oakes. A well with a six inch diameter was drilled for the municipal water supply at Edgeley in 1892 at a depth of 1,365 feet.

By 1896, approximately 400 artesian wells had been drilled to the Dakota Sandstone in North and South Dakota. Of these, the stronger wells had pressures ranging from 100 to 250 pounds per square inch with flows ranging from 500 to more than 4,000 gallons per minute.[18]

On December 1, 1896, a total of 673 deep and shallow flowing wells existed in the State of North Dakota, with 20 of these being considered deep wells. The total flowage from all artesian wells and springs within the State amounts to approximately 18,700 acre-feet per year.[19]

The earlier and deeper wells sunk to the Dakota Sandstone were drilled by the percussion-tool or cable-tool method. However, this method was so expensive that generally it was economically unfeasible to construct individual wells for farm and home use by this means. Shortly after 1900, a new method of drilling known as the "jetting method" came into general use and the cost of constructing artesian wells in the Dakota Sandstone decreased considerably. The "jetting method" of drilling involved the fast and efficient sinking of small holes through soft shale and other materials of a similar nature which are often found overlying artesian aquifers. In addition to reducing drilling costs, this method of drilling made it possible to finish the wells with much less difficulty and less danger of getting out of control.

As a result, thousands of small wells ranging in diameter from 1¼ to 3 inches have been drilled throughout the artesian basin. In 1923, there were between 6,000 and 8,000 artesian wells in North Dakota.[20] Much of the credit for developing the apparatus and methods for construcing small artesian farm wells is due to the late Peter Norbeck, once a prominent well driller in South Dakota and later

[16]W. W. Barrett, "The Red River Valley Artesian Formation," *Sixth Annual Report of the State Superintendent of Irrigation and Forestry,* Jamestown, North Dakota, 1896, page 50.

[17]N. H. Darton, "Preliminary Report on Artesian Waters of a Portion of the Dakotas," *Report of the Secretary of the Interior. Fifty-Fourth Congress,* Volume IV – Part 2, Washington, D. C., 1896, page 661.

[18]Howard E. Simpson, "The Conservation of Artesian Water," North Dakota Geological Survey, Bulletin No. 5, Grand Forks, North Dakota, 1926, p. 10.

[19]W. W. Barrett, "A Condensed Description of North Dakota," *Sixth Annual Report of the State Superintendent of Irrigation and Forestry,* Jamestown, North Dakota, 1896, p. 129.

[20]Oscar E. Meinzer and Herbert A. Hard, *The Artesian-Water Supply of the Dakota Sandstone in North Dakota with Special Reference to the Edgeley Quadrangle,* United States Government Printing Office, Washington, D. C., 1925, p. 75.

the Governor of that State and then a United States Senator.

The greatest influx of artesian well drilling, particularly in the Dakota artesian system, appears to have taken place between 1902 and 1920. It soon became evident to professional engineers and geologists engaged in such drilling that the preconceived idea of an "unlimited amount of water available from a vast underground sea" was false. The decline in the artesian head began when the first wells penetrated the confining clay and shale overlying the underground reservoirs, and this decline has been progressing steadily. The greatest contributing factor in the rapid decline of the artesian head was the tremendous volume of water that was wasted. Under the 1923 well drilling system, at last 95 percent of the flow from artesian wells was wasted.[21]

As a result of the work carried on by Mr. Herbert A. Hard, Chief Engineer of the State Flood Control Commission, and Mr. Howard E. Simpson, North Dakota Geological Survey, and largely through the influence of the North Dakota Well Driller's Association a law was enacted by the State of North Dakota on March 10, 1921, prohibiting the further waste of artesian water and charging the State Geologist or his deputy with the duty of enforcing this law. The State Geologist, A. G. Leonard, assigned the duty of enforcing the artesian-water law to Mr. Howard E. Simpson, who was the Director of the North Dakota Geological Survey and the Head of the Department of Geology and Geography at the University of North Dakota located in Grand Forks. The annual meeting of the North Dakota Well Driller's Association at Grand Forks, North Dakota, in February, 1922, was devoted largely to the subject of artesian-water law enforcement. In conjunction with this meeting an interstate conference on the conservation of artesian water was held with representatives of the North Dakota and South Dakota and United States Geological Surveys present.

Following the enactment of legislation in 1921 in regard to flowing wells, Howard E. Simpson and C. E. Turnbaugh, his deputy, began a systematic inspection of the State's artesian wells and an instruction program for well owners regarding any reductions in flow discharge that should be made. As a result of this legislation, a complete census of all flowing wells was taken in 1921 and checked in 1922. From the data obtained in this census, a card index was made for each of the State's 5,000 artesian wells giving a brief description of each well, its location, and the well owner's name and address. After his inspection of the State's artesian wells, Mr. Simpson had this to say regarding the general situation in 1923 of the State's artesian waters: "North Dakota has six separate and distinct artesian basins. One of these, shared with South Dakota, is, according to federal authority, the most important in America and probably in the world. Due to careless drilling and finishing of wells, to unlimited waste of water, and to failure to control old and 'wild' wells, the pressure and supply of this artesian water is being rapidly exhausted. The highest federal authority estimates the natural storage reservoir already four-fifths drained. The wells have ceased to flow throughout considerable areas including whole belts of townships. It is but a question of a few years time, unless the waste is checked, before the greater portion of the Dakota Artesian Area in North Dakota will cease to yield flowing wells and another valuable natural resource will have gone the way of the forests and natural gas fields of America."[22]

The 1921 census of the State's flowing wells was performed by township assessors, who were required to perform this service annually in connection with their other duties as a result of legislation enacted in 1921. This law remains in effect today and is stated in Section 61-20-05 of the North Dakota Water Laws. However, the inventory was discontinued following completion of the 1923 inventory and was not resumed until the spring of 1967. Why this inventory was never performed again for 44 years is not completely understood. Possibly a statement made by Mr. Howard E. Simpson in "The Sixth Biennial Report of the State Water Geologist" (Jan. 1933) to the Governor and the Twenty-Third Legislative Assembly may have had some bearing on the matter. The statement said this, "The annual listing of the flowing wells by the assessors as required by law is now an unnecessary expense in view of the completion of the first inspection and relatively small number of new wells that are now being drilled."[23] The untimely death on January 31, 1938, of Dr. Simpson was perhaps the greatest contributing factor to the indifference exhibited by legislators and State agencies towards the flowing well inventory during the years from 1938 to 1967.

Certainly the drought of the 1930's and the Second World War limited the number of new flowing wells, but the old wells were still flowing and much water was being wasted in spite of the efforts of Howard E. Simpson, State Water Geologist, and Herbert A. Hard, Chief Engineer of the State Flood Control Commission. The amount of wasted water was no doubt considerably below the 95 percent as stated earlier. This decrease in wasted water was due mainly to the decrease in water pressure.

Following the Second World War, hydraulic rotary drilling machines were introduced into North Dakota. These machines were faster and capable

[21] Herbert A. Hard, "Artesian Wells of North Dakota," Report to the Governor of North Dakota on Flood Control, Bismarck, North Dakota, 1921, p. 13.

[22] Howard E. Simpson, "Artesian Water Conditions," North Dakota Geological Survey, Bulletin No. 2, Grand Forks, North Dakota, 1923, p. 9.

[23] Howard E. Simpson, "The Artesian Waters of North Dakota," North Dakota Geological Survey, Bulletin No. 8, Grand Forks, North Dakota, 1935, pp. 46-47.

of reaching greater depths than jetting machines. As a result of advancements in technology and growing numbers of experienced drilling contractors and plumbers, the condition of flowing wells in North Dakota has been continually upgraded during the past few years. These wells are now generally safe, efficient and, depending upon the well owner, controlled to permit only that amount of flow which the well owner requires.

The Dakota Artesian System still remains the most utilized source of flowing wells in the State. In the southeastern quadrant of the State up to, and in some instances over, 20 flowing wells are drilled annually in each county. In 1963, an artesian system located in the Upper Cretaceous sediments in Mercer, Oliver and the adjacent counties was tapped and since that time, approximately 300 flowing wells have been installed. These sediments which also underlie the Knife and Missouri Rivers drainage should provide flowing wells in the Heart and Cannonball drainage basins providing the land surface is at the proper elevation. Several hundred flowing wells still exist in the Red River Valley although in the northern part the water is generally too highly mineralized for most purposes. Flowing wells are also in existence in the Souris River Loop area, Little Missouri River Valley and other glacial drift regions underlain by buried preglacial or interglacial drainage systems. In addition to these, flowing wells are found along the flanks of the Turtle Mountains, Missouri Coteau and other areas of morainal deposition. In fact, flowing wells can be found at various depths throughout the State where geologic conditions requisite for flowing artesian wells are encountered.

How many flowing wells are in existence in North Dakota today? The answer to this question is unknown. With the exception of township assessors in the southeastern quadrant of the State, where persons know and understand the value of a flowing well, the reception and cooperation asked for during the 1967 flowing well inventory was extremely poor. **How much water do the state's artesian systems discharge at the surface each year?** This too is unknown. A survey such as the type envisioned and begun by Howard E. Simpson in 1921 is needed to secure an answer.

Solution:

In order for the State Water Commission to complete and maintain an accurate inventory of flowing wells in the State, it is imperative that the necessary funds be provided by the State Legislature to carry out this responsibility adequately.

Cooperation, on the part of owners of flowing wells, in order to control the flow of such wells is necessary to avoid costly legal controversies that might develop in some instances.

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Chapter Seven

Beneficial Uses of Water

CHAPTER VII

BENEFICIAL USES OF WATER

WATER USE STANDARDS

Prior to the projection of future water requirements, it is necessary to develop a set of current and projected water use standards. These standards serve as an indicator of the amount of water required to satisfy a particular need, or as in the case of industrial water, to produce a given quantity of goods.

Municipal Use Standards

In planning for future municipal water supplies, projected population estimates for North Dakota cities play a significant role. Other important factors in planning for the State's future urban water supply include increased domestic demands, industrialization, commercial uses and public uses such as parks, swimming pools, etc.

Water use standards for per capita consumption in urban areas are based on the assumption that there will be adequate future supplies where proper management practices are observed. In planning for the development of public water supplies, it is essential that every precaution be taken to protect the public safety and welfare. In this respect, it is considered sound planning to provide a supply which is in excess of projections.

Table 1 shows the projected water use standards for the years 1980 and 2000. Per capita municipal water use in North Dakota averaged 100 gallons per day in 1963 as shown by an inventory of municipal water facilities conducted by the U. S. Public Health Service.[1] The 1963 use was based on those municipalities of 2,500 or more population using surface water, and having an adequate water supply. The somewhat industrialized cities showed an average use of 115 gallons per capita per day in 1965 from information taken from water use reports.[2] A study made by a U. S. Senate Committee on National Water Resources in 1959 indicates that the industrialized cities of less than 100,000 population used an average of 132 gallons per capita per day, and the same type cities of over 100,000 used an average of 150 gallons per capita per day.[3] Population projections indicate North Dakota's urban population will reach approximately 600,000 by the year 2000.[4]

[1]Table 5 Summary of Water Used for Public Supplies, from a study made by John Schefter, North Dakota State University. The Summary was compiled from a 1963 Inventory of Municipal Water Facilities, P.H.S. publication No. 775 (revised) Vol. 6.

[2]Information gathered from 1965 Municipal Water Use Reports made to the State Water Commission using cities with industry involved.

[3]"Future Water Requirements for Municipal Use," *National Water Resources: U. S. Senate Select Committee Report,* Committee Print No. 7, 1960, p. 9.

[4]"Future Water Requirements for Municipal Use," *National Water Resources: U. S. Senate Select Committee Report,* Committee Print No. 7, 1960, p. 1.

TABLE 1. Projected Water Use Standards for Urban Areas in North Dakota

(Gallons Per Capita Per Day)

1960	115
1980	130
2000	150

Domestic and Livestock Standards

The farm and rural nonfarm use of water includes the use of water for household purposes, livestock needs, and the care of lawns, trees and gardens. For planning purposes, the livestock uses have been separated. All other farm and rural nonfarm uses are classified as Domestic Uses. Present and future trends indicate an increase in the rural nonfarm population. Data on the use of water for domestic purposes are not definite enough to allow a distinction between farm and rural nonfarm uses. As a consequence, no distinction is made in this report. It is assumed that the average domestic consumptive use rate is 50 gallons per capita per day.[5]

The projected water use for domestic needs in rural areas is anticipated to increase 10 percent by 1980 and approximately the same increase by the year 2000.[6] These water use standards are shown in Table 2, and are based on the assumption that each household will have a running water system.

Livestock water use standards are taken from a Missouri Basin Inter-Agency Committee work group report, and are shown in Table 3, along with the projected use standards. The basic water needs for livestock on the range will not increase; however, there will be an increase in water use where production can be increased. This situation will appear in dairy and feeding operations and it will be affected by water use for increased meat and dairy production, as well as the demand for more sanitation and pollution control. Here again the increase in water use is estimated to be 10 percent by 1980 and another 10 percent by the year 2000.[7]

TABLE 2. Water Use Standards for Rural Areas

(Gallons Per Capita Per Day)

	1960	1980	2000
Domestic*	50	55	60

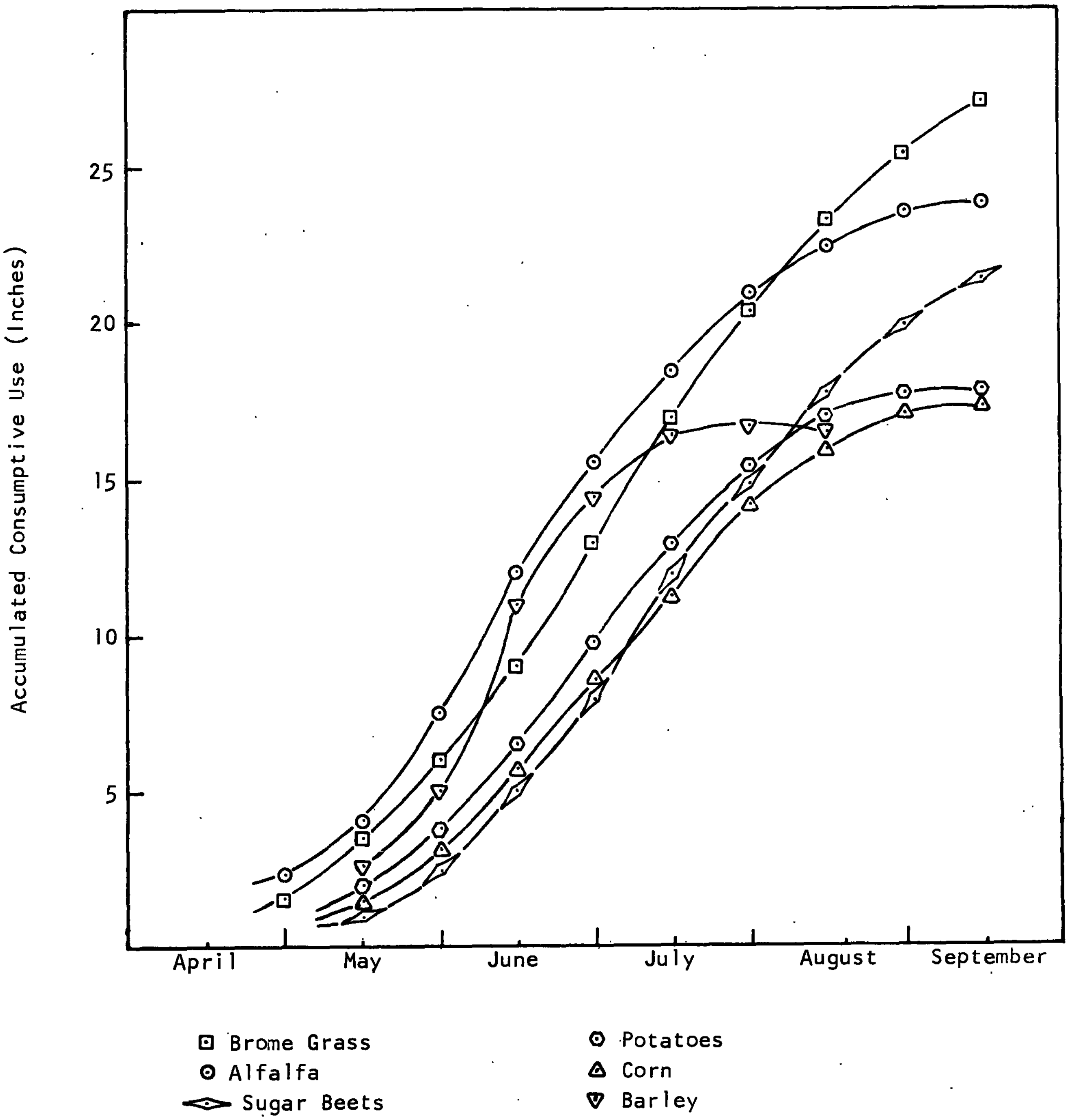
*Domestic use includes all farm and rural nonfarm populations. Rural communities are those with a population of less than 2,500.

[5]"Livestock and Domestic Water Requirements," *Agricultural Task Force Report,* Missouri Basin Inter-Agency Committee, p. 2.

[6]North Dakota State University Extension Service.

[7]North Dakota State University Extension Service.

FIGURE 1



Accumulated Consumptive Use (Inches)
25
20
15
10
5
April
May
June
July
August
September
Brome Grass
Alfalfa
Sugar Beets
Potatoes
Corn
Barley

TABLE 3. Water Use Standards for Livestock

(Gallons Per Head Per Day)	1960	1980	2000
Milk Cows	30	33	36
Beef Cattle	12	13	15
Hogs	4	4.5	5
Sheep	2	2.2	2.5
Chickens	.06	.08	.1
Turkeys	.18	.2	.22

Irrigation Use Standards

The amount of water to be appropriated for irrigation use will vary according to the seasonal consumptive needs for each crop. The inches of water required to produce a given crop in most instances cary within narrow limits for different locations in North Dakota. Differences in net radiation, humidity, wind movement and length of growing season at the different locations account for much of this variation. However, for the State in general the amount of water required to produce a given crop is approximately 17 inches for small grains, 18 inches for corn and potatoes and 22 to 24 inches for alfalfa and sugar beets. Pastures may also be irrigated successfully using a mixture of grasses. For maximum production brome grass has a consumptive use of 27 inches of water.

Figure 1 shows the measured seasonal consumptive water use for some of the crops which are irrigated in North Dakota.[8] Table 1 using information from Figure 1 shows the average moisture needs for the six crops listed, in two week intervals from May 1st through September 15. April moisture needs are shown for alfalfa and brome grass.

Sufficient quantities of water must be supplied to acres being irrigated to assure that the total amount supplied from all sources is equal to the crop's consumptive use. In addition to the consumptive use of irrigation water, the losses of irrigation water must also be considered when formulating standards for the amount of water to be diverted from its source for each acre to be irrigated. In gravity irrigation the losses occur from seepage in canals and ditches. The losses from sprinkler irrigation occur from direct evaporation from the spray itself and evaporation of the water intercepted on the vegetation. Winds cause additional direct evaporation and an uneven distribution pattern. The basic efficiency for both gravity and sprinkler systems is 70 percent.[9] Other loss factors reduce this efficiency to 65 percent in North Dakota.

TABLE 1

	April 1-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug. 1-15	Aug. 15-31	Sept. 1-15	Season Total
Brome Grass	1.5	2.0	2.5	3.0	4.0	4.0	3.5	3.0	2.0	1.5	27
Alfalfa	2.0	2.0	3.5	4.5	3.5	3.0	2.5	1.5	1.3	0.2	24
Sugar Beets		1.0	1.5	2.5	3.0	4.0	3.0	2.5	2.5	1.5	21.5
Potatoes		1.7	1.8	3.0	3.2	3.3	2.5	1.7	0.6	0.2	18
Corn		1.4	1.6	2.7	2.8	3.0	3.0	1.7	1.1	0.2	17
Barley		2.5	2.5	5.5	4.0	2.0	0.5				17

As noted in Figure 2 precipitation in the eastern third of the State averages about 19 inches, in the middle third about 16 inches and in the western third about 15 inches. On the average about 77 per cent of the annual precipitation occurs during crop growing and freeze free season.[10] Since the seasonal consumptive need for crops may be as high as 24 inches, an additional 12 inches of moisture is needed annually to supply irrigated crops. (See Figure 3.)

Considering an average efficiency at present of 65 percent the water necessary to supplement another 12 inches of consumptive use would be approximately 18 inches per acre. Modern farming methods and the use of fertilizer applications are expected to require the maximum use of water. Future use standards as shown in Table 2 are not expected to rise sharply, but by new application measures of sprinkler irrigation and by crop development that will require more seasonal moisture, it it anticipated that the total per acre supply of irrigation water needed by the year 2000 will be 24 inches annually. Improving the efficiency of irrigation systems in the future will not significantly decrease the total amount of water needed.

TABLE 2. Irrigation Use Standards for North Dakota

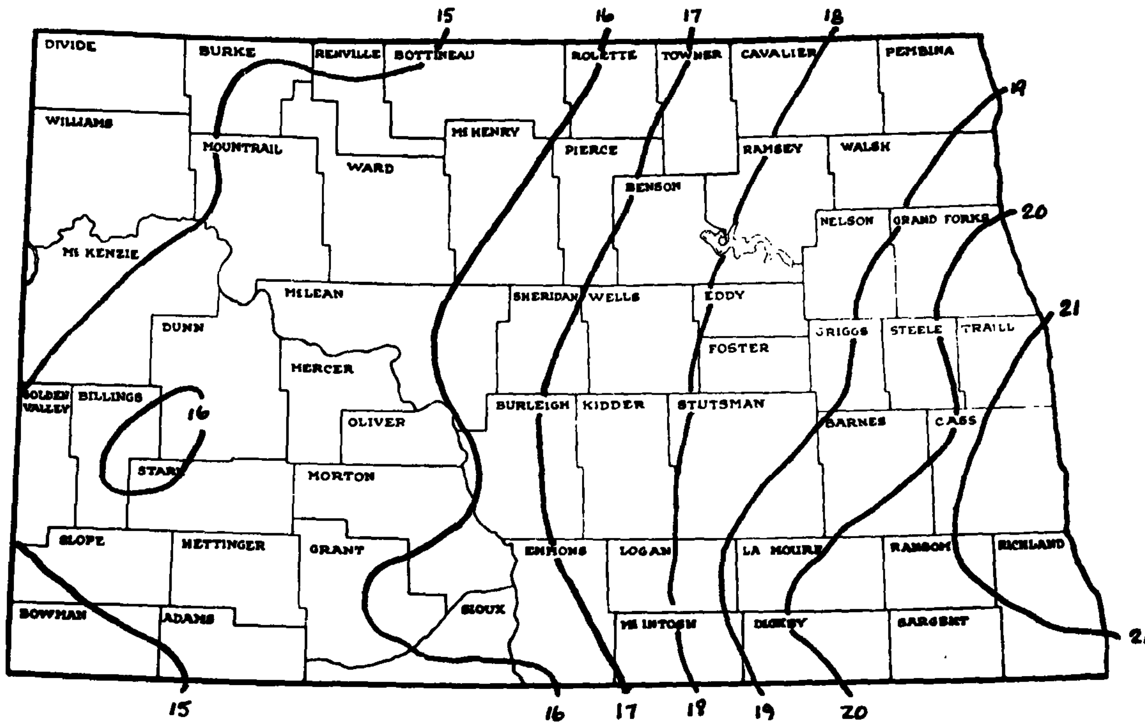
(Inches of Water Needed Per Acre Annually).	
1960	18
1980	21
2000	24

[8] *Product Research Report No. 53*, Agriculture Research Service, North Dakota State University, pp. 28-29.

[9] *Water Supply Book 1A-Hydrology, Appendix II*, U. S. Bureau of Reclamation, p. 28, and *Sprinkler Irrigation*, U. S. Bureau of Reclamation, December 1949, (revised), p. 13.

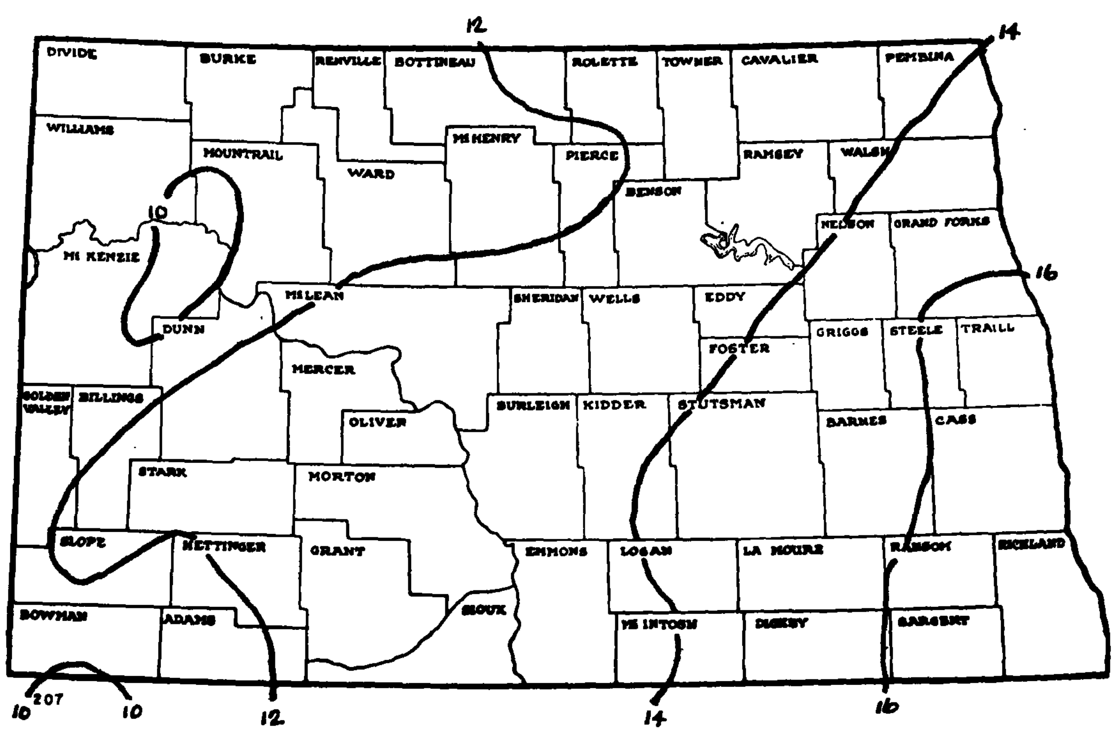
[10] *Climate of the States: North Dakota*, U. S. Department of Commerce, Washington, D. C., p. 1.

FIGURE 2



Average Annual Precipitation (Inches)
Bases on records from 1898-1952 Inclusive

FIGURE 3



Average Annual Precipitation (Inches)
Occurring during the growing season

Industrial Water Use Standards

Many of the industrial water uses in the State are included in the standards set for municipalities. The same is true of some commercial services which are sometimes referred to as industrial. For the purpose of planning, a listing of industrial requirements is shown to allow for separate projections for some of the uses now furnished by municipal water supplies.

Limited records for industrial use in North Dakota make it impossible to set up standards for actual State industrial operations. Table 1 was compiled by the American Water Works Association. The quantities reported below are clearly those of water intake, that is, the amount which is piped into an establishment, rather than consumptive use; the amount discharged to the atmosphere or incorporated into the products of a process. Thus, the wide ranges reflect not only differences in processes or products, but differences in the use of water. In arid areas, where even the most rigorous conservation methods are economically feasible, "intake" is only a fraction of what it may be in areas where water is abundant, although "consumptive use" is virtually the same.

TABLE 1. Industrial Use Standards"

	Production Unit	Water Required (Gallons)
Chemicals		
Alcohol, Industrial (100 proof)	gal.	120
Alumina (Bayer Process)	ton	6,300
Ammonium Sulfate	ton	200,000
Butadiene	ton	20,000-660,000*
Calcium Carbide	ton	30,000
Carbon Dioxide (from flue gas)	ton	20,000
Cottonseed Oil	gal.	20
Gunpowder or Explosives	ton	200,000
Hydrogen	ton	660,000
Oxygen, Liquid	1,000 cu. ft.	2,000
Soap (laundry)	ton	500
Soda Ash (ammonia soda process) 58%	ton	18,000
Sodium Chlorate	ton	60,000
Sulfuric Acid (contact process) 100%	ton	650-4,875*
Foods		
Bread	ton	500-1,000**
Canning	100 cases No. 2 cans	750-25,000**
Corn (wet-milling)	bu. corn	140-240**
Corn Syrup	bu. corn	30-40**
Gelatin (edible)	ton	13,200-20,000**
Meat:		
Packing	ton live animals	4,130
Packing House Operation	100 hog units	55,000
Milk and Milk Products:		
Butter	ton	5,000
Cheese	ton	4,000
Receiving and Bottling	ton	9,000
Sugar:		
Beet Sugar	ton	2,100
Cane Sugar	ton	1,000
Paper and Pulp		
Ground Wood Pulp	ton dry	4,000-5,000*
Kraft Pulp	ton dry	93,000
Soda Pulp	ton dry	85,000
Sulfate Pulp	ton dry	70,000
Sulfite Pulp	ton dry	70,000-133,000*
Paper	ton	39,000
Paperboard	ton	15,000-90,000*
Strawboard	ton	26,000
Petroleum		
Gasoline Natural	gal.	20
Oil Refining	100 bbl.	77,000
Refined Products	100 bbl.	15,000-1,500,000*

	Production Unit	Water Required (Gallons)
Synthetic Fuel		
By Coal Hydrogenation	100 bbl.	728,600
From Coal	100 bbl.	1,115,000
From Natural Gas	100 bbl.	373,600
From Shale	100 bbl.	87,300
Textiles		
Cotton:		
Bleaching	ton produced	60,000-80,000
Dyeing	ton produced	8,000-16,000
Rayon		
Cuprammonium (11% moisture)	ton yard	90,000-160,000**
Viscose	ton yard	200,000
Weave, Dye and Finish	1,000 yard	15,000
Woolens	ton produced	140,000
Miscellaneous		
Cement, Portland	ton	750
Coal and Coke:		
By Product Coke	ton	1,500-3,600**
Washing	ton	200
Electric Power, Steam-Generated	kwhr	-50***
Hospitals	bed per day	135-150
Iron Ore (pig iron)	ton	1,000
Laundries:		
Commercial	ton work	8,600-11,400**
Institutional	ton work	6,000
Leather Tanning:		
Vegetable	100 bbl, raw hide	800
Chrome	100 bbl, raw hide	800
Rock Wool	ton	5,000
Rubber, Synthetic:		
Buna S	ton	631,450
GR-S	ton	28,000-670,000*
Steel (rolled)	net ton	15,000-110,000*
Sulfur Mining	ton	3,000

NOTE: *Ranges from no reuse to maximum recycling.
**Ranges according to products or processes involved.
***Based on a flow requirement for cooling water of 850 gallons per minute per megawatt which is independent of the type of cooling — flow through, cooling pond or cooling tower.

Mining Use Standards

Use standards for mining are limited to instances where water is used in obtaining non-renewable resources, namely sand, gravel, and petroleum. Other mineral production such as salt mining, lignite briquetting and other mining operations use insignificant amounts of water. The future uses of water for mining operations are anticipated to remain nearly constant. Increased efficiences of operation should hold in line the amount of water needed to produce a unit of product.

Sand and gravel wash plants operate in nearly all of the State's 53 counties. Sand and gravel operations vary in the amount of production, and the water use standards shown in Table 1 are based on an average of the sand and gravel wash plant operations.[12]

[11] "Willing Water," American Water Works Association, December, 1953.
[12] North Dakota Redi-Mix Association, Bill Faiman, Secretary, Bismarck, North Dakota.

TABLE 1. Present Water Use for Sand and Gravel Wash Plants*

Water recirculation from settlement pool —	300 acre-feet annually
Fresh water to recharge settlement pool —	60 acre-feet annually

NOTE: *Average operations of 200 eight-hour days annually.

Petroleum mining use of water other than salt or polluted waters has been limited to a few wells where additional unpolluted water has been used to remove excess salts from petroleum crude. This situation occurs mainly in the Red River and the Devonian geological formations. Oil well operators are now increasing production via "secondary recovery" by pressurizing an oil field pool as a unit.

This is accomplished by first removing the crude oil and then replacing it with water. Salt water removed from the petroleum crude is supplanted by unpolluted water to make up the necessary volume. Table 2 shows the anticipated amount of water needed per oil well pumping from the Madison geological formation at the Charlson and Blue Buttes fields located in McKenzie County. It is a policy of the State Water Commission to require the use of mineralized water in such operations, wherever available, rather than the better quality water which may be needed for agricultural and other industrial use. As a consequence, the Petroleum Use Standards noted in the following Table are applicable when nonmineralized water is being used.

TABLE 2. Petroleum Use Standards

	Charlson Field	Blue Buttes Field
Producing Wells	98	129
Approximate 1966 Oil Production (Bbls)*	1,229,760	1,765,162
Approximate 1966 Water production (Bbls)*	603,754	221,946
Approximate 1966 Gas Production (MCF)**	2,614,654	4,714,346
Supplemental Water Needed for One Year (Bbls)*	6,570,000	12,410,000
Total Acre-Feet of Supplemental Water Needed for One Year	840	1,450
Approximate Acre-Feet of Supplemental Water Needed For One Year Per Well	8.6	11.6

Bbls – 42 Gallons
MCF – Million Cubic Feet

Water Quality Use Standards

A set of standards, recently adopted by the State Health Department, requires that water be maintained at certain levels for pollution abatement and quality control. Specific standards are discussed in another section of this report entitled "Quality Control Use." Use standards for water quality indicate the amount of water needed to dilute polluted water to a degree where it may once again be usable.

Many variables must be considered in establishing quality control use standards for the beneficial use of water. Municipalities may differ in the percent of bacteria removed from sewage, and the streams these sewage wastes are emptied into vary greatly in their capacity to dilute the wastes. Wide ranges occur in the amounts of suspended solids present in the effluent released from industrial or processing plants. In agricultural uses such as irrigation, the variance in pollution may be due to soil texture, soil content, the quality of water being applied, and drainage of the irrigated lands.

For design purposes and for operation of present sewage, industrial, or other waste treatment facilities, the following effluent standards are established.[13]

1. Five-day biochemical oxygen demand (BOD): 25 mg/liter daily average with no peak exceeding 50 mg/liter
2. Suspended solids:
   30 mg/liter daily average with no peak exceeding 60 mg/liter (One mg/liter is similar to one part per million, PPM)

The BOD of the daily pollution load for combined sewage is estimated in North Dakota to be .2 pounds per capita. After secondary sewage treatment, most effluents from municipal sewage disposals are .05 pounds or less per capita per day. For industrial and other wastes, the population equivalent (P.E.) can be substituted. Dilution requirements for the discharges of untreated, combined sewage are as high as eight cubic feet per second of flow per 1,000 persons.[14] After secondary treatment, removing an average of 75 percent of the BOD, this flow could be reduced to 2.0 cfs per 1,000 persons. Most North Dakota municipalities are now in excess of 80 percent in their treatment of sewage.[15]

Studies by the Water Supply and Pollution Control Division of the North Dakota State Health Department are not complete enough at this time to establish a table of use standards for uses other than Domestic and Municipal.

Fish, Wildlife and Outdoor Recreation Use Standards

Use standards for this category listed in Table 1 were extracted from "The Standards Study" published by the State Outdoor Recreation Agency.[16] The purpose of the Standards Study was to form a bridge between demand and supply studies and to relate the effective acres of facilities to the number of people those facilities can serve. The Standards Study determines the number of persons an effective acre or mile of outdoor recreation facility can accommodate in one day, the facilities here being water surface expressed in acres. Chapter IX explains the "composite model" numbers used to determine recreation acres.

The space standards in all cases are determined to be those which are applicable to the preferences and customs of North Dakota people who are accustomed to, and prefer, uncongested space for their

[13]"Plan for Implementation of Water Quality Standards," *Water Quality Standards for Surface Waters of North Dakota,* North Dakota State Department of Health, Bismarck, pp. 3-4.

[14]Harold E. Babbitt, *Sewerage and Sewage Treatment,* Sixth Edition, p. 334.

[15]North Dakota Department of Health.

[16]*Standards of Capacity and Use: North Dakota State Outdoor Recreation Plan,* North Dakota State Outdoor Recreation Agency, Bismarck, 1966, p. IV; *The Long Range Plan to 1980: North Dakota State Outdoor Recreation Plan,* North Dakota State Outdoor Recreation Agency, Bismarck, 1966, p. 41; and "Fishing Capacity and Use Guidelines," *Standards of Capacity and Use: North Dakota State Outdoor Recreation Plan,* North Dakota State Outdoor Recreation Agency, Bismarck, 1966.

outdoor recreation pursuits. Through consideration of these space standards in development of future outdoor recreation areas and facilities, persons seeking recreation in the North Dakota out-of-doors will be assured of the quality recreational opportunities to which they are entitled.

TABLE 1. Summary of Person Capacities and Seasonal Days

Activity	Seasonal Days of Use	Average Daily Capacity*	Av. An. Cap.*
Fishing — Game Fish	42 weeks	30-37	34
Fish Habitat**	—	—	—
Waterfowl Hunting	Varies	Varies	3.7
Waterfowl Habitat**	Varies	Varies	
Boating and Water Skiing	109	0.8	87

*Average Daily or Annual Capacity expressed as persons per effective surface acre of water.

**Production Standards are subject to extreme variation due to uncontrollable factors such as weather, water levels and water chemistry. The size of a lake is not necessarily an indication of its general productivity. Generally, however, the proportionate production of fish is higher per acre in smaller lakes than it is for larger lakes. Production for trout ranges from approximately 250 pounds per acre in lakes of up to 25 surface acres to 150 pounds per acre for lakes of 151 to 400 surface acres.

Production of pike, walleye and bass ranges from about 80 pounds per acre in lakes of 5,000 surface acres. Lakes with up to 200 surface acres can produce about 120 pounds of panfish per acre whereas 105 pounds are produced per acre in lakes of 1,000 or more surface acres.

The production capacity of waterfowl habitat is likewise subject to extreme variation. In the absence of any firm standard, a general guideline must serve. On the average, each dugout or stockwater pond can be expected to support 2.3 breeding ducks and each tract of wetlands can be expected to support 4.6 ducks, for an average duck breeding population of 1.5 million birds and a hunting supply of 2.4 million birds.

PRESENT AND PROJECTED WATER USE

The principal uses of water in North Dakota include the following: Municipal and Domestic, Livestock, Irrigation, Industrial, Mining, Quality Control, and Fish-Wildlife-Outdoor Recreation. An essential element of the planning process involves the assessment of present water use and the projection of future use. Present use has been determined by a combination of means including, but not limited to the following: water permits granted, population, interviews with actual users, and official Water Commission records. Future uses have been calculated on the basis of projected population figures and anticipated economic and industrial development.

Domestic and Municipal Water Use in North Dakota

Population figures used herein for farm, rural nonfarm, and urban populations were developed by economic regions whose boundaries follow county lines and also approximate the actual boundaries of the basins mentioned above.

Population figures used for 1960 are actual population figures from the 1960 United States Census. The 1980 population figures were taken from "The People Study" developed as part of the North Dakota Outdoor Recreation Plan by Elmer C. Vangsness, Resource Economist, of the North Dakota State University Extension Service at Fargo, North Dakota.

After the total State farm, rural nonfarm, and urban population figures for the year 2000 were developed, they were distributed among the five major basins on a percentage basis. It was assumed that the approximate percentage distribution of farm, rural nonfarm, and urban population per basin in the year 2000 would be equal to the percentage of farm, nonfarm, and urban population of the total population in 1980.

Table 1 is a compilation of the total State farm, rural nonfarm, and urban population by basin in North Dakota for 1960, 1980 and 2000.

TABLE 1. Total State Farm, Rural Nonfarm, and Urban Population by Basin for 1960, 1980, and 2000 — North Dakota.

YEAR	Type of Population	RIVER BASIN MISSOURI	JAMES	SOURIS	DEVILS LAKE	RED	STATE TOTAL
	Farm	73,141	23,263	30,570	14,702	63,227	204,903
1960	Rural Nonfarm	71,110	23,097	36,912	14,536	60,195	205,850
	Urban	60,032	15,163	36,189	6,298	104,011	221,693
	TOTAL	204,283	61,523	103,671	35,536	227,433	632,446
	Farm	50,000	16,400	20,700	10,200	43,500	140,800
1980	Rural Nonfarm	68,800	18,600	51,900	15,400	66,200	220,900
	Urban	93,300	29,100	51,800	8,300	154,800	337,300
	TOTAL	212,100	64,100	124,400	33,900	264,500	699,000
	Farm	59,100	19,700	21,700	12,900	46,300	159,700
2000	Rural Nonfarm	119,500	33,900	77,100	30,300	101,200	362,000
	Urban	185,900	55,500	84,200	20,000	252,800	598,400
	TOTAL	364,500	109,100	183,000	63,200	400,300	1,120,100

Domestic water use includes both farm and rural nonfarm water use. Municipal water use is based on urban population. Table 2 is a compilation of the domestic and urban populations in North Dakota for 2000. Domestic population for each basin is determined by adding together the farm and rural non-farm populations.

TABLE 2. Domestic and Urban Population by Basin for 1960, 1980 and 2000 — North Dakota.

YEAR	Type of Population	RIVER BASIN MISSOURI	JAMES	SOURIS	DEVILS LAKE	RED	STATE TOTAL
1960	Domestic	144,251	46,360	67,482	29,238	123,422	410,753
	Urban	60,032	15,163	36,189	6,298	104,011	221,693
	TOTAL	204,283	61,523	103,671	35,536	227,433	632,446
1980	Domestic	118,800	35,000	72,600	25,600	109,700	361,700
	Urban	93,300	29,100	51,800	8,300	154,800	337,300
	TOTAL	212,100	64,100	124,400	33,900	264,500	699,000
2000	Domestic	178,600	53,600	98,800	43,200	147,500	521,700
	Urban	185,900	55,500	84,200	20,000	252,800	598,400
	TOTAL	364,500	109,100	183,000	63,200	400,300	1,120,100

Daily use rates used in developing domestic and municipal water needs for each basin were taken from the Water Use Standards Section in the North Dakota State Water Plan. Use rates given below are in gallons per day per person.

	1960	1980	2000
Domestic	50	55	60
Urban	115	130	150

Domestic and municipal water uses shown in Tables 3 and 4 respectively are given in acre-feet per year for each basin in 1960, 1980, and 2000. One acre-foot of water is equal to 325,851 gallons.

TABLE 3. Domestic Water Use by River Basin — North Dakota.

RIVER BASIN	1960	1980	2000
Missouri	8,070	7,320	12,000
James	2,600	2,160	3,600
Souris	3,780	4,470	6,550
Devils Lake	1,640	1,580	2,940
Red	6,910	6,750	9,900
TOTAL	23,000	22,280	34,990

TABLE 4. Municipal Water Use by River Basin — North Dakota.

RIVER BASIN	1960	1980	2000
Missouri	7,730	13,570	31,200
James	1,950	4,240	9,310
Souris	4,660	7,540	14,150
Devils Lake	810	1,210	3,360
Red	13,400	22,500	42,500
TOTAL	28,550	49,060	100,520

TABLE 5. Total Domestic and Municipal Water Use by River Basin in Acre-feet Per Year — North Dakota.

RIVER BASIN	1960	1980	2000
Missouri	15,800	20,890	43,200
James	4,550	6,400	12,910
Souris	8,440	12,010	20,700
Devils Lake	2,450	2,790	6,300
Red	20,310	29,250	52,400
TOTAL	51,550	71,340	135,510

Present and Projected Livestock Water Use in North Dakota

Figures representing the livestock population in each North Dakota drainage basin were taken from the **Biennial Report of the North Dakota Department of Agriculture and Labor (1964 to 1966).** Livestock population figures were developed on the basis of economic regions whose boundaries follow county lines, but closely approximate actual drainage basin boundaries. Projections of livestock populations for 1980 and 2000 were made on the basis of a two percent compound annual increase. This annual increase in livestock numbers is applicable to all classes of livestock.

To determine average water consumption for livestock, the following rates of water use in gallons per day per head were used in compiling this report. Water use rates shown in Table 1 were taken from the Water Use Standards Section of the North Dakota State Water Plan. Livestock use standards are shown for 1965, 1980 and 2000.

TABLE 1. Livestock Water Use Standards — North Dakota.

SPECIES OF LIVESTOCK	Use Per Head (G.P.D.) 1965	1980	2000
Milk Cows	30	33	36
Beef Cattle	12	13	15
Hogs	4	4.5	5
Sheep	2	2.2	2.5
Chickens	0.06	0.08	0.1
Turkeys	0.18	0.2	0.22

Livestock water use is shown in the following Table for each basin in acre-feet per year. One acre-foot of water is equivalent to 325,851 gallons.

TABLE 2. Livestock Water Use in Acre-Feet Annually by Drainage Basin

BASIN	Current	1980	2000
Missouri River	13,387	19,297	32,677
James River	3,971	5,723	9,666
Souris River	3,111	4,472	7,565
Devils Lake	1,263	1,822	3,072
Red River	5,228	7,573	13,007
Totals	26,960	38,887	65,987

PRESENT IRRIGATION USE[17]

	Acres Irrigated Annually	Acre-Feet Used Annually
Missouri River		
Mainstem	35,308	63,554
Direct West Tributaries	1,242	1,255
Direct East Tributaries	10,514	16,790
Yellowstone River	16,421	31,163
Little Missouri River	3,597	3,597
Knife River	1,875	1,875
Heart River	10,892	20,876
Cannonball River	2,893	3,458
Grand River	952	976
TOTAL — **Missouri River Basin**	83,694	145,419
James River Basin	2,873	4,762
Souris River Basin	8,804	14,086
Devils Lake Basin	130	208
Red River — Mainstem	1,742	2,787
Wild Rice River	705	1,144
Sheyenne River	3,021	4,834
Elm River	——	——
Goose River	150	221
Turtle River	188	293
Forest River	150	197
Park River	89	165
Pembina River	56	100
TOTAL — **Red River Basin**	6,101	9,741
GRAND TOTAL — **All Basin**	101,602	174,216

PROJECTED IRRIGATION USE[18]

The demand for water in the upper midwest area of the United States is increasing rapidly as the result of several factors, including an increasing population, per capita consumption of water, emphasis on water based recreation, municipal and industrial uses, and increasing amounts of land being irrigated. As the demands for water increase, given a relatively stable supply, careful planning of water development becomes increasingly important.

[17]Based on 70 percent use of Water Permits granted determined from Annual Use Reports as reported to the State Water Commission (1966).

[18]Prepared by Department of Agricultural Economics, North Dakota State University, Agricultural Experiment Station, Fargo.

The State of North Dakota is endowed with abundant supplies of water from various sources. It is available in natural streams and lakes, underground aquifers, and man-made impoundments, but unfortunately, it is not always available in sufficient quantities at the time and location to fulfill particular demands.

The value of a natural resource is determined in large part by its availability at the time and location most critically needed. In most cases, capital and labor must be employed to make water available at a particular time and location to fulfill a particular demand. Planners must determine the relative economic benefits forthcoming by investing a given amount of money in several alternative water development projects. One criterion available to planners in making this allocation decision is value in use. Therefore, it is necessary to determine the value of water developed for agricultural purposes, in particular, irrigation.

The irrigation of agricultural land is increasing in North Dakota, and with the development and completion of the proposed Garrison Diversion Project, North Dakota will have about 1.3 million acres of irrigated land.

Development of irrigation is of major importance to both North Dakota and the United States. Each year, productive farm land in the United States decreases by about one million acres due to industrial and municipal expansion, highways, airports, golf courses, defense areas, parks, and other development projects. Increased production on the remaining land will be necessary in the future if the food and fiber needed to meet the consumption demand of a larger population is to be met. The increased consumption demand of the 1950's was met by increased production per acre mainly through technology advancements, such as irrigation, fertilizer, improved seed, mechanization, and conservation. It was estimated that increased irrigation development accounted for five to 10 percent of the increase in per acre production from 1951 to 1955, while additional uses of fertilizer contributed about two-thirds of the increased per acre production during this time period.[19]

Irrigation is a means of intensifying the use of land. It can provide for increased production and income from a given land area while also stabilizing income and production. For example, a study comparing dry land and irrigation farming in North Dakota indicates that the physical production of crops and the resulting net income were increased by the use of irrigation.[20] The study also concluded that yield, gross income, and net income variability per farm were reduced by irrigation. The farm yields were stabilized more by irrigation than was net farm income.

Irrigation may alleviate the problems of drought and low net returns per acre faced by North Dakota farmers. Irrigation provides protection against drought, but the value of irrigation as drought insurance depends on the value of the crop grown. Production can be increased by irrigation because crops need the right amount of moisture to obtain the most profitable yields per acre. The increased yields can provide higher net returns per acre than were previously obtained under dry land conditions. Irrigation may also improve the quality and date of maturity for crops, also resulting in higher net returns per acre.

The general objective of research carried on by members of the Agricultural Economics Department of North Dakota State University and reported herein was to determine the most profitable level of irrigation development in the State. Specific objectives were:

(1) To develop methodology for determining the most profitable level of water resource development for irrigation in North Dakota.

(2) To make tentative estimates of future water use and development and the corresponding levels of aggregate supply of agricultural products.

(3) To estimate the potential primary income attributable to water resource development for irrigation in North Dakota.

The geographic areas to which the results of the North Dakota State University study apply include the Missouri, James, Souris, Devils Lake, and Red River drainage basins of North Dakota. (Table 1).

Topography, soil types, rainfall, and crops vary within as well as between drainage basin.

[19]Marvin G. Smith. (ed.), *Adjustments in Agriculture – A National Basebook,* Iowa State Press, Ames, Iowa, 1963, pp. 162-163.

[20]Duane C. Vockrodt. *Risk Measures for Income of Crops and Livestock on Irrigation and Dry Land,* Unpublished M. S. Thesis, North Dakota State University, Fargo, North Dakota, 1961, pp. 75-79.

TABLE 1. Area and Population of Each Major Drainage Basin in North Dakota and Totals for the State

ITEM	DRAINAGE BASIN					STATE TOTAL
	MISSOURI	JAMES	SOURIS	DEVILS LAKE	RED	
Area (Square Miles)						
Hydrologic	33,902	6,910	9,321	4,710	15,822	70,665
Economic	33,408	7,133	11,102	4,829	14,193	70,665
1960 Population	204,283	61,523	103,671	35,536	227,433	632,446

The Linear Programming Procedure

Linear programming is a planning method that is often helpful in decision making which requires a choice among a large number of alternatives. The theoretical concepts upon which the method depends has been known for many years. However, it was during World War II and immediately after that its application to real planning problems first was stressed.

Linear programming is a mathematical technique dealing with non-negative solutions to undetermined systems of linear equations. There are many types of problems that can be formulated into a linear programming framework. The application of linear programming to a specific problem requires that the problem possess three components as follows: an objective, a large number of alternatives to be considered simultaneously, and one or more resource restrictions. The problem analyzed in this study possesses all three of these characteristics. First of all, it is assumed the farmers in the area are concerned about achieving the maximum profit possible with their available resources. Secondly, there are several alternatives available for achieving the objective. Thirdly, there exists limited supplies of resources restricting the number and size of enterprises and level of profit. One of these limiting resources is water for irrigation.

The profit maximizing linear programming model was used in the North Dakota State University study. Given two or more alternative means of achieving the objective, the model chooses the alternative or combination of alternatives which results in the maximum returns possible within the limits of the available resources. The usefulness of this technique is enhanced by the relative efficiency with which it simultaneously handles large numbers of alternative production activities.

The profit equation to be maximized is of the general form

$$II = \overset{n}{\underset{j-1}{E}} Cj \quad Pj$$

where the Cj's are either net revenue per unit of output or costs per unit of input and Pj's are the production activities which appear in a feasible solution. The combination of Pj's multiplied by their respective Cj values which yields the greatest amount of profit is the organization which satisfies the objective of the model.

The Empirical Model

The accuracy of the solutions obtained with any linear programming model is directly related to the exactness of the data pertaining to the variables analyzed. Data for dry land enterprises were obtained from North Dakota Crop Cost and Returns. Above average management practices were incorporated into the models to simulate results applicable to 1980. Since the economic areas and river basins are not synonymous geographically, costs were weighted depending on the areas in each basin.

Data reflecting the acres of potentially irrigable land within each basin were made available by North Dakota State University Soils Department at the request of the North Dakota State Water Commission. The acres actually irrigated in each basin was a function of available irrigation water. Each basin was programmed for five different water levels. On the first run, water was not considered a restriction and the program utilized the maximum amount of water profitable for irrigation. This optimum water supply was reduced by 25, 50, 75, and 100 percent, respectively, to obtain the other four levels. Throughout the study, the return realized was interpreted as return to management and irrigation water applied.

Crop Enterprises

The dry land crop enterprises considered as production alternatives in each basin included wheat, barley, oats, flax, corn silage, alfalfa, and pasture. Corn grain, soybeans, potatoes and sugar beets were also included as alternatives in the Red River Basin. Wheat on fallow was an activity in each drainage basin except the Red River Basin. The Missouri River Basin was the only basin where wheat had to follow fallow. Sugar beets were also assumed planted on fallow.

All dry land production alternatives were considered as potentially irrigable in all basins except corn grain and soybeans, which were alternatives only in the Red and James drainage basins. Yields are presented in Tables 2 and 3.

TABLE 2. Assumed Yields Under Dry Land

DRY LAND ITEM	Unit	DRAINAGE BASIN Missouri	James	Devils Lake	Souris	Red
Wheat Fallow	bu.	25.7	29	28	28	32.5
Wheat	bu.	—	23.5	22	22	27.5
Barley	bu.	30.3	35	31.5	31.5	40
Oats	bu.	41.7	46	40.5	40.5	55
Flax	bu.	8.9	10	9	9	11
Corn Silage	ton	5	6.2	5.4	5.4	8.3
Corn Grain	bu.	—	—	—	—	45
Alfalfa	ton	1.5	2.0	1.6	1.6	2.4
Soybeans	bu.	—	—	—	—	20
Potatoes	cwt.	—	—	—	—	140
Sugar Beets	ton	—	—	—	—	13.5

TABLE 3. Assumed Yields Under Irrigation

Irrigation Item	Unit	DRAINAGE BASIN Missouri	James	Devils Lake	Souris	Red
Wheat	bu.	36	36	36	36	36
Barley	bu.	54	58.5	54	54	58.5
Corn Silage	ton	13.5	18	13.5	13.5	18
Corn Grain	bu.	----	90	----	----	90
Alfalfa	ton	4.3	5	4.3	4.3	5
Soybeans	bu.	----	31.5	----	----	31.5
Potatoes	cwt.	243	270	243	243	270
Sugar Beets	ton	16.2	18	16.2	16.2	18
Oats	bu.	72	85.5	72	72	85.5
Flax	bu.	----	----	----	----	----

Livestock Enterprises

Livestock enterprises were restricted to cattle. The type of livestock activities varied among the basins. Missouri and Souris Basins were restricted to a cow-calf operation which included selling the calf at 400 pounds. The James and Red Basins were restricted to a buy-calf operation and only to the extent they were produced in the Missouri and Souris Basins. A buy-calf operation presumed buying a calf at 400 pounds and selling at 1,000 pounds. The Devils Lake Basin included a cow-calf operation. Alternatives with this operation included selling the calves at 400 pounds, wintering and grain feeding to 700 or 1,000 pounds.

In each basin, the option was present either to feed hay or hay and silage. A choice was also provided for feeding barley or oats. Corn was also a choice in the James and Red Basins.

Resource Restrictions

The resource restrictions developed for each basin are presented in Table 4.

Land and Allotments

The amount of crop land, native hay and native pasture in each drainage basin was determined by correlating the five drainage basins with land resource areas as outlined in the Missouri River Basin Study.

Due to the uncertainty of government programs, it was assumed wheat acreage would not exceed the 1962 through 1966 average acres planted. The procedure was used to establish corn and potato acreages for the Red River Basin, but these acreages were adjusted upward 15 percent. Potato allotments for the other four basins were arbitrarily assigned. Sugar beet allotment for the Red Basin was based on present acreage, increased allotments by present plants and the two new proposed plants at Harwood and Wahpeton, North Dakota. Each of the other basins was alloted acreage to supply one sugar beet processing plant.

TABLE 4. Resource Restrictions for Drainage Basins

ITEMS	Unit	DRAINAGE BASIN Missouri	James	Devils Lake	Souris	Red
Crop Land	Acre	4,678,409	3,274,995	2,487,741	3,928,184	8,472,660
Native Hay	Acre	11,631,398	123,981	66,686	221,354	245,242
Native Pasture	Acre	11,989,791	997,810	474,635	1,838,777	1,131,840
Wheat Allotment	Acre	2,496,300	608,000	627,266	1,258,200	1,676,200
Sugar Beet Allotment	Acre	66,000	66,000	66,000	66,000	150,000
Potato Allotment	Acre	50,000	50,000	25,000	10,000	125,000
Corn Allotment	Acre	----------	----------	----------	----------	175,000
Irrigation Land	Acre	1,171,396	203,682	210,210	739,146	1,578,570

Prices

The assumed input and product prices used in the study are summarized in Table 5. Crop commodity price was taken from Crop Costs and Returns. When differences in prices occurred among economic areas, the weighted average price was determined for use in this study.

Livestock prices were derived from yearly average quotations of selected livestock at West Fargo Union Stockyards. To include all different classes of livestock into one selling activity in the Devils Lake Basin, a statistical regression was used to express the price of each class of livestock in terms of a base price for livestock. Then the selling price for all classes of other livestock will be expressed as a function of the price established for the base livestock class. For this study, the base price for a 400 pound feeder steer was used.

Capital

A restriction was not placed on capital availability in this study. It was assumed capital could be acquired if it was profitable. Capital costs varied depending on its use. An interest rate of seven percent was charged on capital used for irrigation equipment, livestock enterprises, and operating expenses. Capital used for machinery and equipment carried a six percent interest charge on the average annual investment. A land charge of 5.5 percent of the current value of crop land was also included as a cost.

TABLE 5. Assumed Crop Commodity Prices Used in Programming Analysis

ITEMS	Unit	PRICE (Dollars Per Unit) Missouri	James	Devils Lake	Souris	Red
Wheat	bu.	1.80	1.85	1.85	1.80	1.90
Barley	bu.	.80	.90	.85	.80	.95
Oats	bu.	.58	.67	.64	.58	.70
Flax	bu.	2.80	2.85	2.85	2.80	2.90
Corn	bu.	———	1.10	———	———	1.15
Alfalfa	ton.	14.00	14.00	14.00	14.00	14.00
Sugar Beets	ton	13.50	13.50	13.50	13.50	13.50
Potatoes	cwt.	1.40	1.40	1.40	1.40	1.40
Barley Purchased	cwt.	———	1.10	1.05	———	1.15
Sell Beef	cwt.	26.00	24.00	26.00	26.00	24.00

Labor

This study assumed no operator labor supply was available and no restriction was placed on the amount of labor available. However, unless a return of $1.50 per hour was realized, labor was not hired. Migrant labor for sugar beets was included as a production cost. One and eight tenths hours per acre of additional labor was required for land under irrigation. This included time spent getting the system ready for operation in the spring and preparing it for winter in the fall. An additional .5 hours per acre was needed for each application of water applied.

Irrigation Costs

Irrigation costs assumed in this study are summarized in Table 6. Due to new innovations in sprinkler systems increasing the irrigable acres in North Dakota, it was the only method of irrigation considered in this study. Variable costs of irrigation include the cost of energy required for pumping, lubricants, repairs, and maintenance of all irrigation facilities and equipment. Fixed costs include depreciation, insurance, and taxes. Interest on investment is not included in the fixed cost figure. Capital investments in irrigation were accounted for separately in each model.

TABLE 6. Irrigation Costs Used in Linear Programming Analysis

Item	Cost Per Acre
Capital Investment	$ 91.75
Fixed Costs	8.81
Variable Cost	4.15
Additional Fertilizer	
Small Grains	5.16
Corn	9.78
Alfalfa	3.75
Potatoes	15.00
Sugar Beets	15.00

The following tables summarizing Resource Requirements and the Value of Water are extracted from Appendix D, **An Economic Analysis of Water Resources Development for Irrigation in North Dakota, May, 1968.** They are included here for informational purposes and without interpretation. A detailed description of the methodology employed in developing these and other tables is found in the appendix.

TABLE 7. Programmed Optimum Resource Requirements and Income by Irrigation Water Availability Levels, Missouri Drainage Basin, North Dakota

Item	Irrigation Water Availability Level 0	1	2	3	4
Total water used, acre-feet		388,183	776,366	1,164,550	1,544,558
Land irrigated, acres		258,788	517,577	807,936	1,171,396
Capital required, dollars[a]		23,743,799	47,487,690	74,127,944	107,475,491
Labor required, hours	12,989,700	19,634,635	24,796,832	26,040,184	27,524,213
Net income, dollars	32,704,566	47,315,751	52,188,687	56,062,336	59,285,138
Changes in net income:					
From no irrigation, dollars		14,611,185	19,484,121	23,257,770	26,580,572
From preceding level of irrigation, dollars		14,611,185	4,872,936	3,873,649	3,222,802
Net income per acre, dollars	1.83	2.65	2.92	3.14	3.32
Net income from irrigation per acre-foot, dollars		37.63	25.09	20.05	17.20

[a]Capital requirements associated only with irrigation.

TABLE 8. Programmed Optimum Resource Requirements and Income by Irrigation Water Availability Levels James Drainage Basin, North Dakota

Item	Irrigation Water Availability Level				
	0	1	2	3	4
Total water used, acre-feet		76,386	152,772	229,058	305,523
Land irrigated, acres		50,924	101,848	152,705	203,682
Capital required, dollars[a]		4,672,277	9,344,554	14,010,683	18,687,823
Labor required, hours	9,619,525	10,121,171	10,235,376	10,541,751	10,854,238
Net income, dollars	40,099,865	44,796,383	48,052,588	50,429,123	52,804,254
Changes in net income:					
From no irrigation, dollars		4,696,518	7,952,723	10,329,258	12,704,389
From preceding level of irrigation, dollars		4,696,518	3,256,518	2,366,535	2,375,131
Net income per acre, dollars	9.12	10.18	10.93	11.47	12.01
Net income from irrigation per acre-foot, dollars		61.48	52.06	45.09	41.58

[a]Capital requirements associated only with irrigation.

TABLE 9. Programmed Optimum Resource Requirements and Income by Irrigation Water Availability Levels, Souris Drainage Basin, North Dakota

Item	Irrigation Water Availability Level				
	0	1	2	3	4
Total water used, acre-feet		115,806	231,612	347,418	463,224
Land irrigated, acres		77,204	154,408	231,612	308,816
Capital required, dollars[a]		7,083,467	14,166,934	21,250,401	28,333,868
Labor required, hours	9,625,428	10,339,722	10,177,809	10,273,233	10,810,931
Net income, dollars	24,196,590	29,137,710	29,971,299	30,721,924	31,146,115
Changes in net income:					
From no irrigation, dollars		4,941,120	5,774,709	6,525,334	6,949,525
From preceding level of irrigation, dollars		4,941,120	833,589	750,625	424,191
Net income per acre, dollars	4.04	4.87	5.00	5.13	5.20
Net income from irrigation per acre-foot, dollars		42.67	24.93	18.78	15.00

[a]Capital requirements associated only with irrigation.

TABLE 10. Programmed Optimum Resource Requirements and Income by Irrigation Water Availability Levels, Devils Lake Drainage Basin, North Dakota

Item	Irrigation Water Availability Level				
	0	1	2	3	4
Total water used, acre-feet		62,834	125,668	188,502	251,336
Land irrigated, acres		41,889	83,778	125,668	167,557
Capital required, dollars[a]		3,843,315	7,686,631	11,530,039	15,373,354
Labor required, hours	3,850,015	4,380,161	4,737,060	5,071,751	5,269,627
Net income, dollars	17,582,097	22,311,363	24,364,255	25,014,349	25,320,222
Changes in net income:					
From no irrigation, dollars		4,729,266	6,782,158	7,432,252	7,738,125
From preceding level of irrigation, dollars		4,729,266	2,052,892	650,094	305,873
Net income per acre, dollars	5.80	7.37	8.04	8.26	8.36
Net income from irrigation per acre-foot, dollars		75.27	53.97	39.43	30.79

[a]Capital requirements associated only with irrigation.

TABLE 11. Programmed Optimum Resource Requirements and Income by Irrigation Water Availability Levels, Red Drainage Basin, North Dakota

Item	Irrigation Water Availability Level				
	0	1	2	3	4
Total water used, acre-feet		470,057	940,114	1,410,171	1,880,228
Land irrigated, acres		313,371	651,742	1,108,513	1,578,570
Capital required, dollars[a]		28,751,789	59,797,328	101,706,068	144,833,797
Labor required, hours	25,025,635	26,530,631	27,869,950	29,215,074	30,531,234
Net income, dollars	57,793,708	78,958,325	84,000,610	84,834,279	85,529,961
Changes in net income:					
From no irrigation, dollars		21,174,617	26,206,902	27,040,569	27,736,253
From preceding level of irrigation, dollars		21,164,617	5,042,285	833,667	695,684
Net income per acre, dollars	5.87	8.02	8.53	8.61	8.68
Net income from irrigation per acre-foot, dollars		45.03	27.88	19.18	14.75

[a]Capital requirements associated only with irrigation.

TABLE 12. Programmed Optimum Resource Requirements and Income by Irrigation Water Availability Levels, State of North Dakota

Item	Irrigation Water Availability Level				
	0	1	2	3	4
Total water used, acre-feet		1,113,266	2,226,532	3,339,699	4,444,869
Land irrigated, acres		742,176	1,509,353	2,426,434	3,430,021
Capital required, dollars[a]		68,094,648	138,483,238	222,625,320	314,704,427
Labor required, hours	61,110,303	71,006,320	77,817,027	81,141,993	84,990,243
Net income, dollars	172,376,826	222,519,532	238,577,439	247,062,011	254,085,690
Changes in net income:					
From no irrigation, dollars		50,142,706	66,200,613	74,685,185	81,708,864
From preceding level of irrigation, dollars		50,142,706	16,057,907	8,484,572	7,023,679
Net income from irrigation per Net income per acre, dollars		45.04	29.73	22.36	18.38

[a]Capital requirements associated only with irrigation.

Present Industrial Use

North Dakota's principal industry is agriculture, and expectations are that it will continue to maintain its first position. Our rich soil and our climate lend themselves to the production of a variety of important agricultural products. As a consequence, the great majority of manufacturing being carried on within the State is agriculturally-oriented.

Among the food items being produced in North Dakota in increasing quantities are: salt, sugar, butter, soft drinks, potato flakes, flavoring extracts, milk, honey, ice cream, meats, poultry products, eggs, sunflower seeds, candy, jelly and cheese. Many of these items were not manufactured in North Dakota prior to 1957, and the majority of them have noted great gains in the number of establishments, employment, production and value added by manufacturing. Industries catering primarily to the agricultural market in the State produce animal feeds, grain augers, grain boxes, electric branding irons, treated poles and posts, fertilizer, loaders and assorted farm machinery including plows, grain drills, loader tractors, rock pickers and fertilizer attachments.

Other North Dakota industries produce materials needed for construction including bridge planking, sewer tile, brick, cement blocks, lightweight aggregate, metal culverts and structural steel.

In addition to the industries mentioned above, numerous smaller industries are scattered throughout North Dakota. Products produced by these industries include: venetian blinds, jewel bearings, mattresses, maps, buses, ornamental iron work, pottery, rubber stamps, gasoline, tire-handling equipment, dressed and dyed furs, fishing lures, tanks for gas and oil, peat moss, swimming pools, garbage can racks, lubricants and neon signs.

State industries employing over 100 employees include one processing petroleum products, two processing dairy products, one processing grain, one processing meats, one processing potatoes, two bakeries, one which fabricates steel products, one which produces farm machinery, one assembles buses, one producing jewel bearings and three printing houses.

Among the North Dakota industries employing between 50 and 100 employees are two bakeries, one producing dairy products, one processing petroleum products, one sugar beet refinery, one printing firm, two potato processing plants, three processors of building materials, one milling firm, one manufacturer of lignite briquets, five manufacturers of farm machinery and a manufacturer of tire-handling equipment.

Smaller industrial plants employing from 20 to 50 employees are scattered throughout North Dakota. There are 79 plants of this size: 40 are engaged primarily in processing North Dakota's agricultural wealth, 17 are engaged in printing and publishing, eight in stone, clay and glass products and one in fabricating metal products.

North Dakota industrial development saw 22 industries begin operation during 1966. Among these new industries are: several manufacturers serving agricultural needs such as a seed processor, a meat products producer, three manufacturers of farm machinery and a cheese maker. Other products manufactured by these new plants include electrical controls, industrial air heaters, reinforced plastic materials, asphaltic concrete, concrete ready mix, auto-wash equipment, children's training devices, campers for pickup trucks, and commercial printing.[21]

Figures shown in the following Table for present industrial water use are based in part on the annual water use reports filed by those industries who have been granted water use permits by the State Water Commission. In order to account for the water being used by those industries operating in the State and not holding water use permits, it is assumed that these industries use the same amount of water annually as those industries producing similar products and of comparable size who do hold water use permits. Consumptive water use for these industries is assumed to range from three to 10 percent of the annual diversion.

TABLE 1. Present (1967) Annual Water Use in Acre-feet for Industrial Purposes in North Dakota.[22]

Industry	ANNUAL WATER USE IN ACRE-FEET Diversion	Consumptive Use
Power	295,700	8,870
Meat Packing	1,400	140
Petroleum Refining	4,000	200
Livestock Yards	2,000	200
Sugar Beet Refinery	4,000	400
TOTALS	307,100	9,810

[21]Torkelson. *Here Is the New North Dakota*, p. 29.

[22]Industries included in this Table are those which obtain water from other than municipal supplies.

Projected Industrial Use

In spite of its having been basically an exporter of raw materials, North Dakota has a conspicuous potential for industrialization. In order to improve and diversify its economy, the State is endeavoring to induce manufacturers to locate here. From 1954 to 1965, North Dakota displayed the third highest industrial growth rate in the United States.

Economic considerations seem to indicate the bulk of new industries locating in the State will be those that produce goods of reduced weight and volume for shipment to the market, those which can utilize our large amounts of inexpensive energy and those which can make use of raw materials found here and not found in areas near the larger market areas. The potential industrial plants appear to include electric power production, agricultural products processing, livestock feeding, livestock products processing, mineral finishing (ore-separation), petroleum-chemical industry and electro-metallurgical industries.

North Dakota's vast resources have been the subject of numerous new development plans by various segments of industry. The anticipated shift of population from the densely settled East and West to the central part of the United States will help accelerate the industrial growth of North Dakota. This shift will occur because the central portion of the Nation, from Texas to North Dakota, is the only area remaining that has the space available to provide homes for the growing millions of the National population. In addition, the Great Plains needs the industrial development and increased population to keep pace with the remainder of the Nation and if its actual and potential resources are to be developed. Because of its geographical location, North Dakota has a freight advantage in shipping manufactured goods either East or West.

With the completion of the Garrison Diversion Project, irrigation will undoubtedly alter the economy of the region, probably shifting agriculture more towards livestock and livestock products. Another industry which is expected to advance considerably is the mineral resources industry. Led now by coal and petroleum production, there are many mineral resources which await new development. All of these industrial developments must have an ample supply of good quality water. The Garrison Diversion Project will deliver water to many cities of the State — cities near which industry can be located.

Some of the other factors influencing and favoring North Dakota's future industrial development are:

Industrial and Agricultural Research at the Universities

Communities looking favorably toward the development of industry

Inexpensive land costs compared to other economic regions

Local government financing by issuing bonds
Tax exemptions while industry is starting out
Decentralized area in case of atomic warfare[23]

Electric power generating plants using lignite and water near their respective sources have demonstrated their ability to produce low-cost electrical energy. The future development potential of this industry is unlimited because of the huge reserves of coal and water available.[24]

Electric power costs are one of the main factors in the production of aluminum. It is quite possible in the near future that an aluminum producing industry will locate in the State, depending upon the future supply of hydroelectric power available for industrial use.[25]

Iron-ore processing is possible by using lignite and some added coke for carbon requirements. Research is now underway to perfect a process whereby lignite can be used exclusively. A limited number of steel products may soon be produced as a result of the possible location of such a plant in the State Electric pig iron is also a possibility with our inexpensive electrical supply. In this process a small amount of carbon is needed for the chemical reaction, the balance is done electrically. Lignite would be needed to produce the low cost electric energy.[26]

Ammonia and other fertilizer can now be made from either heavy fuel oil or from lignite, though the latter process needs more research. With an ever-growing demand for increased crop production, the products from such a fertilizer plant could be sold in a comparatively small area, eliminating high freight costs.[27]

Salt production is now underway in the State. Future developments in this field will be determined in large measure by the availability of new and expanded markets. One potential market for salt brine is the pulpwood industry in Minnesota and Wisconsin.[28]

Lignite can be used as a raw material for three processes of chemical production. Researchers are now at work developing processes which could result in new industry for North Dakota in the future. The first of these processes is carbonization — a process which reduces lignite to a tar containing phenol, cresols, xylenols and heavier acids. An accompanying large industrial plant would have to be built in order to burn the residual char thus making this an economical process. Hydrogenation which makes use of lignite to produce a liquid fuel, may be a second possible use of lignite. Feasibility of hydrogenation depends upon coal quality and available water supply. A third process, the gasification of lignite, now has no potential market. Future markets are anticipated as industry grows in the State.[29]

Natural gas and petroleum industries will grow as the production of these mineral resources continues and as the market for them grows. The natural gas industry has many areas of the State to bring within the reach of its products.[30]

Processing agricultural products will be one of the factors needed to help boost the farm economy. At present, negotiations are underway to process sugar beets at two plants, and certainly the Garrison Diversion area farmers could supply one or two of these sugar beet refineries in the future. The future can also mean more development of the potato processing industry and a barley malting plant. Also in line with agricultural processing is the livestock industry. The potential is here for one or two large meat packing plants along the Missouri River. The irrigation farmers in the area can provide finished livestock for such a plant.

The main rivers and their tributaries in North Dakota have many potential reservoir sites to serve industry. Plans have been made for some of these and future planning will include the development of additional storage facilities to meet the growing industrial demand. Water pollution will be held to a minimum because future industrial planning can be done with proper methods or safeguards to eliminate unnecessary pollution of the water supply.

Table 1 shows the projected water uses if the aforementioned plants are located in the State. It is assumed that these industrial uses will be supplied with water from sources other than municipal supplies. Projections shown for major food processing plants include the potato processing industry and expected development of new products to be grown and processed in North Dakota.

Present and Projected Mining Use

North Dakota has many mineral resources of economic value to the State. The majority of these mineral deposits are concentrated in the western portion of the State with the exception of sand and gravel and glacial boulders, which are scattered throughout the State. Deposits of lignite, petroleum, clay, and sand and gravel have contributed most to the economic development of the State. Figure 1 shows the approximate location of North Dakota's mineral resources.[31]

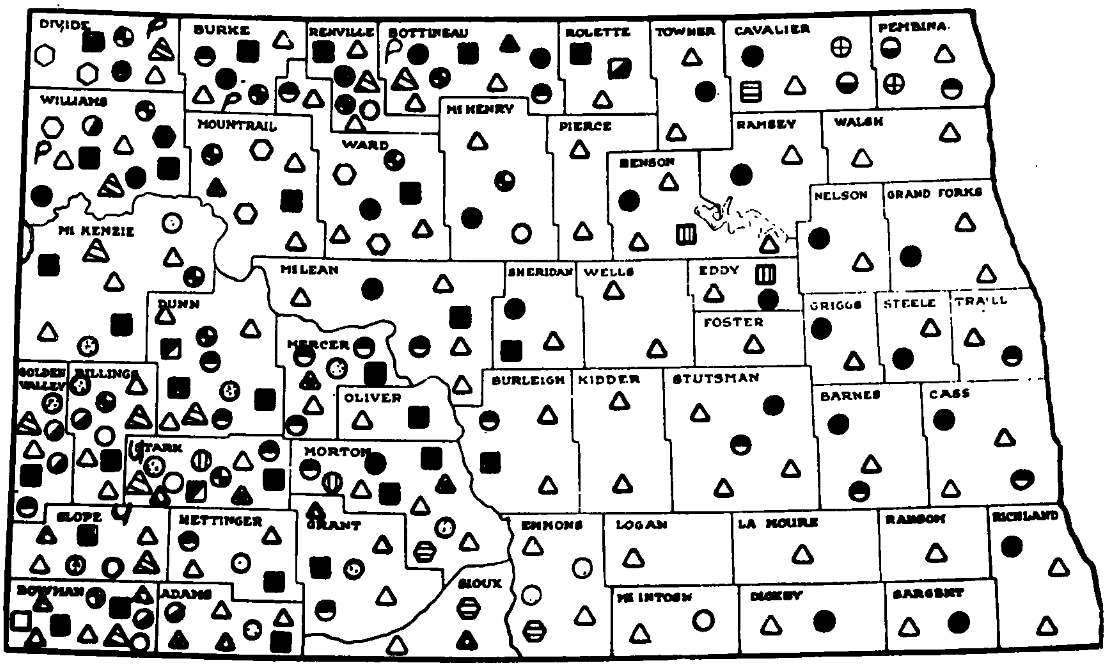
[23]Torkelson. *Here Is the New North Dakota*, p. 29.
[24]*Summary of Industrial Opportunities of North Dakota and Adjoining Areas*, Arthur D. Little, Inc., 1955, p. 3.
[25]*Summary .... Adjoining Areas*, p. 8.
[26]*Summary ... Adjoining Areas*, p. 10.
[27]*Summary .... Adjoining Areas*, p. 13.
[28]*Summary .... Adjoining Areas*, p. 14.
[29]*Summary .... Adjoining Areas*, p. 14.
[30]*Summary .... Adjoining Areas*, p. 16.
[31]David Torkelson (Ed.). "Mineral Resources," Here is the New North Dakota, North Dakota Economic Development Commission, Bismarck, February, 1966, p. 11.

TABLE 1 **ESTIMATED WATER USE FOR ANTICIPATED INDUSTRIAL DEVELOPMENT**

Industry	Production Unit	Estimated Annual Plant Capacity	Water Required in Gallons Per Unit	Estimated Percent Consumptive Use	1980 Number of Plants Developed – 1980	1980 Operational Use Acre-Feet Annually	1980 Consumptive Use Acre-Feet Annually	2000 Number of Plants Developed – 2000	2000 Operational Use Acre-Feet Annually	2000 Consumptive Use Acre-Feet Annually
Meat Packing	Ton-Live Animal	120,000 Ton	4,130	20[a]	2	3,000	600	3	4,500	900
Livestock Yards	1,500 Acre-Feet Annual Use			30[a]	2	3,000	900	3	4,500	1,350
Sugar Beet Refinery	Ton	800,000 Ton	2,100	25[a]	4	20,600	5,160	4	20,600	5,160
Sugar Corn Refinery	Gallon	3,500,000 Gal.	150	20[a]	1	1,600	320	2	3,200	640
Electric Power Plant[b]	Kw/Hr	200,000 Kw/Hr	50	3[a]	10	2,700,000	81,000	24	6,480,000	194,400
Electric Power Plant[c]	Kw/Hr	200,000 Kw/Hr	50	5[a]	4	1,080,000	54,000	4	1,080,000	54,000
Petroleum Refining	100 Bbl.	12,000,000 Bbl.	77,000	10	1	28,400	2,840	1	28,400	2,840
Iron Ore Processing	Ton	1,000,000 Ton	10,000	10	–	—	—	1	310,000	31,000
Aluminum Processing	Ton	1,000,000 Ton	6,300	10	–	—	—	1	194,000	19,400
Ammonia Fertilizer	Ton	100,000 Ton	200,000	10	–	—	—	1	61,500	6,150
Lignite Hydrogenation	100 Bbl.	6,000,000 Bbl.	728,000	20[a]	–	—	—	1	134,000	26,080
Major Food Processing[d]				20[a]	–	40,000	8,000	–	80,000	16,000
			TOTALS			3,876,600	152,820	–	8,397,500	358,640

[a]Consumptive use rates shown reflect evaporation from reservoirs and/or from lagoons and transportation losses
[b]Cooling Water — No Re-use
[c]Cooling Water — Recycling
[d]Potato Industry and future related industries

FIGURE 1. MINERAL RESOURCES OF NORTH DAKOTA[33]



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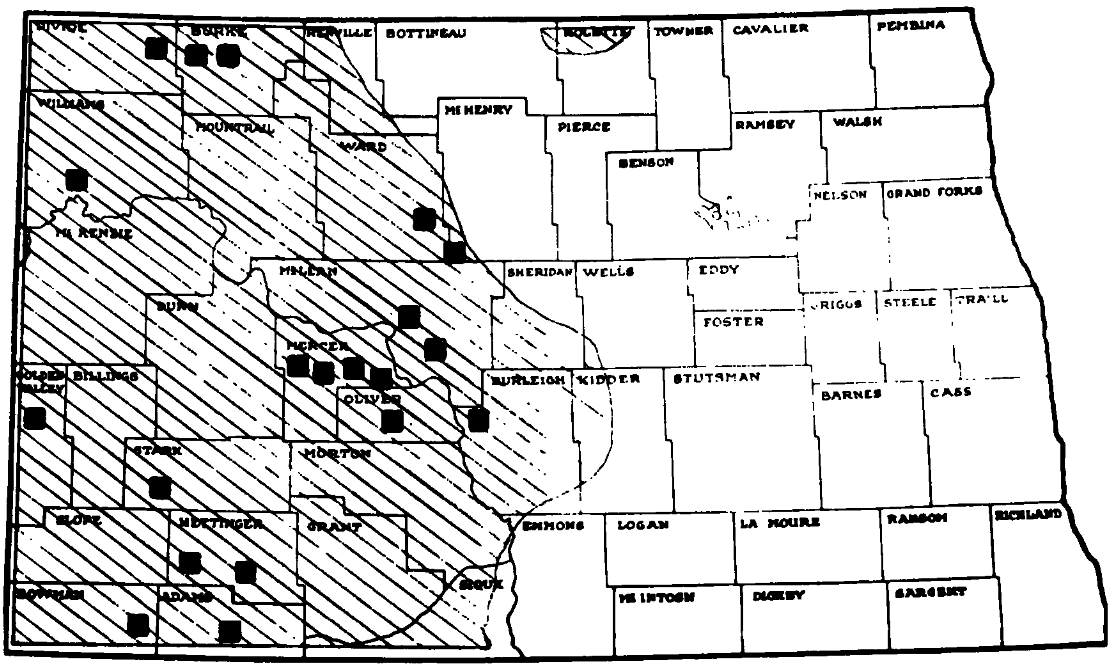
- Bentonitic Clay
- Brick Clay
- Cement Rock (Mostly limestone)
- Clinker (Scoria)
- Fire and Refractory Clay
- Fullers Earth
- Glacial Boulders
- Lignite
- Limestone
- Manganese
- Marl
- Mineral Pigment
- Natural Gas
- Peat
- Petroleum
- Potash
- Pottery Clay
- Quartzite
- Salt
- Sand and Gravel
- Sandstone
- Sodium Sulfate
- Sulfer
- Volcanic Ash
- Uranium and Molybdenum

[33]Symbols shown on this map are not intended to show the exact and/or only location of these minerals within a given part of the State.

North Dakota has the largest deposit of coal in America. Lignite deposits in western North Dakota extend over approximately 28,000 square miles and are estimated to contain about 350 billion tons or 18 percent of the Nation's coal reserves on a tonnage basis. The lignite mining industry in North Dakota has grown considerably in the State during recent years with about 3.9 million tons of lignite mined during fiscal year 1967. Major uses of lignite are for the production of thermo-electricity, heating, and briquetting. Due to technological advances made in recent years, lignite has considerable potential for synthetic petroleum and chemicals in addition to providing energy, heat and power.[33] Figure 2 shows the area where North Dakota's lignite resources are located and the location of those mines operating in 1967.

[33]Torkelson, p. 9.

FIGURE 2. LIGNITE RESOURCES IN NORTH DAKOTA



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Location of North Dakota's lignite resources.

Lignite mines operating in 1966-1967.

[34]*Coal Mine Inspection Department Annual Report*, State of North Dakota, June 30, 1967.

At the present time, North Dakota's most valuable mineral resource is petroleum. North Dakota's petroleum resources are found throughout the western half of the State along with deposits of natural gas. In 1965, North Dakota ranked 13th among the states of the Union in the production of crude oil and eighth in the Nation in liquid hydrocarbon reserves with 444 million barrels. Crude oil production in 1965 was 25,599,000 barrels. Estimated reserves of crude oil in North Dakota as of January 1, 1965, was 444,376,000 barrels.[35] Since the discovery of oil near Tioga in 1951, 711,242,000 barrels of liquid petroleum have been produced in 13 western North Dakota counties. At the end of 1965, 2,012 wells were in production. An average of 36.5 barrels of liquid petroleum is produced daily from each producing well.[36]

North Dakota oil refineries are located at Mandan and Williston, with natural gas refineries at Tioga, McGregor and Lignite.

In 1965, North Dakota's mineral production was valued at $86.5 million. The total value of mineral fuels, including coal (lignite), natural gas, natural gas liquids and crude petroleum produced in 1965 represented 85 percent of that year's total value of mineral production.[37]

[35]Torkelson. *Here Is North Dakota*, p. 10.

[36]David Torkelson (Ed.). "Mineral Resources," *Facts About North Dakota*, North Dakota Economic Development Commission, Bismarck, January, 1967, p. 16.

[37]Torkelson. *Here Is North Dakota*, p. 10.

Clay deposits are found in most parts of North Dakota. These deposits are one of the more abundant and valuable mineral resources in our State. Major uses of clay for the manufacture of bricks, tile, clay pipe and pottery.

Sand and gravel deposits are found throughout the State. Major uses of sand and gravel are road building and other construction operations. Sand is finding an increased market in the electronic industry because of the heavy demand for silicon. Sand and gravel production is anticipated to increase substantially in the future due to increased construction.

In addition to sand and gravel, clay, petroleum and lignite, North Dakota has numerous other mineral resources scattered throughout the State. Included are deposits of salt, sulphur, sodium sulphate, limestone, manganese, uranium and quartzite. Expanding demands by a growing population and increased knowledge about minerals as well as increased industrial development will combine to bring about a substantial increase in the use of the State's mineral resources.

At the present time, very little water is being used for mining purposes in the State, with the exception of sand and gravel mining. Considerable quantities of water are used by sand and gravel wash plants for washing out impurities. There are only a few wells in operation which use fresh water for petroleum production. This water is used to clean out production lines in areas where extremely heavy salt water conditions are present. Salt production in the Williston Basin by means of solution mining, also requires the use of water. Mining of clay and lignite requires little or no water.

Figures shown in Table 1 for present water use for mining purposes are based on information received from the various mining industries. Water use figures shown are given in acre-feet per year per mining industry.

Making projections for water use for mining purposes at the present time is extremely hazardous due to limited information. However, it is anticipated that water use for mining purposes will increase.

TABLE 1 Present Water Use for Mining Purposes in Acre-Feet per Year in North Dakota.

Type of Mining	PRESENT USE Diversion	Consumptive Use
Petroleum (3-4 oil wells)	40	40
Sand and Gravel Wash Plants (25)[88]	1,500	500
Salt Production	200	20

Present and Projected Quality Control Water Use

Existing Federal laws require that before any water from Federal reservoirs is used for the dilution of wastes, i.e., quality control, these wastes must be "adequately treated." The term "adequately treated" is interpreted to mean the removal of approximately 80 percent in 1960, 85 percent in 1980, and 90 percent in 2000 of the biodegradable material in the wastes. This is an attainable figure in modern waste treatment plants, which provide for secondary or biological treatment of wastes in addition to primary treatment. Biodegradable materials are those waste products which are detrimental to the ability of a stream or river to serve as a fine quality recreation or fishing area.

Primary treatment refers to the removal of settable solids from sewage and industrial wastes. A primary sewage treatment plant consists of screens, grit removal chambers, settling tanks, sludge digestors, and sludge drying beds. In addition to these units, some primary treatment plants include chlorination facilities. Primary treatment plants usually remove about 25 to 35 percent of the biochemical oxygen demand and 45 to 65 percent of the total suspended matter. The biochemical oxygen demand refers to the oxygen demand of sewage and industrial wastes in order to bring about the decomposition of these wastes.

Secondary treatment plants are those which provide for treatment of wastes by biological methods to remove additional organic wastes after primary treatment. A secondary treatment plant consists of trickling filters or activated sludge basins, final settling of wastes, and should include chlorination facilities. Secondary treatment plants usually remove 80 to 95 percent of the organic wastes and suspended matter from wastes.

In determining quality control water demands, it has been assumed that a bio-degradable waste will be subjected to secondary treatment before discharge into the stream and the amount of quality control water demanded will be that amount of water required for mixing with the treated wastes to insure no impairment of downstream uses or values.

Dilution requirements for the discharges of untreated, combined sewage are as high as eight cubic feet per second of flow per 1,000 persons. Secondary waste treatment plants in North Dakota in 1960 were removing approximately 80 percent of the biodegradable materials reducing the water requirements for quality control to 1.6 cubic feet per second or 3.2 acre-feet per 1,000 persons per day. Secondary treatment of these wastes by 1980 and 2000 is expected to remove 85 to 90 percent of these waste materials respectively. This will result in a reduction of the water requirements for quality control to 1.2 and 0.8 cubic feet per second or 2.4 and 1.6 acre-feet respectively per 1,000 persons for each time period.

Figures shown in Table 1 for water requirements for quality control in North Dakota are given in acre-feet per year for each river basin and include water requirements for quality control resulting from municipal and industrial uses.

[88]Plants operating approximately 200 eight-hour days per year.

Table 1. Water Requirements for Quality Control in 1960, 1980, and 2000 — North Dakota

Basin	Water Requirements for Quality Control (Acre-Feet Annually) 1960	1980	2000
Missouri	238,600	185,800	212,900
James	71,800	56,200	63,700
Souris	121,100	109,000	106,900
Devils Lake	42,100	27,500	36,900
Red	269,700	231,700	233,800
TOTALS	743,300	610,200	654,200

Present and Projected Fishing Use

Fishing is a favorite pastime of many North Dakotans. Fifty-two percent of all residents participate, and do so an average of nine times a year.

Popularity of the activity is a little greater with residents of small towns than with those in urban areas or on farms. Fishing is the most popular outdoor recreation activity of our senior citizens.

Fishing ranks second only to sightseeing and pleasure driving as the preferred vacation activity of North Dakotans.

The fishing season in North Dakota generally runs for 42 weeks each year for game species, which includes trout, northern pike, walleye, sauger, black bass and muskellunge. Nongame species such as yellow perch, rock bass, white bass, bluegill, crappies, bullhead, catfish and sunfish may be caught year round. Ice fishing is a popular winter activity.

There are over 1,500 square miles of water surface in North Dakota; however, lakes and reservoirs larger than 500 acres do not lend themselves to efficient fisheries management. Garrison Reservoir, and other large impoundments have yielded a number of trophy catch, but the fish yield per acre does not compare to that from smaller bodies of water. It should be noted, however, that the tremendous acreages found in reservoirs of this and even smaller size enables them to contribute a substantial amount of fishing recreation.

North Dakota has about 47,000 acres of intensively managed fishing lakes which will accommodate approximately 1.5 million activity days annually.

In 1965, residents of North Dakota manifested a demand for 2.7 million activity days for fishing. This will increase to over 3.9 million by 1980. There is apparently a great demand for fishing by out-of-state visitors to North Dakota; however, tourist demand has not been measured.

Most fishing lakes in North Dakota are provided through programs of the State Water Commission and State Game and Fish Department, in cooperation with local entities. Fishing opportunities have also been developed in several of the reservoirs in Watershed Projects. Some opportunities are provided by private interests, such as those in large stock water ponds on farms.

To meet needs for fishing, North Dakota will have to provide an additional 61,546 acres of intensively managed fishing lakes by 1980. These lakes should range in size from 50 to 400 acres.

Throughout most of North Dakota, except for the flat Red River Valley area, there are many suitable sites where new fishing lakes could be developed. The supply of natural lakes is not adequate to meet needs.

TABLE 1. Fishing Use — Present and Projected[39]

RIVER BASIN	1965 SUPPLY	1965 CAPACITY	DEMAND 1980	DEMAND 2000	ADDITIONAL NEEDS 1980	ADDITIONAL NEEDS 2000
	Effective Acres	Fisherman Days Available	Fisherman Days Available	Fisherman Days Available	Effective Acres	Effective Acres
Missouri	29,773	952,154	1,516,849	2,067,188	15,262	30,136
James	4,199	150,103	335,686	456,554	5,016	8,282
Souris	4,447	147,833	527,295	721,004	10,256	15,491
Devils Lake	2,004	66,645	259,611	355,120	5,215	7,797
Red	6,469	198,663	1,283,579	1,747,434	25,797	36,875
TOTALS	46,892	1,515,400	3,293,020	5,347,300	61,546	98,581

Present and Projected Waterfowl Use[40]

North Dakota wetlands having essential importance as duck breeding habitat are made up of marshes, swamps, wet meadows, and seasonally flooded lands. The wetlands acreage varies from year to year depending upon water conditions. The State's total wetland acreage of approximately 1,500,000 acres has been classified as containing 36 percent of high value waterfowl, 43 percent of moderate value and 21 percent of low value. The 1950 population of breeding ducks in North Dakota was 1,460,000. This is generally considered an average year. In May of 1967, surveys showed a duck breeding population of 2,620,000 ducks in North Dakota. Nineteen hundred sixty-seven is considered to be a non-representative year, but it is nonetheless an indication of production potential of the 1967 wetlands. Obviously, waterfowl populations

[39] The data included in the foregoing Table is adapted from the "Fishing Use" section of the North Dakota State Outdoor Recreation Plan.

[40] Information contained in this section adapted from James P. Gilligan's *Waterfowl Aspects of Land Use Controversy in Eastern North Dakota*, November 1, 1967.

fluctuate widely from year to year depending on breeding habitat, water conditions and other factors.

The terms high, moderate and low reflect the relative value of the wetlands within North Dakota. Wetlands classified as being of low value in North Dakota would doubtless receive a higher rating were they located in Iowa or Kansas.

RIVER BASIN	Assumed Maximum Waterfowl	Assumed Average Waterfowl	Hunter Demand All Types Game (Hunter Days) 1965	Duck Hunter Demand at 20% (Hunter Days) 1965
Red	430,000	230,000)		
Devils Lake	420,000	220,000)	899,420	179,884
James	460,000	250,000)		
Mouse	610,000	410,000)		
Missouri	680,000	390,000)	534,730	106,946
Totals	2,600,000	1,500,000	1,434,150	286,830

The goal for the Federal wetlands acquisition program, including that which has already been acquired, is 284,005 acres for National Wildlife Refuges, 360,000 acres of waterfowl production areas to be acquired by fee title, and 800,000 acres to be acquired by easement. Approximately 430,000 acres have now been acquired by easement.

The State's permanent water areas are valuable as resting areas for migratory waterfowl. The permanent water area is approximately 600,000 acres made up of reservoirs, streams, inland saline lakes, stock ponds and inland freshwater lakes. Some of the freshwater lakes, stock ponds and a portion of the saline lakes also have value as breeding habitat for waterfowl. The resting areas in North Dakota are of high value to migratory waterfowl for they are used by birds from the Atlantic and Mississippi Flyways in addition to the Central Flyway in which the State is located. It should be added that permanent water areas, while valuable resting areas for migratory waterfowl, are not suitable for duck breeding habitat.

Wetlands classed as those which are ideal for duck breeding habitat have an unstable water level. Replenishment of water supplies for these wetlands is highly dependent on runoff from snow melt. In ideal waterfowl production years, nearly all wetland basins are full from this runoff. The average depth (or ideally so) of these marshes is approximately two to three feet. Consequently, if drought persists for any duration, wetland water levels drop rapidly. This shallowness and periodic drying is a characteristic of the prairie wetlands; and this periodic drying may be one of the most desirable traits that attracts breeding waterfowl to these wetlands. Abundant aquatic plant and animal life production in years following drought make these wetlands even more attractive to breeding waterfowl.

Varying water conditions from year to year create wide fluctuations in duck populations. Due to the man variables it is not possible to set a use standard for waterfowl habitat, thus limiting the projection of water needs for this purpose. One of the questions now under study is whether or not waterfowl production can be increased on the now available breeding habitat. The production of waterfowl in North Dakota appears to depend almost directly on the abundance of the pothole areas and the future waterfowl population will depend upon how much of this pothole type of habitat can be retained.

While there appears to be a great interest in waterfowl hunting, less than 10 percent of North Dakota's present population of 650,000 persons purchased duck stamps for hunting in 1965. Nonresident hunters numbered approximately 2,500 persons in 1965. A 10 percent rate of projected population could bring a waterfowl hunting demand for more than 100,000 persons by the year 2000. Indications are also that the nonresident hunting demand for waterfowl will increase.

Another factor is the nonconsumptive waterfowl use which has been expanding rapidly in recent years. This nonconsumptive use represents the persons becoming interested in bird watching and photography. Recent studies of the use of Horicon Marsh, a National Wildlife Refuge in Wisconsin, illustrate this trend. In 1961 the people who came to just watch the geese nearly doubled the hunters and only 20 percent of these people who came to watch were regular bird watchers. Later studies have shown greater proportional increases for this type of waterfowl use.

Present and Projected Boating and Water Skiing Use

Thirty-six percent of all North Dakotans participate in boating and water skiing activities. They do so almost nine times a year. Participation is greatest by urban residents between the ages of 18 and 24, but the activity is enjoyed by both younger and older persons.

Boating and water skiing activities take place on an average of 109 days from May to October. One acre of water can accommodate approximately 87 persons annually.

North Dakota has over 14,000 acres of exceptional boating lakes, provided with adequate docks, boat launches and parking facilities. These lakes will accommodate 1.2 million users annually.

People of North Dakota, like those throughout the Nation, are developing a rapidly increasing interest in water sports. The trend in our State has been accelerated by the development of a number of lakes and reservoirs created by dams constructed through the State's water development program.

The demand for boating and water skiing in 1965 was measured at 1.7 million activity days. This is estimated to increase to 3.3 million by 1980.

The quantity of well equipped boating lakes must more than double by 1980 if needs of our people are to be met. Construction of more adequate access roads, installation of boat ramps and docks, and development of marinas to offer motor fuel and service can convert much of the present water area into good boating lakes. New lakes and reservoirs will also be needed.

Lakes which are developed to meet fishing needs may often meet needs for boating and water skiing and other water sports. Man-made reservoirs which provide flood control and municipal, industrial and irrigation water supplies can also meet recreation needs if they are properly developed and managed. It is important that the water and outdoor recreation programs in North Dakota continue to be closely coordinated to provide maximum benefit of our water resources.

There are many suitable sites for new water areas throughout North Dakota to meet needs of the people of the State, though it must be acknowledged that Fish, Wildlife and Recreation needs may never be fully met in the Red River Basin because of the scarcity of suitable dam and reservoir sites. The needs for water in the Red River Basin may have to be partially satisfied in other basins. Many Red River Basin people go into Minnesota for their water oriented recreation at a great economic loss to North Dakota. Continued cooperative action on the part of the State and local government, with assistance through Federal sources will enable us to provide for these needs.

TABLE 1. Boating and Water Skiing Use — Present and Projected*

RIVER BASIN	1965 SUPPLY	1965 CAPACITY	DEMAND 1980	DEMAND 2000	ADDITIONAL NEEDS 1980	ADDITIONAL NEEDS 2000
	Effective Acres	Activity Days Available	Activity Days Available	Activity Days Available	Effective Acres	Effective Acres
Missouri	5,588	485,875	876,319	1,383,660	4,488	10,319
James	2,998	260,831	490,735	774,846	2,643	5,908
Souris	1,771	154,007	563,268	889,371	4,704	8,452
Devils Lake	665	57,416	213,138	336,534	1,790	3,208
Red	3,191	277,571	1,117,810	1,764,960	9,658	17,096
TOTALS	14,023	1,235,700	3,261,270	5,149,371	23,283	44,983

*The data included in the foregoing Table is adapted from the "Boating and Water Skiing Use" section of the North Dakota State Outdoor Recreation Plan.

Present and Projected Navigation Use

Historically, there has been no significant commercial navigation on North Dakota's streams. Neither has there been any expressed interest in the future development of this mode of transportation. Generally, the streams are tortuous and narrow, which precludes their use by commercial craft normally used in waterborne commerce. It is, therefore, concluded that navigation need not be given consideration in the development of the State Water Resources Development Plan.

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Chapter Eight

Supply of Water

CHAPTER VIII

SUPPLY OF WATER

North Dakota's share of the world water supply (See following page.) must serve a variety of purposes. It must continue to meet demands for municipal, domestic and livestock water, and it must provide for the growing needs of irrigation, industry and mining. At a time when North Dakotans are finding themselves with more and more leisure time, increasing demands for fish, wildlife and outdoor recreation water are also being felt. Demands for quality control water — water used in the abatement of pollution in North Dakota's rivers and streams — is growing in accordance with increased population, irrigation and industrialization. The water needed to sustain these uses now and in the future must be supplied through precipitation, streamflow, reservoir storage or ground-water reserves, or a combination thereof.

In assessing North Dakota's current water supply, the aforementioned sources must be examined and analyzed. This chapter is a presentation of that examination and analysis.

THE CLIMATE OF NORTH DAKOTA

North Dakota is typically plains country located near the center of the North American Continent. The State is situated in the middle of latitudes, 30° to 49° from the equator, in the interior of a large continent. The changes within this climatic region are almost all so gradual that comparative uniformity of conditions, rather than diversity, often prevails. The eastern part of the State is flat, with an elevation in the Red River Valley of 780 feet at Pembina in the north to 962 feet above sea level at Wahpeton in the south. To the west, there is a gradual rise of terrain until an elevation of 3,506 is reached at White Butte in the southwestern part of the State. The Turtle Mountains in the north central part of the State are only about 500 feet higher than the surrounding area, with the highest elevation about 2,300 feet above sea level.

The temperate climate of the State is exceptionally healthful, as revealed by the comparatively abundant energy of the people and their generally rather ruddy complexions. Summers are usually very pleasant, but hot winds and periods of prolonged high temperatures occur occasionally. However, minimum maximum night time temperatures seldom exceed 70° F. As a consequence, it is unusual to have uncomfortable nights. While open and mild winters are not unknown, North Dakota winters are considered cold, but the low humidity that prevails during the cold season is usually far less penetrating than many other areas having higher temperature readings.

The annual mean temperature for North Dakota ranges from about 36° F in the northeast to 43° F in the extreme south. Temperatures above 100° F are occasionally recorded, and zero temperature readings are common in the winter. The average number of days a year when the temperature reaches 90° F or higher is 14, and the average number with zero or lower is 53. The average growing season is about 121 days, ranging from 110 days in the northeast and north central to 135 in the extreme south. For the State, the average date of the last freeze in the spring is May 19, and the first in the fall is September 18. Freezing temperatures have occurred, however, as late as the first part of June and as early in the fall as the first few days of September.

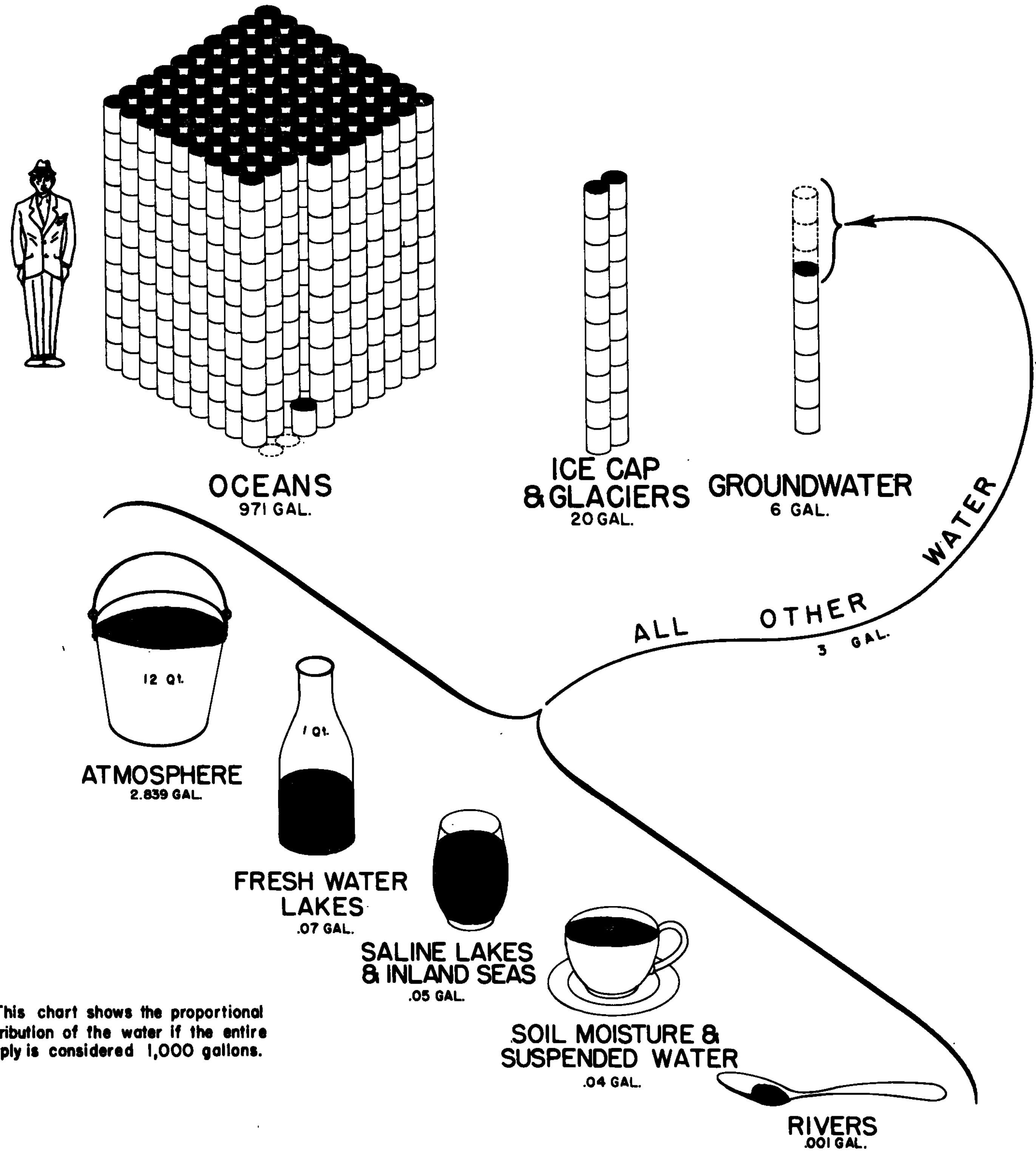
Precipitation in the eastern third of the State averages about 19 inches, in the middle third about 16 inches, and in the western third about 15 inches. On the average, about 77 percent of the annual precipitation occurs during the crop-growing season, April to September, and almost 50 percent falls during May, June and July. The normal precipitation for the driest months, November to February, is about one-half an inch per month. The greatest amount of moisture falls between 5:00 p.m. and 8:00 p.m. and again about midnight. Most of the rain occurs in summer storms accompanied by thunder and lightning, often with great intensity for a short time. The average number of thunderstorm days is 30, mostly in June, July and August. In most years, at least some part of the State is visited by a storm that brings a rainfall of two or three inches in a 24-hour period, and occasionally five or six inches fall in one day. On an average, rain falls about one day in four during the summer months.

The annual number of days with measurable precipitation averages 66, ranging from about 50 in the west to 90 in the east. During the four years, 1933-1936, North Dakota's precipitation averaged slightly more than 12 inches per year. During the four years, 1941-1944, the State's precipitation averaged slightly more than 20 inches. The first light snow in autumn occasionally falls in late September, but usually measurable snowfall does not occur until after October. The average number of days with 0.1 inch or more of snow is 23. The average annual snowfall is 32 inches, with the greatest amount in the northeast and the least in the southwest. Occasionally, there is heavy snowfall in winter, and the snow on the ground accumulates to a considerable depth. Our winter weather is often interspersed with chinook winds which cause sufficient snow melt to bare the ground.

The prevailing direction of the wind in all months of the year is from the northwest, unless it is influenced by local conditions. More southerly

WORLD WATER SUPPLY

1,000 GAL.



This chart shows the proportional distribution of the water if the entire supply is considered 1,000 gallons.

PREPARED BY NORTH DAKOTA STATE WATER COMMISSION winds are observed during the summer than during the winter. The average annual wind velocity is about 11 miles per hour. The highest velocities are in the spring and lowest in late summer. High winds frequently accompany severe thunderstorms. A total of 71 tornadoes were reported during the seven-year period, 1952-1958. Loss of life from tornadoes had been small and there is only one tornado of record that caused considerable property damage.

The average relative humidity is about 68 percent, slightly higher in the east than in the west. Humidity is frequently low during the afternoon in summer, sometimes below 20 percent. Dense fog conditions lasting for periods of two hours or more, are experienced, on an average, only eight days per year.

The average number of clear days is 160, partly cloudy 100, and cloudy 105. On a clear day, the sun shines for more than 15 hours from the middle of May to the end of July. These long hours of sunshine make it possible to grow many crops in what appears to be a comparatively short growing season. The yearly average amount of sunshine is 59 percent of the possible amount, with 74 percent occurring in July and 72 percent in August.

Some of the more important climatological datum referred to above is shown graphically on the following pages.

Average Maximum Temperature (F°), January

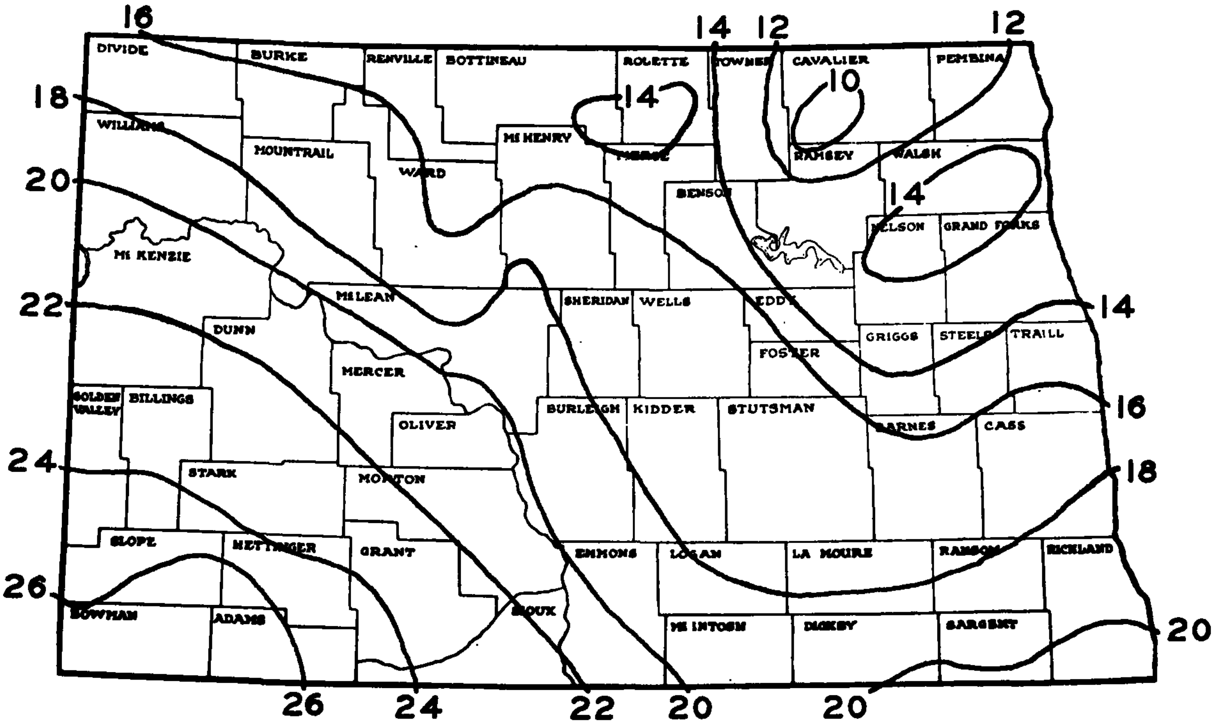


Figure 1

Average Minimum Temperature (F°), January

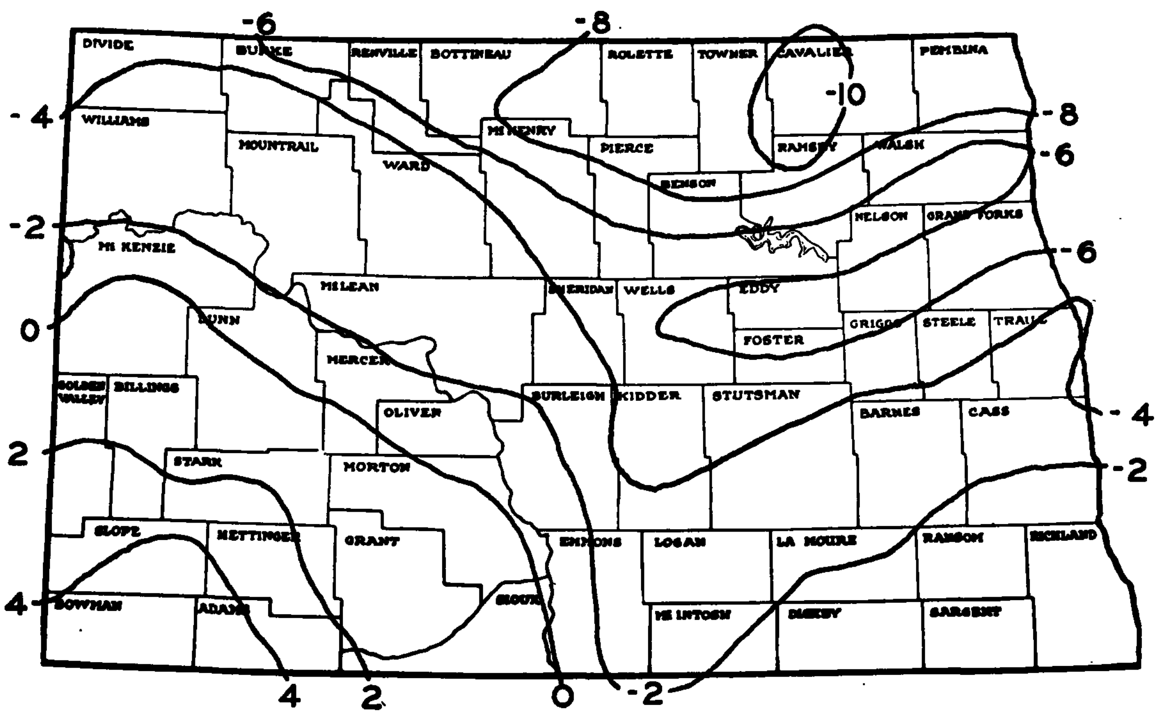


Figure 2

Average Maximum Temperature (F°), July

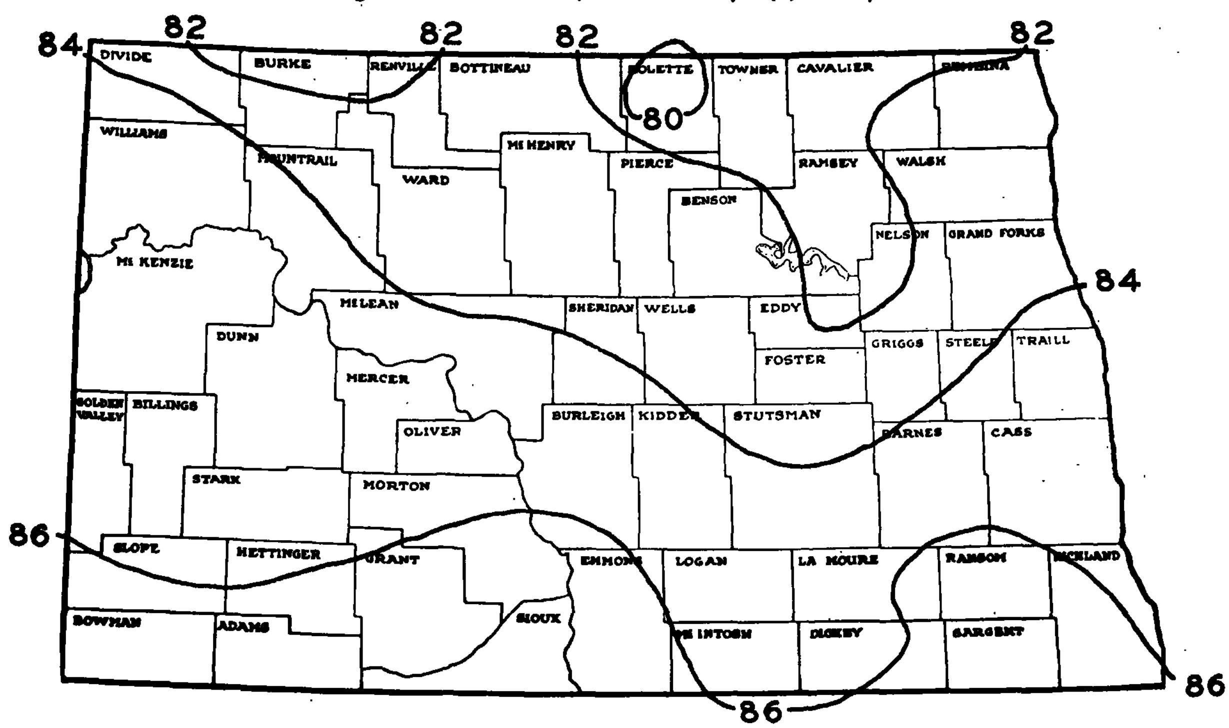


Figure 3

Average Minimum Temperature (F°), July

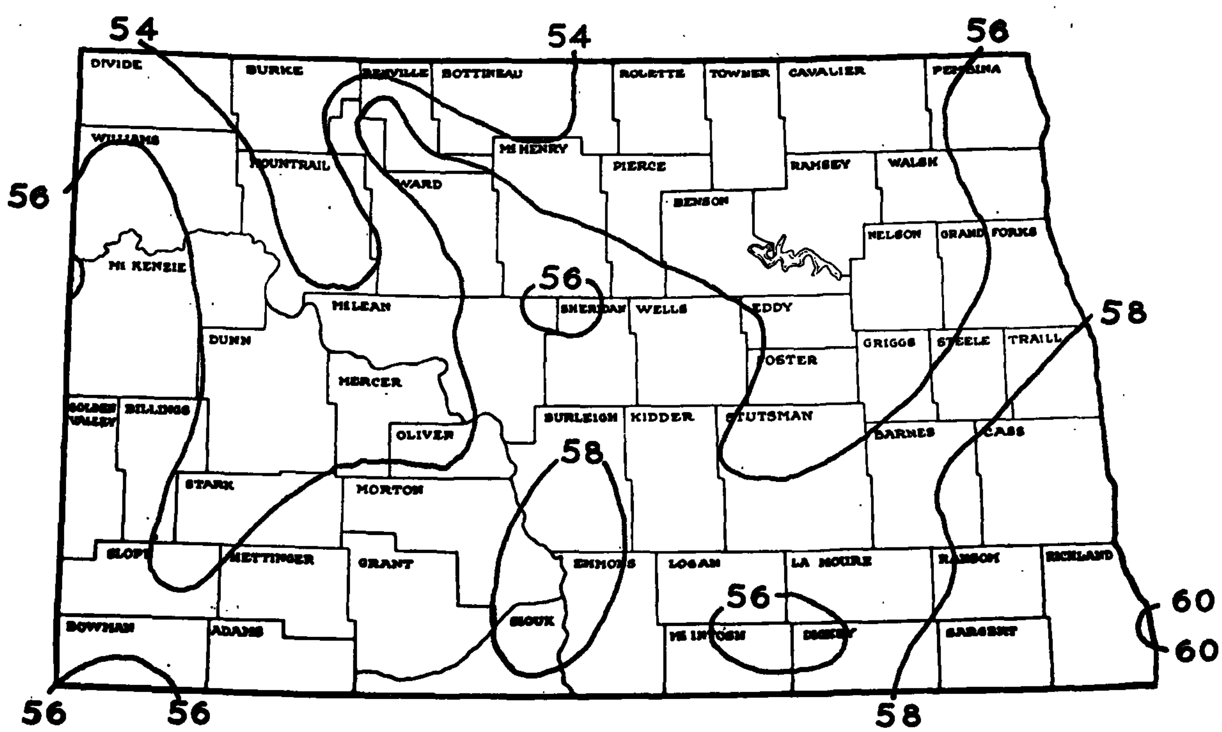


Figure 4

Average Dates of Last Killing Frost in Spring

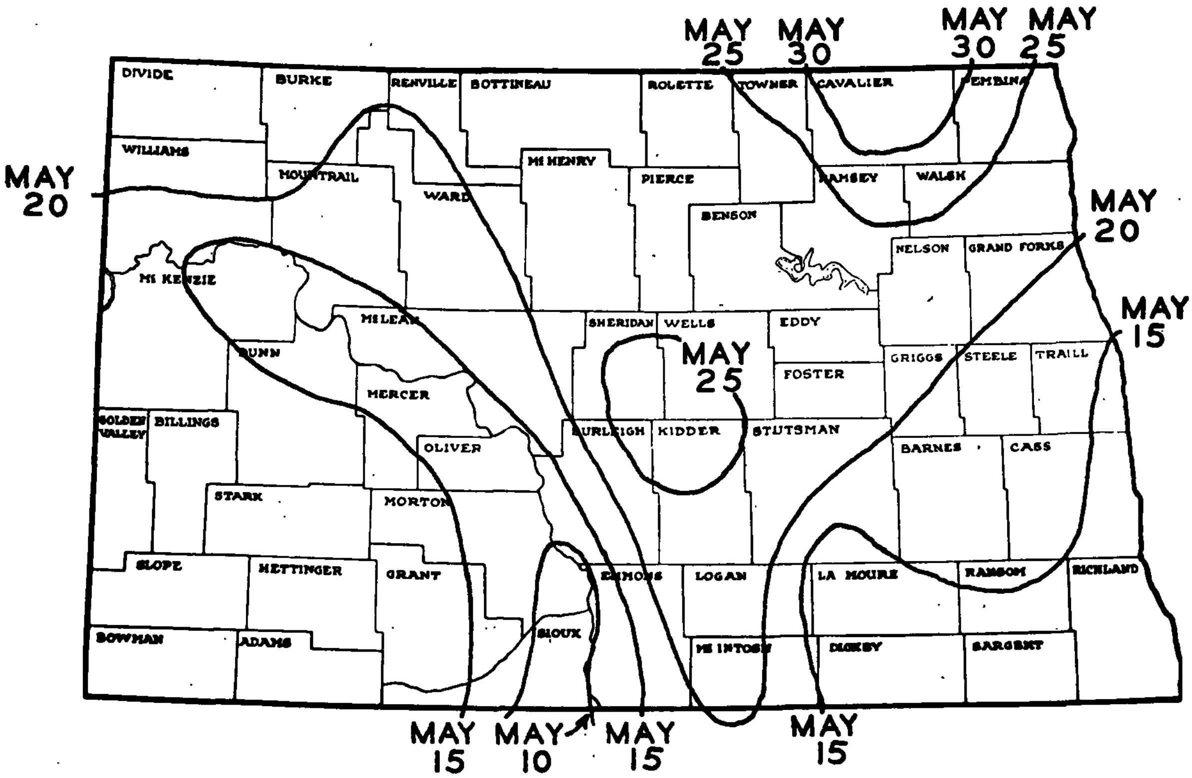


Figure 5

Average Dates of First Killing Frost in Fall

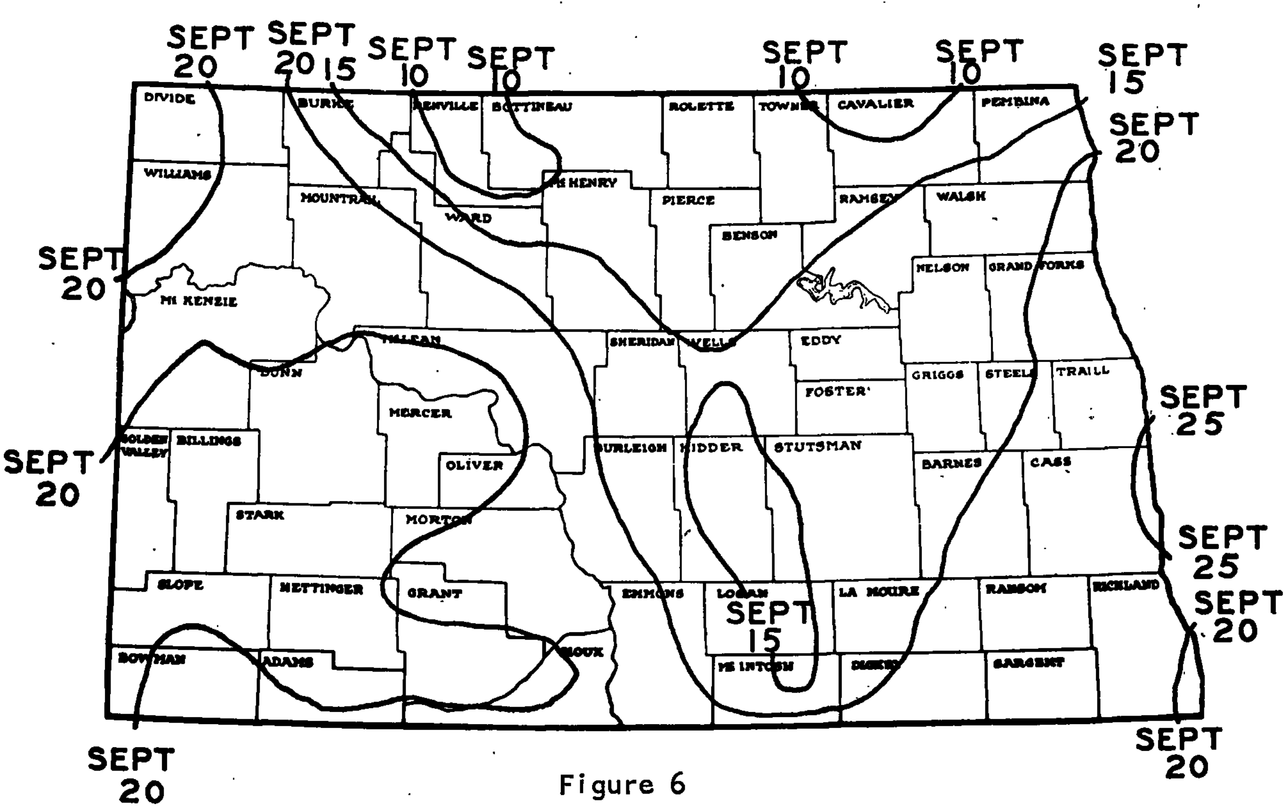


Figure 6

Average Number of Days Without Killing Frost

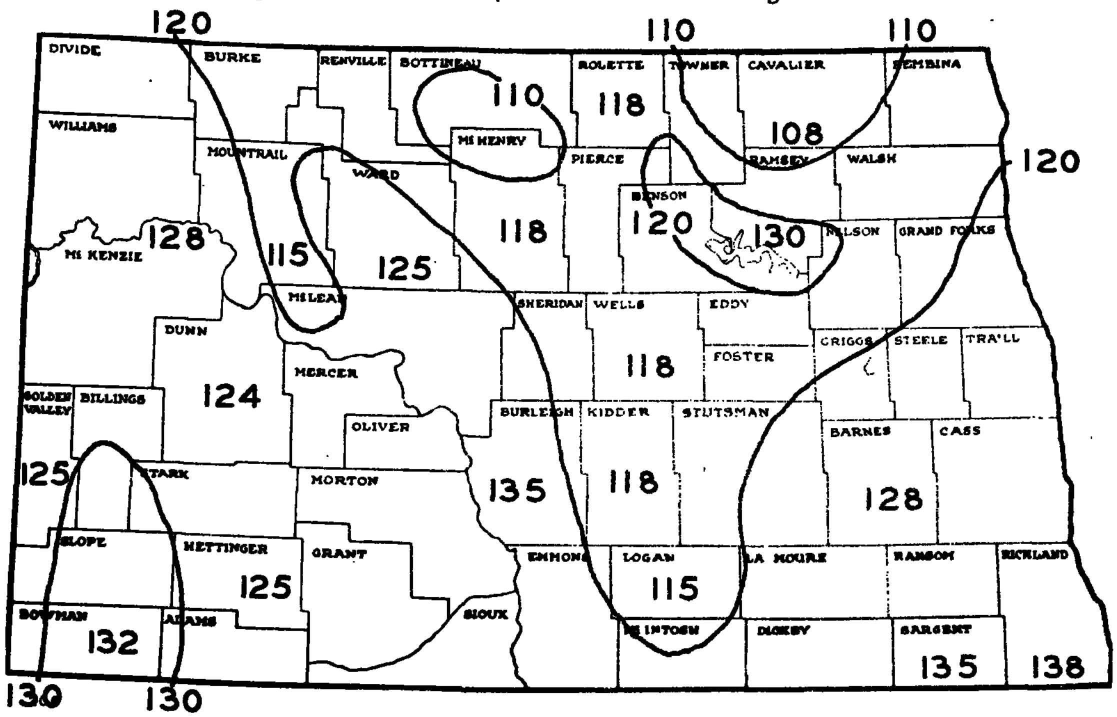


Figure 7

Percent of Years With Less Than 16 Inches of Precipitation

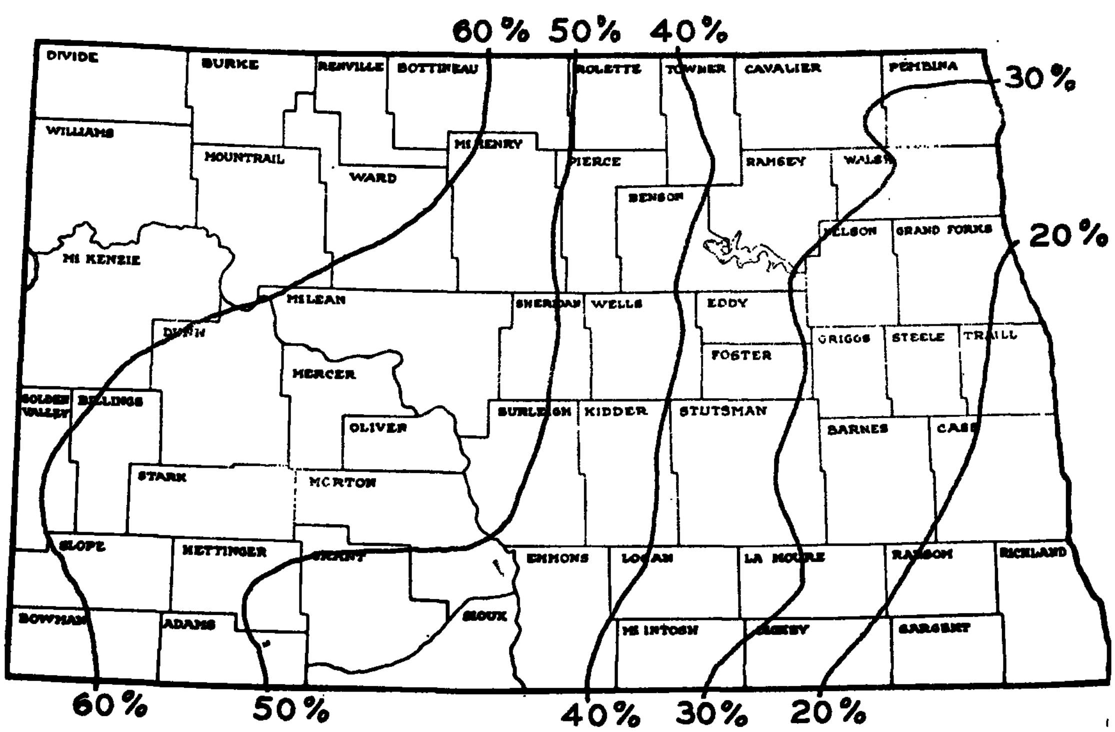


Figure 8

Average Annual Precipitation (Inches)

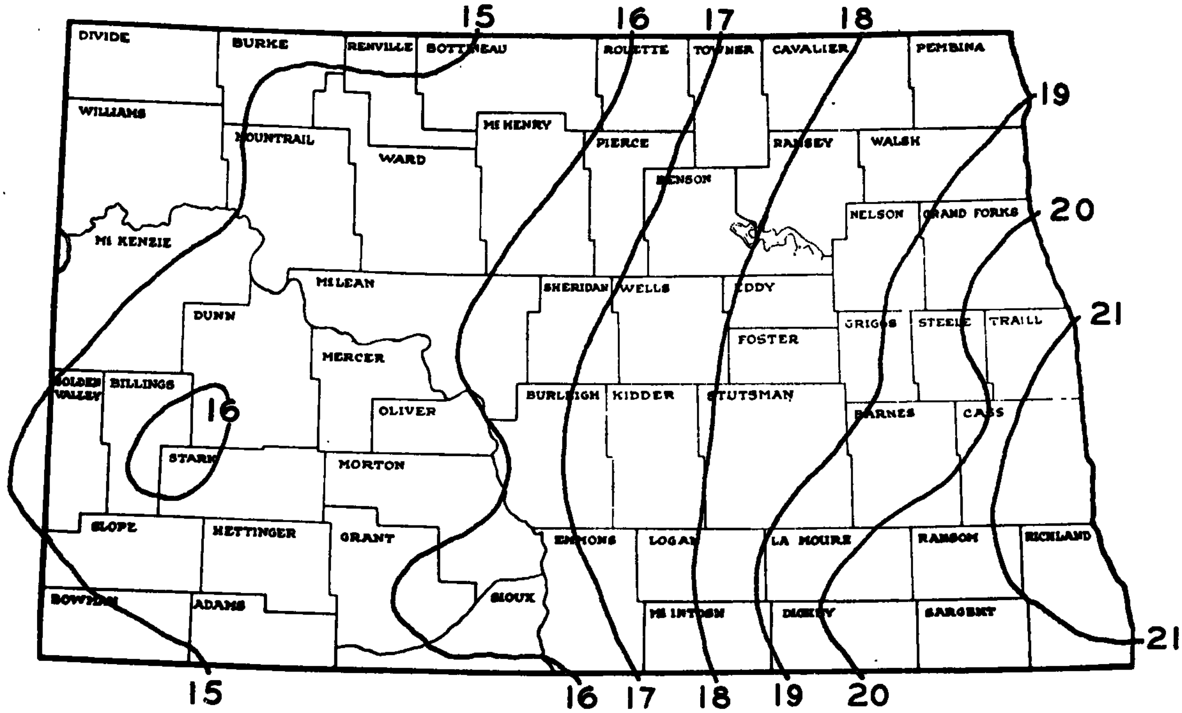


Figure 9

Average Annual Precipitation (Inches)

April to September Inclusive

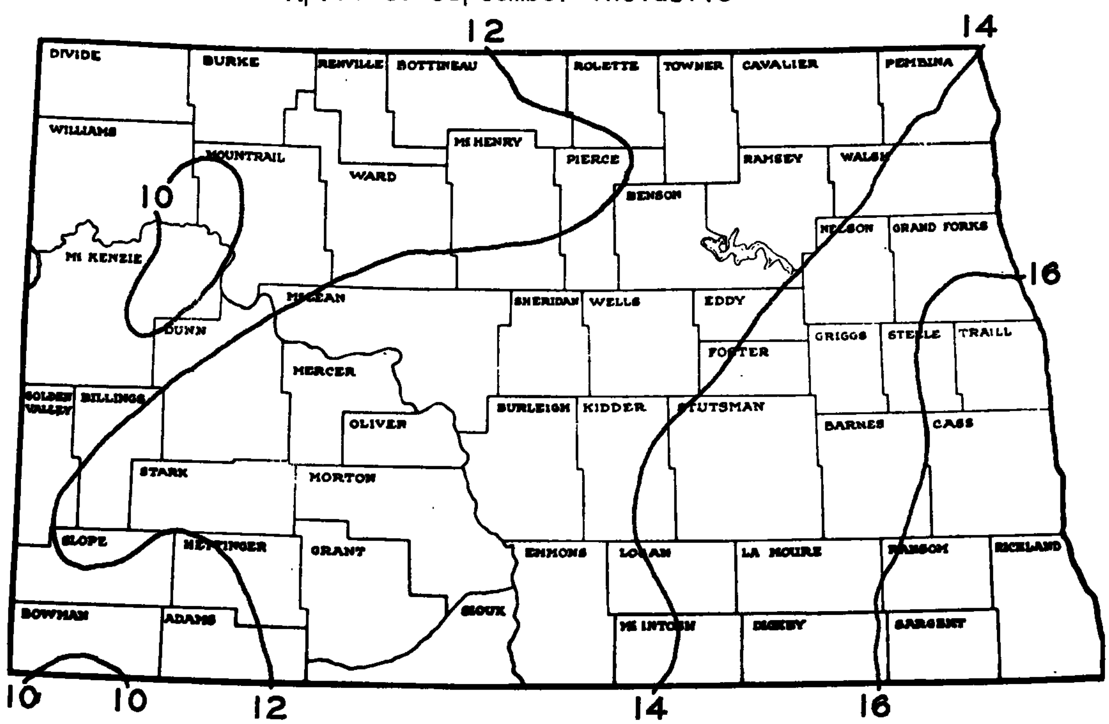


Figure 10

Normal Relative Humidity at Noon During January

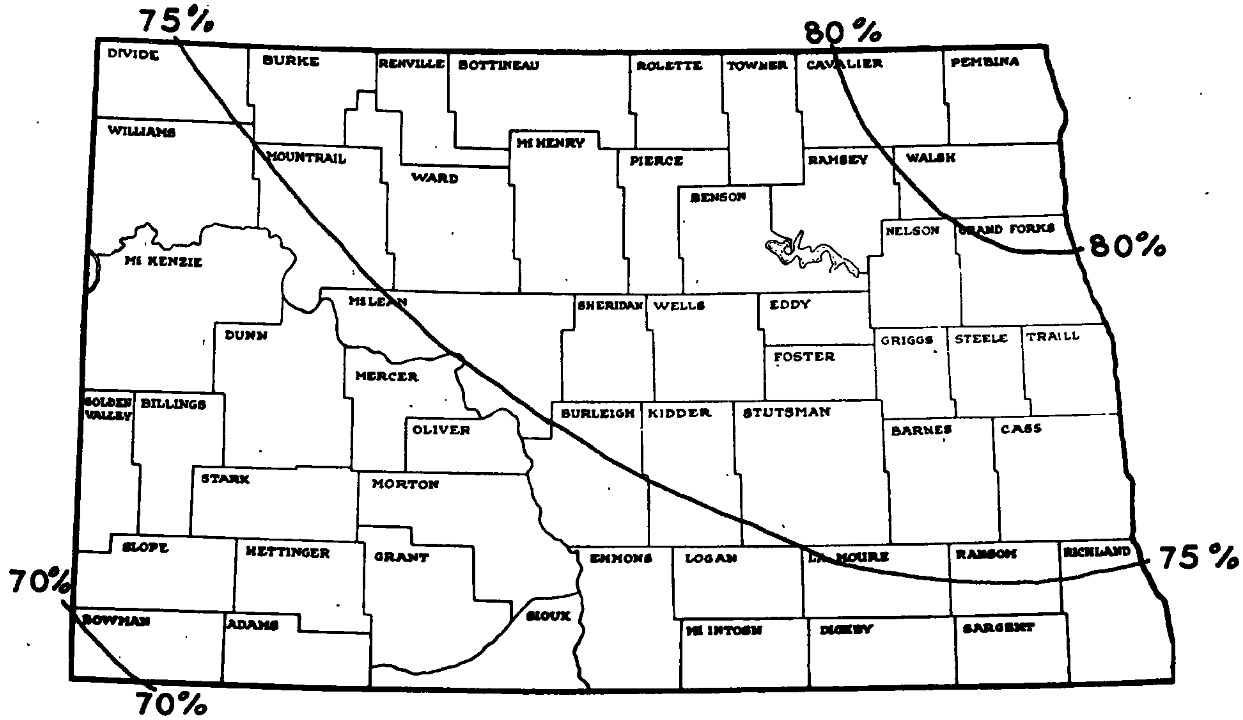


Figure 11

Normal Relative Humidity at Noon During July

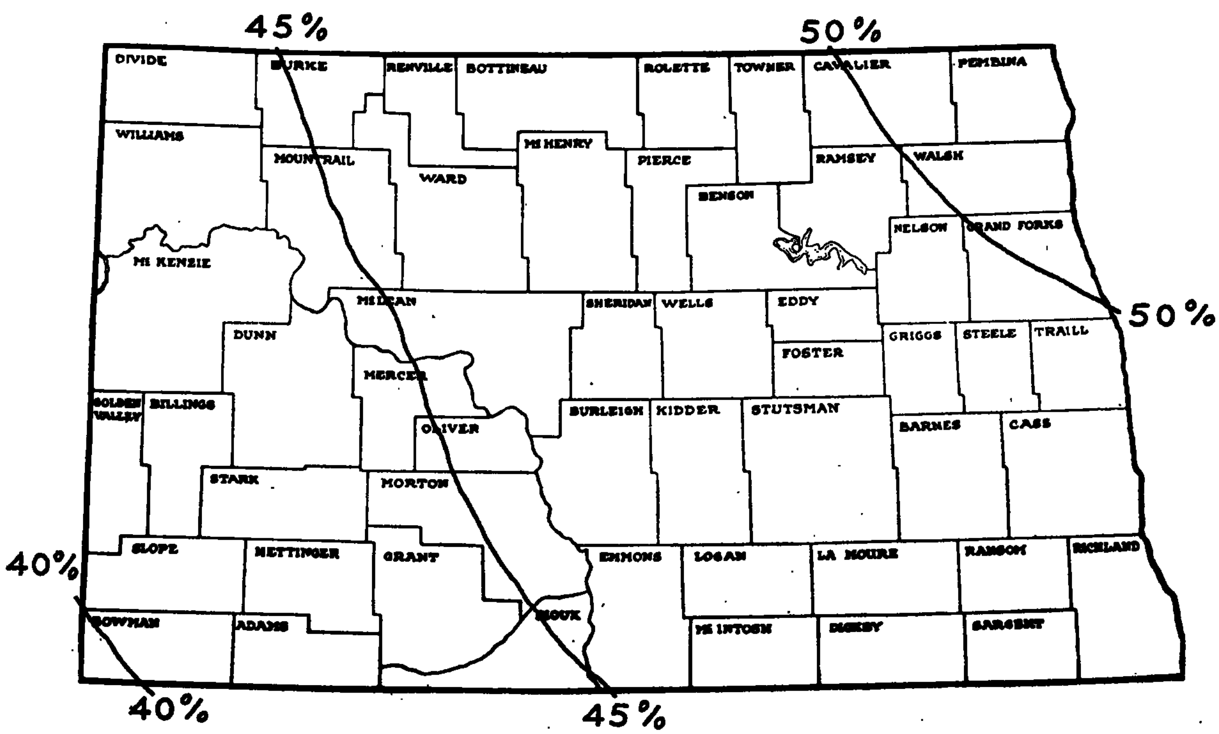


Figure 12

Average Summer Evaporation April - (Inches)
September from Evaporation Tanks

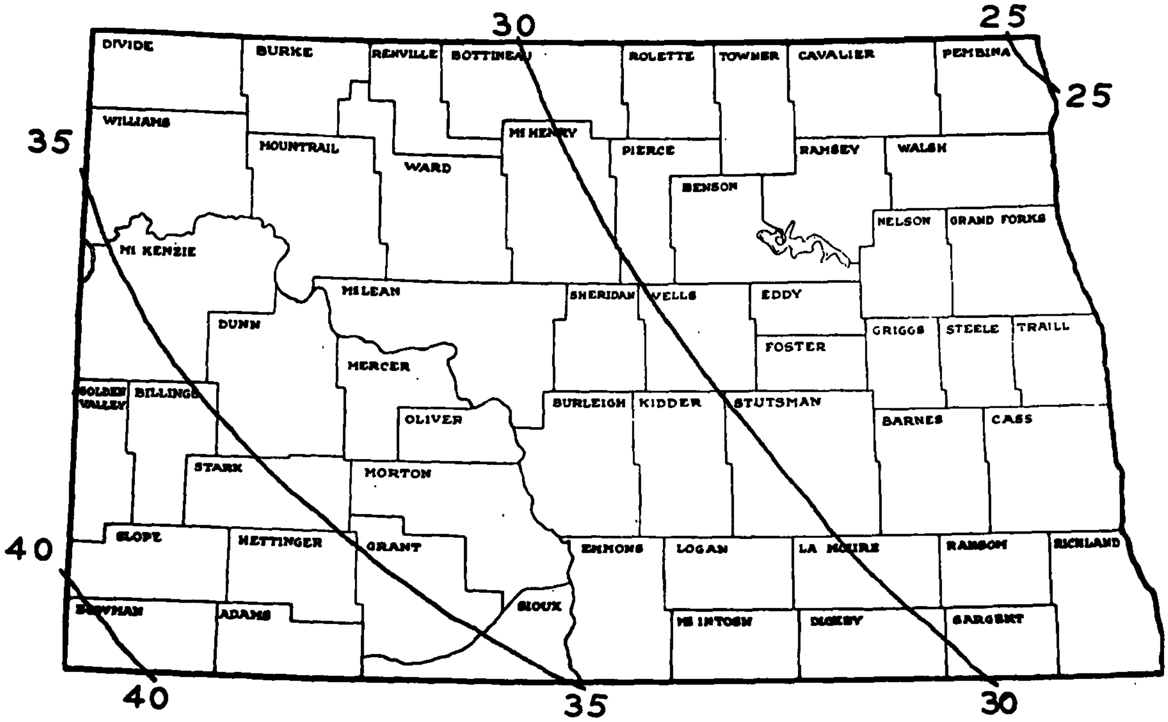


Figure 13

Average Annual Evaporation from Evaporation Tanks (Inches)

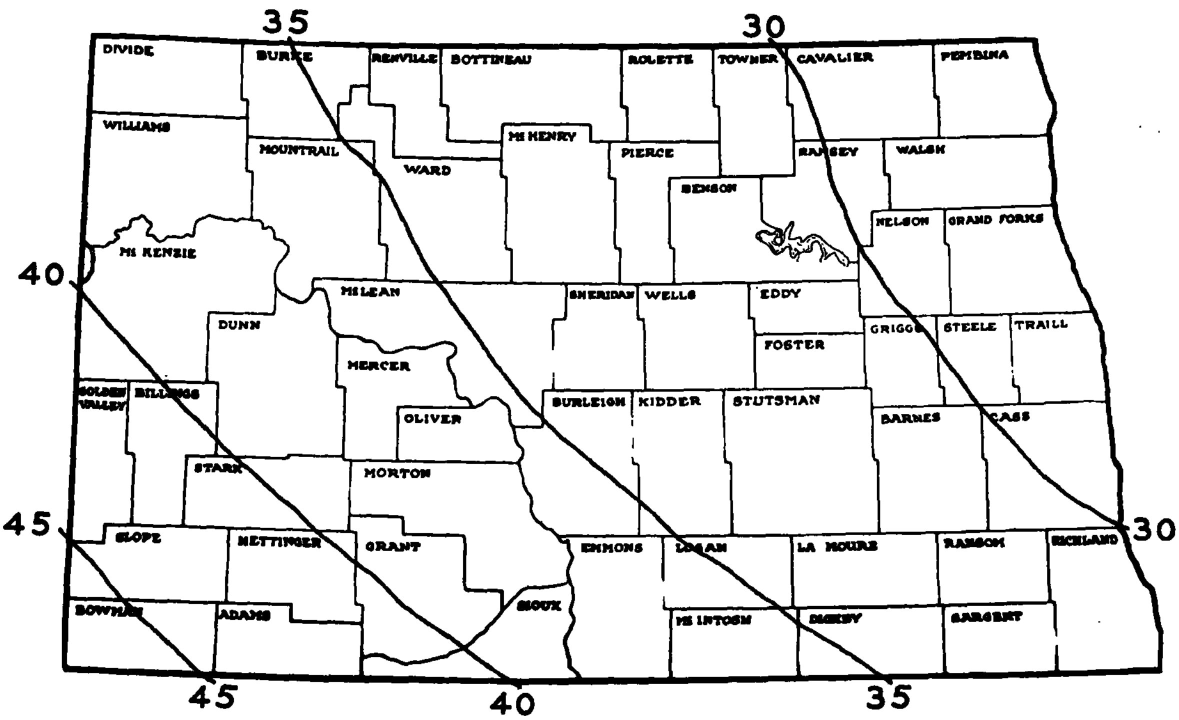


Figure 14

STREAMFLOW

Since the early 1930's, the State of North Dakota has had a cooperative program with the Hydrographic Branch of the U. S. Geological Survey for conducting stream gaging activities. When the State Water Commission was established in 1937, it was designated as the agency to cooperate with the U. S. Geological Survey in a stream gaging program. The data collected from this cooperative program have been of great importance in the planning and development of water resource projects.

In order to serve the needs of mankind and to control the state's streams, it is essential that knowledge be acquired as to their flow. A knowledge of minimum flows is essential in order to provide public and industrial water supplies, to assure dilution of wastes and to insure an adequate water supply for irrigation purposes. The amount of storage needed to alleviate a deficiency during low flow periods must be determined, and the amount of runoff the stream will yield to fill this storage must be known to satisfactorily solve such problems. Power, and Fish, Wildlife and Outdoor Recreation development also demand stream flow information. In order to administer water rights fairly, factual information concerning the amount of water available is important. During flooding, it is helpful to know the peak flow rates and the runoff volume. In finding solutions to flooding, it is essential to know the magnitude and frequency of flood flows.

TABLE 1. SUMMARY OF STREAMFLOW IN NORTH DAKOTA

GAGING STATIONS FOR THE MISSOURI RIVER DRAINAGE BASIN

STREAM	LOCATION NEAR	DRAINAGE AREA SQ. MILES	DRAINAGE AREA NON-CONTRIB. SQ. MILES	NUMBER YRS OF RECORD	AVERAGE DAILY FLOW C.F.S.	AVERAGE ANNUAL YIELD ACRE-FEET	AVERAGE[1] ANNUAL RUNOFF INCHES	MAXIMUM DISCHARGE C.F.S.	DATE	MINIMUM DISCHARGE C.F.S.	DATE
Missouri River	Culbertson, Mont.	91,557		16	9,510	6,885,000	1.41	78,200	Mar 26, 1943	575	Nov 22, 1941
Yellowstone River	Sidney, Mont.	68,812		54	12,790	9,260,000	2.53	159,000	Jun 21, 1921	470	May 17, 1961
Missouri River	Williston	164,500		42	21,960	15,900,000	1.82	231,000	Apr 4, 1930	1,320	Dec 28, 1939
Little Muddy Creek	Williston	875	100	12	27.6	19,980	.49	6,910	Mar 27, 1960	0.2	At various times
White Earth River	White Earth	490		12	18.2	13,180	.50	2,300	Mar 28, 1960	No Flow	Occurs some years
LITTLE MISSOURI SUBBASIN:											
Little Beaver Creek	Marmarth	587		28	38.9	28,160	.90	12,700	Apr 6, 1952	No Flow	Occurs most years
Little Missouri River	Marmarth	4,640		28	312.	225,900	.92	45,000	Mar 23, 1947	No Flow	Occurs most years
Little Missouri River	Medora	6,190		33	360	261,000	.79	65,000	Mar 23, 1947	No Flow	At various times
Beaver Creek	Wibaux, Mont.	351		30	23	16,650	.89	3,780	Mar 21, 1939	No Flow	At various times
Little Missouri River	Watford City	8,310		32	547	396,000	.88	110,000	Mar 25, 1947	No Flow	Occurs most years
Missouri River	Below Garrison Dam	181,400		18	20,500	14,840,000	1.54	348,000	Apr 5, 1952	3,000	Nov 24, 1950
KNIFE RIVER SUBBASIN:											
Knife River	Golden Valley	1,230		40	91.	65,880	1.00	10,900	Apr 16, 1950	No Flow	At various times
Spring Creek	Zap	549		21	38.3	27,730	.95	6,130	Apr 7, 1952	No Flow	At various times
Knife River	Hazen	2,240		33	168.	121,600	1.02	35,300	Jun 24, 1966	No Flow	At times 1933, 59, 62
Turtle Creek	Turtle Lake	310	195	10	0.3	217	.36	91	Feb 27, 1957	No Flow	Occurs each year
Painted Woods Creek	Wilton	427	310	9	4.3	3,110	.50	1,100	Mar 15, 1966	No Flow	Occurs each year
Missouri River	Bismarck	186,400		38	20,550	14,880,000	1.50	500,000	Apr 6, 1952	1,800	Jan 3, 1940
HEART RIVER SUBBASIN:											
Heart River	South Heart	315		20	25.3	18,320	1.10	5,090	Jun 23, 1957	No Flow	At various times
Heart River	Below Dickinson Dam	404		15	19.1	13,830	.65	4,050	Apr 7, 1954	No Flow	At various times
Green River	Gladstone	356		21	31.2	22,590	1.20	5,260	Apr 15, 1950	No Flow	At various times
Heart River	Richardton	1,240		42	96.4	69,790	1.05	23,400	Apr 16, 1950	No Flow	At various times
Heart River	Below Lake Tschida	1,710		23	123	89,050	.98	25,000	Mar 24, 1947	No Flow	At various times
Antelope Creek	Carson	221		18	12.8	9,270	.79	11,100	Apr 16, 1950	No Flow	At various times
Big Muddy Creek	Almont	456		21	33.3	24,110	1.02	20,200	Apr 17, 1950	No Flow	At various times
Heart River	Lark	2,750		20	186.	134,700	.92	29,200	Apr 17, 1950	No Flow	At various times
Sweetbriar Creek	Judson	157		15	8.79	6,360	.76	3,400	Jun 2, 1955	No Flow	At various times
Heart River	Mandan	3,310		33	232	168,000	.95	30,500	Apr 19, 1950	No Flow	At various times
Apple Creek	Menoken	1,680	500	21	39	28,230	.45	6,750	Apr 18, 1950	No Flow	Occurs some years

STREAM	LOCATION NEAR	DRAINAGE AREA SQ. MILES	DRAINAGE AREA NON-CONTRIB. SQ. MILES	NUMBER YRS OF RECORD	AVERAGE DAILY FLOW C.F.S.	AVERAGE ANNUAL YIELD ACRE-FEET	AVERAGE ANNUAL RUNOFF INCHES [1]	MAXIMUM DISCHARGE C.F.S.	DATE	MINIMUM DISCHARGE C.F.S.	DATE
CANNONBALL RIVER SUBBASIN:											
Cannonball River	Regent	580		16	30.5	22,080	.72	6,040	Jun 22, 1957	No Flow	At various times
Cannonball River	Bentley	1,140		23	78.3	56,690	.93	51,800	Apr 17, 1950	No Flow	At various times
Cedar Creek	Haynes	553		16	24.2	17,520	.60	7,870	Apr 7, 1952	No Flow	At various times
Cedar Creek	Pretty Rock	1,340		23	66.7	48,290	.68	48,000	Apr 17, 1950	No Flow	At various times
Cedar Creek	Raleigh	1,750		5				6,000	Mar 15, 1966	No Flow	Occurs most years
Cannonball River	Breien	4,100		32	226	163,600	.75	94,800	Apr 19, 1950	No Flow	Occurs some years
Beaver Creek	Linton	717	100	17	46.2	33,450	1.02	9,800	Apr 8, 1952	No Flow	Occurs some years
GRAND RIVER SUBBASIN:											
N. Fork Grand River	Haley	509		30	29.8	21,570	.80	14,100	Apr 7, 1952	No Flow	At various times

FOOTNOTE:
1/ Runoff in inches is defined as the depth to which the drainage area would be covered if all the runoff for a given period were uniformly distributed on it.

GAGING STATIONS FOR THE JAMES RIVER, SOURIS RIVER AND DEVILS LAKE DRAINAGE BASINS

STREAM	LOCATION NEAR	DRAINAGE AREA SQ. MILES	DRAINAGE AREA NON-CONTRIB. SQ. MILES	NUMBER YRS OF RECORD	AVERAGE DAILY FLOW C.F.S.	AVERAGE ANNUAL YIELD ACRE-FEET	AVERAGE ANNUAL RUNOFF INCHES[1]	MAXIMUM DISCHARGE C.F.S.	DATE	MINIMUM DISCHARGE C.F.S.	DATE
JAMES RIVER DRAINAGE BASIN:											
James River	Manfred	253	197	9	2.06	1,490	.5	555	Mar 27, 1960	No Flow	Occurs each year
Big Slough	Hamberg	60	18	9	1.4	1,010	.45	170	Jul 22, 1965	No Flow	Occurs each year
James River	New Rockford	714	435	16	7.15	5,180	.35	1,140	Mar 20, 1966	No Flow	Occurs most years
James River	Pingree	1,670	990	14	16.2	11,730	.32	1,400	Apr 1, 1966	No Flow	Occurs most years
Pipestem Creek	Buchanan	758	460	16	18.2	13,180	.83	4,480	Apr 17, 1950	No Flow	At various times
James River	Jamestown	2,820	1,650	31	53.4	38,660	.62	6,390	May 13, 1950	No Flow	At times in 1933
James River	LaMoure	4,390	2,600	16	77.1	55,820	.59	5,730	May 16, 1950	No Flow	Occurs some years
Maple River	N.D. State Line	750	270	10	19.0	13,760	.54	2,620	Mar 16, 1966	No Flow	Occurs each year
SOURIS RIVER DRAINAGE BASIN:											
Long Creek[2]	Outram, Sask.	2,020	1,270	7	20.3	14,700	.37	1,330	Mar 27, 1960	No Flow	Occurs each year
Long Creek[2]	Crosby	2,080	1,300	20	24.0	17,380	.42	6,240	Apr 23, 1948	No Flow	Most of the time
Long Creek[2]	Noonan	2,500	1,620	7	25.2	18,240	.39	3,200	Mar 27, 1960	No Flow	Occurs each year
Short Creek[2]	Roche Perce, Sask.	480		6	3.8	2,750	.11	1,360	Mar 28, 1960	No Flow	Occurs each year
Souris River[2]	Sherwood	9,650	6,400	36	96.3	69,720	.40	7,400	Apr 28, 1948	No Flow	Occurs some years
Souris River	Foxholm	10,200	6,700	31	94.6	68,490	.37	3,040	May 16, 1948	No Flow	Occurs some years
Des Lacs	Foxholm	939	400	23	19.7	14,260	.50	2,000	Apr 4, 1949	No Flow	Occurs some years
Souris River	Minot	11,300	7,100	63	135.0	97,740	.44	12,000	Apr 20, 1904	No Flow	Occurs some years
Souris River	Verendrye	12,000	7,400	29	145.0	105,000	.43	4,200	Apr 8, 1949	0.3	At various times
Wintering River	Bergen	176	50	10	3.6	2,610	.39	584	Jul 23, 1965	No Flow	Occurs each year
Wintering River	Karlsruhe	705	420	29	11.1	8,040	.55	3,000	Apr 7, 1949	No Flow	Occurs some years
Souris River	Bantry	13,000	8,100	29	162.0	117,300	.45	4,760	Apr 13, 1949	No Flow	Occurs each year
Willow Creek	Dunseith	142	51	13	15.8	11,440	2.36	410	Apr 17, 1960	No Flow	Occurs most years
Oak Creek	Bottineau	59		13	3.47	2,510	.80	95	Jun 10, 1963	No Flow	Occurs each year
Willow Creek	Willow City	1,160	430	10	19.7	14,260	.37	1,190	Apr 9, 1960	No Flow	Occurs each year
Deep River	Upham	975	605	9	1.84	1,330	.07	580	Apr 5, 1960	No Flow	Occurs each year
Egg Creek	Granville	289	150	10	1.66	1,200	.16	258	Mar 28, 1960	No Flow	Occurs each year
Cutbank Creek[3]	Granville	534	290	10	.002	1.4		1	Apr 13, 1960	No Flow	Occurs each year
Boundary Creek	Landa	230	60	7	6.57	4,760	.53	660	Mar 30, 1960	No Flow	At various times
Souris River	Westhope	17,600	10,700	36	165.0	119,500	.33	6,400	Apr 18, 1949	No Flow	Occurs some years
DEVILS LAKE DRAINAGE BASIN:											
Mauvais Coulee	Cando	387	10	10	7.37	5,340	.31	570	Apr 10, 1960	No Flow	Occurs each year
Edmore Coulee	Edmore	382	100	9	8.91	6,520	.43	875	Apr 23, 1956	No Flow	Occurs each year
Little Coulee	Leeds	280	140	11	1.53	1,110	.15	515	Apr 15, 1956	No Flow	Most of time
Big Coulee	Churchs Ferry	2,510	690	16	13.8	9,990	.11	620	Jun 6, 1950	No Flow	Occurs each year

FOOTNOTES:
1/ Runoff in inches is defined as the depth to which the drainage area would be covered if all the runoff for a given time period were uniformly distributed on it.
2/ Denotes an International Gaging Station.
3/ No flow since April 23, 1960 (North Lake Outlet).

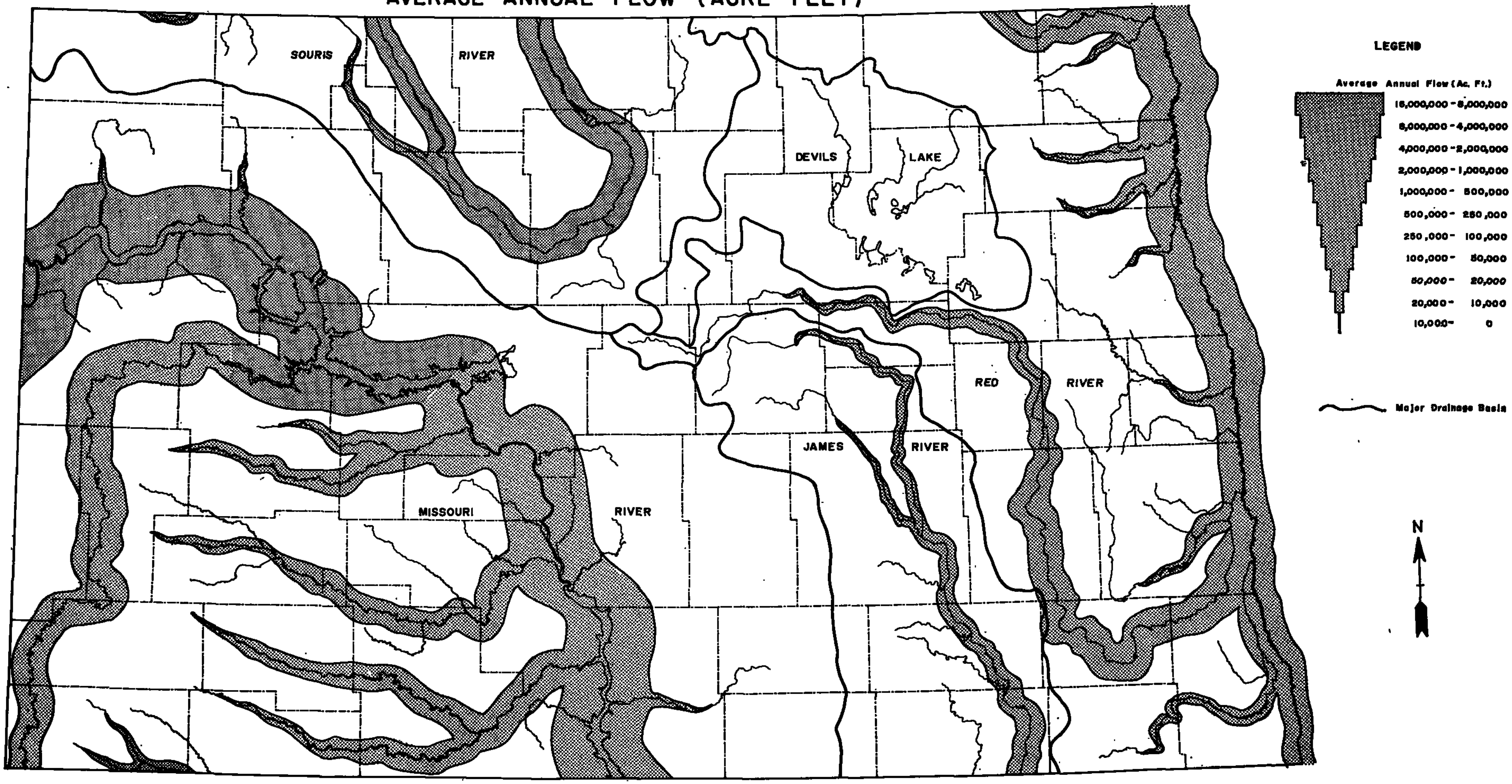
GAGING STATIONS FOR THE RED RIVER OF THE NORTH DRAINAGE BASIN

STREAM	LOCATION NEAR	DRAINAGE AREA SQ.MILES	DRAINAGE AREA NON-CONTRIB. SQ.MILES	NUMBER YRS OF RECORD	AVERAGE DAILY FLOW C.F.S.	AVERAGE ANNUAL YIELD ACRE-FEET	AVERAGE ANNUAL RUNOFF INCHES[1]	MAXIMUM DISCHARGE C.F.S.	DATE	MINIMUM DISCHARGE C.F.S.	DATE
Bois de Sioux	White Rock, S.D.	1,160		25	86.5	62,620	1.01	1,620	Aug 6, 1962	No Flow	Occurs most years
Red River	Wahpeton	4,010		23	534.0	386,600	1.81	7,130	Apr 12, 1952	8.0	Aug 25, 1961
Wild Rice River	Rutland	546	250	7	8.55	6,190	.39	135	Jul 6, 1962	No Flow	Occurs most years
Wild Rice River	Cayuga	955	390	10	18.7	13,540	.45	1,080	Jul 6, 1962	No Flow	Occurs most years
Wild Rice River	Abercrombie	2,080	590	34	66.5	48,140	.61	5,570	Apr 2, 1943	No Flow	Occurs most years
Red River	Fargo	6,800		65	522.0	377,900	1.04	16,300	Apr 15, 1952	No Flow	Occurs most years
Sheyenne River	Harvey	424	270	11	3.78	2,740	.33	224	Apr 11, 1956	No Flow	Occurs most years
N. Fork Sheyenne	Wellsburg	693	490	9	3.64	2,640	.24	216	Apr 2, 1960	No Flow	Occurs most years
Big Coulee	Maddock	146	49	10	2.4	1,740	.34	310	Mar 14, 1966	No Flow	Occurs most years
Sheyenne River	Warwick	2,070	1,310	17	48.8	35,330	.87	4,250	Apr 18, 1956	No Flow	Aug-Sep., 1961
Sheyenne River	Cooperstown	6,470	5,200	22	95.8	69,360	1.03	7,830	Apr 17, 1950	No Flow	Occurs most years
Baldhill Creek	Dazey	691	340	10	10.6	7,670	.41	1,880	Mar 13, 1956	No Flow	Occurs most years
Sheyenne River	Below Baldhill Dam	7,470	5,560	17	105.0	76,020	.75	3,150	Mar 28, 1966	No Flow	1950, 1952, & 1953
Sheyenne River	Valley City	7,810	5,700	28	111.0	80,360	.72	4,580	Apr 28, 1948	No Flow	1938-1941
Sheyenne River	Lisbon	8,190	5,700	10	116.0	83,980	.64	4,260	Mar 30, 1966	No Flow	1956 and 1961
Sheyenne River	Kindred	8,800	5,780	17	174.0	126,000	.78	3,380	Apr 3, 1966	13.0	At various times
Sheyenne River	West Fargo	8,870	5,780	39	154.0	111,500	.68	3,110	Apr 4, 1966	2.0	Dec 14, 1936
Maple River	Enderlin	843	47	10	31.1	22,520	.53	3,390	Apr 12, 1965	0.1	Dec 7-9, 1963
Maple River	Mapleton	1,450	71	22	55.1	39,890	.54	4,840	Jun 17, 1953	No Flow	Occurs most years
Rush River	Amenia	116		20	7.4	5,360	.87	1,230	Apr 14, 1947	No Flow	Occurs most years
Goose River	Portland	517	110	27	25.4	18,390	.85	8,090	May 9, 1950	No Flow	Occurs most years
Goose River	Hillsboro	1,203	110	33	53.1	38,440	.66	9,420	Apr 19, 1950	No Flow	At various times
Red River	Grand Forks	30,100	3,800	84	2,377.0	1,721,000	1.23	80,000	Apr 10, 1897	2.4	Feb., 1937[2]
Turtle River	Manvel	613	57	21	48.4	35,040	1.18	28,000	Apr 19, 1950	No Flow	Occurs most years
M. Br. Forest River	Whitman	73		6	2.12	1,530	.40	240	Apr 11, 1965	No Flow	Occurs each year
Forest River	Fordville	456	120	26	35.8	25,920	1.45	16,400	Apr 18, 1950	No Flow	At various times
Forest River	Minto	740	120	22	47.8	34,610	1.05	16,000	Apr 18, 1950	No Flow	At various times
S. Br. Park River	Below Homme Dam	226		17	26.4	19,110	1.59	13,000	Apr 24, 1950	No Flow	Oct 1-Dec 3, 1949
Cart Creek	Mountain	16.9		12	2.8	2,030	2.25	1,300	Jun 18, 1964	No Flow	At various times
Park River	Grafton	695		35	53.5	38,730	1.05	12,600	Apr 19, 1950	No Flow	Occurs most years
Red River	Drayton	34,800	3,800	17	3,546.0	2,567,000	1.56	86,500	May 12, 1950	7.7	Oct 16, 1936
Hidden Island Coulee[3]	Hansboro	38		5	1.4	1,010	.50	124	Apr 11, 1965	No Flow	Occurs each year
Long River[3]	Sarles	66		5	4.76	3,450	.98	670	Mar 17, 1966	No Flow	Occurs each year
Snow Flake Creek[3]	Snow Flake, Manitoba	348		5	4.8	3,480	.19	227	Apr 14, 1966	No Flow	Occurs each year
Pembina River[4]	Kaleida, Manitoba	2,870		9	114.0	82,530	.54	2,660	Apr 24, 1960	No Flow	Occurs most years
Little Pembina River	Walhalla	182	10	10	16.0	11,580	1.20	4,160	Apr 11, 1960	No Flow	Occurs most years
Pembina River	Walhalla	3,350		27	195.0	141,200	.79	20,400	Apr 18, 1950	No Flow	Occurs some years
Pembina River[3]	Neche	3,410		58	162.0	117,300	.65	10,700	Apr 20, 1950	No Flow	At various times
Herzog Creek	Concrete	18.9		12	2.93	2,120	2.11	260	Apr 2, 1955	No Flow	Occurs each year
Tongue River	Akra	162		15	19.8	14,330	1.67	11,800	Apr 18, 1950	No Flow	At various times
Red River	Emerson, Manitoba	40,200	3,800	54	2,927.0	2,121,000	1.07	95,500	May 13, 1950	0.9	Feb 6-8, 1937

FOOTNOTES:

1/ Runoff in inches is defined as the depth to which the drainage area would be covered if all the runoff for a given time period were uniformly distributed on it.
2/ February 3-5, 12, 16-19, 1937 (Caused by unusual regulation during repair of dam at Grand Forks).
3/ International Gaging Station.
4/ Records furnished by the Water Resources Branch, Department of Northern Affairs and Natural Resources, Canada.

AVERAGE ANNUAL FLOW (ACRE FEET)



NORTH DAKOTA

RESERVOIR STORAGE CAPACITY

Appendix A to the 1968 Interim State Water Resources Development Plan, **An Inventory of Water Storage and Retention Structures in North Dakota,** reports the results of a survey conducted by the Commission to determine the combined capacity of water retention and storage structures found throughout the state. To be useful, an inventory must answer three questions: (1) How much water (acre-feet) is being stored? (2) What is its surface area? and, (3) Where is it being stored? In analyzing the current supply, it is necessary also to determine how the water is being used and by whom. Appendix A, though primarily an inventory, does provide some insight into the matter of which types of water resource developments have been emphasized in past construction efforts.

Appendix A does not present a complete picture of all water retention and storage structures built in the state over the past years because of restrictions on the amount of time which could be devoted to field surveys and because of the sheer number of dams involved. As a result, only those structures with storage or retention capacities of 50 acre-feet or more are included. Many small dams — dams which function primarily as sources of stockwater and as fish and wildlife habitat — are not included. The capacity and surface area of stockwater impoundments constructed under the provisions of the Soil Conservation Service small dams and dugouts program are included in Table 2 of the appendix and they are reported separately in Table 3 of this Chapter, but individual dams and dugouts are not reported in the inventory itself.

In addition to the field surveys conducted by the Commission staff, an extensive search of available records was made. These records, as indicated by the number of blank spaces found in the inventory, were often incomplete. It is the intention of the Commission to update the inventory periodically as new structures are built and as more information pertaining to older dams becomes available.

It should be noted that the storage figures found in the summary table represent only storage **capacity.** Actual storage will vary from year to year according to runoff and use.

TABLE 2. Summary of Reservoir Storage in North Dakota by Function

DRAINAGE BASIN	MUNICIPAL AND DOMESTIC		STOCKWATER		IRRIGATION		INDUSTRIAL AND MINING		QUALITY CONTROL		FLOOD CONTROL		RECREATION	
	Acres	Acre-Feet	Acres	Acre-Feet	Acres	Acre-Feet	Acres	Acre-Feet	Acres	Acre-Feet	Acres	Acre-Feet	Acres	Acre-Feet
Missouri	134	57,998	13,012	51,729	—	3,267,560	7	10,250,100	—	11,030	—	6,052,000	113,517	378,344
Yellowstone	—	—	(310)	(1,133)	—	—	—	—	—	—	—	—	(100)	(517)
Little Missouri	(9)	(50)	(1,714)	(7,300)	—	—	—	—	—	—	—	—	(476)	(3,936)
Knife	—	—	(1,236)	(5,746)	—	—	—	—	—	—	—	—	(1,659)	(9,254)
Heart	—	(3,520)	(2,197)	(8,163)	—	(27,100)	(7)	(28,100)	—	(11,030)	—	(150,000)	(5,081)	(18,712)
Cannonball	—	—	(1,767)	(6,647)	—	—	—	—	—	—	—	—	(1,481)	(9,459)
Grand	—	(3,000)	(257)	(939)	—	—	—	(22,000)	—	—	—	(102,000)	(326)	(2,235)
Western Tribs.	—	—	(763)	(5,006)	—	—	—	—	—	—	—	—	(511)	(4,239)
Eastern Tribs.	(125)	(1,428)	(4,768)	(16,795)	—	—	—	—	—	—	—	—	(19,283)	(76,192)
Mainstem	—	(50,000)	—	—	—	(3,240,460)*	—	(10,200,000)	—	—	—	(5,800,000)	(84,600)	(253,800)
James	319	4,980	2,188	8,792	—	18,195	—	—	—	—	—	200,000	11,500	51,573
Souris	125	634	2,833	9,928	—	2,385	—	—	—	—	—	—	34,208	238,563
Devils Lake	10	100	593	2,151	—	—	—	—	—	—	—	—	6,619	26,307
Red	515	72,188	2,606	9,726	—	—	—	3,672	—	—	—	143,833	13,148	69,277
Wild Rice	—	—	(229)	(826)	—	—	—	—	—	—	—	(2,665)	(1,522)	(7,550)
Sheyenne	(167)	(66,560)	(1,305)	(5,261)	—	—	—	(3,672)	—	—	—	(101,670)	(7,792)	(33,965)
Elm	—	—	(7)	(26)	—	—	—	—	—	—	—	(7,523)	(276)	(996)
Goose	(20)	(360)	(213)	(806)	—	—	—	—	—	—	—	—	(958)	(10,940)
Turtle	(19)	(96)	(79)	(287)	—	—	—	—	—	—	—	—	(291)	(758)
Forest	—	—	(100)	(366)	—	—	—	—	—	—	—	(18,380)	(1,541)	(7,937)
Park	(70)	(2,998)	(296)	(1,055)	—	—	—	—	—	—	—	—	(256)	(861)
Pembina	(72)	(1,174)	(246)	(618)	—	—	—	—	—	—	—	(13,607)	(512)	(6,265)
Minor Tribs.	(167)	(1,000)	(131)	(481)	—	—	—	—	—	—	—	—	—	—
TOTALS	1,103	135,900	21,232	82,326	—	3,288,140	7	10,253,772	—	11,030	—	6,395,833	178,992	764,064

*2,790,000 A.F. of which are allocated for use in the Garrison Diversion Unit.

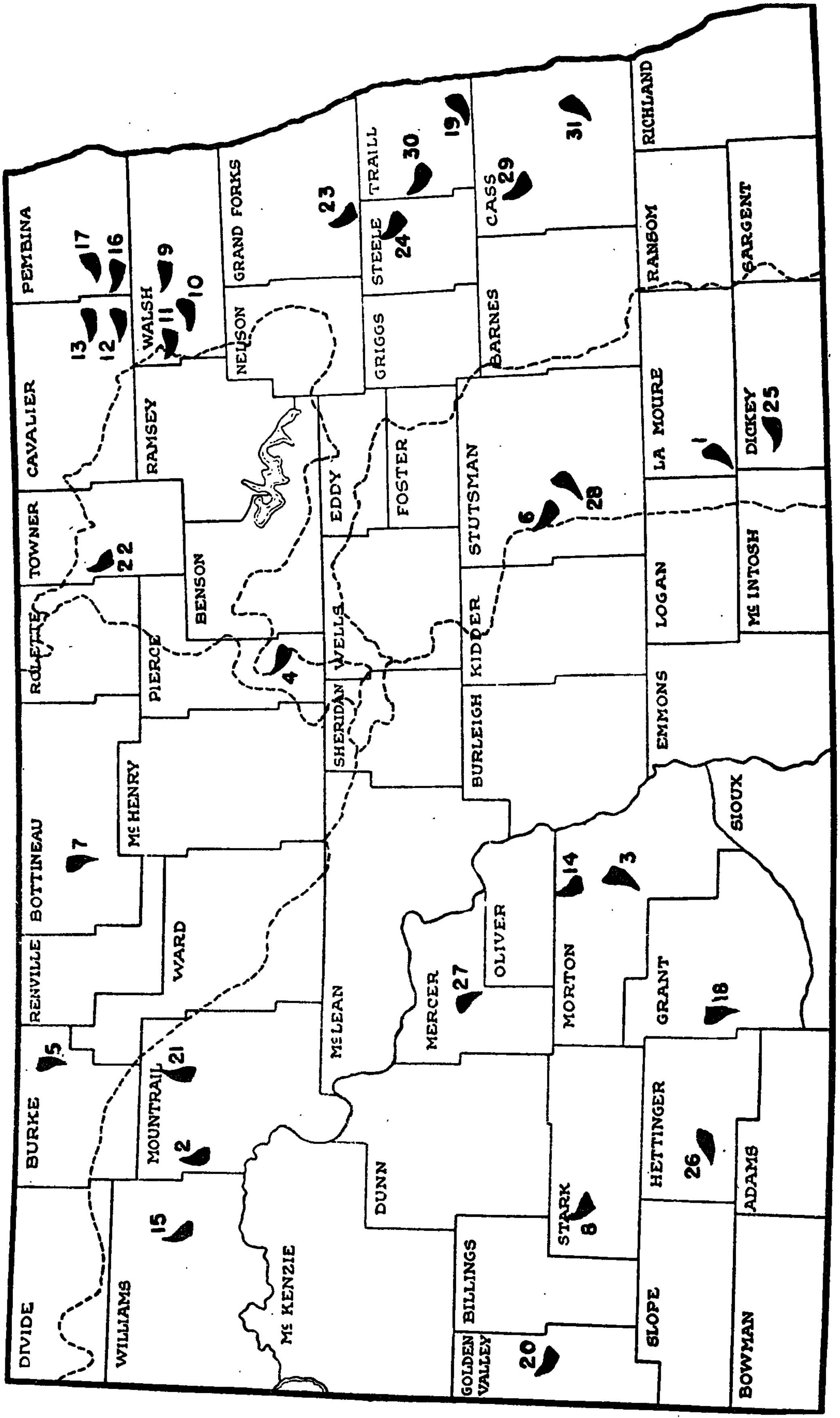
TABLE 3. Soil Conservation Service Dugouts and Small Dams for Livestock Use as of January 1, 1968

Drainage Basin	Surface Acres	Acre-Feet
Missouri River		
Yellowstone River	310	1,133
Little Missouri River	1,692	6,192
Knife River	1,216	5,663
Heart River	2,143	7,843
Cannonball River	1,663	6,087
Grand River	257	939
Western Tributaries	740	4,290
Eastern Tributaries	3,453	11,241
James River	1,344	4,920
Souris (Mouse) River	2,237	8,188
Devils Lake	489	1,791
Red River		
Wild Rice River	209	766
Sheyenne River	972	3,558
Elm River	7	26
Goose River	143	525
Turtle River	79	287
Forest River	100	366
Park River	225	824
Pembina River	193	706
Minor Tributaries	131	481
TOTALS	17,603	65,826

PROGRAMMED PROJECTS

Projects which are currently authorized, under construction or anticipated to be authorized, under construction or completed by December 31, 1969, are, for purposes of this planning effort, considered a part of the current supply. A summary of such programmed projects is found on the following page.

PROGRAMMED STORAGE PROJECTS*



*Anticipated to be in place or under construction by December 31, 1969.

	SWC Project Number	Project Name	Purpose	Surface Area (Acres)	Storage Capacity (Ac. Ft.)	Drainage Area (Sq. Mi.)	River Basin
1.	259	Kulm Dam	Recreation	27	330	66	James
2.	327	White Earth Dam	Recreation	165	1,600	120	Missouri
3.	479	Fish Creek Dam	Recreation	57	1,094	12	Missouri
4.	565	Buffalo Lake Dam	Recreation	1,300	2,100	46	Red
5.	667	Northgate Dam	Recreation	152	1,300	102	Souris
6.	690	Pipestem Dam[1]	Flood Control-Recreation	4,600	135,000	594	James
7.	810	Westhope Dam	Municipal	10	100	12	Souris
8.	926	Dickinson Flood Control Dam	Flood Control	63	625	7	Missouri
9.	929	North Branch Forest[2] River Dam No. 3	Flood Control	179	563	9	Red
10.	929	Middle-South Branch[2] Forest River Dam No. 4	Flood Control	439	5,571	41	Red
			Recreation	197	2,185	41	Red
11.	982	Middle Branch Park[2] River Dam No. 8	Flood Control	110	3,025	20	Red
12.	982	Middle Branch Park[2] River Dam No. 9	Flood Control	85	1,765	10	Red
13.	982	Middle Branch Park[2] River Dam No. 10	Flood Control	98	1,258	8	Red
14.	1292	Doll Dam[2]	Recreation	38	447	6	Missouri
15.	1292	Olson Dam[2]	Recreation	20	160	7	Missouri
16.	1320	Willow Creek Park[2] River Dam No. 1	Flood Control	344	2,178	19	Red
17.	1346	Mount Carmel Dam	Municipal-Recreation	316	4,920	52	Red
18.	1358	Sheep Creek Dam	Recreation	85	1,160	37	Missouri
19.	1365	Grandin Dam	Municipal-Recreation	50	175	156	Red
20.	1382	Camels Hump Butte Dam	Recreation	63	825	7	Missouri
21.	1407	Stanley Dam	Municipal	253	1,550	22	Missouri
22.	1418	Big Coulee Dam	Municipal-Recreation	181	1,425	93	Devils Lake
23.	1424	Northwood Dam	Municipal Recreation	115	1,128	47	Red
24.	1425	Hatton Dam No. 1 and No. 2	Municipal-Recreation	25	200	242	Red
25.	1455	Wilson Dam[2]	Recreation	58	341	52	James
26.	1457	Mott Dam[2]	Flood Control	188	1,461		Missouri
27.	1464	Beulah Dam	Industrial	785	24,000	33	Missouri
28.	1469	Big Buffalo Dam	Recreation	33	400	7	James
29.	1471	Erie Dam	Recreation	102	1,305	11	Red
30.	1476	Mayville-Hillsboro Dam	Municipal-Recreation				Red
31.	1479	Holly-Harwood Dam	Industrial	56	832	7,128	Red

[1]U. S. Corps of Engineers Project
[2]U. S. Soil Conservation Service Projects

GROUND-WATER RESERVES

Table 4 is a summary of the data on the aquifers outlined on the "Progress Map Showing Major Glacial Drift Aquifers in North Dakota and Estimated Potential Yields." Most of the data is derived from the individual county ground-water reports.

The acre-feet in storage was determined by using the average aquifer thickness, area and assuming a porosity for the aquifer of 30 percent. Of this amount of water, about one-half would be available to wells. It must be kept in mind that this figure represents that amount of water in storage at a given time. Potential recharge is not taken into consideration because in most cases insufficient data are available on which to base meaningful estimates The estimated water in storage does not represent a true development potential for some aquifers; however, it should serve as another guideline in estimating potential.

The term "unconfined" as used in Table 4 denotes a water table aquifer. The depth to water can range from the landsurface to several tens of feet below the landsurface. In a water table condition the water level will not rise above the level at which the aquifer was penetrated.

TABLE 4. **AQUIFER DATA SUMMARY**

Aquifer	Counties in Which Described	River Basin	Area (Sq. Mi.)	Average Thickness (Feet)	Av. Depth to Top of Aquifer (Feet)	Average Total Dissolved Solids (Parts per Million)	Est. Water in Storage (Acre-Feet)
MISSOURI RIVER BASIN:							
McKenzie	Burleigh	Missouri	36	30	50-130	1000-1500	210,000
Long Lake	Burleigh	Missouri	32	5-70	90-150	1000	180,000
Lower Apple Creek	Burleigh	Missouri	21	10-100	40-110	-1000	160,000
Glencoe Channel	Burleigh	Missouri	26	50-100	20-60	1500	300,000
Sibley Channel	Burleigh	Missouri	3	75	50-80	-1500	43,000
Wing Channel	Burleigh	Missouri	10	-	45-170		———
Bismarck	Burleigh	Missouri	25	50	20-105	800-1800	240,000
Burnt Creek	Burleigh	Missouri	6	50	10-30	1000-1700	58,000
Wagons Port	Burleigh	Missouri	4	50	-	1300	38,000
Glenview	Burleigh	Missouri	5	-	-	800	———
North Burleigh	Burleigh	Missouri	19	10-50	-	700	110,000
Random Creek	Burleigh	Missouri	8	5-77	-	1400	46,000
Painted Woods	Burleigh	Missouri	20	-30	-	600	38,000
Yellowstone Channel							
Southern Unit	Divide	Missouri & (Souris)	50	-	-	1400-6500	7,300,000
Central Unit	Divide	Missouri & (Souris)	40	47	-	500-2400	200,000
Grenora	Divide	Missouri	93	80	-	1000-2050	190,000
Wildrose	Divide	Missouri	30	-	-	-	———
West Wildrose	Divide & Williams	Missouri	5	26	100	600	18,000
Undifferentiated	Kidder	Missouri	440	50	-	500	4,200,000
Little Muddy	Williams	Missouri	125	70	-	700-2000	1,500,000
Ray	Williams	Missouri	100	60	100	600-2300	1,250,000
Grenora	Williams	Missouri	23	80	-	1200	180,000
Trenton	Williams	Missouri	40	50	20-70	900-3000	420,000
Hofflund	Williams	Missouri	15	45	10-110	900	70,000
JAMES RIVER BASIN:							
Spiritwood	Barnes & Stutsman	James & (Red)	320	50	75-150	600-1100	3,000,000
New Rockford	Eddy, Foster & Wells	James & (Red)	152	110	100	1200-1500	3,200,000
Carrington	Foster & Wells	James	58	40	40	700	470,000
Rosefield	Eddy, Foster & Wells	James	10	35	-	750	———
Bald Hill Creek	Foster	James	3	-	-	830	———
James River	Foster	James	6.5	50	-	500	62,000

TABLE 4 — (Continued)

Aquifer	Counties in Which Described	River Basin	Area (Sq. Mi.)	Average Thickness (Feet)	Av. Depth to Top of Aquifer (Feet)	Average Total Dissolved Solids (Parts per Million)	Est. Water in Storage (Acre-Feet)
James River Basin (Cont.)							
Juanita Lake	Foster	James	5	40	-	550	38,000
Pipestem Creek	Foster & Wells	James	22	25	-	800-1000	96,000
Russell Lake	Foster	James	3	48	-	650	28,000
Marstonmoor Plain	Stutsman	James & (Missouri)	35	28	Unconfined	-	180,000
Rusland	Wells	James	6	50	-	2000	58,000
Rocky Run	Wells	James	5	60	-	600	58,000
Heimdal	Wells	James	15	40	-	500	95,000
Manfred	Wells	James	16	75	-	830	230,000
South Fessenden	Wells	James	3	80	-	2100	46,000
SOURIS RIVER BASIN:							
Yellow Stone Channel							
Northern Unit	Divide	Mouse	-	50	-	850-2600	300,000
Skjermo Lake	Divide	Mouse	25	66	-	800-2550	170,000
RED RIVER BASIN:							
Sand Prairie	Barnes	Sheyenne	8	10	-	-	50,000
Fargo	Cass	Red	10	45	-	-1000	86,000
West Fargo	Cass	Sheyenne	110	60	-	-1600	970,000
Page	Cass	Sheyenne, Elm & Goose	155	30	50	290- 850	900,000
Bantel	Cass	Sheyenne	9	0-80	-	1350	410,000
Sheyenne Delta	Cass	Sheyenne	40	40	Unconfined	500	----------
Eastman	Foster	Sheyenne	14		-	1000	----------
Hamar	Eddy	Sheyenne			-	400	----------
Johnson Lake	Eddy	Sheyenne	3		-	700	----------
Northwest Eddy	Eddy	Sheyenne	2.4	25	-	300	12,000
Central Eddy	Eddy	Sheyenne	16	20	-	320-1350	58,000
Warwick	Eddy	Sheyenne	24	40	-	120- 360	180,000
Sheyenne Village	Eddy	Sheyenne	0.5	9	-	600	1,000
Tokio	Eddy	Sheyenne	1	20	-	-	3,800
Cherry Lake	Eddy	Sheyenne	3	30	-	420	17,000
Elk Valley	Grand Forks	Forest, Turtle & Goose	160	34	-	300-1200	1,000,000
Inkster	Grand Forks	Forest & Turtle	11	30	-	370	63,000
Thompson	Grand Forks	Red	8	18	-	4530	27,000
Sheyenne Delta	Richland	Sheyenne & Wild Rice	300	50	Unconfined	500	4,000,000
Hankinson	Richland	Wild Rice	100	30	Unconfined	400	330,000
Milnor Channel	Richland	Wild Rice	40	30	Unconfined	800	150,000
Brightwood	Richland	Wild Rice	13	40	Unconfined	600	100,000
Fairmount	Richland	Wild Rice		14	80-110	800	----------
Colfax	Richland	Wild Rice			100-150	2200	----------

EXPLANATION

The study of the ground-water resources of North Dakota was begun on a county basis in 1956. Since that time 26 counties have been completed or are currently in progress. The studies are conducted cooperatively by the United States Geological Survey, North Dakota Geological Survey, North Dakota State Water Commission, and the board of county commissioners or water management district. The results of the studies are published in three parts: Part I, Geology; Part II, Ground-Water Basic Data; and Part III, Ground-Water Resources.

Approximately two-thirds of North Dakota is covered by glacial drift. Its thickness is known to range from 0 to 800 feet. Much of the drift consists of material which is too impervious to readily yield water to wells. The major glacial drift aquifers (ground-water reservoirs) consist of sand and gravel.

This map is a summary of the major glacial drift aquifers described in county ground-water reports. These aquifers are considered to have the greatest potential for yielding significant quantities of water for municipal, industrial and agricultural purposes.

The potential yields shown are preliminary estimates of average yields to properly constructed individual wells. The lithology, permeability and saturated thickness of glacial drift aquifers are usually quite variable. Since these properties have the greatest influence on well yields, the yield to wells will also be variable.

For more complete information concerning the areal extent, water quality and water bearing properties of the various aquifers, the reader is referred to individual county ground-water reports. These reports are available from the North Dakota Geological Survey, Grand Forks, North Dakota, and the North Dakota State Water Commission, State Office Building, Bismarck, North Dakota 58501.

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"Buy North Dakota Products"

NORTH DAKOTA STATE WATER COMMISSION

August 22, 1968

Approximate Basin and Sub-Basin of the Garrison Diversion Appropriation

INITIAL STAGE DEVELOPMENT (250,000 ACRES)

Basin	Municipal and Industrial (Acre-Feet)	Irrigation Acres	Irrigation Acre-Feet	Fish, Wildlife and Recreation Acre-Feet	Reservoir Evaporation (Acre-Feet)	Maximum Normal Operation Storage (Acre-Feet)
Missouri River East Tributaries	500	----------	----------	20,000	36,000	400,000[1]
Souris River	26,000	116,000	373,000	20,000	----------	----------
Sheyenne River	----------	50,500	133,000	10,000	22,000	420,000[2]
James River	10,000	59,300	162,000	5,000	4,000	50,000
Wild Rice River	----------	18,500	50,000	5,000	----------	----------
Devils Lake	3,500	5,700	10,000	110,000	----------	----------
TOTALS	40,000	250,000	728,000	170,000	62,000	870,000

SECOND STAGE DEVELOPMENT

Basin	Municipal and Industrial (Acre-Feet)	Irrigation Acres	Irrigation Acre-Feet	Fish, Wildlife and Recreation Acre-Feet	Reservoir Evaporation (Acre-Feet)	Maximum Normal Operation Storage (Acre-Feet)
Missouri River - East Tributaries	500	44,095	110,000	5,000	----------	----------
Souris River	6,000	361,630	1,147,000	25,000	13,000	130,000
Sheyenne River	500	206,445	427,000	10,000	----------	----------
James River	2,500	134,750	348,000	20,000	----------	----------
Wild Rice River	500	10,200	30,000	----------	----------	----------
Devils Lake	----------	----------				
TOTALS	10,000	757,120	2,062,000	60,000	13,000	130,000

ULTIMATE PLANNED DEVELOPMENT

Basin	Municipal and Industrial (Acre-Feet)	Irrigation Acres	Irrigation Acre-Feet	Fish, Wildlife and Recreation Acre-Feet	Reservoir Evaporation (Acre-Feet)	Maximum Normal Operation Storage (Acre-Feet)
Missouri River - East Tributaries	1,000	44,095	110,000	25,000	36,000	400,000[1]
Souris River	32,000	477,630	1,520,000	45,000	13,000	130,000
Sheyenne River	500	256,945	560,000	20,000	22,000	420,000[2]
James River	12,500	194,050	510,000	25,000	4,000	50,000
Wild Rice River	500	28,700	80,000	5,000	----------	----------
Devils Lake	3,500	5,700	10,000	110,000	----------	----------
GRAND TOTALS	50,000	1,007,120	2,790,000	230,000	75,000	1,000,000

[1]Lake Audubon (Snake Creek arm of Lake Sakakawea).
[2]Lonetree Reservoir located on Sheyenne River and headwaters of tributaries to Souris and James Rivers.

Chapter Nine

Requirements for Water Utilization and Control

CHAPTER IX

REQUIREMENTS FOR WATER UTILIZATION AND CONTROL

Of major importance in the development of a plan for the wise and efficient management of water and related land resources is the need to determine present and projected water use and control requirements. Included among the state's basic water uses are municipal and domestic, livestock, irrigation, industrial and mining, fish, wildlife and outdoor recreation, and quality control. Another area which must be considered in developing water and related land resources is that of flood prevention and runoff management.

This Chapter treats each of the state's basic water uses individually, giving the estimated net requirements for each by major drainage basin for 1968, 1980 and 2000. A series of tables at the end of the Chapter summarizes the net annual requirements for each function for each time period on a state-wide basis.

Preceding each group of tables containing the net annual requirement figures for each of the basic water uses is a brief narrative explanation of the methodology employed in developing the data.

Municipal and Domestic Water Requirements

Municipal water is that supplied to communities of 2,500 or more population through central distribution systems. Domestic water is defined as the water used in communities of less than 2,500 population and all water used on the farm with the exception of livestock and irrigation water.

For a more detailed definition of **municipal** and **domestic** water and for an explanation of how projections and standards of use were derived, see Chapter VII.

Tables 1 through 5 of this Chapter summarize annual **municipal** and **domestic** requirements by major drainage basins for the present, 1980, and 2000. **The reader is cautioned to keep in mind that the net requirement figures reflected in these tables are basin-wide requirements and they are expressed in terms of quantity only.** An indicated surplus of municipal and domestic water on a basin-wide basis should not be construed as meaning that local shortages can or do not exist. By the same token, a community may possess an abundant water supply without possessing, at the time, a supply of water which meets the minimum quality standards set by the State Health Department.

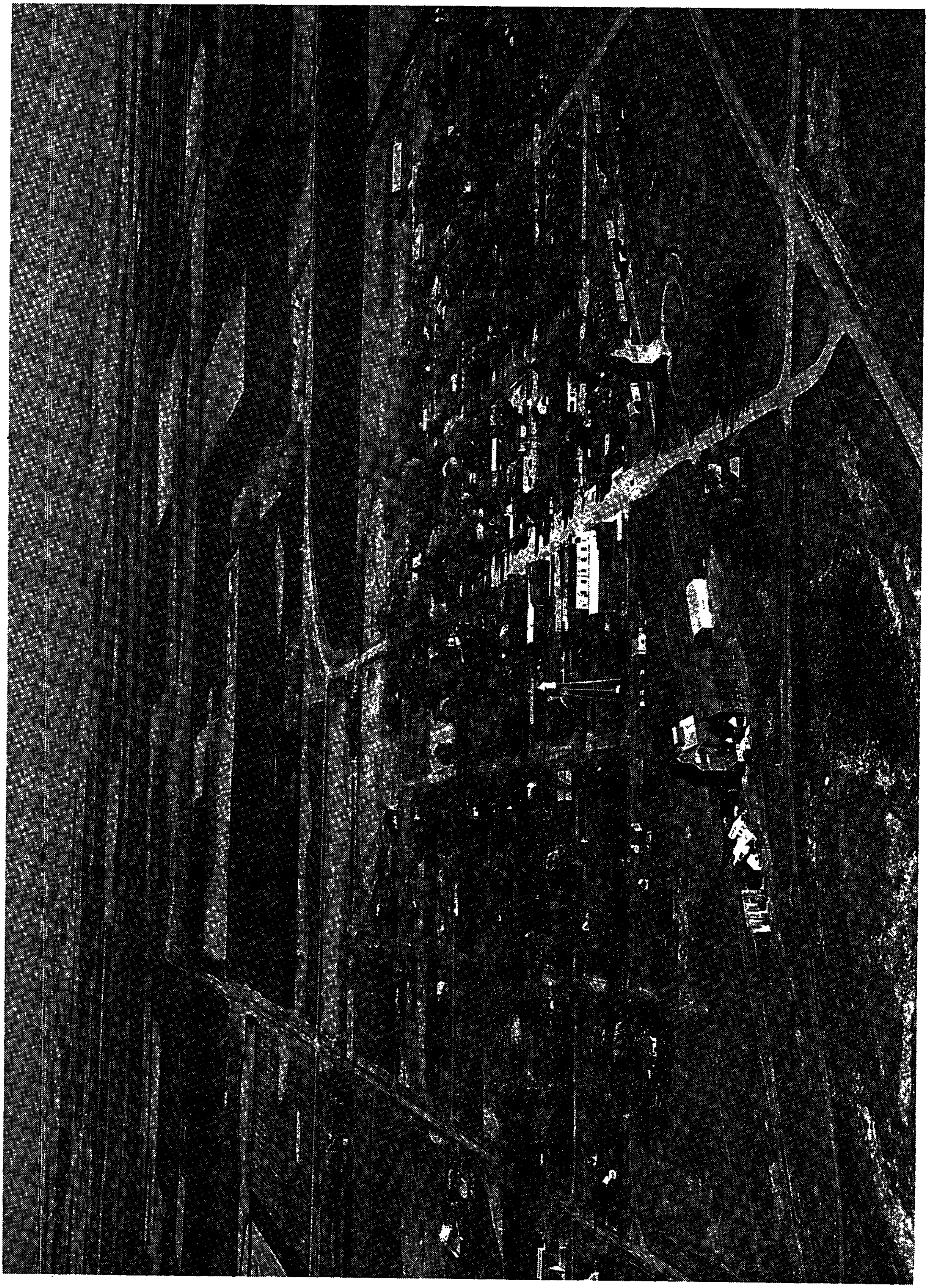


TABLE 1. Municipal and Domestic Water Use — Missouri River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	15,800	20,890	43,200
Consumptive Use Due to Evaporation	402	402	402
Non-Consumptive Use	-------	-------	-------
TOTAL	16,202	21,292	43,602
Current Developed Supply			
Surface Water (acres)	134	134	134
Surface Water (acre-feet)	15,648*	18,598*	29,198*
Ground Water (acre-feet)	8,000	8,000	8,000
Net Requirements (acre-feet)	-7,446**	-5,306**	6,404

*Approximately 7,650 acre-feet in 1968; 10,600 acre-feet in 1980; and 21,200 acre-feet in 2000 supplied by the stream flow of the Missouri River. Municipalities utilizing such water include Bismarck, Mandan, Washburn, and Williston.

**Minus symbol indicates that total basin storage is in excess of total basin requirements. Does not preclude the existence of local shortages.

TABLE 2. Municipal and Domestic Water Use — James River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	4,550	6,400	12,910
Consumptive Use Due To Evaporation	957	957	957
Non-Consumptive Use	-------	-------	-------
TOTAL	5,507	7,357	13,867
Current Developed Supply			
Surface Water (acres)	319	319	319
Surface Water (acre-feet)	4,980	4,980	4,980
Ground Water (acre-feet)	4,550	4,550	4,550
Net Requirements (acre-feet)	-4,023*	-2,173*	4,337

*Minus symbol indicates that total basin storage is in excess of total basin requirements. Does not preclude the existence of local shortages.

TABLE 3. Municipal and Domestic Water Use — Souris River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	8,440	12,010	20,700
Consumptive Use Due To Evaporation	375	375	375
Non-Consumptive Use	-------	-------	-------
TOTAL	8,775	12,385	21,075
Current Developed Supply			
Surface Water (acres)	125	125	125
Surface Water (acre-feet)	2,700*	2,700*	2,700*
Ground Water (acre-feet)	5,697	5,697	5,697
Net Requirements (acre-feet)	378	3,988	12,678

*Provided in part by normal stream flow and in part by periodic releases from Lake Darling.

TABLE 4 Municipal and Domestic Water Use — Devils Lake Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	2,450	2,790	6,300
Consumptive Use Due To Evaporation	150	150	150
Non-Consumptive Use	-------	-------	-------
TOTAL	2,600	2,940	6,450
Current Developed Supply			
Surface Water (acres)	50	50	50
Surface Water (acre-feet)	100	405*	405*
Ground Water (acre-feet)	2,500	2,500	2,500
Net Requirements (acre-feet)	0	35	3,545

*No additional consumptive use by evaporation is included here because the project programmed to furnish the additional 305 acre-feet of municipal water by 1980 is a multiple use project with the evaporation being charged to recreation.

TABLE 5. Municipal and Domestic Water Use — Red River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	20,310	29,250	52,400
Consumptive Use Due To Evaporation	1,545	2,265	2,265
Non-Consumptive Use	-------	-------	-------
TOTAL	21,855	31,515	54,665
Current Developed Supply			
Surface Water (acres)	515	755	755
Surface Water (acre-feet)	72,188	73,553	73,553
Ground Water (acre-feet)	9,110	9,110	9,110
Net Requirements (acre-feet)	-59,443*	-51,148*	-27,998*

*Indicates a surplus of domestic and municipal water storage within the basin. Is attributable, in part, to storage held in Lake Ashtabula for municipal purposes. While it is a surplus, it should be noted that during an extended period of low flows, the surplus could not meet minimum needs for one year.

Livestock Water Use Requirements

Tables 6 through 10 of this Chapter summarize Livestock Water Use Requirements by major drainage basins for the present, 1980, and 2000. Sources of livestock water include ground water, dugouts, and both small and large dams.

Data obtained through a "small dam" inventory recently conducted by the State Water Commission seems, on the surface, to support the idea that current surface water developments alone store nearly as much livestock water as is presently needed. A careful analysis of these data reveals, however, that the current indicated total supply of surface water available for livestock use is, to a degree, an illusion. This is obvious for a number of reasons, including the following: (1) surface water is not always physically accessible to livestock; (2) surface water is generally considered inaccessible during the winter months; (3) during periods of extended low stream flow, surface water is often an uncertain and inferior supply; (4) the occurrence of a surface water supply frequently does not conform to accepted range-management practices; (5) a basin-wide surplus of livestock water does not preclude the possibility of local shortages; (6) surface water storage facilities become less efficient over time because of siltation; (7) embankment or spillway failures are always a possibility; (8) surface water structures require periodic, often costly, maintenance.

In view of these limitations, it is readily apparent that no amount of surface water alone can meet stockwater requirements. Ground water, by necessity, must provide a part of the total stockwater requirement. For purposes of this report, it is assumed that ground water presently provides 50% of the total stockwater required in each basin.

TABLE 6. Livestock Water Use — Missouri River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	13,387	19,297	32,677
Consumptive Use Due To Evaporation	39,036	39,036	39,036
Non-Consumptive Use	-------	-------	-------
TOTAL	52,423	58,333	71,713
Current Developed Supply			
Surface Water (acres)	13,012	13,012	13,012
Surface Water (acre-feet)	50,128	50,128	50,128
Ground Water (acre-feet)	6,693	6,693	6,693
Net Requirements (acre-feet)	—4,398*	1,512	14,892

*Minus symbol indicates that total basin storage is in excess of total basin requirements. It does not preclude the existence of local shortages.

TABLE 7. Livestock Water Use — James River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	3,971	5,723	9,666
Consumptive Use Due To Evaporation	6,564	6,564	6,564
Non-Consumptive Use	-------	-------	-------
TOTAL	10,535	12,287	16,230
Current Developed Supply			
Surface Water (acres)	2,188	2,188	2,188
Surface Water (acre-feet)	8,792	8,792	8,792
Ground Water (acre-feet)	1,985	1,985	1,985
Net Requirements (acre-feet)	— 242*	1,510	5,453

*Minus symbol indicates that total basin storage is in excess of total basin requirements. It does not preclude the existence of local shortages.

TABLE 8. Livestock Water Use — Souris River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	3,111	4,472	7,565
Consumptive Use Due To Evaporation	8,499	8,499	8,499
Non-Consumptive Use	———	———	———
TOTAL	11,610	12,971	16,064
Current Developed Supply			
Surface Water (acres)	2,833	2,833	2,833
Surface Water (acre-feet)	9,928	9,928	9,928
Ground Water (acre-feet)	1,555	1,555	1,555
Net Requirements (acre-feet)	127	1,488	4,581

TABLE 9. Livestock Water Use — Devils Lake Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	1,263	1,822	3,072
Consumptive Use Due To Evaporation	1,779	1,779	1,779
Non-Consumptive Use	———	———	———
TOTAL	3,042	3,601	4,851
Current Developed Supply			
Surface Water (acres)	593	593	593
Surface Water (acre-feet)	2,151	2,151	2,151
Ground Water (acre-feet)	631	631	631
Net Requirements (acre-feet)	260	819	2,069

TABLE 10. Livestock Water Use — Red River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	5,228	7,573	13,007
Consumptive Use Due To Evaporation	7,818	7,818	7,818
Non-Consumptive Use	———	———	———
TOTAL	13,046	15,391	20,825
Current Developed Supply			
Surface Water (acres)	2,606	2,606	2,606
Surface Water (acre-feet)	10,062	10,062	10,062
Ground Water (acre-feet)	2,614	2,614	2,614
Net Requirements (acre-feet)	370	2,715	8,149

Irrigation Water Requirements

The amount of water used for irrigation in North Dakota varies according to its availability, the type of irrigation system being used, the crops being grown, the type of soil being irrigated, the levels of seasonal precipitation, and other climatic conditions. It has been assumed for purposes of this report, that on a state-wide basis the amount of water required to produce a given crop is approximately 17 inches for small grains, 18 inches for corn and potatoes and 22 to 24 inches for alfalfa and sugar beets.

Standards adopted for use in projecting future irrigation water requirements apply primarily to individual, private ground-water systems or gravity systems where the point of diversion, when diversion is necessary, is on or very near the operator's field and where transmission and seepage losses are negligible. Group type systems, with their extensive canals and laterals, will often require water in excess of these standards.

For a more detailed explanation of how future irrigation water requirements were derived see Chapter VII and Appendix D.

The **current** use figures found in Tables 11-15 of this Section were derived from the 1966 Annual Water Use Reports submitted by irrigators to the State Water Commission. Levels of irrigation were determined by assuming that irrigators are using 70 percent of the water for which irrigation water permits have been granted. There has doubtless been some increase in the total acres being irrigated and the acre-feet of water being used since the last Use Reports were received. A reflection of these changes is to be included in future updating of this plan.

Projections used in determining net irrigation water requirements for the three time periods noted earlier are based upon an analysis of irrigable acres on a state-wide basis. The acreage to be irrigated under the authorized Garrison Diversion Unit project is included in this analysis. In October 1967, the State Water Commission approved the Bureau of Reclamation's application to divert 3,145,000 acre-feet annually from the Missouri River. Of the total approved, 2,790,000 acre-feet are for irrigation use. Approximate basin allocations of the Garrison Diversion Unit appropriation for irrigation include: 110,000 acre-feet, Eastern Missouri Tributaries; 1,520,000 acre-feet, Souris (Mouse) River; 560,000 acre-feet, Sheyenne River; 510,000 acre-feet, James River; 80,000 acre-feet, Wild Rice River; and 10,000 acre-feet, Devils Lake.

It should be noted that the figures found in Tables 11-15 following the heading "Current Developed Supply" denote, when they refer to surface water, only the water-holding capacity of structures in existence. Storage for irrigation in Lake Sakakawea and the Snake Creek Impoundment is not included as a part of the "Current Developed Supply" because the works required to deliver water have not been built. Actual storage will vary from season to season and year to year in accordance with precipitation, stream flow and other climatic conditions.

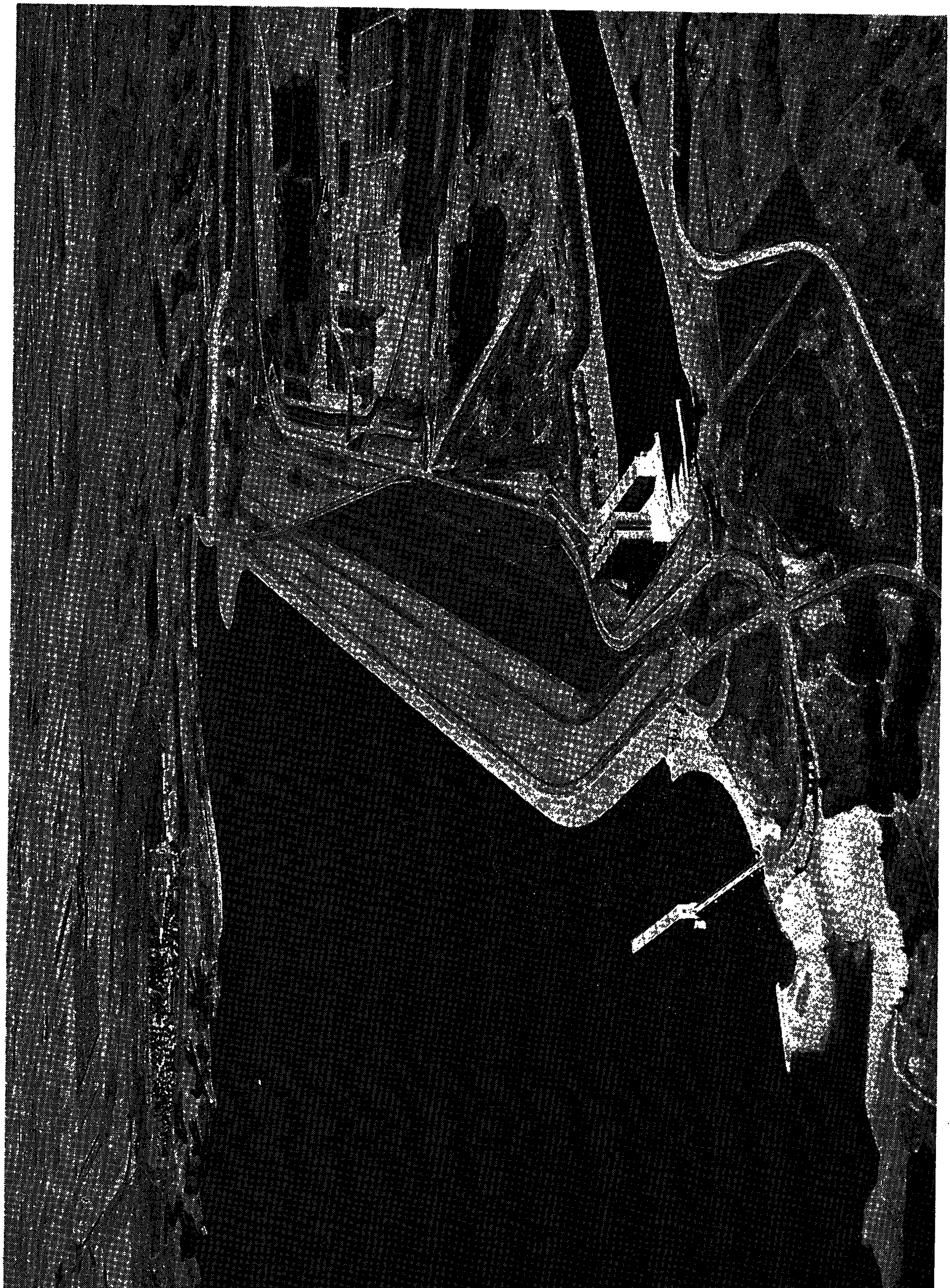


TABLE 11. Irrigation Water Use — Missouri River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	145,419	776,366	1,544,558
Consumptive Use Due to Evaporation	(109,064)	(582,274)	(1,158,418)
Non-Consumptive Use	(36,355)	(194,092)	(386,140)
TOTAL	145,419	776,366	1,544,558
Current Developed Supply			
Surface Water (acre-feet)	127,273	127,273	127,273
Ground Water (acre-feet)	18,146	18,146	18,146
Net Requirements (acre-feet)	————	630,947	1,399,139

TABLE 12. Irrigation Water Use — James River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	4,762	152,772	305,523
Consumptive Use Due to Evaporation	(3,572)	(114,579)	(229,142)
Non-Consumptive Use	(1,190)	(38,193)	(76,381)
TOTAL	4,762	152,772	305,523
Current Developed Supply			
Surface Water (acre-feet)	18,195	18,195	18,195
Ground Water (acre-feet)	3,570	3,570	3,570
Net Requirements (acre-feet)	—17,003*	131,007	283,758

*Indicates a surplus in the currently developed irrigation water supply.

TABLE 13. Irrigation Water Use — Souris River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	14,086	231,612	463,224
Consumptive Use Due to Evaporation	(10,564)	(173,709)	(347,418)
Non-Consumptive Use	(3,522)	(57,903)	(115,806)
TOTAL	14,086	231,612	463,224
Current Developed Supply			
Surface Water (acre-feet)	12,043	12,043	12,043
Ground Water (acre-feet)	2,043	2,043	2,043
Net Requirements (acre-feet)	————	217,526	449,138

TABLE 14. Irrigation Water Use — Devils Lake Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	208	125,668	251,336
Consumptive Use Due to Evaporation	(156)	(94,251)	(188,502)
Non-Consumptive Use	(52)	(31,417)	(62,834)
TOTAL	208	125,668	251,336
Current Developed Supply			
Surface Water (acre-feet)	————	————	————
Ground Water (acre-feet)	208	208	208
Net Requirements (acre-feet)	————	125,460	251,128

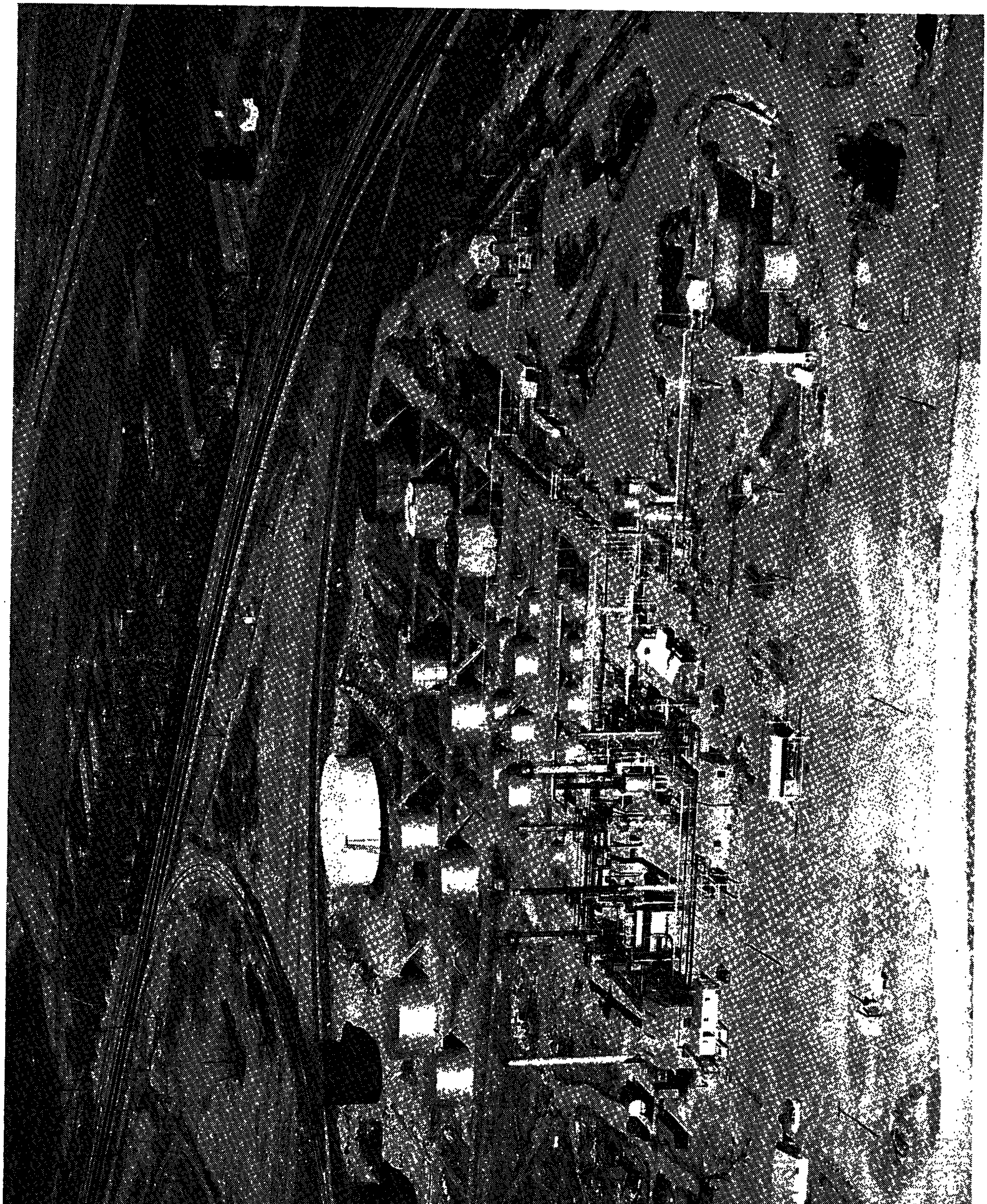


TABLE 15. **Irrigation Water Use — Red River Basin**

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	9,741	940,114	1,880,228
Consumptive Use Due to Evaporation	(7,305)	(705,085)	(1,410,171)
Non-Consumptive Use	(2,436)	(235,029)	(470,057)
TOTAL	9,741	940,114	1,880,228
Current Developed Supply			
Surface Water (acre-feet	----------	----------	----------
Ground Water (acre-feet)	9,741	9,741	9,741
Net Requirements (acre-feet)	----------	930,373	1,870,487

Industrial and Mining Water Requirements

Only in recent years has the quantity of water needed to sustain industry and mining in North Dakota been significant when compared to other uses such as municipal, domestic, irrigation, etc. In the past, the use of water for mining purposes has been restricted largely to sand and gravel operations. This trend is expected to continue although increasing quantities of water will be needed for salt and petroleum recovery.

North Dakota's principal industry is agriculture. Our rich soils and our climate lend themselves to the growing of a variety of important agricultural products. As a consequence, industry has been agriculturally oriented. It is anticipated that with increased irrigated acreage throughout the state, the processing of agricultural products will continue to play an important role in the industrial growth of the state's economy. Industries using large quantities of water such as thermal power generation and petroleum refining, are expected to experience even a more pronounced growth rate during the projection period of this report. Lignite hydrogenation and aluminum and iron ore processing are other heavy water users expected to locate in the state.

The following five Tables summarize current and projected industrial and mining water use requirements by major drainage basin up to the year 2000. The projected use shown is taken from Chapter VII, Table 1, "Estimated Water Use For Anticipated Industrial Development" and an allowance is made for industrial use in addition to that which has been specifically estimated.

TABLE 16. **Industrial and Mining Water Use — Missouri River Basin**

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	300,507	4,105,057**	10,398,707****
Consumptive Use Including Evaporation and Transmission Losses	(10,091)	(151,569)	(491,717)
Non-Consumptive Use	(290,416)	(3,953,488)	(9,906,990)
TOTAL	300,507	4,105,057	10,398,707
Current Developed Supply			
Surface Water (acres)	----------	----------	----------
Surface Water (acre-feet)	10,250,100*	10,271,745***	10,271,745
Ground Water (acre-feet)	1,000	1,000	1,000
Net Requirements (acre-feet)	—9,950,593	—6,167,688	125,962

*10,200,000 acre-feet available only on the mainstem of the Missouri.

**2,700,000 acre-feet for power production, 60,000 acre-feet of which must be provided by storage on tributaries to the mainstem.

***Includes an additional 21,645 acre-feet programmed for development by 1970 (Beulah Dam, SWC Project No. 1464)

****6,480,000 acre-feet for power production, 60,000 acre-feet of which must be provided by storage on tributaries to the mainstem.

TABLE 17. Industrial and Mining Use — James River Basin

	Current	1980	2000
Total Requirements			
(acre-feet)			
Projected Use	107	8,107	33,857
Consumptive Use Including Evaporation and Transmission Losses	(31)	(1,631)	(7,189)
Non-Consumptive Use	(76)	(6,476)	(26,668)
TOTAL	107	8,107	33,857
Current Developed Supply			
Surface Water (acres)	———	———	———
Surface Water (acre-feet)	———	———	———
Ground Water (acre-feet)	107	107	107
Net Requirements			
(acre-feet)	———	8,000	33,750

TABLE 18. Industrial and Mining Use — Souris River Basin

	Current	1980	2000
Total Requirements			
(acre-feet)			
Projected Use	207	8,207	23,357
Consumptive Use Including Evaporation and Transmission Losses	(51)	(1,651)	(12,139)
Non-Consumptive Use	(156)	(6,556)	(11,218)
TOTAL	207	8,207	23,357
Current Developed Supply			
Surface Water (acres)	———	———	———
Surface Water (acre-feet)	———	———	———
Ground Water (acre-feet)	207	207	207
Net Requirements			
(acre-feet)	———	8,000	23,150

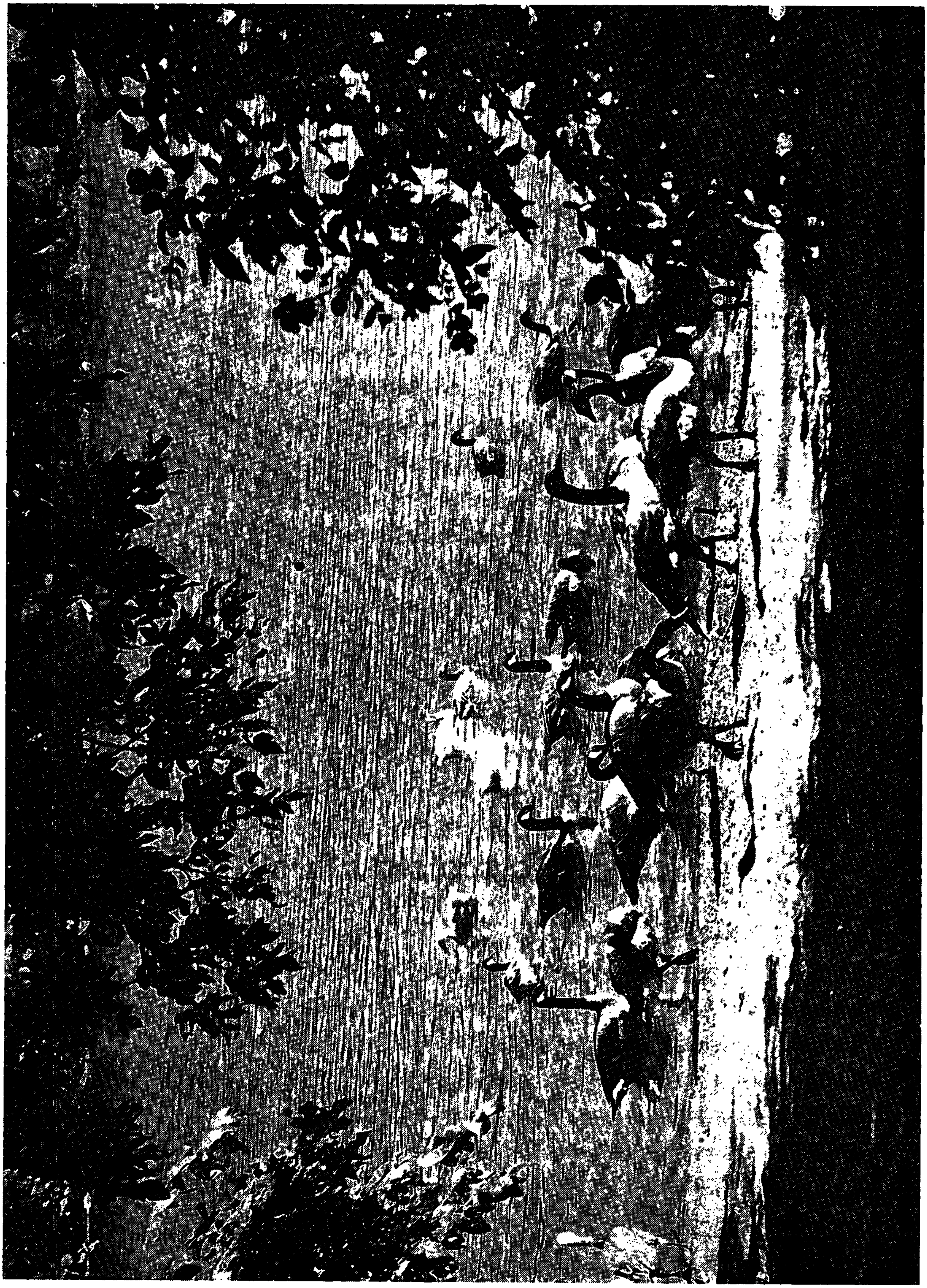
TABLE 19. Industrial and Mining Use — Devils Lake Basin

	Current	1980	2000
Total Requirements			
(acre-feet)			
Projected Use	7*	8,007	24,007
Consumptive Use Including Evaporation and Transmission Losses	(1)	(161)	(481)
Non-Consumptive Use	(6)	(7,846)	(23,526)
TOTAL	7	8,007	24,007
Current Developed Supply			
Surface Water (acres)*	———	———	———
Surface Water (acre-feet)	———	———	———
Ground Water (acre-feet)	7	7	7
Net Requirements			
(acre-feet)	———	8,000	24,000

*Sand and Gravel Operations

TABLE 20. Industrial and Mining Use — Red River Basin

	Current	1980	2000
Total Requirements			
(acre-feet)			
Projected Use	6,307	35,857	63,107
Consumptive Use Including Evaporation and Transmission Losses	(1,890)	(8,723)	(14,581)
Non-Consumptive Use	(4,417)	(27,134)	(48,526)
TOTAL	6,307	35,857	63,107
Current Developed Supply			
Surface Water (acres)	———	———	———
Surface Water (acre-feet)	3,672	3,672	3,672
Ground Water (acre-feet)	2,635	2,635	2,635
Net Requirements			
(acre-feet)	———	29,550	56,800



Fish, Wildlife and Outdoor Recreation Water Use Requirements

Because the types and modes of water involved in wildlife (waterfowl hunting) and in water-oriented outdoor recreation (fishing, boating, water skiing, swimming) are so vastly different, requirements for the two categories have been developed separately.

Projection of demand data indicates that participation in waterfowl hunting can be expected to increase one percent annually during the period covered by this report if the supply of waterfowl is also increased. At this rate, the following demand for waterfowl hunting may be anticipated.

TABLE 21. Waterfowl Hunting Participation

Year	All Hunting**	Waterfowl* Hunting	Hunting** Supply Needed	Export and** Propogation	Birds Totals
1965	1,434,150	286,830	573,000	1,146,000	1,719,000
1970	1,517,050	303,410	606,800	1,213,600	1,820,400
1980	1,750,350	350,000	700,000	1,400,000	2,100,000
1990	1,925,385	385,100	770,200	1,540,400	2,310,600
2000	2,117,920	423,590	847,200	1,694,000	2,541,600

*Hunter Days
**Birds

The current supply of waterfowl areas as noted in Table 22 consists of wetlands, stockwater dams and stockwater dugouts. A conservative estimate would indicate that there will have to be a 50 percent increase in the number of habitat areas by 2000 if waterfowl production is to be capable of supplying needed hunter opportunities.

TABLE 22. Waterfowl Areas — State-wide

Drainage Basin	Current	1980	2000
Red	55,000	64,000	81,000
Devils Lake	54,000	64,000	81,000
James	61,000	72,000	92,000
Mouse	81,000	92,000	117,000
Missouri	96,000	108,000	137,000
TOTALS	347,000	400,000	508,000

Wetlands included in the current supply column noted above average slightly over four acres in size. Should the 2000 supply of wetlands be composed of tracts of two acres, which is acceptable for waterfowl habitat, the total area of wetlands would not have to be increased. It would, however, be necessary to increase the **number** of wetland areas by following land utilization practices including **partial** drainage which would subdivide some of the larger wetland areas into two or more smaller areas. Increasing the number of wetland areas by subdividing the larger wetland areas is beneficial in that the smaller wetlands are better suited for duck propogation.

Current and projected water requirements for fish and water-oriented outdoor recreation use in North Dakota are expressed throughout this report in terms of effective surface acres of water. To be termed effective, an area must afford North Dakotans and their guests "quality" recreation opportunities. Through consideration of the space standards adopted for use in the State Outdoor Recreation Plan and, in turn, for use in this plan, persons seeking recreation in the North Dakota out-of-doors are assured of meeting with such "quality" opportunities.

Space standards data for outdoor recreation activities have been integrated with the indicated demands for such activities over the period of this report and beyond to produce a standard composite model. This model reflects outdoor recreation "requirements" for boating, water skiing, and fishing based on present and projected population data combined with present and assumed future modes of activity participation. Swimming has not been included because (1) capacity data for swimming is nonrepresentative, (2) water quality in lakes is generally not satisfactory for a full season of swimming, (3) if space is available in lakes or reservoirs for other activities, it can be assumed that with proper zoning, swimming space is also available.

Year	Composite Model	X	Population	=	Requirements* (acres)
1965	.1450		652,000		94,540
1970	.1629		664,000		108,165
1980	.1969		699,000		137,633
2000	.2650		1,120,100		296,828

*The existing supply must necessarily be subtracted from the requirements indicator to show the true "Additional Needs."

Tables 23-27 summarize current and projected Fish and Outdoor Recreation Water Use requirements for the present, 1980, and 2000 on a major drainage basin basis. These tables differ from others found in Chapter IX in that they reflect two net requirement figures; one for effective acres (indicating facilities required), and a second for the additional water resources developments needed to meet the net effective surface acres requirement. Figures shown for net requirements in 1980 and 2000 do not presuppose any development beyond the current level of development.

The Fish and Outdoor Recreation water supply data used in compiling Tables 23-27 were extracted from Appendix A to this plan. A summary of the data in Appendix A, **An Inventory of Water Storage and Retention Structures in North Dakota, June 1968**, may be found in Chapter VIII.

It should be noted that the figures entered in the following tables denote only the water holding capacity of the "Current Developed Supply." Actual storages will vary from year to year in accordance with precipitation, runoff, and use.

TABLE 23. Fish and Outdoor Recreation Water Use — Missouri River Basin

	Current	1980	2000
Total Requirements			
Projected use (acres)	31,672	41,762	96,593
Current Developed Supply			
Effective Acres	35,361	35,361	35,361
Surface Acres Stored and Available for Recreation Use (Potentially Effective Acres)	78,156	78,156	78,156
Net Requirements*			
Effective Acres	— 3,689	6,401	61,232
Additional Development Needed to Meet Net Requirements for Effective Acres (Surface Acres)**	—81,845	—71,755	—16,924

*Minus symbol indicates a surplus of effective acres available for recreation needs within the basin. This does not preclude, however, the possibility of local shortages.

**This figure includes both those surface acres which are currently stored and available for recreation use (as potentially effective acres) and currently developed effective acres which are in excess of current needs.

TABLE 24. Fish and Outdoor Recreation Use — James River Basin

	Current	1980	2000
Total Requirements			
Projected Use (acres)	6,543	12,621	28,912
Current Developed Supply			
Effective Acres	7,197	7,197	7,197
Surface Acres Stored and Available for Recreation Use (Potentially Effective Acres)	4,303	4,303	4,303
Net Requirements*			
Effective Acres	—654	5,424	21,715
Additional Development Needed to Meet Net Requirements for Effective Acres (Surface Acres)	—4,957**	1,121	17,412

*Minus symbol indicates a surplus of effective acres available for recreation use within the basin. This does not preclude, however, the possibility of local shortages.

**This figure includes both those surface acres which are currently stored and available for recreation use (as potentially effective acres) and currently developed effective acres which are in excess of current needs.

TABLE 25. Fish and Outdoor Recreation Use — Souris River Basin

	Current	1980	2000
Total Requirements			
Projected Use (acres)	16,621	24,494	48,495
Current Developed Supply			
Effective Acres	6,218	6,218	6,218
Surface Acres Stored and Available for Recreation Use (Potentially Effective Acres)	27,990	27,990	27,990
Net Requirements			
Effective Acres	10,403	18,276	42,277
Additional Development Needed to Meet Net Requirements for Effective Acres (Surface Acres)	—17,587**	—9,714	14,287

TABLE 26. Fish and Outdoor Recreation Water Use — Devils Lake Basin

	Current	1980	2000
Total Requirements			
Projected Use (acres)	5,510	6,675	16,478
Current Developed Supply			
Effective Acres	2,669	2,669	2,669
Surface Acres Stored and Available for Recreation Use (Potentially Effective Acres)	3,950	3,950	3,950
Net Requirements			
Effective Acres	2,841	4,006	13,809
Additional Development Needed to Meet Net Requirements for Effective Acres (Surface Acres)	—1,109**	56	9,859

TABLE 27. Fish and Outdoor Recreation Water Use — Red River Basin

	Current	1980	2000
Total Requirements			
Projected Use (acres)	35,280	52,080	106,080
Current Developed Supply			
Effective Acres	9,660	9,660	9,660
Surface Acres Stored and Available for Recreation Use (Potentially Effective Acres)	3,488	3,488	3,488
Net Requirements			
Effective Acres	25,620	42,420	96,420
Additional Development Needed to Meet Net Requirement for Effective Acres (Surface Acres)	22,132	38,932	92,932

Quality Control (Pollution Abatement) Water Use

Quality Control Water is the water needed for mixing with municipal and industrial wastes, which has undergone primary and secondary treatment, to insure no impairment of downstream uses or values.

Primary treatment refers to the removal of settable solids. Primary treatment removes about 25 to 35 percent of the biochemical oxygen demand and from 45 to 65 percent of the total suspended matter. Secondary treatment plants typically remove from 80 to 95 percent of the remaining organic wastes and suspended matter. In 1960 secondary treatment plants in North Dakota were removing approximately 80 percent of the biodegradable materials found in sewage and industrial wastes. Biodegradable materials are those waste products which are detrimental to the ability of a stream or river to serve as a fine quality recreation or fishing area. The efficiency of sewage treatment plants is expected to continue improving. As a consequence, it is anticipated that plants will be removing approximately 85 percent in 1980 and 90 percent in 2000 of the biodegradable materials present in wastes.

Tables 26 through 30 summarize Quality Control water requirements for the present, 1980, and 2000 by major drainage basin.

TABLE 28. Quality Control (Pollution Abatement) Water Use — Missouri River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	238,600	185,800	212,900
Consumptive Use Including Evaporation and Transmission Losses	----------	----------	----------
Non-Consumptive Use	(238,600)	(185,800)	(212,900)
TOTAL	238,600	185,800	212,900
Current Developed Supply			
Surface Water (acres)	----------	----------	----------
Surface Water (acre-feet)	11,030	11,030	11,030
Ground Water (acre-feet)	----------	----------	----------
Net Requirements (acre-feet)	227,570	174,770	201,870

TABLE 29. Quality Control (Pollution Abatement) Water Use — James River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	71,800	56,200	63,700
Consumptive Use Including Evaporation and Transmission Losses	----	----	----
Non-Consumptive Use	(71,800)	(56,200)	(63,700)
TOTAL	71,800	56,200	63,700
Current Developed Supply			
Surface Water (acres)	----	----	----
Surface Water (acre-feet)	----	----	----
Ground Water (acre-feet)	----	----	----
Net Requirements (acre-feet)	71,800	56,200	63,700

TABLE 30. Quality Control (Pollution Abatement) Water Use — Souris River Basin

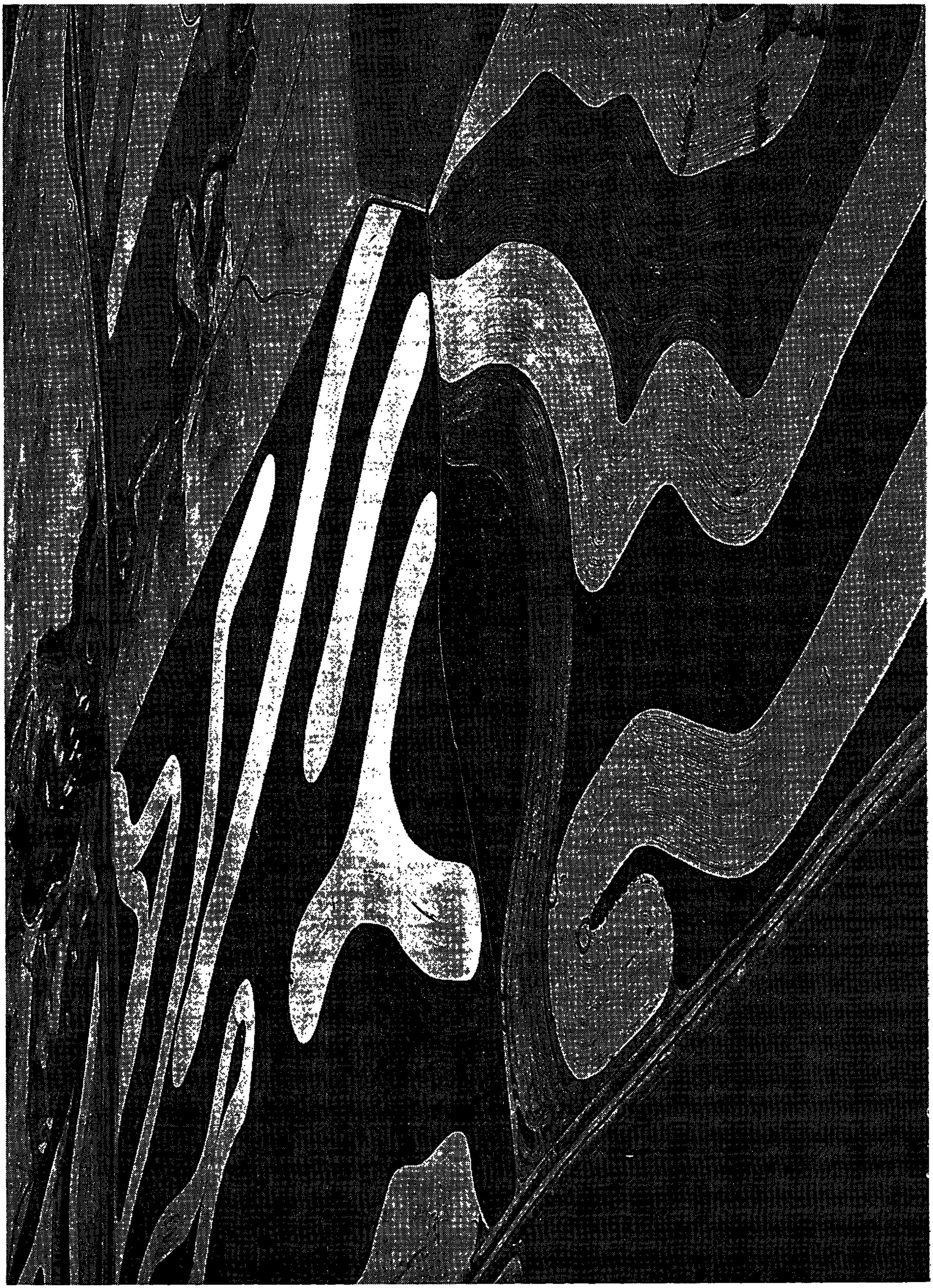
	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	121,100	109,000	106,900
Consumptive Use Including Evaporation and Transmission Losses	----	----	----
Non-Consumptive Use	(121,100)	(109,000)	(106,900)
TOTAL	121,100	109,000	106,900
Current Developed Supply			
Surface Water (acres)	----	----	----
Surface Water (acre-feet)	----	----	----
Ground Water (acre-feet)	----	----	----
Net Requirements (acre-feet)	121,100	109,000	106,900

TABLE 31. Quality Control (Pollution Abatement) Water Use — Devils Lake Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	42,100	27,500	36,900
Consumptive Use Including Evaporation and Transmission Losses	----	----	----
Non-Consumptive Use	(42,100)	(27,500)	(36,900)
TOTAL			
Current Developed Supply	42,100	27,500	36,900
Surface Water (acres)	----	----	----
Surface Water (acre-feet)	----	----	----
Ground Water (acre-feet)	----	----	----
Net Requirements (acre-feet)	42,100	27,500	36,900

TABLE 32. Quality Control (Pollution Abatement) Water Use — Red River Basin

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	269,700	231,700	233,800
Consumptive Use Including Evaporation and Transmission Losses	----	----	----
Non-Consumptive Use	(269,700)	(231,700)	(233,800)
TOTAL	269,700	231,700	233,800
Current Developed Supply			
Surface Water (acres)	----	----	----
Surface Water (acre-feet)	----	----	----
Ground Water (acre-feet)	----	----	----
Net Requirements (acre-feet)	269,700	231,700	233,800



Flood Prevention and Runoff Management Requirements

Floods constitute a major source of damage to urban and agricultural areas in most of North Dakota's major river basins. The Red River Basin or segments thereof almost each year face severe flood problems. Other areas such as Minot and Velva in the Souris River Basin are subjected to flooding at less frequent intervals. The Cannonball and Cedar Rivers in the Western Dakota Tributaries portion of the Missouri River Basin face less damaging floods, less frequently. For the most part, flood damages in North Dakota are greater in agricultural areas than in urban areas due to losses resulting from inundation and destruction of crops in the field, from delayed planting, and from planting of excessively wet land in which seeds will not readily germinate. Other rural flood damages include erosion, increased weed infestation, damage to road grades and bridge approaches, livestock losses, and the destruction of fences, stacked hay and cut wood.

Possibly one of the most difficult problems to overcome in caring for municipal flood control is the complacency of the residents or the imposition on interests that might be adversely affected by the construction of necessary flood protective works. This is especially true in areas where partial flood protection may have been constructed at a time when flood control structures were based on flood data developed during the 1930 drouth period. The Corps of Engineers in their standard project flood computations indicate that the resulting damages to several of our cities would be almost catastrophic. We have some recent evidences of such catastrophies as was the case in the Velva flood of 1962 when three people lost their lives. Extensive flooding also occurred on the Knife and Heart Rivers and Square Butte Creeks in June 1966. In fact, had the rainfall that occurred in the latter three basins fallen in one, which nature could have so wrought, there could have been a considerable loss of life and great property loss.

Figures shown in Tables 33-37 indicate the total requirements for flood control in urban and agricultural areas for the present, 1980, and 2000 as well as the amount of flood control provided for urban and agricultural areas by currently developed works for each of these time periods by major drainage basin. The net requirements for flood control in each basin represent the difference between the total requirements and currently developed works for each time period and type of damage.

Figures shown in these tables are based on information adapted from studies prepared by the Corps of Engineers and from Work Group II reports on the Tentative Needs and Problems in the Missouri River Basin by the Missouri Basin Inter-Agency Committee in conjunction with various State and Federal agencies.

TABLE 33. Flood Prevention and Runoff Management — Missouri River Basin

	Current	1980	2000
Total Requirements:			
Urban Areas (average annual damages in 1960 dollars)	183,000	386,000	728,000
Agricultural Lands (acres flooded or susceptible to flooding)	541,024	541,024	541,024
Current Developed Works:			
Urban Areas (average annual damages prevented in 1960 dollars)	319,000	319,000	319,000
Agricultural Lands (acres drained or protected by retention works)	60,314	60,314	60,314
Legal Drains (acres protected)	—	—	—
Net Required Works:			
Urban Areas (average annual protection needed in 1960 dollars)	—136,000	67,000	409,000
Agricultural Land (acres of land needing protection)	480,710	480,710	480,710
Bank Stabilization:			
Urban	$1,000,000	$1,000,000	$1,000,000
Agricultural (acres)	50,000	50,000	50,000

TABLE 34. Flood Prevention and Runoff Management — James River Basin

	Current	1980	2000
Total Requirements:			
Urban Areas (average annual damages in 1960 dollars)	70,000	218,000	518,000
Agricultural Lands (acres flooded or susceptible to flooding)	46,275	46,275	46,275
Current Developed Works:			
Urban Areas (average annual damages prevented in 1960 dollars)	93,000	93,000	93,000
Agricultural Lands (acres drained or protected by retention works)	3,100	3,100	3,100
Legal Drains (acres protected)*	30,144	30,144	30,144
Net Required Works:			
Urban Areas (average annual protection needed in 1960 dollars)	—23,000	125,000	425,000
Agricultural Land (acres of land needing protection)	13,031	13,031	13,031

*This figure was computed on the basis of records currently on file with the State Water Commission.

TABLE 35. Flood Prevention and Runoff Management — Souris River Basin

	Current	1980	2000
Total Requirements:			
Urban Areas (average annual damages in 1960 dollars)	3,440,000	3,850,000	4,670,000
Agricultural Lands (acres flooded or susceptible to flooding)	355,690	355,690	355,690
Current Developed Works:			
Urban Areas (average annual damages prevented in 1960 dollars)	2,160,000	2,420,000	2,940,000
Agricultural Lands (acres drained or protected by retention works)	————	————	————
Legal Drains (acres protected)*	121,490	121,490	121,490
Net Required Works:			
Urban Areas (average annual protection needed in 1960 dollars)	1,280,000	1,430,000	1,730,000
Agricultural Land (acres of land needing protection)	234,200	234,200	234,200

*This figure was computed on the basis of records currently on file with the State Water Commission.

TABLE 36. Flood Prevention and Runoff Management — Devils Lake Basin

	Current	1980	2000
Total Requirements:			
Urban Areas (average annual damages in 1960 dollars)	————	————	————
Agricultural Lands (acres flooded or susceptible to flooding)	188,800	188,800	188,800
Current Developed Works:			
Urban Areas (average annual damages prevented in 1960 dollars)	————	————	————
Agricultural Lands (acres drained or protected by retention works)	32,800	32,800	32,800
Legal Drains (acres protected)	————	————	————
Net Required Works:			
Urban Areas (average annual protection needed in 1960 dollars)	————	————	————
Agricultural Land (acres of land needing protection)	156,000	156,000	156,000

TABLE 37. Flood Prevention and Runoff Management — Red River Basin

	Current	1980	2000
Total Requirements:			
Urban Areas (average annual damages in 1960 dollars)	1,980,000	2,240,000	2,770,000
Agricultural Lands (acres flooded or susceptible to flooding)	3,763,500	3,763,500	3,763,500
Current Developed Works:			
Urban Areas (average annual damages prevented in 1960 dollars)	590,000	660,000	820,000
Agricultural Lands (acres drained or protected by retention works)	159,200	159,200	159,200
Legal Drains (acres protected)*	2,864,300	2,864,300	2,864,300
Net Required Works:			
Urban Areas (average annual protection needed in 1960 dollars)	1,390,000	1,580,000	1,950,000
Agricultural Land (acres of land needing protection)	740,000	740,000	740,000

*This figure was computed on the basis of records currently on file with the State Water Commission.

SUMMARY TABLES

Summary Tables 1-7 reflect the state's total requirements for the various uses of water for each time period on a state-wide basis. They are a summary of the preceding tables indicating the total requirements for each of the state's major water uses for each time period.

SUMMARY TABLE 1. Municipal and Domestic Water Use — State-Wide

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	51,550	71,340	135,510
Consumptive Use Due to Evaporation	3,429	4,149	4,149
Non-Consumptive Use			
TOTAL	54,979	75,489	139,659
Current Developed Supply			
Surface Water (acres)*	1,143	1,383	1,383
Surface Water (acre-feet)	95,616	100,236	110,836
Ground Water (acre-feet)	29,857	29,857	29,857
Net Requirements (acre-feet)	—70,534**	—54,604**	—1,409**

*When applicable.
**Indicates a storage surplus on a state-wide basis for this category of development.

SUMMARY TABLE 2. Livestock Water Use — State-Wide

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	26,960	38,887	65,987
Consumptive Use Due to Evaporation	63,696	63,696	63,696
Non-Consumptive Use			
TOTAL	90,656	102,583	129,683
Current Developed Supply			
Surface Water (acres)*	21,232	21,232	21,232
Surface Water (acre-feet)	81,061	81,061	81,061
Ground Water (acre-feet)	13,478	13,478	13,478
Net Requirements (acre-feet)	—3,883**	8,044	35,144

*When applicable.
**Indicates a storage surplus on a state-wide basis for this category of development.

SUMMARY TABLE 3. Irrigation Water Use — State-Wide

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	174,216	2,226,532	4,444,869
Consumptive Use Due to Evaporation	(130,661)	(1,669,898)	(3,333,651)
Non-Consumptive Use	(43,555)	(556,634)	(1,111,218)
TOTAL	174,216	2,226,532	4,444,869
Current Developed Supply			
Surface Water (acres)*	————	————	————
Surface Water (acre-feet)	157,511	157,511	157,511
Ground Water (acre-feet)	33,708	33,708	33,708
Net Requirements (acre-feet)	—17,003**	2,035,313	4,253,650

*When applicable.
**Indicates a storage surplus on a state-wide basis for this category of development.

SUMMARY TABLE 4. Industrial and Mining Use —State-Wide

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	307,135	4,165,235	10,543,035
Consumptive Use Due to Evaporation	(12,064)	(163,735)	(526,107)
Non-Consumptive Use	(295,071)	(4,001,500)	(10,016,928)
TOTAL	307,135	4,165,235	10,543,035
Current Developed Supply			
Surface Water (acres)*	————	————	————
Surface Water (acre-feet)	10,253,772	10,275,417	10,275,417
Ground Water (acre-feet)	3,956	3,956	3,956
Net Requirements (acre-feet)	—9,950,593**	—6,114,138**	263,662

*When applicable.
**Indicates a storage surplus on a state-wide basis for this category of development.

SUMMARY TABLE 5. Fish and Outdoor Recreation Water Use — State-Wide

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use (effective acres)	95,626	137,632	296,558
Current Developed Supply			
Effective Acres	61,105	61,105	61,105
Surface Acres Stored and Available for Recreation Use (Potentially Effective Acres)	72,242	72,242	72,242
Net Requirements			
Effective Acres	34,521	76,527	235,453
Additional Development Needed to Meet Net Requirements for Effective Acres (Surface Acres)	—37,721*	4,285	163,211

*Indicates a storage surplus on a state-wide basis for this category of development.

SUMMARY TABLE 6. Quality Control — State-Wide

	Current	1980	2000
Total Requirements (acre-feet)			
Projected Use	743,200	610,200	654,200
Consumptive Use Due to Evaporation	———	———	———
Non-Consumptive Use	(743,200)	(610,200)	(654,200)
TOTAL	743,200	610,200	654,200
Current Developed Supply			
Surface Water (acres)*	11,030	11,030	11,030
Surface Water (acre-feet)	———	———	———
Ground Water (acre-feet)	———	———	———
Net Requirements (acre-feet)	732,270	599,170	643,170

*When applicable.

SUMMARY TABLE 7.—Flood Prevention and Runoff Management — State-Wide

	Current	1980	2000
Total Requirements:			
Urban Areas (average annual damages in dollars)	5,673,000	6,694,000	8,686,000
Agricultural Lands (acres flooded or susceptible to flooding)	4,895,289	4,895,289	4,895,289
Current Developed Works:			
Urban Areas (average annual damages prevented in dollars)	3,162,000	3,492,000	4,172,000
Agricultural Lands (acres drained or protected by retention works)	255,414	255,414	255,414
Legal Drains (acres protected)	3,015,934	3,015,934	3,015,934
Net Required Works:			
Urban Areas (protection needed in dollars)	2,511,000	3,202,000	4,514,000
Agricultural Land (acres of land needing protection)	1,623,941	1,623,941	1,623,941
Bank Stabilization: Urban	$1,000,000	$1,000,000	$1,000,000
Agricultural (acres)	50,000	50,000	50,000

Chapter Ten

Developments to Meet Water Requirements to the Year 2000

CHAPTER X

DEVELOPMENTS TO MEET WATER REQUIREMENTS TO THE YEAR 2000

A. Introduction and Scope

1. "Guidelines for Framework Studies," published by the Federal Water Resources Council stipulates that the "basic objective in the formulation of framework plans is to provide a broad guide to the best use or combination of uses of water and related land resources of a region to meet foreseeable short- and long-term needs."

   Developments proposed for the five major North Dakota river basins are shown on a broad scale, generally, unless planning on major developments has progressed sufficiently to warrant separate delineation. They are intended as a guide to future water resources development in North Dakota.

   Resources are estimated for the developments proposed to meet the anticipated water utilization and control requirements. Modifications in the developments proposed could result as detailed plans are made for each of the sub-basins within each major river basin. Development of sub-basin plans to indicate the potential needs which may be served is envisioned as the next State Water Plan phase is initiated in early 1969.

   The following tables, along with the narrative for each major river basin, outline the proposed developments to meet envisioned requirements for the time periods 1969-1980 and 1981-2000.

MISSOURI RIVER BASIN

		1980	2000
1. **Annual Requirements to Be Met** — (from Chapter IX)			
a. Municipal and Domestic Use	Total	21,292 A.F.	43,602 A.F.
	Net	—5,306 A.F.*	6,404 A.F.
*Indicates basin-wide surplus although there may be sub-basin or local shortages.			
b. Livestock Use	Total	58,333 A.F.	71,713 A.F.
	Net	1,512 A.F.	14,892 A.F.
c. Irrigation Use (optimum)	Total	776,366 A.F.	1,544,558 A.F.
	Net	630,947 A.F.	1,399,139 A.F.
d. Industrial and Mining Use	Total	4,105,057 A.F.	10,398,707 A.F.
	Net	—6,167,688 A.F.**	125,962 A.F.
	Tributaries	(60,000 A.F.)	(60,000 A.F.)
**Indicates surplus which is stored by Garrison Dam and allocated to Ind. Use.			
e. Fish, Wildlife and Outdoor Recreation Use—			
Surface Acres	Net	—71,755*	—16,924*
Facilities	Net	6,401 Ac	61,232 Ac
Wetlands	(#)	12,000	12,000
Wetlands	Net	24,000 Ac	58,000 Ac
f. Quality Control	Total	185,800 A.F.	212,900 A.F.
	Net	174,770 A.F.	201,870 A.F.
g. Flood Prevention and Runoff Managment (Urban)	Total damages	$386,000	$728,000
	Net damages	$67,000	$409,000
Agricultural Land	Total	541,024 Ac	541,024 Ac
	Net	480,710 Ac	480,710 Ac
Bank Stabilization	Net	$1,000,000	$1,000,000
		50,000 Ac	50,000 Ac
h. Summary of A.F. requirements	Total	5,146,848	12,271,480
	Net	—5,365,765	1,748,267
	Tributaries	60,000	60,000

2. **Current Supply** (Chapter VIII)

a. Reservoir Storage by Function — A.F.

(1) Municipal and Domestic	57,998
(2) Stockwater	51,729
(3) Irrigation	3,267,560
(4) Industrial and Mining	10,250,100
(5) Recreation (113,517 A)	378,344
(6) Wetland Areas — No.	96,000
(7) Quality Control	11,030
(8) Flood Control	6,052,000

b. Programmed Projects — A.F.

(1) Recreation (428 A.)	5,286
(2) Flood Control	2,086
(3) Municipal	1,550
(4) Garrison Diversion Unit	
(a) Initial Stage — develop by 1980	
(b) One Million acre project — develop by 2000	

c. Ground-Water — A.F.

(1) Developed to date	33,839
(2) Potential aquifers — est. yield 20% (13,091,000 A.F. storage)	2,618,200

3. **Developments Proposed to Meet 1980 and 2000 Requirements** (Table 1)

a. Municipal and Domestic — A reservoir is currently programmed to provide 1000 A.F. for Municipal purposes. The total gross anticipated requirement for municipal water by 1980 is 21, 292 A.F. Planning criteria for this water use is three times the estimated annual use in order to assure a sustained yield. Since the net requirements in 1980 are currently shown as —5,306 A.F., or basin-wide "surplus", the total net requirement for planning purposes is about 37,000 A.F. To meet these requirements it is anticipated 10,500 A.F. would be included in multi-purpose reservoirs; 15,000 A.F. in multi-purpose aquifer developments; and 10,000 A.F. from single purpose aquifer developments. Multi-purpose aquifer means one developed for more than one use.

Using similar planning criteria as for 1980, the year 2000 requirements are estimated at 68,000 A.F. To meet these requirements it is proposed that 25,000 A.F. be included in multi-purpose reservoirs, 25,000 A.F. in multi-purpose aquifer developments; and 18,000 A.F. in single purpose aquifer developments. Municipal use includes water required for swimming pools.

b. Livestock

Livestock gross water requirements by 1980 are estimated to be 58,333 A.F. Using a planning criteria of one and one-half times the total anticipated requirement and taking into account the current developed supply for this purpose, the anticipated net requirement for livestock water are estimated at 30,000 A.F. annually. To provide this water it is proposed that 5,000 A.F. be obtained from multi-purpose aquifer developments, 10,000 A.F. from single purpose stock dams; and 15,000 A.F. from single purpose aquifer developments.

Using the same planning criteria as 1980, for the year 2000 it is anticipated that an additional 21,000 A.F. of water will be required for livestock use. To meet this requirement it is proposed that 10,000 A.F. be obtained from multi-purpose aquifer developments, 5,000 A.F. from single purpose stock dams and 6,000 A.F. from single purpose aquifer developments.

c. Irrigation

The irrigation requirements are for optimum development and it is not anticipated that these needs can be met fully unless there is a large diversion which would supply more water to the western tributaries. Requirements indicate that irrigation development will need 776,360 acre-feet of water. It is proposed that 125,000 acre-feet be obtained by developing multi-purpose ground-water aquifers; develop 30,000 acre-feet by group irrigation from main stem water; constructing multi-purpose reservoirs to provide 50,000 A.F. and obtain an additional 90,000 A.F. from single purpose aquifer developments. These anticipated requirements are based on economic studies conducted by the North Dakota State University and reported in Appendix D of the State Water Plan.

Anticipated requirements for the year 2000 are an additional 768,192 A.F. for private and group irrigation projects. Developments proposed include 150,000 A.F. from multi-purpose aquifers; 100,000 A.F. from multi-purpose reservoirs; and 320,000 A.F. from single purpose aquifers. Irrigation projects using water from the main stem reservoirs could account for another 70,000 acre-feet for irrigation development.

d. Industrial and Mining
Requirements for industrial and mining use indicate that 60,000 A.F. annually will need to be developed on tributaries of the Missouri River mainstem. A sustained yield factor of three was applied to provide for carryover storage in the event of insufficient runoff or aquifer recharge. It is proposed that by 1980 135,000 A.F. be developed utilizing multi-purpose reservoirs; 10,000 A.F. from multi-purpose aquifer developments; 20,000 A.F. from single purpose aquifers; and 15,000 from a programmed storage project. To meet the anticipated requirements to the year 2000, multi-purpose reservoir developments should provide 270,000 A.F.; multi-purpose aquifers 20,000 A.F.; and single purpose aquifers 40,000 A.F.

e. Outdoor Recreation
Requirements for 1980 show a surplus of basin wide surface waters but there will be some needs for certain areas. Facilities for public use should be provided at an additional 6,401 acres. Wetland areas show a need for 24,000 acres to be developed. To meet the requirements for additional surface acres, programmed reservoirs include 430 acres; multi-purpose reservoirs should provide 5,200 acres and single purpose reservoirs 2,000 acres. The facilities required near the currently developed and proposed reservoirs would include such items as sanitary facilities, picnic tables, camping facilities, wells, boat docks, swimming beaches, bath houses, parking areas, and general landscaping. Wetland developments are proposed in aggregate acres, however, many of these requirements are anticipated to be met in connection with stockwater reservoir developments.

By the year 2000 public use facilities at an additional 57,000 surface acres should be developed for outdoor recreation use and an additional 34,000 acres of wetlands will be required. Facilities should be provided at multi-purpose reservoirs covering 26,000 acres, at single purpose reservoirs covering 4,000 acres, and it is estimated that 40,000 acres will be available by improving present facilities and by putting in more facilities on the future proposed reservoirs. The facilities proposed would be similar to those mentioned in the 1980 developments and wetland areas for wildlife enhancement and propagation should be planned in connection with stockwater and other types of water management installations.

f. Quality Control
Anticipated net requirements for Quality Control include low flow augmentation by 1980 of 174,770 acre-feet and a total by 2000 of 201,870 acre-feet. Developments are proposed to partially meet the anticipated requirements for 1980 by using 35,000 A.F. from multi-purpose storage structures, and 22,000 A.F. from single purpose reservoirs. By the year 2000, an additional 145,000 A.F. is needed to be developed. Multi-purpose reservoirs should include 40,000 A.F.; irrigation return flows, 10,000 A.F.; and single purpose and multi-purpose reservoirs, 95,000 A.F.

g. Flood Prevention and Runoff Management
Net urban damages to be prevented by 1980 are estimated at $67,000 annually and agricultural lands requiring flood prevention and runoff management are estimated at 480,710 acres. To meet these requirements, $60,000 annual damage prevention is currently programmed and $150,000 annual damage protection can be provided by flood control and flood prevention projects. Multi-purpose reservoirs will provide 100,000 acres of annual damage reductions and watershed management will provide 40,000 acres of annual damage reductions. Channel improvements and flood prevention projects could provide annual protection for 40,000 acres.

By the year 2000 it is anticipated that annual urban net damages would be $409,000 less the $210,000 of 1980 developments and the agricultural lands requiring protection would be the 1980 carryover of 301,000 acres. It is proposed that multi-purpose reservoirs provide protection to 120,000 acres, and watershed management to protect 100,000 acres. Channel improvements and flood prevention projects will protect another 1,000 acres of agricultural damages and $200,000 annual urban damages.

Present bank stabilization authorized will provide $500,000 annual urban damage protection and 12,000 acres annual protection to agricultural lands. The need is for $1,000,000 annual damage reduction and 50,000 acres of agricultural lands protected. The balance of $500,000 damage prevention should be in the 1969-1980 period as well as 25,000 acres of agricultural land protection. The balance of agricultural land protection in the amount of 25,000 acres can be provided after 1980 and applied after the extremely critical areas are stabilized.

4. **Costs.**

Estimated first costs, based on current prices, for developments proposed for the 1969-1980 time period are **$99,800,000.** Anticipated costs for the developments proposed during the period 1981-2000 are **$161,200,000.**

These costs include only the land and capital improvements required to control or make available the resource. Additional costs would be incurred for such items as pipelines, intakes, treatment facilities, interest and the like to apply the water to beneficial use.

5. **Resources.**

a. An estimated 68,500 acres of land will be required for the proposed developments during the period 1969-1980. Land needs were estimated on the basis of average fee and easement requirements for various types of water utilization and control works.

   Developments proposed during the 1981-2000 period will require an estimated 93,500 acres.

b. Storage facilities for surface waters will be required for 624,920 acre-feet by 1980 and an additional 837,000 acre-feet by 2000. Detailed site surveys and reservoir regulation plans could modify these estimates in varying degrees depending upon run-off conditions and purpose of the storage.

c. Surface acres were estimated on the basis of an average water depth of 15 or more feet for most purposes and three feet for stockdams and wetlands. Water surface acres estimated for developments to 1980 are 55,525 and for the period 1981-2000, an additional 62,300 acres.

d. Groundwater withdrawals from aquifer developments proposed would be 325,000 acre-feet annually by 1980 and an additional 684,000 acre-feet annually by 2000. The multi-purpose aquifer developments are proposed in view of the unique physical nature of this resource and the inherent advantages in costs and management of multi-purpose developments.

e. Streamflow depletions are estimated to be increased by 1,453,605 acre-feet by 1980 in the Missouri River Tributaries and another 2,908,900 acre-feet annually would be depleted annually by the proposed developments at the time period 2000.

   Some streamflow depletions in the amount of 5% of the groundwater withdrawals are estimated since the Missouri Basin glaciation indicates contributions to streamflow from ground-water aquifers.

TABLE 1. MISSOURI RIVER BASIN

DEVELOPMENTS	RESOURCES Land (Acres)	Storage A. F.	Surface Acres	G.W. Withdrawal A. F.	Streamflow Effect-A. F. + or —
Programmed by 1980					
Garrison Diversion	20,000*	400,000*	12,000*		—1,000,000
Recreation Reservoirs	900	5,285	430		— 1,290
Municipal Reservoirs	300	1,550	255		— 1,765
Watershed Management	200	1,460	190		— 100
Industrial Reservoir	1,000	24,000	785		— 17,500
Dickinson Flood Control	100	625	65		— 50
Bank Stabilization					
Future Multi-Purpose Projects					
Reservoirs (medium size)					
1980 (4)	10,000	160,000	8,000		— 99,500
2000 (8)	20,000	320,000	16,000		— 203,000
Aquifers					
1980				180,000	— 9,000
2000				235,000	— 12,000
Watershed Management					
1980	1,000	10,000	800		— 2,400
2000	6,000	60,000	4,800		— 14,400
Garrison Diversion					
2000					—2,145,000
Reservoirs (large size)					
1980 (2)	24,000	300,000	16,000		— 188,000
2000 (1)	24,000	300,000	12,000		— 316,000
Future Single Purpose Projects					
Linton Flood Control					
1980					
Flood Prevention Projects					
1980					
2000					
Recreation Reservoirs					
1980 (6)	4,000	20,000	2,000		— 6,000
2000 (12)	8,000	40,000	4,000		— 12,000
Aquifers					
1980				145,000	— 7,000
2000				449,000	— 25,000
Small Dams & Dugouts					
1980	3,000	30,000	3,000		— 19,000
2000	1,500	15,000	1,500		— 9,500

FUNCTIONAL REQUIREMENTS SERVED ANNUALLY

Municipal & Domestic (A. F.)	Livestock (A. F.)	Irrigation (A. F.)	Industrial (A. F.)	Recreation & Facilities Acres	Quality A. F.	Flood Prevention $ & Acres
500	—	—	—	6,500 F.	—	—
				430 R.	—	—
—	—	—	—	430 F.	—	—
1,000	—	—	—	—	—	—
—	—	—	—	—	—	$ 40,000
—	—	—	15,000	—	2,000	—
—	—	—	—	—	—	$ 20,000
—	—	—	—	—	—	$ 500,000 B
				—	—	12,000 A.B.
10,500	—	10,000	45,000	2,000 R.	10,000	20,000 A.
—	—	—	—	2,000 F.	—	—
25,000	—	20,000	90,000	6,000 R.	20,000	40,000 A.
—	—	—	—	6,000 F.	—	—
15,000	5,000	125,000	10,000	—	25,000	—
25,000	10,000	150,000	20,000	—	30,000	—
—	—	—	—	200 R.	—	40,000 A.
—	—	—	—	200 F.	—	—
—	—	—	—	2,000 R.	—	100,000 A.
—	—	—	—	2,000 F.	—	—
500	—	100,000	—	12,000 F.	10,000	—
—	—	40,000	90,000	3,000 R.	10,000	80,000 A.
—	—	—	—	3,000 F.	—	—
—	—	80,000	180,000	6,000 R.	20,000	80,000 A.
—	—	—	—	6,000 F.	—	—
—	—	—	—	—	—	$ 50,000
—	—	—	—	—	—	$ 100,000
—	—	—	—	—	—	$ 40,000 A.
—	—	—	—	—	—	$ 200,000
—	—	—	—	—	—	81,000 A.
—	—	—	—	2,000 R.	—	—
—	—	—	—	2,000 F.	—	—
—	—	—	—	4,000 R.	—	—
—	—	—	—	4,000 F.	—	—
10,000	15,000	90,000	20,000	—	10,000	—
18,000	6,000	320,000	40,000	—	65,000	—
—	10,000	—	—	—	—	—
—	5,000	—	—	—	—	—

DEVELOPMENTS		RESOURCES Land (Acres)	A. F.	Surface Acres	G.W. Withdrawal A. F.	Streamflow Effect-A. F. + or −
Bank Stabilization						
	1980	----------	----------	----------	----------	----------
	2000	----------	----------	----------	----------	----------
Wetlands						
(12,000)	1980	24,000	72,000	24,000	----------	— 72,000
(17,000)	2000	34,000	102,000	24,000	----------	— 102,000
Irrigation Projects						
	1980	----------	----------	----------	----------	— 30,000
	2000	----------	----------	----------	----------	— 70,000
Improvements at Present Storage						
	2000	----------	----------	----------	----------	----------
TOTAL — 1980		68,500	624,920	55,525	325,000	—1,453,605
TOTAL — 2000		93,500	837,000	62,300	684,000	—2,908,900

R. — Recreation Water Surface Acres
F. — Public Use Recreation Facilities
W. — Wetlands
A. — Acres
A.F. — Acre-Feet
B — Bank Stabilization
* — Indicates Snake Creek or Audubon Reservoir which is now in place

FUNCTIONAL REQUIREMENTS SERVED ANNUALLY

Municipal & Domestic (A. F.)	Livestock (A. F.)	Irrigation (A. F.)	Industrial (A. F.)	Recreation & Facilities Acres	Quality A. F.	Flood Prevention $ & Acres
----------	----------	----------	----------	----------	----------	$ 500,000 B
----------	----------	----------	----------	----------	----------	25,000 A.B.
----------	----------	----------	----------	----------	----------	20,000 A.B.
----------	----------	----------	----------	24,000 W.	----------	----------
----------	----------	----------	----------	34,000 W.	----------	----------
----------	----------	30,000	----------	----------	----------	----------
----------	----------	70,000	----------	----------	----------	----------
----------	----------	----------	----------	40,000 F.	----------	----------
37,000	30,000	295,000	180,000	24,000 W.	57,000	$ 210,000
----------	----------	----------	----------	7,630 R.	----------	180,000 A.
----------	----------	----------	----------	14,130 F.	----------	$ 1,000,000 B
				----------	----------	37,000 A.B.
68,500	21,000	740,000	330,000	34,000 W.	145,000	$ 200,000
----------	----------	----------	----------	18,000 R.	----------	301,000 A.
----------	----------	----------	----------	70,000 F.	----------	20,000 A.B.

		1980	2000
1. **Annual Requirements to Be Met** — (from Chapter IX)			
a. Municipal and Domestic Use	Total	7,357 A.F.	13,867 A.F.
	Net	—2,173	4,337
b. Livestock Use	Total	12,287 A.F.	16,230 A.F.
	Net	1,510	5,453
c. Irrigation Use	Total	152,772 A.F.	305,523 A.F.
(Optimum)	Net	131,007	283,758
d. Industrial and Mining Use	Total	8,107 A.F.	33,857 A.F.
	Net	8,000	33,750
e. Fish and Outdoor Recreation			
Surface Acres	Net	1,121	17,412
Facilities	Net	5,424 acres	21,715 acres
Wetlands	(#)	10,000	30,000
Wetlands	Net	20,000 acres	60,000 acres
f. Quality Control	Total	56,200 A.F.	63,700 A.F.
	Net	56,200	63,700
g. Flood Prevention and Runoff Management (Urban)	Total Damages	$218,000	$518,000
	Net Damages	$125,000	$425,000
(Ag. Lands)	Total	46,275 acres	46,275 acres
	Net	13,031	13,031
h. Summary of A. F. Requirements	Total	236,723	433,177
	Net	194,544	390,998
2. **Current Supply** (Chapter VIII)			
a. Reservoir Storage by Function — A.F.			
(1) Municipal and Domestic			4,980
(2) Stockwater			13,712
(3) Irrigation			18,195
(4) Recreation (11,500 A.)			51,573
(5) Flood Control			200,000
b. Programmed Projects — A.F.			
(1) Recreation (1,038 A.)			1,071
(2) Flood Control			135,000
(3) Quality Control (portion of FC)			9,000
(4) Conservation Storage — Municipal			10,000
(5) Garrison Diversion Unit — 1980 initial stage			
2000 complete stage			
c. Ground-water — A.F.			
(1) Developed to Date			10,841
(2) Potential Aquifers — estimated yield — 20% (3,781,000 A. F. Storage)			756,200

3. Developments to Meet 1980 and 2000 Requirements — Table 2

a. Municipal and Domestic Use

In order to assure a sustained yield of water the planning criteria for this use is based on a factor of three times the requirements. Using this factor and deducting the current developed supply, the 1980 requirement is 12,541 acre-feet annually. This can be supplied by 5,000 acre-feet of water from the Garrison Diversion Unit, 550 from a multi-purpose reservoir, and 7,000 from multi- and single-purpose aquifer development.

Using the same planning factor, the 2000 requirement is 27,613 acre-feet. This can be met by the scheduled 2,500 acre-feet from Garrison Diversion, 15,000 acre-feet from multi-purpose and 10,000 from single purpose aquifer development.

b. Livestock Use

By using a planning factor of 1.5 times the requirement and accounting for the current developed supply, it is estimated that the 1980 and 2000 requirements for this use are 6,653 and 5,915 acre-feet annually respectively. Both requirements can be readily met by the development of small dams and dugouts and single purpose aquifers. Developments from dams and dugouts are estimated to be 3,500 acre-feet by 1980 and another 3,150 by 2000. Aquifer developments should include 3,000 acre-feet by 1980 and an additional 3,000 acre-feet by 2000.

c. Irrigation Use

Based on soils studies of irrigable land, the optimum irrigation use is estimated to be 152,772 acre-feet by 1980 and 305,323 by 2000. The Garrison Diversion plan is to import more than this amount for irrigation, however, some of the irrigation water will be used for Quality Control and some may have to support industrial use which would be needed to make maximum use of land for irrigation. Developments by 1980 of 140,00 acre-feet of Garrison Diversion water is expected as well as 3,000 and 10,000 acre-feet respectively from multi- and single-purpose aquifers. Likewise, the 305,000 acre-feet requirement by 2000 is anticipated to be met by the development of 275,000 acre-feet of water from Garrison Diversion, 5,000 from multi-purpose and 25,000 from single purpose aquifers

d. Industrial and Mining Use

Industrial water use in the basin will largely depend upon the type of irrigated crops grown and the need to process these crops in the local area. For this use a planning criteria factor of three was again used and the requirements for 1980 and 2000 are 24,014 and 77,450 acre-feet respectively. For 1980 the developments should be as follows: 12,000 acre-feet from Garrison Diversion, 5,000 acre-feet from the authorized Pipestem reservoir, 2,000 acre-feet from a multi-purpose reservoir, 6,000 acre-feet from multi-purpose aquifers and 3,000 acre-feet from single purpose aquifers. The estimated development for 1980 is 5,000 acre-feet above the requirement because of the apparent need for more agricultural products processing industry in the central part of the State.

The 2000 requirement of 77,450 acre-feet can be met by using 43,000 acre-feet from Garrison Diversion and 35,000 from multi- and single-purpose aquifers. It should be noted that the amount of irrigation will depend somewhat on processing plants and the water for these plants could be supplied by the waters diverted from the Garrison Reservoir.

e. Fish, Wildlife and Outdoor Recreation

The 1980 requirements show a need for 1,121 effective surface acres of water for recreation and 5,424 acres require added facilities. The recreation acres can be developed by using 2,620 acres of the programmed storage and 1,400 from proposed multi- and single-purpose storage. The same projects require 5,020 acres of facility developments by 1980. By 2000, the requirements are for 16,291 surface acres of recreation water and facilities for 16,291 acres. Recreation reservoirs of the 250 acre size can provide for only about 10% of the surface area needed. Additional acres can be provided if the Jamestown Reservoir will someday carry water at a higher elevation. Facilities are limited to development around the small recreation reservoirs and possible additional development around the present storage facilities. Unless something now unforeseen takes place, some of the other basins will have to absorb part of the recreation activity requirements of the James River Basin by the year 2000.

Wetlands development will need up to 40,000 acres of development by 2000. The Garrison Diversion Unit has scheduled to supply 25,000 acre-feet of water annually which will help serve these acres and part of the requirement will be met by the building of small dams and dugouts.

f. Quality Control Use

The principal need for quality control will be to dilute irrigation return flows and to care for possible pollution from agricultural products processing plants. The requirements are for 63,700 A.F. by 2000. It is anticipated that by 1980, 15,000 acre-feet will be furnished by Garrison Diversion, 9,000 by Pipestem Dam and 3,000 from aquifer development. By 2000 Garrison Diversion is estimated to be supplying an annual amount of 30,000 acre-feet plus another 6,000 supplied by aquifers.

g. Flood Prevention and Runoff Management

Urban protection in the amount of $125,000 annually is needed by 1980 and another 300,000 will be needed by 2000. The Pipestem Reservoir will provide approximately $200,000 annual damage protection and the balance can be provided by channel improvement and other flood protection works. Estimated protection for these projects are $50,000 by 1980 and another $175,000 by 2000. The total requirement for agricultural land protection is 13,031 acres. The Pipestem Reservoir will protect 3,000 acres. The balance to be split evenly by 1980 and 2000 can be met by 3,000 acres of protection annually from snagging and clearing projects and 7,000 from legal drains.

4. **Costs**

Estimated first costs, based on current prices, for proposed developments during the time period 1969-1980 are **$31,500,000.** Anticipated costs for developments proposed during the 1981-2000 period are **$50,400,000.**

These reconnaissance type estimates include costs for land and capital improvements to control or make available the resource. Additional costs would be incurred for such items as pipelines, intakes, treatment facilities, interest, and the like to apply the water to beneficial use.

5. **Resources**

a. Land acquisition for the various projects is estimated to be 35,150 acres by 1980 and another 44,000 acres by 2000. It is noted that the requirement for wetlands acreage appears to be quite high, but this figure may be misleading depending upon what use can be made of some of the present areas.

b. The storage figures are 267,100 acre-feet by 1980 and an additional 142,000 by 2000. These figures include Missouri River Diversion.

c. Surface acres are quite moderate in relation to the size of the basin, 27,670 acres by 1980 and another 41,500 by 2000. The comparatively small amount of acreage needed is due to the fact that not much large storage is anticipated. The main uses will be supplied by Garrison Diversion waters, thus reducing storage needs.

d. Groundwater withdrawals, which include all estimated uses, are 35,500 acre-feet by 1980 and an additional 99,000 acre-feet by 2000. Ground water studies have not been completed as yet and the actual potential is unknown, therefore, the anticipated developments have been only a small percentage of estimated yield.

e. Streamflow effects show a depletion of 80,950 acre-feet by 1980 and another 129,400 by 2000. These figures include a 5% depletion by ground water use. While these figures appear quite high as compared to the average yield for the basin, it should be again noted that there is a large import of water via the Garrison Diversion Project. A further import of water from the same source could be accomplished.

TABLE 2. — JAMES RIVER BASIN

DEVELOPMENTS			Land (Acres)	Storage A. F.	Surface Acres	G.W. Withdrawal A. F.	Streamflow Effect-A. F. + or −
			RESOURCES				
Programmed by 1980							
Garrison Diversion			3,000	50,000	1,500		
Recreation Reservoirs		(3)	250	1,100	120		— 350
Pipestem Reservoir			8,000	135,000	4,600		— 12,000
Future Multi-Purpose Projects							
Multi-Purpose Reservoir	1980	(1)	900	6,000	450		— 3,900
Garrison Diversion	2000						
Aquifers	1980					14,000	— 700
	2000					31,000	— 1,500
Future Single Purpose Projects							
Recreation Reservoirs	1980	(4)	3,000	15,000	1,000		— 3,000
	2000	(6)	4,000	22,000	1,500		— 4,500
Aquifers	1980					21,500	— 1,000
	2000					68,000	— 3,400
Small Dams and Dugouts	1980						
	2000						
Snagging and Clearing	1980						
	2000						
Legal Drains	1980						
	2000						
Flood Prevention Works	1980						
	2000						
Wetlands							
(10,000)	1980		20,000	60,000	20,000		— 60,000
(20,000)	2000		40,000	120,000	40,000		— 120,000
Improvements at Present Storage	2000						
TOTAL — 1980			35,150	267,100	27,670	35,500	— 80,950
TOTAL — 2000			44,000	142,000	41,500	99,000	— 129,400

R. — Recreation Water Surface Acres
F. — Public Use Recreation Facilities
W. — Wetlands
A. — Acres
A.F. — Acre-Feet

FUNCTIONAL REQUIREMENTS SERVED ANNUALLY

Municipal & Domestic (A. F.)	Livestock (A. F.)	Irrigation (A. F.)	Industrial (A. F.)	Recreation & Facilities Acres	Quality A. F.	Flood Prevention $ & Acres
5,000	—	140,000	12,000	—	15,000	—
—	—	—	—	120 R.	—	—
—	—	—	—	120 F.	—	—
—	—	—	5,000	2,500 R.	9,000	$ 200,000
—	—	—	—	3,000 F.	—	3,000 A.
550	—	—	2,000	400 R.	—	—
—	—	—	—	400 F.	—	—
2,500	—	275,000	43,000	—	30,000	—
4,000	—	3,000	6,000	—	1,000	—
15,000	—	5,000	10,000	—	1,000	—
—	—	—	—	1,000 R.	—	—
—	—	—	—	1,500 F.	—	—
—	—	—	—	1,500 R.	—	—
—	—	—	—	2,000 F.	—	—
3,000	3,500	10,000	3,000	—	2,000	—
10,000	3,000	25,000	25,000	—	5,000	—
—	3,150	—	—	—	—	—
—	3,000	—	—	—	—	—
—	—	—	—	—	—	1,500 A.
—	—	—	—	—	—	1,500 A.
—	—	—	—	—	—	3,500 A.
—	—	—	—	—	—	3,500 A.
—	—	—	—	—	—	$ 50,000
—	—	—	—	—	—	$ 175,000
—	—	—	—	20,000 W.	—	—
—	—	—	—	40,000 W.	—	—
—	—	—	—	5,000 F.	—	—
12,550	6,650	153,000	28,000	4,020 R.	27,000	$ 250,000
—	—	—	—	5,020 F.	—	8,000 A.
—	—	—	—	20,000 W.	—	—
27,500	6,000	305,000	78,000	1,500 R.	36,000	$ 175,000
—	—	—	—	7,000 F.	—	5,000 A.
—	—	—	—	40,000 W.	—	—

		1980	2000
1. **Annual Requirements to Be Met** (from Chapter IX)			
a. Municipal and Domestic Use	Total	12,385 A.F.	21,075 A.F.
	Net	3,613	12,678
b. Livestock Use	Total	12,971 A.F.	16,064 A.F.
	Net	1,488	4,581
c. Irrigation Use (Optimum)	Total	231,612 A.F.	463,224 A.F.
	Net	217,526	449,138
d. Industrial and Mining Use	Total	8,207 A.F.	23,357 A.F.
	Net	8,000	23,150
e. Fish and Outdoor Recreation			
Surface Acres	Net	— 9,714	13,287
Facilities	Net	18,276 acres	32,277 acres
Wetlands	(#)	11,000	36,000
Wetlands	Net	22,000 acres	72,000 acres
f. Quality Control	Total	109,000 A.F.	106,900 A.F.
	Net	109,000	106,900
g. Flood Prevention and Runoff Management (Urban)	Total Damages	$3,850,000	$4,670,000
	Net Damages	1,430,000	$1,730,000
(Agricultural Land)	Total Damages	355,690 acres	355,690 acres
	Net Damages	234,200 acres	234,200 acres
h. Summary of Acre-feet Required	Total	374,175	630,620
	Net	339,627	596,447
2. **Current Supply** (Chapter VIII)			
a. Reservoir storage by function — A.F.			
(1) Municipal and Domestic			634
(2) Stockwater			9,928
(3) Irrigation			2,385
(4) Industrial and Mining			———
(5) Recreation (34,208 acres)			238,563
(6) Wetland Areas — (No.)			81,000
(7) Quality Control			———
(8) Flood Control			———
b. Programmed Projects — A. F.			
(1) Municipal and Domestic			100
(2) Recreation (152 acres)			1,300
c. Groundwater — A.F.			
(1) Developed to Date			80,999
(2) Potential Aquifers — estimated yield — 20% (4,220,000 storage)			844,000

3. Developments Proposed to Meet 1980 and 2000 Requirements

a. Municipal and Domestic

Currently, one reservoir with a 100 acre-feet capacity is programmed to provide for storage for municipal purposes. Municipal water requirements by 1980 are anticipated to be 12,385 acre-feet. The planning criteria used in providing for this water is three times the estimated annual use in order to assure a sustained yield. The net requirement in 1980 would be 37,155 acre-feet minus the current developed supply of 8,397 for a total of 28,758 acre-feet.

Of this 28,758 acre-feet, 26,000 acre-feet may be supplied from the Garrison Diversion Unit in its initial stage of development. An additional 4,758 acre-feet should be supplied by single and multi-purpose aquifer developments and by the construction of two multi-purpose reservoirs. Municipal water requirements for the year 2000 are estimated to be 26,070 acre-feet. Of this 26,070 acre-feet, 6,000 acre-feet may be supplied from the Garrison Diversion Unit in its second stage of development. Of the remaining 20,070 acre-feet, it is proposed that 6,270 acre-feet be supplied by single and multi-purpose reservoirs and 13,800 acre-feet by single and multi-purpose aquifer developments.

b. Livestock

The gross water requirement for livestock use by 1980 is estimated to be 12,971 acre-feet. By using a planning criteria of one and one-half times the total anticipated requirement and taking into account the currently developed supply for this purpose the anticipated net requirement for livestock water use is estimated to be 7,973 acre-feet. To provide for this water, it is proposed that 4,000 acre-feet be provided by single purpose stock dams and 3,973 acre-feet from single purpose aquifer developments. By 2000, it is anticipated that 4,640 acre-feet of water will be required for livestock use in addition to that needed to meet the 1980 level of livestock water use. To meet this requirement it is proposed that 2,000 acre-feet be provided by single purpose stock dams, and 2,120 acre-feet from single purpose aquifer developments.

c. Irrigation

By 1980 it is anticipated that an additional 217,526 acre-feet of water will be needed for irrigation. The Garrison Diversion Unit in its initial stage of development will supply the Souris River Basin with 323,000 plus acre-feet of water for irrigation.

The anticipated irrigation water requirement by the year 2000 is 231,612 acre-feet in addition to the 1980 requirement. Development of the Garrison Diversion Unit second stage would supply the Souris River Basin with an additional 1,000,000 plus acre-feet of water beyond that supplied in the initial stage of its development.

d. Industrial and Mining

Projected water requirements for industrial and mining use show a need for 8,000 acre-feet of water by 1980. In order to assure a continuing supply, a sustained yield factor of three was applied to provide for carry-over storage in the event of insufficient run-off or aquifer recharge. Based on total requirements of 8,207 acre-feet, this gives us a net requirement of 24,414 acre-feet of water for industrial and mining purposes. To meet this need it is proposed that 14,414 acre-feet be provided by multi-purpose reservoirs, 4,550 from multi-purpose aquifers, and 1,500 from single purpose aquifers. The proposed Minot flood control reservoir would serve a multiple purpose in that it would allow extra use of Lake Darling water for municipal and industrial purposes as well as to help control the flow of waters released from Lake Darling.

Anticipated additional requirements for mining and industrial waters by the year 2000 are 23,150 acre-feet. Applying a sustained yield factor of two plus to provide for carryover storage in the event of insufficient runoff or aquifer recharge gives us a requirement of about 55,550 acre-feet of water. To meet this need it is proposed that 4,550 acre-feet be provided by multi-purpose reservoirs, 25,000 from the Garrison Diversion Unit, 10,000 from multi-purpose aquifers, and 16,000 acre-feet from single purpose aquifers.

e. Outdoor Recreation

The requirements for outdoor recreation in 1980 show a need for development of facilities for 18,276 acres. Wetland developments are proposed in aggregate acres, however, many of these requirements are anticipated to be met in connection with single purpose stockwater reservoir developments and by wildlife waters supplied by the Garrison Diversion Unit. By the year 2000 an additional 14,287 surface acres should be developed for outdoor recreation use along with facilities for 24,000 acres. Approximately 25,000 additional wetlands or 50,000 acres of wetland area may be needed by the year 2000. Multi-purpose reservoirs, including Garrison Diversion reservoirs, should be developed to provide 8,300 surface acres for recreation. Single purpose reservoirs should provide an additional 6,000 surface acres of water. The facilities proposed would be similar to those mentioned in the 1980 developments and wetland areas for wildlife enhancement and propagation should be planned in connection with stockwater and other types of water management installations.

In addition to these needs, there is a need for development of an additional 11,000 wetlands, or about 22,000 acres by the year 1980. The facilities required on the developed and proposed reservoirs include such items as sanitary facilities, picnic tables, camping facilities, wells, boat docks, swimming beaches, bath houses, parking areas, and general landscaping.

f. Quality Control

The requirements for quality control are 109,000 acre-feet by 1980 and the figure goes down with the progressing years due to the anticipated increase in percentage of treatment as it affects sewage and industrial wastes. The requirements can be met by the Garrison Diversion waters which are in excess of irrigation needs and by releases of flood control reservoir waters above the City of Minot. The Garrison Diversion waters will dilute the stream flows before they enter another basin or before entering Canada. Eventually provisions will be made to reuse the major portion of Garrison Diversion water in North Dakota through the installation of pumps thereby limiting flows that cross the border to natural flows only.

g. Flood Prevention and Runoff Management

The total agricultural lands flood prevention requirement is 234,000 acres. Anticipated watershed protection projects will provide protection for 30,000 acres by 1980 and 80,000 acres by 2000. The remaining 124,000 acres would be protected by a flood control dam above Minot along with related Souris River flood control works such as channel improvement through Minot to care for Des Lacs River flood flows that could attain 4,000 c.f.s.

Urban protection needed is $1,430,000 annually by 1980 and $300,000 additional by 2000. The annual protection from the Minot flood control project will be approximately $1,200,000 and related flood prevention projects downstream will provide another $230,000 of annual protection. The remaining urban needs of $300,000 will have to be provided by additional flood prevention works by the year 2000.

4. Costs

Estimated first costs, based on current prices, for proposed developments during the 1969-1980 period are **$66,000,000.** Developments proposed for the 1981-2000 period are estimated to cost **$86,400,000.**

These costs include only the land and capital improvements required to control or make available the resource. Additional costs would be incurred for such items as pipelines, intakes, treatment facilities, interest and the like to apply the water to beneficial use.

5. Resources
   a. Lands needed to meet requirements total approximately 146,115 acres. The lands needed are for effective surface acres of water for the various uses plus the lands required to provide the necessary access and recreational facilities. Land requirements by 1980 are 61,415 acres and 2000 land requirements are 84,700 acres.
   b. Storage facilities needed are approximately 876,000 acre-feet, 461,900 of which are needed by 1980 and 414,500 by 2000. This figure includes 130,000 acre-feet of storage which will be provided by Garrison Diversion. The 414,500 acre-feet indicated for development by 1980 includes an estimated 250,000 acre-feet of flood control storage on the Souris and Des Lacs Rivers.
   c. Surface area needed for water storage will be 47,662 acres by 1980 and 71,000 by 2000 for a total of 116,662 acres. These acres to be developed are based on an average depth of three feet of water needed for wetlands and 10 to 15 feet average depth on the reservoirs depending upon their intended purpose.
   d. Groundwater withdrawals are estimated to be 13,000 acre-feet by 1980 and an additional 47,300 acre-feet by 2000. In view of the cost of developing and controlling an aquifer it is proposed that multiple use aquifer developments are preferable. However, locations of municipalities or industries needing groundwater may show the need to develop many single purpose aquifers.
   e. Streamflow depletions are estimated to be 122,390 acre-feet by 1980 and another 202,205 acre-feet by 2000 for a total of 324,595 acre-feet. This exceeds the annual yield of streams in the Souris River Basin by approximately 200,000 acre-feet. To help offset this deficit, 45,000 acre-feet annually will be imported for wildlife uses by the Garrison Diversion Unit. Also this same diversion will import irrigation water in excess of anticipated requirements and this will assist in alleviating streamflow deficits. The wetlands evaporation was used to show depletion waters in the chart and in many instances these wetlands waters will be replaced by non-contributing drainage areas within the basin.

      Indications are that some additional trans-basin diversion to the Souris River Basin for future uses should be planned.

TABLE 3.—SOURIS RIVER BASIN

DEVELOPMENTS		Land (Acres)	Storage A. F.	Surface Acres	G.W. Withdrawal A. F.	Streamflow Effect-A. F. + or −
		RESOURCES				
Programmed Projects by 1980						
Garrison Diversion Unit						
Municipal Reservoir	(1)	15	100	10		— 300
Recreation Reservoir	(1)	300	1,300	152		— 456
Future Multi-Purpose Projects						
Garrison Diversion						
2000		8,000	130,000	6,500		
Multi-Purpose Reservoir						
1980	(2)	2,000	12,000	1,000		— 6,072
2000	(4)	4,000	24,000	2,000		— 11,820
Aquifer Development						
1980					6,500	— 400
2000					20,000	— 1,000
Watershed Management						
1980		600	3,000	500		— 300
2000		1,200	6,000	1,000		— 600
Minot Flood Control Reservoir & Channel Improvement						
1980		20,000	300,000	15,000		— 18,000
Flood Prevention Works						
1980						
Single Purpose Projects						
Recreation Reservoirs						
1980	(6)	15,000	75,000	7,500		— 22,500
2000	(8)	20,000	100,000	10,000		— 30,800
Aquifer Development						
1980					6,500	— 350
2000					27,300	— 1,365
Small Dams and Dugouts						
1980		1,500	4,500	1,500		— 8,473
2000		1,500	4,500	1,500		— 6,620
Flood Prevention Works						
2000						
Wetlands Areas						
(11,000) 1980		22,000	66,000	22,000		— 66,000
(25,000) 2000		50,000	150,000	50,000		— 150,000
Improve Present Storage						
1980						
TOTAL — 1980		61,415	461,900	47,662	13,000	— 122,390
TOTAL — 2000		84,700	414,500	71,000	47,300	— 202,205

R. — Recreation Water Surface Acres
F. — Public Use Recreation Facilities
W. — Wetlands
A. — Acres
A.F. — Acre-Feet

FUNCTIONAL REQUIREMENTS SERVED ANNUALLY

Municipal & Domestic (A. F.)	Livestock (A. F.)	Irrigation (A. F.)	Industrial (A. F.)	Recreation & Facilities Acres	Quality A. F.	Flood Prevention $ & Acres
26,000	—	323,000	5,000	—	30,000	—
100	—	—	—	—	—	—
—	—	—	—	—	—	—
6,000	—	1,000,000	25,000	6,000 R.	60,000	—
—	—	—	—	10,000 F.	—	—
658	—	—	2,414	1,000 R.	—	—
—	—	—	—	1,000 F.	—	—
1,270	—	—	4,550	1,800 R.	—	—
—	—	—	—	1,800 F.	—	—
3,000	—	—	3,500	—	—	—
10,000	—	—	10,000	—	—	—
—	—	—	—	300 R.	—	30,000 A.
—	—	—	—	300 F.	—	—
—	—	—	—	500 R.	—	80,000 A.
—	—	—	—	500 F.	—	—
—	—	—	12,000	3,000 R.	20,000	$1,200,000
—	—	—	—	5,000 F.	—	124,000 A.
—	—	—	—	—	—	$ 230,000
—	—	—	—	5,000 R.	—	—
—	—	—	—	10,000 F.	—	—
—	—	—	—	6,000 R.	—	—
—	—	—	—	12,000 F.	—	—
1,000	4,000	—	1,500	—	—	—
8,800	2,500	—	16,000	—	—	—
—	3,973	—	—	—	—	—
—	2,120	—	—	—	—	—
—	—	—	—	—	—	$ 300,000
—	—	—	—	22,000 W.	—	—
—	—	—	—	50,000 W.	—	—
—	—	—	—	2,000 F.	—	—
30,758	7,973	323,000	24,414	22,000 W.	50,000	$1,430,000
—	—	—	—	9,300 R.	—	154,000 A.
—	—	—	—	18,300 F.	—	—
26,070	4,640	1,000,000	55,550	50,000 W.	60,000	$ 300,000
—	—	—	—	14,300 R.	—	80,000 A.
—	—	—	—	24,300 F.	—	—

		1980	2000
1. **Annual Requirements to Be Met** (from Chapter IX)			
a. Municipal and Domestic Use	Total	3,940 A.F.	6,450 A.F.
	Net	1,035*	3,545
b. Livestock Use	Total	3,601 A.F.	4,851 A.F.
	Net	819	2,069
c. Irrigation Use (Optimum)	Total	125,668 A.F.	251,336 A.F.
	Net	125,460	251,128
d. Industrial and Mining	Total	8,007 A.F.	24,007 A.F.
	Net	8,000	24,000
e. Fish, Wildlife and Outdoor Recreation Use			
Surface Acres	Net	56	9,859
Facilities	Net	4,006 acres	13,809 acres
Wetlands	(#)	10,000	27,000
Wetlands	Net	20,000 acres	54,000 acres
f. Quality Control	Total	27,500 A.F.	36,900 A.F.
	Net	27,500	36,900
g. Flood Prevention and Runoff Management (Agricultural Land)	Total Damages	188,800 acres	188,800 acres
	Net Damages	156,000	156,000
h. Summary of Acre-feet Required	Total	168,716 A.F.	323,544 A.F.
	Net	27,500	36,900
2. **Current Supply** (From Chapter VIII)			
a. Reservoir storage by function — acre-feet			
(1) Municipal and Domestic			100
(2) Stockwater			2,151
(3) Irrigation			—
(4) Industrial and Mining			—
(5) Recreation (6,619 acres)			26,307
(6) Wetland Areas (No.)			54,000
(7) Quality Control			—
(8) Flood Control			—
b. Programmed Projects — acre-feet			
(1) Municipal and Domestic			305
(2) Recreation (181 acres)			1,425
c. Groundwater — acre-feet			
(1) Developed to Date			3,346
(2) Potential Aquifers			Not investigated

*Modified to reflect anticipated population trend reversal.

3. Developments Proposed to Meet 1980 and 2000 Requirements — Table 4.

a. Municipal and Domestic

Using a factor of three for planning criteria to assure a sustained supply of municipal water, the total requirement by 1980 is 8,915 acre-feet of water. This figure was arrived at by increasing the original requirement three times and deducting the current developed supply. Of the programmed projects, one reservoir is being constructed to supply 300 acre-feet of water for the city of Bisbee and the Garrison Diversion Unit will supply 3,500 acre-feet of water annually to the Basin by 1980. Aquifer development should supply 5,415 acre-feet.

Developments to meet municipal requirements by the year 2000 should include two multi-purpose storage reservoirs similar to the one now programmed and approximately 4,235 acre-feet of water can be supplied by ground-water aquifers. Due to the uncertainty of the adequate ground water it is anticipated that the Garrison Diversion Unit may need to supply another 1,000 acre-feet of water. Other trans-basin diversion or import of water in the amount of 5,000 acre-feet will need to be developed by 2000.

b. Livestock

Using the same procedure as for municipal water, the planning criteria factor of 1.5 shows a need for 4,494 acre-feet of livestock water by 2000. The requirement by 1980 for 2,719 acre-feet of water can be met by the development of 1,719 acre-feet from aquifer development and 1,000 acre-feet in small dams and dugouts.

The 2000 requirement will have to be met in much the same manner, developing approximately 785 acre-feet of water from aquifers and an additional 1,000 acre-feet in small dams and dugouts.

c. Irrigation

The requirements for irrigation are based on optimum use of irrigable land available. The requirements are 125,460 acre-feet of water by 1980 and an additional 125,668 by 2000. The Garrison Diversion Unit will supply 16,000 acre-feet of water by 1980 and estimated aquifer development of 9,460 acre-feet. By 2000, in addition to an estimate of 25,668 acre-feet of water from aquifer development, the Garrison Diversion Unit could furnish another 20,000 acre-feet. The added development by the Garrison Diversion Unit is expected as more water is made available by practicing sprinkler instead of gravity irrigation.

In order to make up the deficit, irrigation supply should be made up of some additional trans-basin diversion or other import of water in the amount of 70,000 acre-feet annually by 1980 and another 110,000 by 2000.

d. Industrial and Mining

Requirements for this use were determined to be 24,014 acre-feet of water by 1980 and another 48,000 acre-feet by 2000. These requirements were arrived at by using a sustained yield factor of three. The 1980 needs can be met through the development of 6,014 acre-feet from ground-water aquifers and the use of 18,000 acre-feet of water from the increased storage in Devils Lake as a result of Garrison Diversion. The 2000 requirement can likewise be met by 12,000 acre-feet of ground-water and 36,000 acre-feet of lake water. The use of this amount of water from Devils Lake and/or surrounding lakes should not seriously affect the water quality.

e. Outdoor Recreation

The requirements show that more development is needed for recreation facilities than for surface acres of water. The anticipated development of public use facilities for 3,000 acres in the Devils Lake area by 1980 coupled with the 1,100 acres of recreation and facilities from single and multi-purpose reservoirs and recreation reservoirs will more than make up the requirement of 56 surface acres for recreation and facilities for 4,006 acres. The 2000 requirements are for 9,859 acres of recreation water surface and facilities for 13,809 acres. Recreation reservoirs could furnish 1,000 acres, multi-purpose reservoirs 200 acres and watershed management 400 acres of each recreation and facilities. The balance of recreational acres and facilities needed will be amply provided by the restoration of Devils Lake and other lakes. Needed facility development will follow the same general line as mentioned for other basins. An additional need for a large resort development along the same plan as was once proposed for Lake Sakakawea (Garrison Reservoir) may assert itself in the Devils Lake Basin. Wetland areas needed will be 20,000 acres by 1980 and an additional 34,000 acres by 2000. These acreages are based on two acres for one unit of wetland area. Part of the wetlands areas will be supplied by small dams and dugouts and by wildlife waters from the Garrison Diversion Unit.

f. Quality Control

The quality control requirement total of 39,900 acre-feet needed for both the 1980 and 2000 eras will be more than met by the development of the initial phase of the Garrison Diversion project. The proposed diversion of water will not only restore the waters of the Devils Lake Chain; it will also enhance water quality. Multi-purpose aquifer development will be needed to provide some municipal water quality enhancement in the amount of 2,000 acre-feet by 1980 and another 3,000 acre-feet by the year 2000.

g. Flood Prevention and Runoff Management Requirements for flood protection in the Devils Lake Basin are limited to farm land protection. The total need is for 156,000 acres to be protected. The requirements can be met by watershed management of the Starkweather and Edmore watersheds along with watersheds drained by Mauvais Coulee and its tributaries.

4. **Costs**

Estimated first costs, based on current prices, for developments during the period 1969-1980 are $11,100,000. Developments proposed for the 1981-2000 period are estimated at $22,500,000.

These reconnaissance type estimates include only the land and capital improvements required to control or make available the resource. Added costs would be incurred for items such as pipelines, intakes, treatment facilities, interest, and the like to apply the water to beneficial use.

5. **Resources**

a. Land needed for the proposed developments will total approximately 15,360 acres by 1980 and another 40,000 acres by 2000 plus the acreage that will be developed in conjunction with the Garrison Diversion Project. This acreage estimate is based on the land needed to develop recreation facilities in addition to effective surface acres needed for recreation.

b. The storage facilities required to provide needed developments will be for 52,425 acre-feet of water by 1980 and an additional 126,000 by 2000. Detailed site surveys and reservoir regulation could vary these storage amounts. Requirements above annual yield of the Basin will be supplied by Garrison Diversion and other trans-basin diversions or import of water.

c. Surface acres of water are based on varying reservoir depths (three to 10 feet) depending on the type and use of the reservoir. Estimated surface acres of water is 13,381 by 1980 and another 37,700 by 2000. Here again the restoration of Devils Lake and other lakes will increase the surface acres by a very sizable amount. Estimated increase in surface acres will include development of wetlands in noncontributing areas.

d. Ground water withdrawals from the various aquifers will be near 24,000 acre-feet by 1980 and another 45,000 acre-feet by 2000. The aquifers in this Basin have not been fully investigated; however, it is anticipated that further ground water tests will reveal a greater supply than estimated.

e. Basin streamflow depletions by 1980 should be about 39,682 acre-feet and an added 113,385 by 2000. This amount of water is in excess of the average runoff from the basin by some 141,000 acre-feet. Garrison Diversion will import 110,000 acre-feet annually for wildlife and the refilling of Devils Lake. The deficit will be further reduced by the supplying of some wetlands areas in noncontributing areas of the basin.

It is recommended that further development be planned for additional trans-basin diversion or other import of water for the Devils Lake Basin.

TABLE 4.—DEVILS LAKE BASIN

DEVELOPMENTS		Land (Acres)	Storage A. F.	Surface Acres	G.W. Withdrawal A. F.	Streamflow Effect-A. F. + or −
		RESOURCES				
Programmed Projects by 1980						
Garrison Diversion Unit						
Multi-Purpose Storage		360	1,425	181		— 847
Future Multi-Purpose Projects						
Garrison Diversion Unit						
2000						
Multi-Purpose Reservoir						
1980	(1)	500	1,500	200		— 900
2000	(1)	500	1,500	200		— 900
Watershed Management						
Edmore & Starkweather 1980		3,000	15,000	2,000		— 2,700
Mauvais Coulee 2000		3,000	15,000	2,000		— 2,700
Aquifer Development						
1980					3,214	— 160
2000					6,735	— 335
Future Single-Purpose Projects						
Recreation Dams						
1980	(2)	1,000	3,000	500		— 1,500
2000	(4)	2,000	6,000	1,000		— 3,000
Aquifer Development						
2000					20,494	— 1,075
1980					38,953	— 1,950
Small Dam and Dugouts						
1980		500	1,500	500		— 2,500
2000		500	1,500	500		— 2,500
Wetlands Areas						
(10,000) 1980		10,000	30,000	10,000		— 30,000
(17,000) 2000		34,000	102,000	34,000		— 102,000
Trans-Basin or Other Import of Water						
1980						
2000						
TOTAL — 1980		15,360	52,425	13,381	23,708	— 39,682
TOTAL — 2000		40,000	126,000	37,700	45,688	— 113,385

R. — Recreation Water Surface Acres
F. — Public Use Recreation Facilities
W. — Wetlands
A. — Acres
A.F. — Acre-Feet

FUNCTIONAL REQUIREMENTS SERVED ANNUALLY

Municipal & Domestic (A. F.)	Livestock (A. F.)	Irrigation (A. F.)	Industrial (A. F.)	Recreation & Facilities Acres	Quality A. F.	Flood Prevention $ & Acres
3,500	—	16,000	18,000	3,000 F.	34,900	—
300	—	—	—	181 R.	—	—
—	—	—	—	181 F.	—	—
1,000	—	20,000	36,000	8,300 R.	—	—
—	—	—	—	12,200 F.	—	—
300	—	—	—	200 R.	—	—
—	—	—	—	200 F.	—	—
300	—	—	—	200 R.	—	—
—	—	—	—	200 F.	—	—
—	—	—	—	400 R.	—	80,000 A.
—	—	—	—	400 F.	—	—
—	—	—	—	400 R.	—	76,000 A.
—	—	—	—	400 F.	—	—
500	—	—	1,014	—	2,000	—
1,735	—	—	2,000	—	3,000	—
—	—	—	—	500 R.	—	—
—	—	—	—	500 F.	—	—
—	—	—	—	1,000 R.	—	—
—	—	—	—	1,000 F.	—	—
4,315	1,719	9,460	5,000	—	—	—
2,500	785	25,668	10,000	—	—	—
—	1,000	—	—			
—	1,000	—	—			
—	—	—	—	20,000 W.	—	—
—	—	—	—	34,000 W.	—	—
—	—	50,000	—	—	—	—
5,000	—	110,000	—	—	—	—
8,915	2,719	95,460	24,014	20,000 W.	36,900	80,000 A.
—	—	—	—	1,281 R.	—	—
—	—	—	—	4,281 F.	—	—
10,535	1,785	155,668	48,000	34,000 W.	3,000	76,000 A.
—	—	—	—	9,900 R.	—	—
—	—	—	—	13,800 F.	—	—

		1980	2000
1. **Annual Requirements to be met** — (from Chapter IX)			
a. Municipal and Domestic Use	Total	31,515 A.F.	54,665 A.F.
	Net	—51,148*	—27,998*
b. Livestock Use	Total	15,391 A.F.	20,825 A.F.
	Net	2,715	8,149
c. Irrigation Use (Optimum)	Total	940,114 A.F.	1,880,228 A.F.
	Net	930,373	1,870,487
d. Industrial and Mining	Total	35,857 A.F.	63,107 A.F.
	Net	29,550	56,800
e. Fish, Wildlife and Outdoor Recreation Use			
Surface Acres	Net	38,932	92,932
Facilities	Net	42,420 acres	96,420 acres
Wetlands	(#)	9,000	26,000
Wetlands	Net	18,000 acres	52,000 acres
f. Quality Control	Total	231,700 A.F.	233,800 A.F.
	Net	231,700 A.F.	233,800 A.F.
g. Flood Prevention and Runoff Management — Urban	Total	$2,240,000	$2,770,000
	Net	1,580,000	1,950,000
Agricultural Land	Total	3,763,500 acres	3,763,500 acres
	Net	740,000	740,000
h. Summary of Acre-feet Required	Total	1,254,577 A.F.	2,252,625 A.F.
	Net	1,143,190	2,141,238
2. **Current Developed Supply** (from Chapter VIII)			
a. Reservoir Storage by Function — A.F.			
(1) Municipal and Domestic			72,188
(2) Stockwater			9,726
(3) Irrigation			———
(4) Industrial and Mining			3,762
(5) Recreation (13,148 surface acres)			69,277
(6) Wetland Areas (#)			55,000
(7) Quality Control			———
(8) Flood Control			143,833
b. Programmed Projects — A. F.			
(1) Municipal and Domestic			1,603
(2) Recreation (628 surface acres)			8,310
(3) Flood Control			19,455
c. Groundwater — A. F.			
(1) Developed to Date			24,100
(2) Potential Aquifers — est. yield 20% (11,844,800 Storage)			2,368,960

*Indicates basin wide surplus and does not preclude any local shortages.

3. **Developments Proposed to Meet 1980 and 2000 Requirements — Table 5**

a. Municipal and Domestic

In order to assure a sustained yield of water the planning criteria for municipal use is based on a factor of three times the annual requirement. Using this factor the net requirement for 1980 is 94,545 acre-feet less the developed supply of 82,663 A.F. or 11,882 A.F. Programmed storage projects will supply about 1,000 A.F. of this requirement and future anticipated multi-purpose projects will provide more than the balance of water needed by 1980. The 5,000 A.F. projected for aquifer development for municipal use will take care of the needs where storage facilities will not supply the needs.

Using the same factor for the year 2000, the requirements for municipal and domestic use will be 82,663 A.F. or 70,761 more than in 1980. A surplus of proposed development in 1980 of 17,231 reduces the amount of requirement in the year 2000 to 54,560 acre-feet. This development is shown in Table 5 as 24,760 acre-feet from multi-purpose reservoirs, 14,770 from multi-purpose aquifers and 15,000 from single purpose aquifers.

b. Livestock

Using a planning criteria of 1.5 for livestock use, the 1980 requirement is for 10,410 acre-feet. These requirements can be met with the development of 3,000 and 4,000 acre-feet respectively from multi-purpose and single-purpose aquifers and 3,000 acre-feet developed by the construction of small dams and dugouts.

The requirements for the year 2000 of 8,251 acre-feet can be similarly met with the development of 3,000 acre-feet from single purpose aquifers and 5,251 acre-feet from small dam and dugout developments.

c. Irrigation

Of the 930,373 acre-feet of water needed by 1980 and the 1,870,000 acre-feet needed by 2000 for irrigation, the Garrison Diversion Unit will supply an estimated 183,000 acre-feet of water by 1980 and another 640,000 by 2000. Groundwater development should be 500,000 acre-feet by 1980 and another 530,000 by 2000 in order to meet the requirements. It may be possible to obtain more of the Garrison Diversion water for irrigation at a future date. The proposed Pembilier Dam will furnish an estimated 17,000 acre-feet of irrigation water by 1980.

d. Industrial and Mining

The requirements for this use in the Red River Basin will be mostly for industrial purposes rather than mining. For this basin a planning criteria factor of 1.5 is used rather than three as in the other basins. It is anticipated that this will be enough increase over projected requirements to assure a sustained yield of water. Using this factor the net requirement for 1980 is 51,978 acre-feet and another 31,555 by 2000. The 1980 requirement can be met by utilizing the 500 acre-feet of programmed development; 45,000 acre-feet from proposed multi-purpose reservoirs; 832 from the Holly Harwood Dam and single purpose aquifer development in the amount of 2,646 acre-feet The Holly Harwood Dam is proposed to be built for use by a sugar beet processing plant. The proposed multi-purpose reservoirs listed in Table 5 are in some stage of planning. The proposed supply of water from aquifers can supply such plants as sugar corn processing, etc.

e. Outdoor Recreation

In addition to the requirements for effective surface acres needed for recreation an almost like amount of recreational facilities is needed. The facilities should include sanitary facilities, picnic grounds, camping areas, wells, boat docks, swimming beaches, bath houses, parking areas and general landscaping. The 1980 requirements of facilities for 42,420 acres and 38,932 acres of recreation water may be short of development by that time and the balance will have to be provided in the 1980-2000 period, or the needs will have to be met at some other location. The recreation and facilities acreage shown in Table 5 closely parallel each other except for the Garrison Diversion Unit where the facility development is expected to be less than the surface acres of water. Surface water development should be 13,700 acres from multi-purpose storage, 15,000 from Garrison Diversion and 3,000 from recreation storage. Facilities would be met by 8,500 acres at Garrison Diversion storage, 15,925 at multi-purpose storage and 3,000 at single purpose storage.

For 2000 the requirements for both recreation and recreation facilities will amount to 54,000 acres each. These requirements can be met by the development of perhaps six multi-purpose reservoirs furnishing 15,000 acres of surface water and 10 recreation reservoirs for another 20,000 acres. It is anticipated that Garrison Diversion will supply an additional 3,000 acres for recreation by 2000 and watershed management will develop an estimated 1,000 acres. The balance of effective surface acres in the amount of 15,000 can be provided by additional flood control reservoirs of which three more may be needed. Developments for facilities to go with the water-related recreation areas will be required at each project.

The wetlands requirements using two acres of water per average area multiplied by the number of areas shows need for 18,000 acres by 1980 and another 34,000 by 2000. This is based on raising five ducks per area. It is recommended that these acreages be in small areas so that as many ducks as possible may be propagated for hunting needs and for export. Small dams and dugouts will provide many of these areas as well as wetlands developed from some of the Garrison Diversion waters.

f. Quality Control

It appears that the 1980 requirements of 231,700 acre-feet needed for quality control will not be entirely furnished by the anticipated developments. The 1980 requirements can be partially met by using 20,00 acre-feet of the excess or return flow from Garrison Diversion and approximately 155,000 acre-feet from proposed multi-purpose reservoirs. The balance can be made up by 2000 using an additional 13,000 acre-feet from Garrison Diversion, 10,000 from future proposed multi-purpose reservoirs, 23,000 from multi-purpose and single purpose aquifers and by using 11,000 acre-feet from additional flood control reservoirs.

g. Flood Prevention and Runoff Management

Damages in both urban and rural areas are anticipated to be quite extensive in the 1969-1980 period and then taper off as more of the flood control structures are functioning. The requirements show a need by 1980 for urban damage protection of $1,580,000 annually and protection of 740,000 acres of farm land. By 2000 the farm lands will remain protected if the requirement is fully met by 1980; however, it is anticipated that there will be some carryover requirement into the 1981-2000 period.

The major flood protection works by 1980 can be accomplished by the construction of the proposed projects listed in Table 5 which include the Pembilier Reservoir, a Sheyenne River Reservoir, a Goose River Reservoir and a Park River Reservoir. Other contributing protection would come from legal drains, watershed management, snagging and clearing and other flood prevention projects.

Additional urban protection by 2000 could be met by more multi-purpose reservoirs, recreation reservoirs, legal drains, snagging and clearing as shown in Table 5 as well as major flood control reservoirs and flood prevention projects where channel work is needed. Urban needs which will be met by these projects are $450,000 annual damage prevention which includes carryover from 1980 requirements. Rural flood control protection for 243,000 acres of land could be also provided by these projects to complete the 740,000 acre protection requirement.

4. **Costs**

Estimated first costs, based on current prices, for proposed developments during the period 1969-1980 are **$316,600,000.** Anticipated development costs for the 1981-2000 time period are **$354,500,000.**

These reconnaissance type estimates include only costs for land and capital improvements to control or make available the resource. Additional costs would be incurred for such items as distribution facilities, treatment facilities, interest, and the like to apply the water to beneficial use.

5. **Resources**

a. The land needs by 1980 are estimated to be 123,935 acres and by 2000 the needs are estimated at another 178,000 acres. This estimate is based on land and easement requirements to construct the various types of reservoirs and control works.

b. Storage facilities required for surface waters will be 1,225,105 acre-feet by 1980. This figure includes about 500,000 acre-feet of flood storage to be released after the runoff season. Proposed sites may vary and reservoir regulation plans could somewhat alter the storage requirements. By 2000 additional storage is estimated to be required in the amount of 1,032,000 A.F. of which at least 250,000 A.F. would be temporary flood storage.

c. Surface area needed for the above storage will vary from an average of three feet for wetlands to over 10 feet for other types of water impoundments. Estimates are 88,719 acres by 1980 and another 128,000 acres by 2000.

d. Groundwater withdrawals are estimated at 517,646 A.F. by 1980 and an additional 596,377 by 2000. Most groundwater development is needed for irrigation.

e. Streamflow depletions or depletions of the annual yield of rivers in the basin are estimated to be 261,653 acre-feet by 1980 and an additional 405,640 acre-feet by 2000. These figures include an estimated 5% of the stream flow to be used for groundwater or aquifer recharge. The average annual yield of the Red River Basin is in excess of 2,000,000 acre-feet of water. The Garrison Diversion Unit will provide return flows to the basin streams at an estimated amount of 70,000 acre-feet annually by 1980 and approximately double that amount by 2000.

TABLE 5.—RED RIVER BASIN

DEVELOPMENTS		Land (Acres)	Storage A. F.	Surface Acres	G.W. Withdrawal A. F.	Streamflow Effect-A. F. + or −
		RESOURCES				
Programmed Projects by 1980						
Garrison Diversion		30,000	420,000	25,500	———	———
Multi-Purpose Reservoir	(3)	1,305	13,804	870	———	— 4,842
Recreation Reservoir	(1)	204	1,305	102	———	— 306
Municipal Reservoir	(3)	112	375	75	———	— 600
Watershed Management		1,214	8,789	816	———	— 1,757
Future Multi-Purpose Projects						
Pembilier Reservoir 1980		15,500	130,000	10,000	———	— 37,000
Sheyenne River Reservoir 1980		26,000	412,000	14,300	———	— 56,500
Park River Reservoir 1980		10,000	60,000	6,000	———	— 49,000
Goose River Reservoir 1980		4,000	20,000	2,000	———	— 13,600
Garrison Diversion 2000		10,000	50,000	5,000	———	— 15,000
Reservoirs 2000	(6)	40,000	250,000	20,000	———	— 115,315
Aquifer Development 1980		———	———	———	11,000	— 550
2000		———	———	———	29,890	— 2,000
Watershed Management 1980		10,500	70,000	7,000	———	— 3,000
2000		11,000	75,000	6,000	———	— 20,000
Future Single Purpose Projects						
Holly Harwood Reservoir 1980		100	832	56	———	— 168
Wahpeton Flood Protection 1980		———	———	———	———	———
Grand Forks Flood Protection 1980		———	———	———	———	———
Recreation Reservoirs 1980	(5)	6,000	30,000	3,000	———	— 9,000
2000	(10)	40,000	225,000	20,000	———	— 60,000
Aquifer Development 1980		———	———	———	506,646	— 25,330
2000		———	———	———	566,487	— 28,325

FUNCTIONAL REQUIREMENTS SERVED ANNUALLY

Municipal & Domestic (A. F.)	Livestock (A. F.)	Irrigation (A. F.)	Industrial (A. F.)	Recreation & Facilities Acres	Quality A. F.	Flood Prevention $ & Acres
—	—	183,000	—	15,000 R.	20,000	—
—	—	—	—	8,500 F.	—	—
728	—	—	500	625 R.	—	6,000 A.
—	—	—	—	625 F.	—	—
				100 R.	—	—
—	—	—	—	100 F.	—	—
—	—	—	—	—	—	—
375	—	—	—	—	—	14,000 A.
3,000	—	17,000	—	2,000 R.	23,000	$ 150,000
—	—	—	—	4,000 F.	—	20,000 A.
10,000	—	—	30,000	5,500 R.	128,000	$ 400,000
—	—	—	—	6,000 F.	—	100,000 A.
4,000	—	—	10,000	3,000 R.	7,000	$ 60,000
—	—	—	—	3,000 F.	—	23,000 A.
5,000	—	—	5,000	1,400 R.	1,800	12,000 A.
—	—	—	—	1,400 F.	—	—
—	—	640,000	—	3,000 R.	13,000	—
—	—	—	—	3,000 F.	—	—
24,760	—	—	11,355	15,000 R.	10,000	$ 50,000
—	—	—	—	15,000 F.	—	20,000 A.
5,000	3,000	—	3,000	—	—	—
14,800	—	—	10,000	—	15,000	—
—	—	—	—	1,800 R.	—	100,000 A.
—	—	—	—	1,800 F.	—	—
—	—	—	—	1,000 R.	—	—
—	—	—	—	1,000 F.	—	73,000 A.
—	—	—	832	—	—	—
—	—	—	—	—	—	$ 700,000
—	—	—	—	—	—	$ 90,000
—	—	—	—	3,000 R.	—	—
—	—	—	—	3,000 F.	—	—
—	—	—	—	20,000 R.	—	10,000 A.
—	—	—	—	20,000 F.	—	—
—	4,000	500,000	2,646	—	—	—
15,000	3,000	530,000	10,000	—	8,000	—

TABLE 5.—RED RIVER BASIN (Continued)

DEVELOPMENTS			RESOURCES Land (Acres)	Storage A. F.	Surface Acres	G.W. Withdrawal A. F.	Streamflow Effect-A. F. + or —
Legal Drains							
	1980		————	————	————	————	————
	2000		————	————	————	————	————
Small Dams							
	1980		1,000	4,000	1,000	————	— 6,000
	2000		3,000	10,000	3,000	————	— 9,000
Snagging and Clearing							
	1980		————	————	————	————	————
	2000		————	————	————	————	————
Flood Control Reservoirs							
	(2000)	(3)	40,000	320,000	40,000	————	— 54,000
			————	————	————	————	————
Flood Prevention Projects (channel work)	2000		————	————	————	————	————
Wetlands Areas							
(9,000)	1980		18,000	54,000	18,000	————	— 54,000
(17,000)	2000		34,000	102,000	34,000	————	— 102,000
TOTALS — 1980			123,935	1,225,105	88,719	517,646	— 261,653
			————	————	————	————	————
			————	————	————	————	————
TOTALS — 2000			178,000	1,032,000	128,000	596,377	— 405,640
			————	————	————	————	————
			————	————	————	————	————

R. — Recreation Water Surface Areas
F. — Public Use Recreation Facilities
W. — Wetlands
A. — Acres
A.F. — Acre-Feet

FUNCTIONAL REQUIREMENTS SERVED ANNUALLY						
Municipal & Domestic (A. F.)	Livestock (A. F.)	Irrigation (A. F.)	Industrial (A. F.)	Recreation & Facilities Acres	Quality A. F.	Flood Prevention $ & Acres
------	------	------	------	------	------	116,000 A.
------	------	------	------	------	------	60,000 A.
------	3,410	------	------	------	------	------
------	5,251	------	------	------	------	------
------	------	------	------	------	------	16,000 A.
------	------	------	------	------	------	10,000 A.
------	------	------	------	15,000 R.	11,000	$ 250,000
------	------	------	------	15,000 F.	------	70,000 A.
------	------	------	------	------	------	$ 150,000
------	------	------	------	18,000 W.	------	------
------	------	------	------	34,000 W.	------	------
28,103	10,410	700,000	51,978	18,000 W.	179,800	$1,400,000
------	------	------	------	32,425 R.	------	407,000 A.
------	------	------	------	26,425 F.	------	------
54,560	8,251	1,170,000	31,355	34,000 W.	57,000	$ 450,000
------	------	------	------	54,000 R.	------	243,000 A.
------	------	------	------	54,000 F.	------	------

B. Nonstructural Items

The following items require additional consideration and further study in most of the State's river basins:

1. U. S. Geological Survey topographic mapping needs
2. Zoning requirements (including flood plain management)
3. Reservoir operation modifications
4. Monitoring water quality
5. Lake eutrophication
6. Interstate compacts
7. Water permits granted or available
8. Timing and financing proposed developments
9. Economic values and impacts of developments
10. Research
11. Groundwater surveys

C. Summary

1. Total resources required to provide the proposed developments for entire State are shown by time periods as follows:

	1969-1980	1981-2000
a. Land (acres)	304,350	440,200
b. Water Storage (acre-feet)	2,631,450	2,551,500
c. Water Surface (acres)	232,957	340,500
d. Groundwater Withdrawals (acre-feet)	914,854	1,472,365
e. Streamflow Effect (acre-feet)	—1,958,280	—3,759,530

2. Functional requirements to be served annually by the proposed developments for the entire State are shown by time periods as follows:

	1969-1980	1981-2000
a. Municipal and Domestic Use (acre-feet)	117,326	193,080
b. Livestock Use (acre-feet)	57,752	41,666
c. Irrigation Use (acre-feet)	1,566,460	3,370,668
d. Industrial and Mining Use (acre-feet)	301,406	542,905
e. Recreation — Surface Acres	54,656	107,700
— Facilities for Acres	71,156	179,100
— Wetlands (acres)	104,000	192,000
f. Quality Control Use (acre-feet)	350,700	301,000
g. Flood Prevention		
Urban ($ damages prevented)	3,290,000	1,125,000
Agricultural Lands (acres protected)	829,000	705,000
Bank Stabilization		
($ damages prevented)	1,000,000	————
(acres protected)	37,000	20,000

3. Costs were determined by reconnaissance type estimates for the broad categories of development. They include estimated Federal, local and State governments, quasi-public, and private investment required to control or make available the resource for beneficial use. By river basin and time period they are:

Basin	1969-1980	1981-2000
Missouri River	$99,800,000	$161,200,000
James River	31,500,000	50,400,000
Souris River	66,000,000	86,400,000
Devils Lake	11,100,000	22,500,000
Red River	316,600,000	354,500,000
Totals	$525,000,000	$675,000,000

Based on local and State government per capita tax projections for water resources development, the cost allocations are estimated as follows:

Basin	1969-1980	1981-2000
Local and State Governments	$ 81,400,000	$178,000,000
Federal Government	391,100,000	429,500,000
Quasi-public and Private	52,500,000	67,500,000
Totals	$525,000,000	$675,000,000

As cost allocations are modified by the Congress and Legislature and new financing techniques are developed, the estimated allocations could be varied substantially. These allocations are intended as a broad guide to assist in the budgeting process over the long term.

Chapter Eleven

Responsibilities and Revenue Sources

CHAPTER XI

RESPONSIBILITIES AND REVENUE SOURCES

TABLE OF CONTENTS

A. Introduction

The "Responsibilities and Revenue Sources" Section of the State Water Plan is intended to:

1. Examine revenue sources from all types of governmental entities and catalogue these sources;
2. Delineate responsibilities of agencies for various functions relating to water resources;
3. Summarize the related governmental programs;
4. Present recommendations for revenue procurement and utilization for water resources development; and
5. Relate the available fiscal resources to the required natural resources developments projected to the year 2000.

B. Scope

1. Revenue Sources from and Responsibilities of governmental entities directly involved in some function related to water resources only will be considered in this Section. Obviously, the private sector has a responsibility in certain areas for development as well as providing the monetary resources directly.
2. Government, presumably, is charged with performing functions for the public which services may best be provided through this collective arrangement. The "general health and welfare of the people" concept is applicable to government's activities in water resources management since the very nature of the resource precludes avoidance of this concept.
3. Within the maze of programs, policies, and procedures which have and are being proliferated, it appears preferable to merely "highlight" the current and projected responsibility and revenue data on a comprehensive basis.

C. Responsibilities — Agency Delineation

The responsibilities for water resources management are categorized into five major functions commensurate with the program budget of the principal State Agency concerned with water resources — the State Water Commission.

1. Administrative and Legal — Includes providing general administrative support, accounting and fiscal services, and legal counsel as well as administering and enforcing applicable laws, maintaining files, publishing data and reports, and representing the entity in matters relating to intrastate, interstate, and international waters.
2. Comprehensive Planning — Includes developing, maintaining and up-dating comprehensive water resources plans for major basins and sub-basins by providing and interpreting basic data concerning economics, hydrology, land use, water requirements, projected needs for water utilization and control, financing and related statistics to meet future water management needs. Also, participating in comprehensive planning efforts being directed through River Basin Commissions and Coordinating Committees.
3. Investigations, Research, Surveys and Design — Includes the application of technical knowledge required in the development of specific projects and programs for water resources utilization and management. Specifically, this function includes
   - (a) surveying areas for specific projects and preparing topographic maps;
   - (b) obtaining and assembling data for land and/or easement acquisition;
   - (c) accumulating and analyzing soils data for foundations and borrow areas;
   - (d) gaging streams and measuring lakes;
   - (e) preparing plans and specifications for all types of facilities;
   - (f) conducting research, experimental studies, and demonstrations; and

(g) cataloguing the data on ground and surface waters.

4. Construction — Includes provision of physical facilities for the utilization and control of the state's water resources for all beneficial purposes. Such facilities include:
   (a) Dams and related appurtenances to create impoundments;
   (b) Outdoor recreation public use areas;
   (c) Irrigation canals, dikes, land leveling, pumps, and related works for application of water to the lands;
   (d) Works for flood prevention and control, erosion abatement, drainage, and stream channel changes; and
   (e) Pilot wells for ground-water utilization and for gathering hydrologic data.

5. Operation and Maintenance — Includes the operation, maintenance, or modification of structures or facilities required for the utilization and control of water resources.

   The following table indicates the numerous local, state and Federal entities involved in some function related to water resources along with their principal area of responsibility; eg., Pollution abatement, Irrigation, Flood Prevention and Control, Fish and Wildlife, Outdoor Recreation, etc.

D. **Revenue Sources and Estimates**

1. State Government

   a. The State's 1967-69 Biennial Budget is $350,989,875 for all purposes. The respective state government functions, their budgets and percentages of the total Budget are as follows:

Function	1967-69 Budget	Percent of Total
General Government	$ 10,204,046	2.9
Education	112,393,368	32.2
Health & Welfare	73,079,679	20.9
Regulatory Agencies	9,063,106	2.5
Public Safety & Security	6,690,471	1.9
Agriculture & Industrial Development	15,694,015	4.4
Recreation & Natural Resources	6,737,356	1.9
Highways	116,497,815	33.2
Miscellaneous	630,000	.1
	$350,989,875*	100%

*145,638,670 General Fund — $205,351,205 Special Funds

   b. Based on the various state agencies' functions related to water resources, it is estimated that for the 1967-69 biennium, $3,600,000 or 1% of the total State Budget, are directed toward the water program.

   c. The principal revenue sources for the State Budget are Sales, Income and Excise Taxes, Special User Fees, and Federal grants. Property taxes are not currently levied by the State; however, the State Board of Equalization may levy up to four (4) mills on the taxable valuation. The following schedule shows the "1966 Taxable Valuation of Property in North Dakota" by river basin-economic region:

River Basin — Region	1966 Taxable Valuation
Missouri	$218,708,354
James	74,721,839
Souris	101,912,763
Devils Lake	46,620,895
Red	251,074,708
State Total	$693,038,559

   A four-mill levy, currently, would yield approximately 2.7 million dollars annually to the State.

   d. North Dakotans pay an average annual per capita tax of $6.80 for state and local government water resources development functions or 1.4% of the total annual per capita tax. Using this basis and 1980 projected per capita taxes of $1,070 and 2000 projected per capita taxes of $1,610 the water resources per capita tax annually is projected to be $14.98 in 1980 and $22.54 in 2000.

   Based on these per capita figures for State and local government revenue, the trend indicates water resources function annual budgets of:

   $ 4.4 million — 1968
   10.4 million — 1980
   25.2 million — 2000

2. County Governments

   a. The County Boards of Commissioners are charged with responsibilities concerning all water resource management functions and are authorized by North Dakota law to cooperate with Federal, State and other local entities in these functions.

   b. Revenues obtained through the County General fund mill levy (maximum 18 mills) may be utilized along with grants, special assessments, and contributions. In addition, counties receiving oil and

	1 — Adm.	2 — Comp. Plan	3 — Inv.	4 — Const.	5 — O & M	Principal Area of Responsibility
State Agencies						
Attorney General	X					Law
Economic Development Comm.		X				Industrial
Game and Fish Department		X	X	X	X	Fish and Wildlife
State Geologist		X	X			Groundwater
Health Department	X	X	X			Pollution Abatement
Highway Department		X	X	X		Drainage and Roadways
Historical Society		X				Archeological
Laboratories Department			X			Chemical Quality
Natural Resources Council	X	X				Coordination
Outdoor Recreation Agency	X	X				Outdoor Recreation
Park Service		X				Outdoor Recreation
Soil Conservation Service		X	X		X	Flood Prevention
State Water Commission	X	X	X	X	X	All
N. Dak. State University		X	X			Research
University of North Dakota		X	X			Research
Adjutant General (Civil Defense)		X		X		Defense
State School of Forestry		X	X			Forests
County Agencies						
Board of Commissioners	X	X	X	X	X	All
Special Districts						
Water Management Districts	X	X	X	X	X	All
Park Districts			X	X	X	Outdoor Recreation
Irrigation Districts			X	X	X	Irrigation
Drainage Districts			X	X	X	Drainage
Garrison Diversion CD	X	X	X	X	X	Irrigation
Soil Conservation Districts			X	X	X	Flood Prevention
Municipalities						
Cities	X	X	X	X	X	Municipal and Industrial Water, Flood Prevention
Federal Agencies						
Agriculture:						
Soil Conservation Service		X	X	X	X	Flood Prevention
Farmers Home Administration	X					Financing
Forest Service		X				Forests
Economic Res. Service		X				Agricultural Economics
Commerce:						
Rural Areas Development		X				Financing
Economic Development Adm.		X				Financing
Weather Bureau (ESSA)		X	X			Weather
Office of Business Economics		X				Economic Projections
Transportation:						
Bureau of Public Roads			X	X	X	Drainage and Roadways

	1 – Adm.	2 – Comp. Plan	3 – Inv.	4 – Const.	5 – O & M	Principal Area of Responsibility
Defense:						
Corps of Engineers	X	X	X	X	X	Flood Control, Municipal & Industrial Water
Health, Education & Welfare:						
Public Health		X	X			Pollution Abatement
Housing & Urban Development:						
Urban Renewal		X	X	X		Financing
Community Facilities Ad.				X		Financing
Interior:						
Bureau of Outdoor Recreation		X				Outdoor Recreation
Bureau of Indian Affairs		X	X	X	X	Indian Reservations
Bureau of Land Management		X	X			Outdoor Recreation
National Parks		X	X	X	X	Outdoor Recreation
Bureau of Reclamation		X	X	X	X	Irrigation, Municipal and Industrial Water
Bureau of Sport Fisheries and Wildlife		X	X	X	X	Fish and Wildlife
Federal Water Pollution Control Board		X	X			Pollution Abatement
U. S. Geological Survey		X	X			Mapping, Gaging, Ground-water Inventory
Bureau of Mines		X				Minerals
Bureau of Commercial Fisheries		X	X			Commercial Fisheries
Office of Saline Water		X	X			Saline Research
Office of Water Resources Research		X	X			Research
Water Resources Council Basin Commission	X	X				Planning
Souris-Red-Rainy River Basins Commission		X				Coordination - Planning

gas production revenues (currently 13) may expend 40% of such revenues for water resources functions by transferring, by resolution, from the county road fund (57-51-15 NDCC).

3. Special Districts
   a. Water Management Districts
      (1) These Districts have broad responsibilities in all water resources functions. Managed by electors appointed by the county boards of commissioners, the districts obtain revenue through special assessments and ad valorem property tax levies limited to three (3) mills.
   b. Irrigation Districts
      (1) Organized principally for applying water to irrigable lands, these districts are managed by a Board of Directors elected by the landowners and obtain revenues from special assessments levied against the irrigable lands.
      (2) Flood irrigation district directors are appointed by the county governing board with costs met also through special assessment levies.
   c. Drainage Districts
      (1) The Board of Drain Commissioners is appointed by the county governing body and has the responsibility of establishing and maintaining drainage works as may be required. Administrative expenses are paid from revenues collected pursuant to a maximum two-tenths (.2) mill property tax levy. Special assessments are levied against benefited lands to pay drain construction costs. The levy for cleaning out and repairing a drain may not exceed fifty (50) cents per acre on any agricultural lands in a drainage district.
   d. Garrison Diversion Conservancy District
      (1) The District, operated by elected directors, presently covers a 25-county area in eastern and central North Dakota. Its primary responsibility is the "Garrison Diversion Unit," a Bureau of Reclamation project being developed for irrigation, recreation, municipal, industrial, and fish and wildlife water use.
      (2) A maximum one (1) mill levy is authorized for the District's operation and for meeting obligations in connection with construction, operation and maintenance of the Garrison Diversion Unit in cooperation with the Bureau of Reclamation and local irrigation districts.
   e. Soil Conservation Districts
      (1) At present all of the area in North Dakota is included in a soil conservation district whose activities are financed by contributions and charges made for use of special District equipment. Their primary responsibility is to carry out a soil and water conservation program on cooperating farms through participation in State Soil Conservation Committee and U. S. Department of Agriculture programs.
   f. Park Districts
      (1) County park districts are operated by a Board appointed by the county commissioners which Board includes the county commissioners. Their principal function related to resources is to provide, operate and maintain water-based outdoor recreation areas and facilities.
      (2) These Boards may levy one-half (.50) mill and cities may be excluded from such levy unless the governing board consents to the levy. By an election, the levy may be increased.

4. Municipalities
   a. Cities have responsibilities in all functions related to water resources; principally, provision of municipal and industrial water supplies. Revenues are obtained from general levies and user fees. Warrant and bond issues are frequently used as a method of financing capital improvements.

5. Federal Agencies
   a. The principal Federal agencies, their functional responsibilities and water management concern are outlined in the table in Section C of this report.
   b. Financing of Federal Agency activities is generally on a specific project or program basis with appropriations being made annually by the Congress to the respective agencies based on recommendations of the President. Matching grants are provided the State and local government for various programs involving water resources. (See "Catalog of Federal Aids to State and Local Governments" January 10, 1966, U. S. Congress.)

E. Recommendations

1. Provide for a "future water projects reserve fund" in the State to meet the anticipated nonfederal costs of extensive water resource development projects envisioned.

2. One method of providing revenue for such a fund would be to create a "capital improvements" fund for all major state construction and levy up to four (4) mills annually for the "capital improvements" fund. From this fund, the Legislature could allocate certain amounts for the "future water projects reserve fund" or for specific projects.

3. Federal legislation should be modified to provide "block grants" to the states for the various projects and programs related to water resources development and allow the States to apportion the funds as deemed necessary.

4. Upon completing a proposed plan of development for the State, the resources of all agencies and entities involved in water resources functions should be coordinated sufficiently to provide the outlined requirements through conscientious utilization of both natural and financial resources. The principal objective or policy to be promulgated in these efforts is that **"the well-being of all of the people of the state shall be the overriding determinant in considering the best use, or combination of uses, of water and related land resources."**

F. Summary

1. Responsibilities for water resources management are categorized into five major functions; namely,
   a. Administrative and Legal
   b. Comprehensive Planning
   c. Investigations, Research, Surveys and Design
   d. Construction
   e. Operation and Maintenance

2. In addition to regular city, township and county governments, six (6) types of special districts may be created for specific purposes and provision is made in the law for these local government entities to provide revenues through mill levies, special assessments, user fees, bond issues, and the like.

3. Based on the preceding section, "X. — Developments to Meet Water Requirements to 2000," the annual costs would average $40 million.

Chapter Twelve

Recommendations

CHAPTER XII

RECOMMENDATIONS

Compiled herein are recommendations proposed to alleviate the varied water resources related problems in North Dakota. The problems are discussed in Chapter VI of this report giving a statement of the problem, its history and suggested alternative solutions.

I. FEDERAL:

A. The United States Congress should remove the apparent cloud upon the State's unused waters from the lakes, rivers and streams in North Dakota by disclaiming any interest thereto, except as the same applies to the right to appropriate and beneficially utilize water from these sources.

B. The current Soil Conservation Service technical assistance procedure in wetlands drainage projects should be modified so completed project plans rather than mitigation conditions may be presented to the project sponsor and affected landowners.

C. Federal reclamation laws should be modified to at least permit the irrigation of 640 acres of land by individual landowners on Federal irrigation projects. Federal acreage limitations should be reviewed and reappraised in the light of differences in soils, climate, types of farming, and crop production existing throughout the 17 western states. The so-called Engle Formula may offer a solution to this long-time inequity.

D. Charges should not be made for water withdrawn from Corps of Engineers' reservoirs for agricultural purposes.

II. LOCAL AND STATE AGENCIES:

A. To facilitate and accelerate the orderly development of North Dakota's water resources, water management districts should be established over the entire State.

B. Any lack of coordination between the State agencies and local legal entities can be resolved by conscientious efforts on the part of all concerned to adhere to the policy "That the well-being of all of the people of the State shall be the over-riding determinant in considering the best use, or combination of uses, of water and related land resources."

C. The initiation by the Federal Government of a grants-in-aid program — similar to fish and wildlife, recreation and irrigation projects — is needed to satisfy the growing need for water storage reservoirs for municipal purposes.

D. The installation of pumps at the Buford-Trenton Irrigation Projects is necessary to avoid losses due to aggradation and supplement the diverted water now pumped from the Missouri River.

E. Timely reseeding or resodding of excavated areas, coupled with the necessary chemical measures, could alleviate any noxious weed problem.

F. Mosquito incubation at storage reservoirs can be greatly reduced by water level management practices and controlled chemical applications.

G. Communities should take whatever steps necessary to have their water resources surveyed and studied. Comprehensive water resources planning efforts should be focused upon the anticipated requirements for heavy water using industries.

III. LEGISLATION:

A. To alleviate the financial limitations placed on project oriented agencies by the State's present budgetary policies:

1. Budgets should be submitted and appropriations allocated on a twofold basis — one for the strictly administrative functions and one for the project and program functions of the agency. The administrative budget could be on the basis of "object" items and the projects and programs budget could be on the basis of broad categories such as (for the State Water Commission) Comprehensive Planning, Engineering Investigations, Design and Research, Construction, and Operation and Maintenance.
2. Carry-over funds for projects and programs should be allowed since such activities are subject to the vagaries of weather and numerous other unforeseen happenings which preclude their completion in a specific fiscal period from the start of planning.
3. Project participation payments should be credited to the fund from which the project costs are paid for more efficient administration.
4. Since relatively large capital expenditures are required for water resource development projects, a procedure should be established for the accumulation of funds each biennium to create a reserve for major capital improvements. Such a proposal was submitted in HB 724, 40th Legislative Assembly, but was not enacted into law.

B. Legislation needs to be enacted or administrative rules and regulations adopted to prevent the overdraft of ground-water aquifers and provide for their proper management.

C. Legislation should be enacted requiring original field notes on the original surveys of North Dakota's lands to be on file in each county office to make them readily available to county engineers and surveyors for their use in conducting surveys.

D. Legislation is needed to institute well drilling standards for the State to improve construction of water wells. Under this legislation only those well drillers meeting certain qualifications should be licensed. (North Dakota had the first well drillers association in the United States and is probably the only State without licensing.)

IV. COORDINATION, OPERATION AND MAINTENANCE:

A. A three year post-construction period should be provided by governmental constructing agencies during which operation and maintenance costs growing out of that construction would be cared for by the constructing agency. After the three year post-construction period, the project would be turned over to the project sponsors to assume subsequent operation and maintenance costs.

B. All agencies and individuals, including voluntary organizations and associations, should remain aware of their responsibilities for coordinating their water-released planning and construction activities with the North Dakota State Water Commission to insure a well coordinated water resources development program within the State.

V. WATER MANAGEMENT DISTRICTS:

A. The formation of "hydrologic basin commissions" composed of one or more members from each of the water management districts having a land area within a given hydrologic unit. The function of this commission would be to coordinate the activities of the various districts which are directed to the solving of water related problems basin-wide in scope.

B. Flood plain studies need to be initiated in each of the five major river basins to delineate or recommend zones along the State's streams and rivers to which specific regulations need to be applied.

VI. TOPOGRAPHIC MAPPING:

A. There is a growing need for topographic mapping on the basis of mean sea level datum to prevent unnecessary duplication of survey activities by various agencies performing topographic mapping.

B. A topographic mapping program should be undertaken for the entire State using five foot contours on land possessing elevation differences of less than 100 feet per square mile and on 10 foot intervals for those areas having a greater change in elevation.

VII. POLLUTION:

A. The following steps are necessary in order to prevent the continued pollution of North Dakota's streams and lakes:

1. Prohibiting untreated domestic sewage and industrial wastes to be discharged into waters.
2. Taking further steps to prevent the continued sedimentation of North Dakota's streams and lakes. Continued research is needed in this respect.
3. Continuing farming methods and conservation practices to avoid topsoil erosion by wind and water.
4. Preventing stream bank erosion by the construction of bank rectification works.
5. Accelerating the shelter belt program.

B. Ground-water pollution from irrigation projects can be reduced materially by intensive studies on the effects of irrigation through the use of pilot projects. The canal seepage problem can be resolved by the use of lined canals and through the use of pipelines wherever possible. Another improvement could be made by installing a subsurface drainage system where soils indicate that pollution may become a problem.

VIII. GROUND WATER

A. The present method of issuing water rights on a "forever" basis needs to be reviewed and modified in order to bring about the full development of ground-water resources. In some areas it may become desirable for landowners to cooperate in establishing a rotation system of pumping if withdrawal of water by one landowner is adversely affecting withdrawals made by others.

B. To properly manage and utilize ground-water resources, more information is needed in regard to the location, size and chemical quality of ground-water aquifers. The following steps are suggested for gathering this and other pertinent data relevant to the State's ground-water resources:

1. Carry out detailed investigations to determine the quantity and quality of the water in the aquifers.
2. Determine discharge from the aquifer by natural means and by wells as accurately as possible.

3. Develop a network of observation wells to provide a monitoring system indicating water level fluctuations in the various aquifers.
4. Construct analog models of aquifers where management problems arise.
5. Carry on basic research for developing methods and techniques for artificially recharging buried glacial drift aquifers.
6. Continue the present cooperative groundwater investigation program on a countywide basis in order to identify aquifers with regard to location, water quality, and estimates as to potential yields of individual wells.

IX. WATERSHEDS:

A. A water management plan for individual watersheds should be provided to:
   1. Protect landowners from random sheetwater flooding.
   2. Stabilize water levels for existing wetland areas.
   3. Provide water for other uses, such as municipal, stockwater, irrigation, industrial, recreation and quality control.
   4. Protect adjacent lands from flooding which might occur due to improvements for these purposes.

B. Various measures and practices which may be instituted to control sedimentation include:
   1. Soil conservation and land management
   2. Proper highway and railroad construction
   3. Desilting works
   4. Channel and revetment works
   5. Bank stabilization
   6. Special dam construction
   7. Improved reservoir operation
   8. Snagging and clearing of stream channels
   9. Dredging operations
   10. Channel changes

X. BANK STABILIZATION:

A. The Federal Government must recognize that the Missouri River between the Oahe Reservoir and Garrison Dam is no longer a free-flowing river if the problem of bank stabilization along this stretch of the Missouri River is to be solved.

B. Congress should enact legislation authorizing the U. S. Army Corps of Engineers to proceed immediately with the installation and future maintenance of additional protective works required to stabilize the Missouri River banks below Garrison Dam.

C. Until such time as the banks have been stabilized the main stem reservoir operations should be revised to stabilize Garrison Reservoir releases. Reducing excessively high wintertime releases under the ice would minimize bank erosion.

D. In the Yellowstone River subbasin consideration must be given to the installation of major bank stabilization works.

E. Federal legislative action is required to amend the 1963 Flood Control Act authorizing additional bank erosion rectification works. Responsibility for their operation and maintenance is the Federal Government's rather than the State's since the derived benefits from these projects extend beyond the local area.

XI. FLOOD PROTECTION:

A. Protection against flood damages to agricultural lands and urban areas can be achieved by employing the following measures:
   1. Soil and water conservation treatment on the uplands.
   2. Retention structures on the tributaries.
   3. Main stem structures storing large amounts of flood water.
   4. Channel improvements for many of the State's streams and rivers.
   5. Flood-plain zoning for those land areas subject to flood damages each year where other means of control are not utilized or not sufficient.
   6. Effective emergency planning and action.

XII. DRAINAGE:

A. Determine the land area from which excess runoff accumulates and provide stable channels consistently designed to provide flood protection to counteract changes in the natural drainage.

B. The total drainage area benefited by an improvement should assist in providing cost participation in the lands, channel and related appurtenances required for the removal and control of excess runoff.

C. Sufficient rights-of-way should be acquired by purchase or through easements to provide adequate area for future operation and maintenance of channel improvements.

D. In those areas where agricultural drainage contributes to river flows, studies should be made utilizing runoff data to determine if the amount of water added through drainage is offset by flood storage to avoid undue flooding which could occur on the smaller streams.

E. The solution to the drainage problem in North Dakota consists of two basic parts:
   1. Education of the public and landowners in general on the subject of total water

management with drainage being that part of water management concerned with excess runoff from precipitation after all potential retention sites including sloughs have been utilized as part of the total water management program.

2. A concentrated community effort on the part of all interested parties is needed to establish public "roadways" for water, taking into consideration such things as depth, width, slope and gradient.

XIII. IRRIGATION:

A. Initiate studies to review present irrigation standards for land and water in order to determine if these standards require revision or updating.

B. Investigate the use of saline water for irrigation.

C. Research the use of poor quality water in order to establish criteria for its use for irrigation and to determine or develop crops which are more tolerant of low quality water.

D. Field studies are needed in areas where marginal or submarginal water is being used for irrigation in order to determine the effect of these waters on plant growth and land quality compared to that of better quality water.

E. State-wide studies should be conducted to obtain detailed information in regard to soil topography, soil type, soil texture, soil depths, slope, drainage, and water table.

XIV. GENERAL:

A. All potential reservoir sites within the State should be catalogued and measures taken to discourage all development except agricultural within areas deemed suitable for reservoirs. Sites thus selected should be studied further for refinement of topographic data followed by the necessary foundation studies. Consideration should also be given to acquiring lands destined eventually for inundation by reservoirs.

B. Storage dams should be installed to regulate flows so most of the water could be put to beneficial use thus eliminating excess runoff flows being lost to beneficial use.

C. Project maintenance involves the provision and utilization of equipment and crews from the State Water Commission to conduct periodic inspections and to perform maintenance on all water resource projects. Equipment and crews should be sufficient to make inspections at intervals of no less than once each six months and to perform the required maintenance immediately.

WATER MEASUREMENTS

1 Gallon
= 231 cubic inches
= 0.13368 cubic foot
= 8.34 pounds

1 Cubic Foot
= 1,728 cubic inches
= 7,4805 gallons
= 62.4 pounds

1 Acre Foot
= 325,851 gallons
= 43,560 cubic feet

1 Cubic Foot Per Second
= 448.83 gallons per minute
= 26,929.8 gallons per hour
= 646,317 gallons per day
= 0.9917 acre inch per hour (usually taken as 1)
= 1.9835 acre feet per 24 hour day (usually taken as 2)
= 50 miners inches in North Dakota

1 Million Gallons Per Day
= 3.0689 acre feet per day
= 1120 acre feet per year
= 1.547 cubic feet per second

1 Inch Runoff Per 24 Hours
= 26.889 cubic feet per second per square mile
= 0.0420 cubic feet per second per acre
= 18.857 gallons per minute per acre

1 Inch Per Hour
=1.0083 cubic feet per second per acre (usually taken as 1)

LAND MEASUREMENTS

1/8 Mile
= 10 chains = 40 rods = 660 feet

1/4 Mile
= 20 chains = 80 rods = 1,320 feet

1/2 Mile
= 40 chains = 160 rods = 2,640 feet

1 Mile
= 80 chains = 320 rods = 5,280 feet

One Chain
= 4 rods = 66 feet

One Rod
= 16.5 feet

One Acre
= 43,560 square feet = 10 square chains
208.7 feet X 208.7 feet = one acre

Glossary

GLOSSARY

A

ACCRETION
The addition of soils or the accumulation of land by gradual deposition from a lake or river which adds to land already in possession of the owner.

ACRE-FOOT
A unit for measuring the volume of water. One acre-foot of water is equal to the quantity of water required to cover one acre of land to a depth of one foot and is equal to 43,560 cubic feet or 325,851 gallons. The term is commonly used in measuring volumes of water used or stored.

ACTIVITY DAY
Participation by an individual in a specific outdoor recreation activity during any part of a day.

AGGRADATION
The gradual build-up of eroded materials at the headwaters of a lake or reservoir.

ALLUVIAL FAN
Alluvial fans are built by rivers issuing from mountains upon lowland. They are low-cone-shaped heaps, steepest near the mouth of the valley, and sloping generally outward with ever decreasing gradient.

ANALOG MODEL
A simulation of an aquifer by electrical or mathematical means to study ground-water flow systems.

ANNUAL
This refers to the 12-month period from January 1st of a given year through December 31st of the same year, sometimes termed the "calendar year."

ANNUAL FLOOD
The highest peak discharge in a water year.

APPROPRIATION DOCTRINE
The doctrine under which the first user of water acquires a priority right to continue the use, and contiguity of land to the watercourse is not a factor. The priority right in North Dakota is obtained by securing a permit.

AQUIFER
A geologic formation or structure sufficiently permeable to yield water to wells or springs.

ARTESIAN WATER
Ground water under sufficient pressure to rise above the level at which the water-bearing bed is reached in a well. The pressure in such an aquifer commonly is called artesian pressure, and the rock containing artesian water is an artesian aquifer.

AVERAGE ANNUAL DAMAGES
Flood and related damages computed as a uniform annual series. Average annual flood damages are computed on the basis of the expectancy in any one year of the various amounts of flood damage that would result from floods throughout the full range of potential magnitude. Average annual damages from stream-bank and gully erosion are also expressed as a uniform estimate of annual damages.

AVERAGE ANNUAL RUNOFF
Average of water year runoff in inches for the total record.

AVERAGE ANNUAL YIELD
The arithmetic average of all complete water years of record whether or not they are consecutive. The term "average" is generally reserved for average of record, and "mean" is used for averages of shorter periods, namely, daily mean discharge.

B

BED LOAD
Soil rock particles and other debris rolled along the bottom of a stream by the moving water, as contrasted with the "silt load" carried in suspension.

BENEFICIAL USE
Any water use which enables the user to derive a profit or a benefit from such use.

BIOCHEMICAL OXYGEN DEMAND
Abbreviated as B.O.D.; a measure of oxygen demand of sewage and industrial wastes. B.O.D. in the stream is a measure of oxygen used by living organisms in decomposing these wastes.

C

CAPACITY (Fish and Wildlife)
An estimate used as a guide of fisherman-days or hunter-days which might be realized if all habitat were utilized at a high level.

CLIMATE
The sum total of the meteorological elements that characterize the average and extreme condition of the atmosphere over a long period of time at any one place or region of the earth's surface. The collective state of the atmosphere at a given place or over a given area within a specified period of time.

COLLUVIAL
Deposits composed chiefly of the debris from sheet erosion deposited by unconcentrated surface runoff or slope wash, together with talus and other mass movement accumulations.

COMPACT
An agreement between certain named states for the adjustment of conflicting interests on Interstate streams.

CONSERVATION STORAGE
Storage of water for later release for useful purposes such as municipal water supply, power or irrigation in contrast with storage capacity used for flood control.

CONSUMPTIVE USE OF WATER
This refers to water consumed by vegetable growth in transpiration and building plant tissue, and to water evaporated from adjacent soil, from water surface, and from foliage. It also refers to water similarly consumed and evaporated by urban and nonvegetative types of use.

CONTAMINATION
Impairment of the quality of water to a degree which creates a hazard to public health through poisoning or spread of disease.

CROPLANDS
Land currently tilled, including cropland harvested, crop failure, summer fallow, idle cropland, cropland in cover crops or soil improvement crops not harvested or pastured, rotation pasture, and cropland being prepared for crops, or newly seeded crops. Cropland also includes land in vegetables and fruits including those grown on farms for home use. All tame hay is included as cropland. Wild hay is excluded from cropland and included in pasture and range.

CUBIC FEET PER SECOND (CFS)
A unit expressing rates of discharge. One cubic foot per second is equal to the discharge of a stream of a rectangular cross section, one foot wide and one foot deep, flowing water an average velocity of one foot per second.

CURRENT DEMANDS
The numerical expression of present desire for goods and services associated with current economic standards.

CURRENT NEEDS
Current demands which are not being satisfied by the present level of resource development.

D

DEAD RESERVOIR STORAGE
The volume in a reservoir below the lowest outlet or operating level.

DEGRADATION (River Beds)
The general lowering of the stream bed by erosive processes, especially by the removal of material through erosion and transportation by flowing water.

DELIVERED WATER
The water delivered to a farmer's headgate in the case of irrigation use, or to an individual's meter in the case of urban use, or its equivalent. It does not include direct precipitation.

DEMAND
The numerical expression of the desire for goods and services associated with an economic standard for their attainment.

DEMAND (Fish and Wildlife)
The estimated desire for fishing and hunting expressed in man-days which might be realized if all habitat were utilized at a high level.

DEPLETION (Water)
That portion of a water supply withdrawn, applied or intercepted that is consumptively used.

DETENTION DAM
An artificial barrier for temporarily impounding water and sediment retention.

DISPOSAL SYSTEM
A system for disposing of wastes, either by surface or underground methods, and includes sewerage systems, treatment works, disposal wells and other systems.

DIVERSION
The taking of water from a stream or other body of water and transferring such water by a canal, pipe or other conduit to another water course or to the land, in the case of an irrigation system.

DIVERSION DAM
An artificial barrier designed to permit taking of water from a stream into a canal, pipe, or other conveyance facility.

DOMESTIC WATER SUPPLY
Household uses associated with ranch and farm operations as well as household uses in all communities with populations of 2,500 or less.

DRAINAGE AREA
The area drained by a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.

DRAINAGE BASIN
A part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water with all tributary surface streams and bodies of impounded surface water.

DRAINAGE DIVIDE
The rim of a drainage basin.

DUCK (or Goose) DAY
A duck (or goose) present on an area for any part of a day.

E

EFFECTIVE PRECIPITATION
That portion of the direct precipitation which is consumptively used and which does not contribute to stream flow or percolation.

EFFLUENT STREAM
A stream or reach of a stream fed by ground water.

ENGLE FORMULA
The formula which permits the furnishing of water from Reclamation projects to lands in excess of the 160 acre limitation. Under the formula, the excess landowner pays interest charges on his share of the irrigation costs for water delivered to lands in excess of 160 acres per person.

ENHANCEMENT
Intensified utilization of a particular land area or water resource.

EUTROPHICATION
The aging process of a lake which is characterized by an abundant accumulation of nutrients supporting a dense growth of plant and animal life, the decay of which depletes the shallow waters of oxygen.

EVAPORATION
The process by which water is changed from the liquid or solid state into the vapor state. In hydrology, evaporation is vaporization that takes place at a temperature below the boiling point.

EVAPOTRANSPIRATION
Water withdrawn from a land area by evaporation from water surfaces, soil, and plant transpiration.

F

FIELD CAPACITY
The capacity of a given soil to retain water for plant life.

FISHERMAN DAY
Any part of a day spent fishing by an individual.

FISHERMAN DAYS CAPACITY
The total annual user days of sport fishing per acre or mile which a given body of water or reach of stream will provide and sustain at a specified level of management.

FLOOD
An overflow or inundation that comes from a river or other body of water, and causes or threatens damage.

FLOOD CONTROL STORAGE
Storage of water in reservoir to abate flood damage.

FLOOD, MAXIMUM PROBABLE
The largest flood for which there is any reasonable expectancy.

FLOOD PEAK
The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge. Flood crest has nearly the same meaning, but since it connotes the top of the flood wave, it is properly used only in referring to stage — thus crest stage, but not crest discharge.

FLOOD PLAIN
A strip of relatively smooth land bordering a stream, built of sediment carried by the stream. It is called a living flood plain if it is overflowed in times of high water; but a fossil flood plain if it is beyond the reach of the highest flood.

FLOOD STAGE
The stage at which overflow of the natural banks of a stream begins to cause damage.

FLOODWATER OR FLOOD DAMAGE
The economic loss caused by floods including damage by inundation, erosion, scour, or sediment deposition on flood plain areas. Floodwater damages result from physical damages or losses, emergency costs, and business or financial losses. Evaluation may be based on the cost of replacing, repairing, or rehabilitating; the comparative change in market or sales value; or the change in income or production caused by flood experience.

FLOODWAY
The channel of a river or stream and those parts of the flood plains adjoining the channel, which are reasonably required to carry and discharge flood water or floodflow of any river or stream.

FLOWING WELLS
An artesian well having sufficient head to discharge water above the land surface.

FREEBOARD
The vertical distance between a designed maximum water level and the top of a structure.

FREE GROUND WATER
A body of ground water not immediately overlain by impervious materials, and moving under control of the water table slope.

FREE WATER
The presence of water in the soil in a sufficient quantity to cause water drops when placed under pressure.

FUTURE NEEDS
The projected demands which are not satisfied by projected capability of the present level of development.

G

GAGING STATION
A particular site on a stream, canal, lake or reservoir where systematic observations of gage height or discharge are obtained. When used in connection with a discharge record, the term is applied only to those gaging stations where a continuous record of discharge is obtained.

GROUND WATER
Water in the ground that is in the zone of saturation, from which wells, springs and ground-water runoff are supplied.

GROUND WATER OVERDRAFT
The rate of net extraction of ground water from a ground-water basin in excess of safe ground water yield.

H

HUNTER DAY
Any part of a day spent hunting by an individual.

HUNTER DAYS
Annual hunter-days which a resource area will provide at a specified level of management.

HYDROLOGIC CYCLE
A convenient term to denote the circulation of water from the sea, through the atmosphere, to the lands; and thence, with many delays, back to the sea by overland and subterranean routes, and in part by way of the atmosphere without reaching the sea.

HYDROLOGY
The science of water, its properties, laws and distribution.

I

IMPAIRED FLOW
The actual flow of a stream with any given stage of upstream development.

INTERMITTENT STREAM
A stream that flows only part of the time or through only part of its reach.

IRRIGATION
The controlled application of water to lands to supply water requirements not satisfied by rainfall.

IRRIGATION CONSUMPTIVE USE
The quantity of water that is absorbed by the crops and transpired or used directly in the building of plant tissue together with that evaporated from the cropped area.

IRRIGATION DISTRICT
A public and quasi-municipal corporation authorized by law in several states, comprising a defined region or area of land which is susceptible of one mode of irrigation from a common source and by the same system of works. These districts are created by proceedings in the nature of an election under the supervision of a court, and are authorized to purchase or condemn the lands and waters necessary for the system of irrigation proposed and to construct necessary canals and other works, and the water is apportioned ratably among the landowners of the district. (Flood irrigation districts are created by boards of county commissioners.)

IRRIGATION EFFICIENCY
The ratio of consumptive use of applied irrigation water to the total amount of water applied, expressed as a percentage.

IRRIGATION WATER SERVICE AREA EFFICIENCY
The ratio of consumptive use of applied irrigation water in a given service area to the gross amount of water delivered to the area, expressed as a percentage.

J

K

KILOWATT (KW)
The electrical unit of power or rate of doing work, which equals 1,000 watts or 1.341 horse power.

KILOWATT HOUR (KWH)
The basic unit of electrical energy. It equals one kilowatt of power applied for one hour.

L

LAND SUBSIDENCE
The sinking or settling of land to a lower level.

LEGAL DRAIN
An improvement of capacity to carry excess runoff within existing natural channels, existing ditches, or wholly new ditches which has been initiated, established, constructed, and will be maintained as the statutory responsibility of an accredited sponsoring agency under the applicable requirements of Chapter 61-21 of the North Dakota Century Code.

LIMNOLOGY
That branch of hydrology pertaining to the study of lakes.

LITER
The basic unit of measure for capacity in the metric system, equal to 61.025 cubic inches or 1.0567 liquid quarts.

M

MEANDER
The widening of a stream channel.

MILLIGRAM (mg)
One thousandth of a gram which in turn is the basic unit of weight in the metric system equal to 1/28th of an ounce or .0022046 pound.

MINERAL FUELS
Fuels that include petroleum, natural gas, the coals and today the metal; uranium.

MINERAL RESERVES
Discovered ore, petroleum, or natural gas of established extent and grade producible but not yet produced.

MINERAL RESOURCE
Mineral deposit known to the extent that it is regarded as having present or future utility.

MULTIPLE-PURPOSE RESERVOIR
A reservoir planned so the water stored may be used for more than one purpose.

N

NATURAL FLOW
The flow of a stream as it would be if unaltered by upstream diversion, storage, import, export, or change in upstream consumptive use caused by development.

NEED
The difference between demands for a specified time and the capability of the existing level of resource development projected to the time considered.

NET RESERVOIR EVAPORATION
The evaporation water loss from a reservoir after making allowance for precipitation on the reservoir, and runoff that would have occurred from that precipitation from the land area covered by the reservoir. Net reservoir evaporation equals the total evaporation minus the precipitation on the reservoir plus the runoff from the land area covered by the reservoir.

O

OBSERVATION WELL
An observation well is a cased hole in the ground that is used to monitor ground water levels.

P

PERMEABILITY (Rock)
The capacity of a rock to transmit water. The field coefficient or permeability of an aquifer is the coefficient of transmissibility divided by the saturated thickness of the aquifer in feet.

POLLUTION
Impairment of the quality of water to a degree which does not create a hazard to public health, but which adversely and unreasonably affects such water for beneficial use. (See "Contamination.")

POPULATION EQUIVALENTS
Population equivalents describe the pollutional effect of various waste discharges in terms of a corresponding effect of discharging raw sewage from an equivalent number of human population. Each P. E. represents the waste contributed by one person in a single day.

POROSITY (Rock)
The porosity of a rock is its property of containing openings or interstices. It is the ratio (usually expressed as a percentage) of the volume of openings in the rock to the bulk of the volume in the rock.

PRECIPITATION
As used in hydrology, precipitation is the discharge of water, in liquid or solid state, out of the atmosphere, generally upon a land or water surface. It is the common process by which atmospheric water becomes surface water or subsurface water. The term "precipitation" is also commonly used to designate the quantity of water that is precipitated.

PRIMARY TREATMENT
The removal of settleable solids from sewage and industrial wastes. Units of primary sewage treatment plant consist of screens, grit removal chambers, settling tanks, sludge digestors and sludge drying beds and may include chlorination facilities. Primary treatment plants generally remove 25 to 35 percent of the BOD and 45 to 65 percent of the total suspended matter.

PROJECT
Any separable physical unit or group of closely related units, existing, undertaken, or to be undertaken within a specific area for control and development of water and related land resources, which can be established and utilized independently or as an addition to an existing project, and can be, or has been, considered as a separate entity for purposes of evaluation.

Q

QUALITY OF WATER
Those characteristics of water affecting its suitability for beneficial uses.

R

RAINFALL
The quantity of water that falls as rain only.

RECREATION NEED
The difference between projected recreation demands and the capability of the resources currently available and developed to satisfy those demands.

REQUIREMENTS
A desirable or essential demand needing satisfaction.

RESERVOIR
A pond, lake or basin, either natural or artificial, for the storage, regulation, and control of water.

REVETMENT STRUCTURE
A structure of stone, cement, sand bags, etc., to protect a wall, river bank or bank of earth.

RIPARIAN DOCTRINE
The doctrine under which the owner of land contiguous to a stream has certain rights in the flow of the water, by virtue of such land ownership.

RIVER BASIN
The hydrographic area drained by a major river and its tributaries; and including all closed basins within the topographic divides separating the drainage from adjacent major drainages.

RIVER REACH
Any defined length of a river.

RUNOFF
That amount of the precipitation that appears in surface streams. It is the same as streamflow unaffected by artificial diversions, storage or other works of man in or on the stream channels.

RUNOFF IN INCHES
Defined as the depth to which a drainage area would be covered if all of the runoff for a given period were uniformly distributed on it.

RURAL POPULATION
All population not classed as urban and is divided into rural farm and rural nonfarm population.

RURAL FARM POPULATION
All residents living on farms of ten acres or more with production sold at $250 or more in the previous year.

RURAL NONFARM POPULATION
All rural population not classed as farm. This includes residents of unincorporated settlements, hamlets, villages and incorporated cities, villages and towns, both categories having less than 2,500 population.

S

SECONDARY RECOVERY
The recovery obtained by any method whereby oil or gas is produced by augmenting the natural reservoir energy, as by fluid injection. It usually implies substantial depletion of the reservoir before injection of fluids, followed by a secondary development period.

SECONDARY TREATMENT
Additional treatment following primary treatment to remove additional organic wastes. Units of a secondary treatment plant comprise, in addition to primary treatment, trickling filters or activated sludge basins, final settling of wastes, and should include chlorination facilities. Secondary treatment generally removes from wastes 80 to 95 percent of the BOD and suspended matter, expressed as averages or mean values except for bacterial densities.

SEDIMENT
Fragmental or clastic mineral particles derived from soil, alluvial, and rock materials by processes of erosion; and transported by water, wind, ice and gravity.

SEDIMENT STORAGE (Reservoir)
Sediment deposition occurs throughout a reservoir. In reservoirs where sediment encroachment is predicted, an allowance is made for sediment deposition in planning the storage requirement.

SEDIMENTATION
The continued deposit of sedimentary materials such as soil and other debris in lakes, streams, rivers and reservoirs.

SEWERAGE SYSTEM
Pipelines or conduits, pumping stations, and force mains, and all other structures, devices, appurtenances, and facilities used for collecting or conducting wastes to an ultimate point for treatment or disposal.

STORAGE DAM
An artificial barrier for impounding water or sediment.

STREAM
A general term for a flowing body of water. In hydrology the term is generally applied to the water flowing in a natural channel as distinct from a canal. More generally, as in the term "stream gaging," it is applied to the water flowing in any channel, natural or artificial.

STREAMBANK EROSION (Riverbank Erosion)
Destruction of land areas from active cutting of streambanks or riverbanks by flowing water.

STREAMBANK EROSION DAMAGE (Riverbanks)
Value of land areas destroyed, the loss of value due to threat of future erosion, and destruction or damage of buildings, bridges, utilities, or other structures located on the land areas destroyed by erosion.

SUBBASIN
Hydrographic areas drained by tributaries or groups of tributaries of a major river basin, including associated closed basins.

SURCHARGE STORAGE (Reservoir)
Reservoir space from the maximum water surface elevation down to the highest of the following elevations.
A. Top of exclusive flood control capacity
B. Top of multiple or joint use capacity
C. Top of active conservation capacity

T

THERMAL POLLUTION
Pollution caused by discharge of water from thermal electric generating or other such plants using river water for cooling.

TOPOGRAPHIC MAPS
Maps with lines of equal elevation which show the surface features of a region, including hills, valleys, rivers, lakes, canals, bridges, roads, cities, etc.

TOTAL STORAGE (Reservoir)
The volume of a reservoir below the maximum designed water surface level including dead storage.

TOTAL SUSPENDED SOLIDS
Solids found in waste water or in the stream which can be removed by filtration. The origin of suspended matter may be man-made wastes or natural sources such as silt from erosion.

TRANS-BASIN DIVERSION
The diversion of water from one river basin to one or more other river basins.

TRANSPORTATION
The process by which water vapor escapes from the living plant, principally the leaves, and enters the atmosphere.

TREATMENT WORKS
Any plant or other works used for the purpose of treating, stabilizing or holding wastes.

TRIBUTARY
A stream or river that flows into a larger one.

U

URBAN POPULATION
All persons living in (a) places of 2,500 inhabitants or more incorporated as cities, villages or towns and (b) the densely settled urban fringe, whether incorporated or unincorporated.

V

VESTED RIGHTS
Rights which have so completely and definitely accrued to or settled in a person that they are not subject to be defeated or cancelled by the act of any other private person, and which it is right and equitable that the government should recognize and protect.

W

WANTS
Desires or needs often expressed as requirements to be fulfilled.

WASTES
Sewage, industrial wastes, and all other liquid, gaseous, solid, radioactive, or other substances which may pollute or tend to pollute any waters.

WATER CONSERVATION
The care, preservation, or protection of water resources.

WATER MANAGEMENT DISTRICT
A water management district is a legal entity established by the State Water Commission upon the petition of either the local board of county commissioners or a majority of the freeholders within the proposed district having authority to participate in all phases of water development, utilization and control.

WATER REQUIREMENT
The water needed to provide for all beneficial uses and for all irrecoverable losses incidental to such uses.

WATERSHED
A drainage basin or catchment area.

WATERS OF THE STATE
All waters within the jurisdiction of the State including all streams, lakes, ponds, impounding reservoirs, marshes, watercourses, waterways, and all other bodies or accumulations of surface water, natural or artificial, public or private, situated wholly or partly within or bordering upon the state, except those private waters which do not combine or effect a junction with natural surface or underground waters.

WATER UTILIZATION
This term is used in a broad sense to include all employments of water by nature or man, whether consumptive or nonconsumptive, as well as irrecoverable losses of water incidental to such employment, and is synonymous with the term "water use."

WATER YEAR
The 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends.

WATER YIELD
The runoff from the drainage basin, including ground water outflow that appears in the stream, plus ground water that bypasses the gaging station and leaves the basin underground, and minus ground water inflow that moves into the drainage basin underground from adjacent drainage basins. Water yield is the precipitation minus the evapotranspiration.

X

Y

Z

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