THE MISSOURI RIVER BASIN DEVELOPMENT PROGRAM AND THE WATER RESOURCES DIVISION, U.S. GEOLOGICAL SURVEY, 1946-83

U.S. GEOLOGICAL SURVEY

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By Hugh H. Hudson

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U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary
U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

For additional information
write to:

U.S. Geological Survey
Water Resources Division
Box 25046, Mail Stop 406
Federal Center
Denver, CO 80225-0046

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SUMMARY

The Missouri River Basin Development Plan, also known as the Pick-Sloan Plan, was authorized by Congress in the Flood Control Act of 1944 for the development and management of the water resources of the basin by the U.S. Department of the Interior and the U.S. Army Corps of Engineers. The Department, with the U.S. Bureau of Reclamation as its lead agency and the U.S. Geological Survey in a supporting role, was assigned the responsibility for irrigation and associated development in the headwater areas of the "irrigation States," under the Departments Missouri River Basin Development Program, also known as the Missouri River Basin (MRB) Program. The Corps was authorized to construct flood-control and navigation works along the main stem of the Missouri.

Under the U.S. Geological Survey's Missouri River Basin Project, which was established to coordinate Survey activities related to implementation of the Missouri River Basin Development Program, the four operating divisions of the U.S. Geological Survey were assigned initial roles commensurate with their traditional functions: topographic and geologic mapping by the Topographic and Geologic Division, respectively; river surveys by the Conservation Division; and water-resources information by the Water Resources Division. All four branches of the Water Resources Division were initially involved: the Surface Water Branch to provide data pertaining to streamflow; the Quality of Water Branch to provide data pertaining to surface-water quality and sediment transport in streams; the Ground Water Branch to prepare a series of comprehensive reports on ground water for key areas of the basin; and the Water Utilization Branch to prepare reports that analyzed and interpreted streamflow records. The Conservation and Geologic Divisions ended their participation by 1949 and 1960, respectively. Active participation by the Water Utilization Branch ended in 1953.

Henry G. Beckman was named to represent the U.S. Geological Survey in Missouri River Basin Development Program matters in the field and to coordinate the activities of the four branches of the Water Resources Division under the MRB Program, which the Division established in support of the Survey's project. He served in that capacity until 1956 when the Division was re-organized and the position of Division Hydrologist was established. S. Keith Jackson became the Division Hydrologist for the region responsible for the MRB Program and, thus, inherited the Survey responsibilities previously borne by Beckman. Administration and coordination of the MRB Program activities became a staff function under Jackson's direction.

The first year of funding for the Missouri River Basin Development Program was fiscal year 1946. Funds for the U.S. Geological Survey and other Interior bureaus were provided by transfer from the U.S. Bureau of Reclamation, which received the funds via the public-works appropriation. This method of funding prevailed through fiscal year 1971 and engendered misunderstandings between the Bureau of Reclamation and the Ground Water Branch over whether the ground-water program was to serve the site-specific, short-term needs of the Bureau or was to consist of longer-term, comprehensive studies culminating in complete, published reports designed to serve other users of ground-water information. George H. Taylor served as supervisor, spokesman, and advocate for the Ground Water Branch in discussions with the Bureau until 1957, when he was re-assigned.

Beginning in fiscal year 1972, the MRB program became a part of the Water Resources Division's Federal Program, retained its MRB identity for a few years, then became the major component of an element of the Federal Program called "Records in support of other Interior agencies."

Funds used by the Water Resources Division to support the MRB program, adjusted to the 1972 level of inflation, varied from a maximum of $2.4 million in fiscal year 1951 to a minimum of $300,000 in fiscal year 1983, the last year of funding. The budget was unstable during its first 15 or so years. After increasing to an all-time high in fiscal year 1951, the budget decreased to a near all-time low in fiscal year 1955, necessitating the re-assignment of many Water Resources Division staff including most of those assigned to ground-water studies for the MRB program, and, indirectly, quelling the disagreement between the Ground Water Branch and the Bureau of Reclamation.

From fiscal year 1946 through fiscal year 1983, the Water Resources Division expended nearly $28 million to provide water-resources information in support of the Missouri River Basin Development Plan. Until the mid-1950's, a major feature of the Division's MRB program was a series of areal ground-water investigations. Many gaging stations were operated and much water-quality and fluvial-sediment data were collected, published, or otherwise provided to the other Interior bureaus participating in the Missouri River Basin Development Program. After the mid-1950's, the MRB program was devoted largely to hydrologic-data collection, and areal ground-water studies were less prominent.

Results of the Water Resources Division's MRB program are contained in 154 interpretive reports and in about 300 data reports. Water-resources information obtained during the MRB program provided the basis for subsequent Division programs, including the preparation of a plan in the 1960's for development of the water and related land resources of the basin and in the 1970's for the Coal-Hydrology Program.

The MRB program not only resulted in a maturing of the organization of the Water Resources Division, but also provided rationale for decentralization of program administration and for other organizational and administrative improvements in the Division. The MRB program re-introduced quality-of-water studies to the Missouri River basin after a long absence, and was a factor in the emergence of water-quality investigations from a laboratory environment to full participation in water-resources studies of the U.S. Geological Survey. The MRB program also provided the crucible for tempering the Division's report-completion policy where the issue was on-demand service work versus complete studies with reports designed to accommodate the needs of a greater audience.

INTRODUCTION

The Missouri River Basin Development Program, which was established to coordinate U.S. Department of the Interior activities related to implementation of the Missouri River Basin Development Plan, significantly affected the Water Resources Division of the U.S. Geological Survey. Although the Division's activities related to this program have been eclipsed by other activities of the Division, the imprint of the program remains in the wealth of hydrologic information it has generated, in the working relationships with other agencies that developed during the early days of the program, and, perhaps to a more limited extent, in beneficial organizational changes in the Water Resources Division that were affected by program experiences. In an exclusive category of effects are those engineers, geologists, and chemists who spent their early years working in the program, and later became the administrative and technical leaders of the Division.

Purpose and Scope

A complete history of the Missouri River Basin Development Program should contain many references to Federal legislation, the work of other Federal agencies, budgets, and to the floods and droughts that periodically ravaged the basin. This report, however, makes no pretension of being a complete history of the program. This report is a limited account of the involvement of the Water Resources Division of the U.S. Geological Survey in the program and of the effects of that involvement on the Division. A certain amount of legislative history, budgets and budget procedures, and development of Federal-agency jurisdictional responsibilities is provided, simply to provide essential perspective to this account.

To those who are accustomed to a view of the Water Resources Division unencumbered by branches, the emphasis contained in this report on the involvement of the branches may seem excessive, they had a significant role in the activities associated with the program, but that's the way it was. When the program began, the Division's branches were rather autonomous and operated somewhat independently of each other. To portray the branches in a lesser role would not be in keeping with their prominence until the early 1960's.

More of the attention in this report is given to the Ground Water and Quality of Water Branches and less to the Surface Water Branch. This is by no means a reflection of a minor Surface Water Branch role, but simply acknowledges a continuance of existing activities by Surface Water Branch during the program. The job of the Surface Water Branch was large, but its organization and staff, for the most part, were in place when the program began. In contrast, the Ground Water and Quality of Water Branches not only had to develop new modes of operation decentralized from Washington, D.C., but had to establish offices and laboratories throughout the basin and then equip and staff those new facilities. Also, there was mutual agreement between the U.S. Geological Survey and the U.S. Bureau of Reclamation as to the Surface Water Branch role, which resulted in freedom from the policy tugs of war that occupied much of the time of Ground Water Branch staff.

This report might appear to over emphasize the early years of the program. During its first 10 years, however, the Water Resources Division's share of the program budget nearly overtook the Federal-Program budget of the Division. The Division staff funded by the program expanded rapidly, then was largely disbanded as the budget markedly collapsed. Those also were the years marked by internal and external disagreements about the proper function of the Ground Water Branch relative to needs for information as perceived by other Interior bureaus, particularly the U.S. Bureau of Reclamation. Those early years also were a time of emergence of the Quality of Water Branch from its headquarters laboratories to a role of active participation in water-resources investigations. It also was during those early years that the field organization of the branches matured and developed the rationale for an integration of their activities that culminated in reorganization and abolishment of the field branches in the 1960's. Thus, much of the history of the program, in terms of its effects on the Division, is contained in those early years.

Acknowledgments

Preparation of this report offered the pleasure of contacting several former associates in the U.S. Geological Survey, most of whom are now retired, who were involved in or were close observers of the Missouri River Basin Development Program in its early days. All gave generously and enthusiastically of time and advice to assure that the writer had access to correspondence, personnel lists, early reports, and recollections of events that made writing this account not only possible, but enjoyable. Among those who were especially helpful were Paul C. Benedict, W.H. (Walt) Durum, George E. Ferguson, A. Ivan Johnson,

Stanley W. (Stan) Lohman, Thad G. McLaughlin, Quentin F. (Quent) Paulson, Irene Paulsen, Lester R. (Les) Petri, and Bruce H. Ringen.

Ray Bentall told me of the existence of George H. Taylor's files. William M. (Bill) Kastner and his staff located and sent to me several boxes of material that George had meticulously organized so that he could write a history of the Water Rsources Division's MRB program. It is indeed unfortunate that George's failing health prevented his undertaking the task. His history probably would have been more detailed.

Each of the Water Resources Division District Chiefs and staff in the basin helped assemble the lists of reports that were prepared under the MRB program.

The writer drew extensively from Follansbee's (undated, see Selected References) History of the Water Resources Branch of the United States Geological Survey, Volume 4, July 1, 1939 to June 30, 1947, and from Durum's (1978) Historical Profile of Quality of Water Laboratories and Activities, 1879-1973. Much of the background of the Pick-Sloan Plan came from a paper by Larkin (1980) of the Missouri River Basin Commission published in the proceedings of the October 28, 1980, Seminar on the Pick-Sloan Missouri Basin Program. The seminar was sponsored by the Commission and the Western States Water Council.

It was Alfred (Al) Clebsch, Jr., however, who made the preparation of this account possible. He maintained the Geological Survey's tradition of valuing its history by asking that the account be prepared and by providing the support essential to its preparation.

ORIGIN OF THE MISSOURI RIVER BASIN DEVELOPMENT PLAN

The Missouri River Basin Development Plan, or Pick-Sloan Plan, for development of the Missouri River basin was formally authorized by Congress in the Flood Control Act of 1944. The involvement of the U.S. Geological Survey in the implementation of this plan began with the Flood Control Act of July 3, 1945, "*** appropriating for the Interior Department Bureau of Reclamation--Missouri River Basin, $3,200,000."

A paper presented at a seminar on the Pick-Sloan Missouri Basin Program in 1980 (Larkin, 1980) contained the following statements about the Missouri River basin:

> "Water--too much or too little--has been a crucial issue in the region since settlers first struggled to make their homes there in the 1800's.
>
> "In the mid-1800's, settlers coming into the region from the more humid Eastern and Southern states found a Great American Desert. Almost two-thirds of the central basin, the Great Plains, receives less than 20 inches of precipitation annually.
>
> "The Homestead Act of 1862 offered free land, up to 160 acres, for anyone willing to cultivate for three years. By 1877, however, framers of the Desert Land Act recognized that the West required new agricultural methods if settlers were to survive there. By offering land at a cheap rate to anyone who would settle and irrigate within five years, the act supported settlement and nudged settlers into the new ways of farming that were required for survival.

"In 1902, the Reclamation Act was passed to further enhance development of dry lands in the West. The Act set up a fund to be used at the discretion of the Secretary of the Interior for studies, survey, and construction of irrigation projects in 16 Western States. The projects were to reclaim otherwise unproductive lands for agricultural use.

"The fund was to be established with money from the sale of public lands in the 16 (later 17) states. A significant primary effect of the Act was to establish Interior's role, and subsequently its Bureau of Reclamation, as the Federal agency concerned with fostering agriculture by irrigation in the arid Western States.

"Subsequent acts gave the Bureau authority to undertake specific projects having irrigation as a primary focus. In 1906, the focus was expanded to include development of hydropower wherever needed to support irrigation. At the same time, the Secretary of the Interior was authorized to lease surplus power where it would not impair service to irrigation and to sell water for municipal use in towns near reclamation reservoirs.

"The Corps of Engineers was first given jurisdiction to maintain the Nation's navigable rivers in the interest of interstate commerce in 1824. A series of river and harbor acts re-emphasized the early authority. Other responsibilities were later delegated to the Corps whenever navigability of the waterway or technical capability were of concern.

"In 1939 *** Congress turned to the [Secretary of the Interior] for a plan of relief for the drought-plagued lands of the Dust Bowl, once the Great Plains.

"In 1943 *** motivated by devastating floods, the House Committee on Flood Control passed a resolution asking the Corps of Engineers to produce a plan for flood control and other purposes in the Missouri River Basin.

"*** when Congress asked the Bureau and the Corps for plans to manage water in the Missouri River Basin, a comprehensive plan for the well-being of the entire basin was sought from each."

The Secretary believed that most of the Interior bureaus were concerned in one way or another with water-resources development and that their interests and roles should be coordinated. He directed the formation of a Departmental water-resources committee to unify the individual bureau roles and named C.G. Paulsen as Chairman. The committee accomplished little because of looming war-related priorities. The committee however, was re-activated on May 2, 1944, with W.G. Hoyt as Executive Secretary, and with orders to devote full time to the task of coordinating bureau interests in development of the Missouri River basin.

The Corps of Engineers' plan was authored by Colonel Lewis A. Pick, then head of the Missouri River Division of the Corps and, later, its Chief of Engineers. The Corps' plan was presented to the Congress in March 1944 as House Document 475 (78th Congress, 2nd Session). The Bureau's plan,

authored by Assistant Commissioner of Reclamation W. Glenn Sloan, followed a month later and was published as Senate Document 191 (78th Congress, 2d Session).

As reported by Larkin (1980), "*** the compromise (which became known as the Pick-Sloan Plan) had the practical impact of awarding jurisdiction to the bureau for the reservoirs and other units along tributaries and preserving Corps responsibility for the mainstem components from Fort Peck, Montana, to the mouth."

The Missouri River Basin Development Plan or Pick-Sloan was then authorized by Congress in the Flood Control Act of 1944.

U.S. GEOLOGICAL SURVEY'S "WATER PLANS FOR THE MISSOURI RIVER BASIN"

The Missouri River Basin Development Plan was precedent-setting in the comprehensive, multiple-purpose objectives of its component proposals. The plan was designed primarily to provide four basic benefits--flood control, irrigation, power generation, and improvement of navigation on the lower Missouri River. The plan envisioned more than 100 dams, 150 irrigation projects involving 5 million acres, 30 or more powerplants, improved water supplies for at least 19 communities, hundreds of miles of flood-control levees and dikes, and about 700 miles of channelization for navigation. In a letter included in Senate Document 191 (78th Congress, 2d Session), Secretary Ickes said "Substantial and material benefits would accrue through recreational use of the water and facilities proposed: through their use in fish and wildlife conservation, through pollution abatement, silt control and the recharge of lakes and ground waters."

An interagency Board of Review's statement on the major aspects of the plan, including its hydrologic requirement also was included in Senate Document 191 (78th Congress, 2d Session). Regarding hydrology, the Board of Review recommended substantial increases in appropriations to the U.S. Geological Survey for streamgaging, saying that lack of State appropriations for matching should not be allowed to delay implementation of the plan.

Functions of Interior bureaus, other than those of the U.S. Bureau of Reclamation, are described in appendices to Senate Document 191 (78th Congress, 2d Session). Most are portrayed on maps separate from that report; however, the value of adequate water information was acknowledged by the inclusion of a narrative appendix by the U.S. Geological Survey on "Water Plans for Missouri River Basin" (Appendix A). In their entirety, the Survey's water plans were ambitious, and committed the Surface Water, Ground Water, Quality of Water, and Water Utilization Branches of the Water Resources Division to specific activities.

The U.S. Geological Survey's water plans included the construction and operation of 125 additional gaging stations. Most of these gaging stations were to be located on tributaries to the Missouri River in headwater areas.

There was not only a paucity of ground-water information in the basin, but unparalleled opportunities existed for conjunctive use of surface and ground water to meet the objectives of the Missouri River Basin Development Plan. Consequently, the plans for investigating the ground-water resources of the basin were extensive and intensive. The U.S. Geological Survey's water plans envisioned the purchase and continuous operation of drilling rigs for test-hole construction. These test holes were necessary for the examination of potential recharge areas, identification and mapping of significant areas

supporting phreatophytes and affected by large-scale withdrawals by wells, pumping tests, geologic mapping, and operation of observation wells. The drilling of test holes was to be done on a county-by-county basis, of which there were about 400 in the basin. Priority would be given to about 30 counties where ground-water problems were most urgent.

The U.S. Geological Survey's water plans for water-quality studies placed major emphasis on sediment loads of streams because of the need for such information in estimating reservoir duration and maintenance of channelized river channels included in the navigation system. The water plans also provided for the collection of chemical-quality data from streams for use in agricultural and industrial planning. The autonomous branch operations of those days made it easy to overlook the need in the water plans to budget for the analysis of samples obtained in the course of ground-water studies. This omission was soon rectified.

The role of the Water Utilization Branch was less well defined. It was anticipated that the agencies involved in planning and constructing projects would benefit by having reports prepared from basic streamflow information modified to reflect climactic oscillations, the hydrologic evolution of the basins, and the effects of constructed works on streamflow.

WATER RESOURCES DIVISION ACTIVITIES IN THE MISSOURI RIVER BASIN PRIOR TO THE MISSOURI RIVER BASIN DEVELOPMENT PROGRAM

A quick review of Water Resources Division activities in the Missouri River basin, and funding patterns just prior to the Missouri River Basin Development Program might help place the Survey's water plans in perspective.

In fiscal year 1945, the entire expenditure by the Water Resources Division for its water-resources investigations in the Missouri River basin was $316,300, of which $136,800 came from the "Gaging streams" appropriation to the U.S. Geological Survey. Although the Federal/State Cooperative Program was in place in all basin States, it provided only $95,300 from all sources in fiscal year 1945. The cooperative program at that time was largely devoted to surface-water work. The U.S. Army Corps of Engineers transferred $68,700 to the Survey from its appropriation for certain streamflow records, and $15,500 was paid by other Federal agencies for water data, mostly gaging-station records.

Measurements of streamflow in the basin by the U.S. Geological Survey were begun in 1889 with the establishment of four gaging stations in Montana. The work was expanded to Nebraska in 1891, to Kansas and Wyoming in 1895, to Colorado in 1897, to North Dakota in 1901, to Missouri and South Dakota in 1903, and to Iowa in 1917. Cooperation with the States in streamgaging began in Kansas, Nebraska and Wyoming in 1895; in Colorado in 1897; in North Dakota in 1901; and in Montana in 1906. Although cooperative programs with many of the States in earlier years were intermittent, all States in the basin have cooperated with the Geological Survey continuously since 1934 in surface-water investigations.

Ground-water investigations by the U.S. Geological Survey began much later than the streamgaging program. Although ground-water studies were initiated as part of the Federal/State Cooperative Program as early as 1895 in Kansas, the first ground-water studies of consequence in the Missouri River basin were those by O.E. Meinzer in the Lodgepole Valley in Wyoming and Nebraska in 1915 (Meinzer, 1919).

The drought of the 1930's generated an increasing interest in the development of ground-water supplies. This, along with the provision for Federal matching of State funds, which had been approved by

the Congress in 1928, gave impetus to a rapid expansion of the ground-water program. Cooperation with Nebraska began in 1930, with South Dakota in 1935, with Kansas and North Dakota in 1937, with Iowa in 1939, with Wyoming in 1941, and with Colorado in 1945. With the exception of Meinzer's work in the Lodgepole Valley, little Federal funding had been available for ground-water studies in the Missouri River basin. Prior to the Missouri River Basin Development Program, the only other-Federal-agency funds transferred to the U.S. Geological Survey for ground-water work in the basin was $5,000 from the U.S. Bureau of Reclamation in fiscal year 1941. This represented the first request by the Bureau for ground-water assistance in the basin.

In fiscal year 1945, there were no systematic chemical-quality or sediment programs in the basin, nor had such programs been active for nearly 40 years. The first collection of water-quality by the U.S. Geological Survey in the Missouri River basin began in 1905 but lasted only a few years.

That work was part of the investigations of irrigation possibilities in the West, conducted by the Reclamation Service, which had been established in 1902 and placed in the Hydrographic Branch of the U.S. Geological Survey. The investigations were designed as systematic studies to determine the effects of the salinity of water on the growth of crops, and the effects of suspended sediment on the silting of canals and reservoirs. There were 55 water-quality stations established in the western States under this program, of which 17 were in the upper Missouri River basin. The water-quality stations were located at gaging stations and measured various chemical constituents, dissolved solids, and suspended-sediment loads. Due to lack of funds, the water-quality program was discontinued in 1906.

Other early water-quality work was conducted by the U.S. Geological Survey in Kansas in cooperation with the State Board of Health. This work was begun in 1906 and continued into 1908. Data pertaining to the chemical quality of streams were collected at 10 sites in the Missouri River basin during this period. Samples also were collected and analyzed from wells completed in several of the more productive aquifers in Kansas.

The Water Utilization Branch also was included in the U.S. Geological Survey's water plans for a Water Resources Division effort in the Missouri River basin although this branch had no data-collection program and its field staff was the small Soil and Moisture Conservation Unit in Billings. This unit reported to H.V. Peterson in Los Angeles (later in Salt Lake City) and worked primarily on U.S. Bureau of Land Management range-moisture problems.

ESTABLISHING THE WATER RESOURCES DIVISION'S MISSOURI RIVER BASIN PROGRAM

The Flood Control Act of July 3, 1945, with its appropriation of money, set the Interior Department's Missouri River Basin Development Program in motion. Contained in this appropriation to the U.S. Bureau of Reclamation and in annual appropriations for the next quarter century were specific amounts of money identified for transfer to the other Interior bureaus that had roles in the program. Funds directed to the U.S. Geological Survey by this act for the Survey's Missouri River Project were to start the water-resources studies and to provide first-year funding for the Survey's Topographic, Geologic, and Conservation Divisions.

With four rather independent branches participating in the program, the Water Resources Division took the necessary step of naming a representative to serve as Division spokesman and to coordinate the activities of the branches in the basin. The Division chose Henry C. Beckman for this role, with the title, Regional Engineer. In early 1946, the Secretary created the Interior Missouri River Basin Field Committee

and Beckman was named U.S. Geological Survey representative on the committee by the Director. His alternate was Ralph A. March, District Engineer, Surface Water Branch, Bismarck, North Dakota. In order to provide a central figure for the coordination of all Geological Survey divisions involved in the program, the Director also designated Beckman Program Coordinator for the Survey. Beckman continued to work out of Rolla, Missouri, where he was District Engineer, Surface Water Branch, prior to his regional appointment.

The roles of the Geologic and Conservation Divisions were minor, but the Topographic and Water Resources Divisions were major participants in the U.S. Geological Survey's Missouri River Basin Project. The Geologic Division's assistance was primarily in engineering geology with emphasis on construction materials and geologic mapping. The Conservation Division completed several river surveys at the U.S. Bureau of Reclamation's request, but then dropped out of the project in 1948. The Geologic Division continued in the project until the early 1960's. The Topographic Division was funded to provide the modern topographic maps needed in planning Missouri River Basin Development Program projects.

With the transfer of funds to finance work in 1946, the Water Resources Division's MRB program was underway, but the field organization of the Division was only partly in place.

When the MRB program began, the Surface Water Branch was operating in all the basin States and had district offices in Denver, Colorado; Helena, Montana; Bismarck, North Dakota; Lincoln, Nebraska; Rolla, Missouri; and Iowa City, Iowa. Iowa, Minnesota and Missouri, however, are not "irrigation States" and were, therefore, not part of Interior's Missouri River Basin Development Program.

Surface Water Branch operations in Colorado and Wyoming were being conducted as a single district under Robert Follansbee. A.H. Tuttle was District Engineer for Montana, and North Dakota and South Dakota were combined as a single district under Ralph A. March. Douglas D. Lewis was District Engineer for Nebraska.

For several years prior to 1941, Surface Water Branch operations in Kansas were headed by J.B. Spiegel, District Engineer, whose headquarters was in Topeka. By 1941, the activities in Kansas had decreased to a level that could no longer support a district office, so Kansas was designated a subdistrict with its headquarters in Rolla. With the increased work in Kansas for the MRB program, Topeka again became headquarters for a re-established Kansas district on July 1, 1946. Spiegel was re-appointed District Engineer.

Establishing and staffing field offices and laboratories, and otherwise launching their parts of the MRB program required much greater effort by the Ground Water and Quality of Water Branches. Operation of both branches had been rather highly centralized in Washington, D.C., and neither had large staffs available for the program. The Quality of Water Branch in early 1946, for example, had only 42 members nationwide. It had neither field offices nor laboratories in the basin. Ground Water Branch operations of any significant scale generally were limited to the central and lower basin States where district offices existed.

The decision was made in early 1946 to establish a regional headquarters for the MRB program in Lincoln, Nebraska, where district offices for the Surface Water and Ground Water Branches had been in operation for several years. The Surface Water Branch named a representative to the new regional office, but his relationship to other Surface Water Branch offices in the basin was as an advisor, not as a supervisor. The regional representative of the Quality of Water Branch, however, was in charge of branch activities throughout the basin. The role of the Ground Water Branch representative lay somewhere in between. He supervised those who were assigned MRB projects in basin States where Ground Water

Branch district offices had not yet been established, and worked through the heads of district offices where such offices existed.

Roy E. Oltman transferred from the St. Paul, Minnesota, office of the Surface Water Branch to Lincoln early in 1946 to serve as head of the Surface Water Branch's Field Unit of Special Reports and Investigations.

The Ground Water Branch chose George H. Taylor as its regional supervisor. Taylor had been discharged from the Army in January 1946, was temporarily assigned to Washington, D.C., and transferred to Lincoln in July. He relieved G.A. Waring who had been in charge of the work pending the arrival of a permanent supervisor.

When the MRB program started, cooperative ground-water studies were underway in Colorado, Kansas, and Nebraska. Stanley W. Lohman was in charge of the Kansas studies until August 1945 when he moved to Denver to establish the Colorado District for the Ground Water Branch and to become its first District Geologist. He was succeeded in Kansas by Vinton C. Fischel. Also under Lohman's supervision, as District Geologist in Denver, was a limited Federal/State Cooperative Program in Wyoming. Ground-water studies in Nebraska were under the direction of Herbert A. Waite, District Geologist, Lincoln. The ground-water studies for the MRB program in these States were done largely by existing district staff with additional personnel added as needed.

There also were small Federal/State cooperative ground-water programs underway in North and South Dakota when the MRB program began. They were supervised by P. Eldon Dennis, headquartered in Grand Forks, North Dakota. The remoteness of Grand Forks from ground-water-project areas resulted in the establishment, in March 1949, of an office in Bismarck, North Dakota, for MRB program work in North and South Dakota. George A. LaRocque, Jr. on his return from military service, was placed in charge of that office.

Frank A. Swenson was selected to supervise ground-water studies for the MRB program in Montana and northern Wyoming. Swenson reported to the Ground Water Branch from Geologic Division's Military Geology Branch in early 1946. His headquarters initially was in Culbertson, Montana, but it was moved to Billings in June 1948.

Paul C. Benedict was selected as the supervisor of the Quality of Water Branch part of the MRB program. He reported to Lincoln in March 1946, from Des Moines, Iowa, where he had been working on the improvement of sediment-sampling equipment.

Benedict's principal assistant in starting the water-quality studies of the MRB program was Herbert A. (Herb) Swenson, who transferred to Lincoln from Boise, Idaho, in October 1946. Benedict looked after the sediment studies that comprised the major part of the water-quality studies, and delegated immediate oversight of the chemical-quality activities to Swenson.

A first order of business for the Quality of Water Branch was to establish laboratories for sediment and chemical analysis. The first to be placed in operation was the regional water-quality laboratory in Lincoln, which opened for business on March 6, 1946. A sediment laboratory also was established in Worland, Wyoming, during the same month. In June 1946, a sediment laboratory was opened in Dickinson, North Dakota, and, in April of the following year, sediment-laboratory operations were begun in Norton, Kansas. At about the same time, a sediment laboratory began operating in Rapid City, South Dakota.

The Water Utilization Branch representative in the Lincoln regional office was Byron C. Colby, who moved to Lincoln in April 1946.

By early 1946, all four branches were established in Lincoln, but two were in the State Capitol Building and two were in a privately owned office building. In an effort to become better coordinated, the local branch heads organized themselves into a Lincoln Staff Committee. There still was confusion, however, on the part of the public and other agencies seeking information. There were problems of misrouted mail and other communications difficulties until August, when space was found for all branches in a downtown office building.

A copy of the Office Directory as of October 1, 1950, is attached as Appendix B. This directory lists the entire Water Resources Division staff in Nebraska and members of the Ground Water and Quality of Water Branches elsewhere in the basin who reported, at that time, directly to Taylor and Benedict in Lincoln. The directory reflects the regional nature of the Lincoln office with respect to Ground Water Branch and Quality of Water Branch staffs assigned to the MRB program and, by its omission, the somewhat autonomous State-by-State operations of the Surface Water Branch.

BUDGETS AND THE DEVELOPMENT OF MISSOURI RIVER BASIN DEVELOPMENT PROGRAM POLICY

It was not intended in an early outline of this account to give the budgets of the various principals involved with the Missouri River Basin Development Program major prominence. As notes were assembled, old personnel lists examined, products of the program reviewed, and correspondence debating program policy was read, however, it became increasingly obvious that a presentation of the various budgets must precede or at least accompany, an account of the development of program policy. The Missouri River Basin Development Program budget, in the way it was legislated and administered, and in the waves its major increases and decreases created, exerted a considerable effect on the Water Resources Division's MRB program and indeed, on the Division as a whole. The word "program" here, is used in the broad sense that embraces people, organization, jurisdictional relationships, and products.

The Flood Control Act of July 3, 1945, that appropriated funds to the U.S. Bureau of Reclamation for work in the Missouri River basin contained $1,669,200 specified for use by the U.S. Geological Survey in fiscal year 1946. These funds were distributed to the four operating divisions of the Survey under the Survey's Missouri River Basin Project as follows:

Topographic	$650,000
Geologic	265,000
Conservation	300,000
Water Resources	454,200

Funds made available to the four Survey divisions by this system during fiscal years 1946-1959 are listed in table 1. Funds available to the Water Resources Division for its MRB program during fiscal years 1946-1983 are listed in table 2.

Almost as soon as the Missouri River Basin Development Program started, a disagreement surfaced between the U.S. Geological Survey and the U.S. Bureau of Reclamation over the role of the Geological Survey as related to the ground-water problems (and opportunities) of the program. The disagreement, that erupted frequently during the next 10 years, was rooted in the legislation and administration of the program budget.

Table 1.--*U.S. Geological Survey's Missouri River Basin Project allotments, fiscal years 1946-1959*

[----, no allotment]

Fiscal year	Division					
	Topographic	Geologic	Conservation	Water Resources	Director's Office	Total
1946	$650,000	$265,000	$300,000	$454,200	----	$1,669,200
1947	713,600	310,600	----	435,800	----	1,460,000
1948	1,000,000	272,800	95,200	482,000	----	1,850,000
1949	2,375,500	*315,000	*-5,000	619,500	----	3,305,000
1950	2,373,000	290,000	----	994,---	$43,000	3,700,000
1951	2,895,000	482,500	----	1,351,000	171,500	4,900,000
1952	2,050,000	360,000	----	981,500	108,500	3,500,000
1953	2,043,500	359,000	----	978,500	119,000	3,500,000
1954	950,000	155,000	----	500,000	55,000	1,660,000
1955	919,000	99,000	----	398,000	59,000	1,475,000
1956	974,000	106,800	----	609,000	70,200	1,760,000
1957	1,005,800	51,000	----	637,200	66,000	1,760,000
1958	1,053,900	52,900	----	664,100	69,100	1,840,000
1959	717,100	52,900	----	448,500	47,500	1,266,000
Total	$19,720,400	$3,172,500	$390,200	$9,553,300	$808,800	$33,645,200

* After Conservation Division transferred $50,000 ($45,000 allotment for 1949 plus $5,000 from 1948 carryover) to Geologic Division.

H. S. Beckman
March 5, 1959

Table 2--*Water Resources Division's Missouri River Basin Program allotments, fiscal years 1946-1983*[*]

[----, no allotment; e, estimated]

Fiscal year	Branch					
	Surface Water	Ground Water	Quality of Water	General Hydrology[**]	Head-quarters	Total
1946	$206,200	$100,000	$98,000	$50,00	----	$ 454,200
1947	176,268	114,285	109,677	16,955	$19,515	435,800
1948	141,268	135,615	151,000	21,185	32,650	482,000
1949	170,000	180,000	187,875	38,000	43,625	619,500
1950	330,300	283,500	305,200	20,000	55,000	994,000 e
1951	410,000	416,000	422,000	36,000	67,000	1,351,000
1952	311,000	306,000	311,000	25,000	28,500	981,500
1953	304,600	303,000	303,000	25,000	42,900	978,500
1954	161,700	153,000	157,200	----	28,100	500,000
1955	137,200	95,700	139,100	----	26,000	398,000

Table 2--*Water Resources Division's Missouri River Basin Program allotments, fiscal years 1946-1983**—Continued

[----, no allotment; e, estimated]

Fiscal year	Branch					Total
	Surface Water	Ground Water	Quality of Water	General Hydrology**	Head-quarters	
1956	212,080	153,930	206,600	3,175	33,215	609,000
1957	239,180	166,685	194,310	3,165	33,860	637,200
1958	282,895	130,500	215,365	6,330	29,000	664,100
1959	190,725	93,930	136,645	4,220	22,980	448,500
1960	269,717	173,364	132,711	4,745	23,645	609,200
1961	285,249	172,237	183,577	9,405	20,296	651,100
1962	303,382	152,369	193,588	9,407	20,550	606,200 e
1963						598,900
1964						642,200
1965						620,000 e
1966						834,200 e
1967						808,200 e
1968						757,000 e
1969						667,000 e
1970						825,000
1971						775,000
1972						714,000
1973						787,900
1974						775,700
1975						845,000
1976						870,000
1977						962,480
1978						866,000 e
1979						924,000
1980						906,200
1981						850,800
1982						698,700
1983						670,700

* Not available by organizational unit after fiscal year 1962.

** Water Utilization Branch until fiscal year 1948; Branch of Technical Coordination until fiscal year 1956.

The U.S. Bureau of Reclamation held to the opinion that since the U.S. Geological Survey's role in the program was funded initially as money appropriated to the Bureau, it held a proprietary position in setting priorities of the Survey's work. Beckman and the Surface Water and Quality of Water Branches agreed in

principle with the Bureau. The Ground Water Branch, however, backed by the Director of the Survey, believed differently. The Ground Water Branch had laid out its plans in Senate Document 191 (78th Congress, 2d Session) to which there was no disagreement by the Department or the Congress. The Branch held to its belief that funds appropriated to the Bureau and transferred to the Survey were to finance the plans described in Senate Document 191 (78th Congress, 2d Session) and that the procedure was, in itself, insignificant; how the budget was handled was no more than a matter of legislative expedience. Even though the Quality of Water Branch did not disagree with the Bureau's need for site-specific data, the Branch held the same position as the Ground Water Branch that longer-term, comprehensive studies were needed, and believed strongly in the need for interpretive reports. The Quality of Water Branch, however, abstained from assuming an adversarial role by simply doing both; it provided data as needed, then interpreted those data in the form of comprehensive reports.

Correspondence and conferences between the U.S. Geological Survey and the U.S. Bureau of Reclamation in the field began in the fall of 1947 that produced, by February 1948, a mutually acceptable "Definition of the Duties and Responsibilities of the U.S. Geological Survey and the U.S. Bureau of Reclamation Pertaining to Ground-Water Studies Under the Missouri Basin Program." (See Appendix C-1).

Almost immediately thereafter, it was discovered that a more general agreement on geologic work, including regional ground-water studies, had been signed by the Director of the Geological Survey, and the Commissioner of the Bureau of Reclamation, on November 30, 1945. (See Appendix C-2). There is no explanation for the communications lapse between Survey headquarters and the field during this period of rather intense negotiation. Taylor supposed that the agreement was developed by the Geologic Division without the knowledge of the Water Resources Division.

But even with the two agreements in effect, the differences in program philosophy between the U.S. Geological Survey and the U.S. Bureau of Reclamation were not resolved. At considerable risk of oversimplification, the problem lay between the Survey's adherence to its "Water Plans for Missouri River Basin" and the emphasis in those plans on a series of areal ground-water studies, and on the Bureau's need for site consultation directly related to current project planning and construction. The Survey's program of ground-water investigations was based largely on a series of areal studies, each of which required a schedule of data collection and interpretation that spanned several years of effort to produce a report that measured up to Survey standards. The Bureau, in contrast, needed rapid results and ready availability of ground-water information, and it pressed strongly for ground-water assistance more responsive to its immediate and frequently changing priorities.

In fact, it was conceded that the U.S. Bureau of Reclamation was not interested in nor did its needs require the comprehensive and well-rounded reports that are prescribed by U.S. Geological Survey standards. In many instances, the Bureau's needs were met by supplying data or parts of a report and, from its point of view, the extra time and work involved in preparing comprehensive reports not only impeded the Bureau's planning, but unjustifiably increased the costs of the investigations. There are instances when the Bureau had lost interest in a report and preferred the study be ended when, during the course of the project, the Survey had obtained the data needed by the Bureau. Survey policy, however, was and is, to complete as comprehensive a report, as is practicable, and to make the results available and useful, not only to Federal and State cooperators but to the public as well. Reconciling the conflict between the two points of view was difficult.

Another vexing aspect of the problem was the reimbursable nature of the costs of water studies. By law, all investigational, planning and construction costs had to be charged to specific projects in the Missouri River basin. This was not much of a problem until the early 1950's when it was realized that the

costs of the U.S. Bureau of Reclamation's projects were about twice the initial estimates. In 1955, the Bureau asked the Secretary to prepare legislation so that about 60 percent of investigation funds could be declared non-reimbursable. The request was made to the Secretary, possibly to Congress, and the outcome is not known to the writer. It appears likely, however, that higher authority agreed, because the intensity of this issue was obviously decreased. In later years, program funds were, in fact, determined to be non-reimbursable.

The problems were temporarily exacerbated in mid-summer 1949 when the Lower Missouri Region (Region 7) of the U.S. Bureau of Reclamation distributed the November 1945 memorandum of understanding and the "Definition of the Duties of the U.S. Geological Survey and the U.S. Bureau of Reclamation Pertaining to Ground-Water Studies Under the Missouri Basin Program" with its own statement on ""Procedures and Policy Regarding Ground-Water Investigations, Region 7" (Appendix C-3). The "Definition of the Duties ***" statement (Appendix C-1) was that developed largely by the Water Resources Division, but in consonance with Bureau field staff.

The intended effect of the U.S. Bureau of Reclamation Region 7's policy statement was to impart practical and workable substance to the 1945 memorandum of understanding and to the 1948 "Definition of the Duties ***" statement by recognizing and accommodating the U.S. Geological Survey's concern with areal and general ground-water studies and the Bureau's concern with site-specific ground-water problems. The policy statement even provided a yardstick to help distinguish between the two types of ground-water problems. Region 7 noted the availability of ground-water specialists assigned to several offices and divisions of the Bureau for assistance in those ground-water problems that would be retained within the Bureau.

An enduring aspect of the U.S. Bureau of Reclamation Region 7's policy statement was the formalization of a procedure to fully describe and rank in priority order those elements of ground-water assistance to be requested of the U.S. Geological Survey. Those elements were to be relatively free of ad hoc changes in priority. The submission of water-resources information needs, including surface water and water quality, ranked by priority was adapted by other Interior bureaus and remained as the cornerstone of planning the MRB program each year by the Water Resources Division.

A copy of the U.S. Bureau of Reclamation Region 7's policy statement went to its headquarters and stimulated the Commissioner's office to write to the regional offices of the Bureau in Denver and Billings. The Acting Assistant Commissioner's memorandum of September 20, 1949, made it clear that the primary objective of the U.S. Geological Survey's program was "*** to provide for a broad comprehensive study of the ground-water resources of the basin in order to eliminate the existing deficiency in ground-water data." The secondary objective of the Survey's program was "*** to provide *** specific ground-water information for the planning, design, and operation of *** projects ***" The Acting Assistant Commissioner also asked that the priority-of-needs approach be replaced with "*** clear objective statements of the problems with the request that the Survey solve those problems." The priority procedure, however, remained in place. The Acting Assistant Commissioner also advised against dividing the ground-water studies in a way that gave the appearance of two competing ground-water programs in Interior.

The suggestion that statements of the problems be substituted for data needs ranked by priority was made again in the mid 1970's. This time, however, the suggestion came from within the Water Resources Division and was aimed not at the U.S. Bureau of Reclamation, but at the other Interior bureaus whose experience in transforming data into problem solutions was considerably less than in the Bureau. Again, the suggestion was not successfully implemented.

Protagonists on both sides of the issue used the Missouri River Basin Development Program budget procedure to support their contention. There were those in the U.S. Bureau of Reclamation who believed that, because program funds came initially into their budget, the Bureau was entitled to call the major program shots. Others in the U.S. Geological Survey contended that the budget procedure was a mechanism of legislative convenience and the administration of programs supported by these transferred monies was to be no different from those supported by appropriations made directly to the Survey, except that the work must be within the Missouri River basin.

In a statement prepared in July 1954 in an effort to settle the argument by logic and analogy, Beckman said:

> "The concept that is held of the Missouri Basin program of the Geological Survey has a vital bearing on the way it should be conducted.
>
> "One concept might be that the Survey's Missouri Basin program is identical with its regular National program as to (1) the permissible uses of the funds and (2) the objectives and nature of the work to be performed, so long as it is within the physical boundaries of the basin. If this is the correct view, the Survey should have full latitude to devise its program to best fulfill the overall need for this information without giving preference to the needs of any single agency.
>
> "A second concept might be that the Missouri Basin program was intended by the Budget Bureau and the Congress to be a complement to the Survey's regular program and that it should be designed primarily to supply the basic information needed by the Interior agencies in developing the water and related land (including mineral) resources of the basin; and thereafter to meet the needs of other Federal agencies in this field as fully as practicable. As the Bureau of Reclamation's part in this program is considerably larger than that of the other Interior agencies, Reclamation's needs would warrant primary, but not sole, consideration.
>
> "No pronouncement by the Bureau of the Budget nor any act of the Congress specifically states which of these concepts is the correct one. There are, however, many indirect sources of evidence which tend to uphold the second concept."

Beckman endorsed the second concept and cited several incidents or examples that supported or helped formulate his point of view. Although his opinion appears to have been held also by other Interior bureaus and by other U.S. Geological Survey participants in the program, including the Topographic, Geologic, and Conservation Divisions, his program philosophy was acceded to but not fully accepted by the Ground Water Branch.

Beckman's statement, forged through 10 years of personal association with the program during its formative years, is considered sufficiently perceptive that it is retained in this account as Appendix D.

The issue was never resolved by force of logic, strength of persuasion or even by fiat. It simply became moot when the bottom dropped out of the budget in fiscal years 1954 and 1955. Then and since, there was neither money nor staff to continue the endeavor of areal ground-water studies at the scale that was underway in the halcyon days of the late 1940's and early 1950's.

The Water Resources Division's MRB program budget contained extraordinary experiences for the Division. Organizing, staffing, and operating on the increasing budgets that peaked at about $1.35 million in fiscal year 1951 was difficult in many ways, but the marked decrease to about $0.4 million by fiscal year 1955 was traumatic. Particularly hard hit by this precipitous decrease were the Ground Water and Quality of Water Branches, which, during the first few years of the MRB program, had established and staffed field and regional offices expressly for MRB program work.

It was during this period of budget decreases that the distribution of funds directed to the U.S. Geological Survey for the use of its four divisions was questioned. The Topographic and Water Resources Divisions were much more amply funded than were the Geologic and Conservation Divisions. For example, the Topographic Division, during the first 14 years of the Survey's Missouri River Basin Project, received about $20 million, or about twice that that allocated to the Water Resources Division.

When Missouri River Basin Development Program cuts had to be made in the middle 1950's, the U.S. Bureau of Reclamation had decided topographic and geologic mapping had caught up with their planning, and that program adjustments should spare, insofar as possible, the water-resources studies In a letter dated October 23, 1953, the Commissioner of the U.S. Bureau of Reclamation requested the Director of the U.S. Geological Survey, to re-distribute funds between topographic mapping, geologic mapping, and water-resources studies to avoid what was termed "*** an intolerable reduction in water-resources investigations as compared to topographic and geologic mapping". The Commissioner's request was denied.

The Office of Management and Budget, then the Bureau of the Budget, evidently did not care to see the practice continued of appropriating Missouri River Basin Development Program funds to the several Interior bureaus via the U.S. Bureau of Reclamation's budget. In fiscal year 1955, the Bureau of the Budget took "other Interior" funds out of the Bureau of Reclamation's budget and made each bureau responsible for its share. Congress objected, overrode the Bureau of the Budget and restored those monies to Bureau of Reclamation's part of the Public Works budget to keep the program budget and possibly the reimbursability concept intact.

The Missouri River Basin Development Program budget for the U.S. Geological Survey and other Interior bureaus remained in the U.S. Bureau of Reclamation's appropriations until the early 1970's. In fiscal year 1971, the House Public Works Committee reversed its 1955 decision and asked that the various bureaus in Interior make provision for their program requirements in their regular budget estimates, beginning in fiscal year 1972.

Also in fiscal year 1972, the U.S. Bureau of Reclamation, in company with other Interior bureaus, again requested the Director of the U.S. Geological Survey, to adjust the proration of the Survey's Missouri River Basin Project funds between the Topographic and Water Resources Divisions to provide greater financial support for needed water-resources studies. This time, the Topographic Division acceded, and ordered a $50,000 transfer of its budget base to the Water Resources Division effective the following fiscal year, to be repeated in successive fiscal years until an as-yet-undefined parity was reached. The first fiscal year's transfer was made, but then the division's share of the Missouri River Basin Project budget became absorbed within the Federal-Program budgets of each division, rapidly lost its identities, and no further transfers were made.

In the Water Resources Division, the MRB program budget was placed within the Collection of Basic Records (CBR) part of its Federal-Program budget and identified as "MRB" for a few years. The "MRB" label was then deleted, and the MRB program was wholly integrated with other components of the CBR part of the Federal Program in the a budget process. Funds for MRB program activities continued to

decrease and, by fiscal year 1976, the budget estimates and justifications did not acknowledge an MRB program.

There had been speculation throughout the existence of the Water Resources Division's MRB program over how the MRB program budget might have fared had it been integrated into the Federal Program of the Division rather than having been a relatively minor element of the budget of the U.S. Bureau of Reclamation. A graphical comparison between the Division's Federal-program and MRB program budgets, both adjusted to the 1972 level of inflation, for fiscal years 1946-83 is shown in figure 1. During this period, Federal-Program budget generally increased steadily, but was subject to few serious reversals. In some contrast, the MRB program budget was unstable during its first 15 years, and then generally decreased until funding ended in fiscal year 1983. The instability might be attributed, in part, to the dependence of the budget, during fiscal years 1946-72, on Public Works appropriations, and, therefore, subject, at times, to impoundment via Executive Order. There are no breaks in the graph of MRB program funds that can be readily tied to those years when the MRB program budget became the responsibility of the U.S. Geological Survey or when the MRB program lost its identity.

It must be acknowledged that direct comparison between the two budgets might be misleading in view of the significant changes in content of both programs during fiscal years 1946-1983. In the late 1940's, much if not most of the Federal Program supported the collection of hydrologic records and relatively little support was given to research or areal studies. By the early 1980's, the principal thrust of the Federal Program was in research and complex areal studies that transcended local or State interests. The evolution of the MRB program was in the opposite direction. It, paradoxically, changed from an early, substantial emphasis on areal studies to a program devoted largely to the collection of site-specific hydrologic data.

MATURING YEARS

The organization of the Water Resources Division developed rapidly during the early years of the Division's MRB program. Significant factors in this development were the increasing MRB program budgets for a few years, a steady expansion in the Division's Federal/State Cooperative Program, and work for other Federal agencies.

By the end of fiscal year 1952, there was a Ground Water Branch office in each basin State and a Surface Water Branch district office in all but South Dakota and Wyoming. The Lincoln regional offices had developed, as Taylor had planned, into a technical and administrative center for ground-water studies for the MRB program throughout the basin. Taylor had created a hydrologic laboratory in Lincoln to make permeability, specific yield, and other hydraulic tests of soil and rock with A. Ivan Johnson as its Chief. Within a short time, however, the hydrologic laboratory had extended its service area to projects well beyond the boundaries of the basin. Taylor also had organized and staffed a reports-assistance group to help process MRB program ground-water reports.

Within a few years of its establishment, the Quality of Water Branch laboratory in Lincoln had expanded to nearly 40 employees. Its outposts in the basin were termed Area Offices and were located in Norton, Kansas; Rapid City, South Dakota; and Riverton and Worland, Wyoming. Satellite sediment laboratories, largely to minimize the logistical problems of large quantities of sediment samples, were operated in those cities. The Quality of Water Branch organization provided for no "district" offices until the mid-1960's.

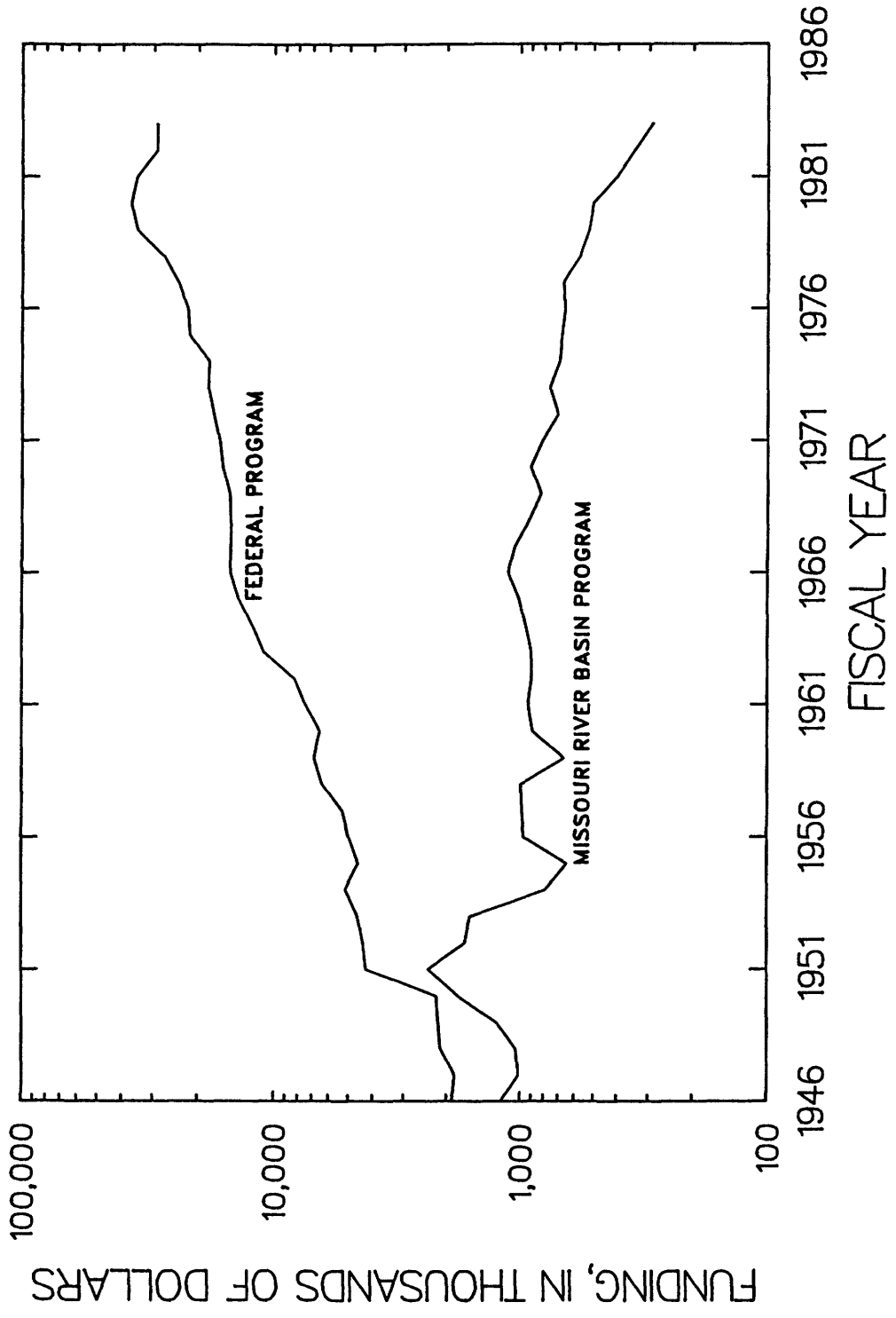

Figure 1.—Graphical comparison of the Water Resouces Division's Federal-Program and Missouri River Basin Program budgets, adjusted to 1972 constant dollars.

The budget for the MRB program peaked in fiscal year 1951 and then decreased rapidly for the next 2 fiscal years. Staffing and field activities remained at rather high levels through early fiscal year 1953. A copy of the Water Resources Division's personnel directory showing staff and offices in the basin, by States, as of January 1, 1953, is attached as Appendix E.

The area served by the Lincoln water-quality laboratory expanded beyond the boundaries of the Missouri River basin and eventually included 10 States. Then, as the MRB program was reduced and water-quality laboratories were established elsewhere, the regional role of the Lincoln water-quality laboratory decreased and, by 1971, it served only the Water Resources Division's programs in Nebraska. In the early 1950's the Rapid City sediment laboratory burned and was not replaced. The Dickinson sediment laboratory ceased operations in 1953 and the sediment laboratory in Norton was closed in 1958. The Worland sediment laboratory survived until August 1982 when it too ceased operations.

The Water Utilization Branch became the Branch of Technical Coordination (later the Branch of General Hydrology) and ended its active participation in the MRB program when the budget was decreased markedly in fiscal year 1953.

The momentum developed by the extensive ground-water studies prior to the severe budget decreases kept the Lincoln regional staff of the Ground Water Branch busy for a couple more years after the budget collapsed. Even though the project staff was decimated (for example, during 1954, 6 of the 7 engineers and geologists assigned to the MRB program ground-water studies in Montana were transferred to jobs elsewhere in the country) there remained the need to complete reports on work done prior to 1954. These tasks were largely completed by 1956. The hydrologic laboratory that had been in operation in Lincoln since 1952 was moved to Denver to provide service nationwide to ground-water projects.

In 1957, there was a reorganization of the Water Resources Division that caused a re-shuffling of administrative duties in the MRB program. The Division reorganization and administrative changes created no significant effects on the technical content or field activities of the MRB program. The reorganization did, however, deal out part of the original cast and bring in some new players.

A principal objective of the reorganization was to decentralize technical and administrative supervision of field activities from Washington, D.C., to several area offices. This was done by establishing and staffing the position of Division Hydrologist in each of four regions of the country. Beckman became the first to occupy that position in the area designated "Mid-Continent Area" with headquarters nominally in St. Louis. Beckman continued to operate for a brief period out of Rolla, however, and then retired in 1957.

The Rocky Mountain Area, which was adjacent to and west of the Mid-Continent Area, included the high-plains and mountain States to the Continental Divide and, therefore, included the Missouri River basin and its program. In 1957, S. Keith Jackson was named Division Hydrologist for this area and replaced Beckman as the U.S. Geological Survey member of the Interior Field Committee and as coordinator of the Water Resources Division's MRB program activities. Denver was selected as the headquarters city for the Rocky Mountain Area. The Rocky Mountain Area office (later Central Region) and its succession of Division (later Regional) Hydrologists continued to coordinate the MRB program.

Along with the Water Resources Division reorganization, the branches decentralized their operation by establishing the positions of Branch Area Chief for each branch in each of the area offices. This provided a staff for each Division hydrologist of senior representatives of the four technical branches of the Division. Also during 1957, Taylor was given the new job of operations research engineer for the Ground Water Branch, with his headquarters remaining in Lincoln. He continued work until early 1961

when he retired. In May 1958, Benedict was named Chief of Research for the Quality of Water Branch with headquarters in Washington, D.C.

At the district level, however, branch operations were still administratively and organizationally independent of each other. During the early and mid-1960's, Surface Water Branch district offices were established in South Dakota and Wyoming, upgrading the subdistrict offices that had been supervised out of Bismarck and Denver, respectively. There were, now, district offices for surface-water and ground-water operations in each Missouri River basin State. In some of the States, however, the branch district offices were in different cities.

The Quality of Water Branch did not establish district offices in each State, but designated selected offices that had been mainstays in the MRB program as district offices, each with two or more States under their responsibility. Under this arrangement, Worland, Wyoming, became the district headquarters for quality-of-water work in Wyoming and Montana, and Lincoln, Nebraska, became the district office for all the remaining basin States except Colorado, which became part of the Salt Lake City, Utah, district operation.

During the 1960's, the reorganization continued toward integration of branch activities in the field. This was done by abolishing branch designations and combining ground-water, surface-water and water-quality activities of the Division under a Water Resources Division District Chief, usually selected from the incumbent branch District Chiefs and timed to coincide with other local personnel changes, such as retirements or transfers. These changes were completed in the Missouri River basin States by 1967. In this phase of the reorganization, the position of Branch Area Chief was eliminated.

DEVELOPMENT OF WATER RESOURCES DIVISION ANNUAL OPERATIONAL PROGRAMS

During the first 8 or so years of the Missouri River Basin Development Program, meetings between the Water Resources Division, the U.S. Bureau of Reclamation and other Interior bureaus to arrange or adjust each participant's operational programs were frequent. Those were years of unstable budgets and disagreements over the role of the Ground Water Branch in the program, and there were several layers of bureaucracy involved in formulating programs.

In the earliest years, each participant's proposed operational program for each year was reviewed in the Office of the Secretary. The Secretary's Office, however, soon delegated this function to the Interior Missouri River Basin Field Committee. Their review, however, was largely obligatory, and resulted in few if any substantive changes. The Water Resources Division kept the Field Committee informed about operation-program details until 1972. Then, when the Field Committee's area of interest was determined by Executive Order to be comprised of States rather than river basins, this practice was abandoned.

A procedure, schedule, and format for planning each year's operational program was developing during these early years that, for the most part, has withstood the test of time.

About mid-fiscal year, the Water Resources Division asked each participating Interior bureau at their highest field level to examine their needs for water-resources information for the following fiscal year. The bureaus were requested to provide lists of needs relevant to the Missouri River Basin Development Program, taking into account the ongoing operational programs, and indicating the relative priority of each item, including items of ongoing work requested by that bureau. In the parlance of recent times, this was "zero-base" budgeting in which all work items, old and new, competed for a place in the next year's

operational program. Each bureau provided their priority lists to the Water Resources Division some 4 or 5 months before the beginning of the new fiscal year.

Meetings were then held 3 or 4 months before the beginning of the new fiscal year in the Denver (for the lower basin) and Billings (for the upper basin) regional offices of the U.S. Bureau of Reclamation. Each of those meetings, attended by representatives of State or regional offices of Interior bureaus that were involved in the program, served as a forum for discussion of each item of work; its cost, why the information was needed within a framework of possible alternatives and, in some instances, a re-examination of work items and priorities. This pair of annual meetings provided the basis for the Water Resources Division at its regional level to prepare a preliminary operational program for the following fiscal year. It was preliminary in that actual funds were not yet available, only an estimated level of funding.

The preliminary operational program of the Water Resources Division, inevitably scaled down from the total of the requests, was then returned to the other Interior bureaus for final adjustments. When the appropriated money became available, the operational program was then given a fine tuning and set into motion.

Beginning with fiscal year 1977, the Water Resources Division consolidated all elements of the Federally funded activities of the Division at National Headquarters. The former MRB program then became one of six elements of the CBR component of the Federal Program for which final funding decisions and allocations of money were headquarters responsibilities. The procedure for putting the annual operational program together in the field remains the same today. The six elements of the CBR component of the Federal Program are:

1. Records in support of adjudications and compacts.
2. National streamflow quantity/quality accounting network.
3. Hydrologic-benchmark network.
4. Records in support of other Interior agencies.
5. Records in support of Federal agencies outside the Department of the Interior.
6. Records in support of Federal hydrologic interests.

Item 4 in the above list is the former MRB program. From habit, or lack of a more descriptive term, it is still referred to in the field as the MRB program.

Although the MRB program was eclipsed by other programs of the Water Resources Division that produce water-resources information, State water agencies in the basins view the remnant of the MRB program as an important supplement to their cooperative programs with the Division. Their keen interest in the MRB program was brought to the attention of the Division in the mid-1960's when the Division was criticized by the Kansas Water Board for discontinuing the operation of an MRB program-supported gaging station, which provided streamflow records important to the State of Kansas. Through fiscal year 1983, the Division took special precautions to keep State agencies informed about changes in the MRB program and, particularly, to give State agencies time to accommodate, in their budgets, items of MRB program work of such low priority that they were destined to be dropped from the MRB program. This was not easy to do, nor in all cases successful. Since fiscal year 1983, the Division has continued its policy of informing States agencies of Division plans affecting the remnant of the MRB program. Even today, there is not unanimous agreement with Division plans.

The marked budget decreases in fiscal years 1953 and 1954 decimated the Ground Water Branch staff working in the MRB program. These budget constraints and the emergence of other high-priority

ground-water studies elsewhere in the Nation combined to markedly decrease the ground-water role in the MRB program to little more than the maintenance of observation wells. This situation prevailed through the mid-1960's when a series of studies of ground-water resources of Indian reservations in the Dakotas and Montana was started for the U.S. Bureau of Indian Affairs.

It was also during the mid-1960's that the MRB program provided funds for studies of the hydrology of "prairie potholes" in North Dakota. The issue was drainage and reclamation versus the maintenance of natural habitat for waterfowl.

When development of coal became an issue in the 1970's, the focus of the MRB program shifted somewhat to accommodate some coal-hydrology needs of other Interior bureaus, particularly the U.S. Bureau of Land Management. MRB program funds were used to augment cooperative studies in several North Dakota counties where there were extensive Federally owned deposits of coal. The addition of MRB program funds to those studies permitted a more detailed examination of the water resources associated with coal than would have been possible otherwise.

Still, the MRB program in its later years was largely a water-data activity, providing streamflow, chemical, sediment, and ground-water-level biological data at sites where such information was needed in support of Interior programs in the basin. In fiscal year 1979, a typical later year of the program, the program provided for the collection of streamflow and water-quality data at about 165 stream sites and other kinds of data, mostly water levels, in some 2 dozen other areas. The composition of the program for fiscal year 1979 is contained in Appendix G.

TECHNICAL CONTENT AND PRODUCTS OF THE WATER RESOURCES DIVISION'S MISSOURI RIVER BASIN PROGRAM

The proposed, initial contributions of the four branches to the Water Resources Division's MRB program are summarized on pages 6 and 7. Re-stated briefly, the Surface Water Branch was to construct and operate 125 gaging stations. Life was more complicated for the Ground Water Branch that had staked out a program based on comprehensive investigations and complete reports on ground-water systems in the basin. This resulted in the previously reported disagreements with the U.S. Bureau of Reclamation. The Quality of Water Branch was to collect and analyze samples of stream water from some 3 dozen sites for their chemical and sediment characteristics. The Water Utilization Branch had a rather free hand in selecting its mission and chose, generally, to analyze trends in the relation between precipitation and runoff.

The Surface Water Branch districts fulfilled their obligations to the MRB program free of the major issues that bedeviled the relationship between the Ground Water Branch and the U.S. Bureau of Reclamation. The initial Surface Water Branch obligation was to install and operate 125 gaging stations distributed as follows:

Colorado	10	North Dakota	13
Kansas	13	South Dakota	13
Montana	36	Wyoming	18
Nebraska	22		

Most of the stations were in operation by June 30, 1947.

Another 15 or so gaging stations needed to meet construction and operating needs of the U.S. Army Corps of Engineers along the mainstem of the river also were built and operated for, and funded by, the Corps.

By the end of 1947, water samples for chemical analyses by the Quality of Water Branch were collected daily at 12 gaging stations operated by Surface Water Branch. Samples for chemical analysis were collected less frequently at an additional 63 gaging stations. Samples for sediment analysis also were collected regularly at 41 gaging stations and irregularly at a number of other gaging stations. Surface Water Branch personnel assisted in collecting and forwarding the samples to the water-quality laboratories and, in return, the Quality of Water Branch offices in Norton, Kansas; Worland, Wyoming; and possibly in Rapid City, South Dakota, operated gaging stations in their areas of operations and provided streamflow records to Surface Water Branch offices for publication in the annual Water-Supply Papers.

Floods in 1948, 1950, 1952, 1953, and 1956 provided a somewhat serendipitous dividend to the MRB program. Peak-discharge determinations were made that provided valuable information for project design. Water-Supply Papers 1137-A, 1260-B, and 1320-E listed in Appendix F contain reports on those floods. Peak discharges, particularly those of April 1956, were a basis for re-evaluating the design of spillways at mainstem dams.

In his report to the Water Resources Division conference held in Chicago, May 24-27, 1954, Taylor chose as the text for his comments, the 24th verse, 6th chapter of the Book of Matthew: "No man can serve two masters ***." The point Taylor was making, somewhat dramatically, was the difficulty he was experiencing in satisfying the U.S. Bureau of Reclamation's need for ground-water data limited to specific project sites and his deeply rooted conviction that his group must do more in order to satisfy the ultimate objectives of the Missouri River Basin Development Plan. Taylor's goals, which were shared by Benedict and the Quality of Water Branch, were to broaden the investigations and to publish the results in narrative, tabular, and map format for the benefit of other agencies and the public, and according to U.S. Geological Survey standards. His deference to the Bureau's view of proper ground-water assistance was not wholehearted. His insistence on more complete studies and reports is amply illustrated in the list of reports resulting from the Division's MRB program comprising Appendix F. Most of the 157 interpretive reports listed are in accordance with Taylor's and Benedict's view of the program.

The Quality of Water Branch had the better of both worlds. It supplied data on the chemical and sediment characteristics of streams at sites where such information was requested by the U.S. Bureau of Reclamation and other Interior bureaus, then collaborated with the Ground Water Branch in the preparation of interpretive reports, thereby maximizing the utility of the water-quality data. A typical report of this type is "Ground-water resources of the Riverton irrigation project area, Wyoming, by D.A. Morris, C.M. Hackett, K.E. Vanlier, and E.A. Moulder, with a section on Chemical quality of ground water by W.H. Durum, 1959" which is Water-Supply Paper 1375 in Appendix F.

Interpretative reports by the U.S. Geological Survey on various aspects of the water resources of the Missouri River basin, funded partly or entirely by the Water Resources Division's MRB program, total 157. Most were published by the Geological Survey, however, State interest in the results of the program is evident by State-agency publication of a significant number of the reports. The interpretive reports contained in Appendix F are summarized below by State and by type of publication:

Publication Type	State								
	Colorado	Kansas	Montana	Nebraska	North Dakota	South Dakota	Wyoming	Multi-State	Total
Water-Supply Paper*	5	1	9	20	5	3	8	5	56
Professional Paper*				1	3				4
Circular*			3	11	4	3	11	3	36
Hydrologic-Investigations Atlas*	1		2	3	1	5		1	13
Water-Resources Investigations Report*			1	1					2
Open-File Report*	1	3	4	1	4	9		2	24
State publication		6	1		7	3			17
Other		1	4						5
Total	7	11	24	37	24	23	19	11	157

* U.S. Geological Survey report series.

For many years records of stage or discharge of streams and contents or stage of lakes and reservoirs were published in a series of U.S. Geological Survey Water-Supply Papers entitled "Surface Water Supplies of the United States." These Water-Supply Papers were published annually; one for each major drainage area of the country. Surface-water records obtained for the MRB program were inserted in downstream order with surface-water records obtained by the Geological Survey for other programs and published in Water-Supply Papers for the entire Missouri River basin (designated in this series as Part 6). Through September 30, 1960, the end of water year 1960, these Water-Supply Papers were in an annual series; then the records were compiled in 5-year periods for 1961-65 and for 1966-70. Since 1961, surface-water data have been released by the Survey in annual reports on a State-by-State basis.

Selected records of ground-water levels from the MRB program and other Water Resources Division programs were published until 1974 in a series of Water-Supply Papers entitled "Ground-Water Levels in the United States", which were published at 5-year intervals.

Records of chemical quality, water temperature, and suspended sediment were published through 1970 in a companion series of Water-Supply Papers entitled "Quality of Surface Waters of the United States." Water-quality data obtained for the MRB program until 1971 were included in this series.

Beginning with water year 1971, surface-water, ground-water and water-quality data have been published by the U.S. Geological Survey in a single, annual report for each State.

The water-resources data obtained under the MRB program are, therefore, contained in many U.S. Geological Survey publications. Although the designation of each series and the geographical coverage of each have changed, the format for each data set generally has remained unchanged. Streamflow data obtained under the MRB program through fiscal year 1983 will be found in about 180 publications, ground-water-level data in about 19 publications, and water-quality data in about 115 publications of the Geological Survey.

SOME OBSERVATIONS ON THE EFFECTS OF THE MISSOURI RIVER BASIN DEVELOPMENT PROGRAM ON THE WATER RESOURCES DIVISION

There can be little argument that the Missouri River Basin Development Program strongly affected the Water Resources Division. When the program began, funding for water-resources studies was minimal, field staff was small, the Division organization was immature, and much of the Division's administrative and technical direction was centralized in Washington, D.C. Less clear, however, are the relative values of those effects or even if some effects are positive or negative. One of the earliest effects was clearly negative.

The State Geologist of South Dakota had started an observation-well program in 1936 and, in 1939, began cooperating with the U.S. Geological Survey to enlarge the program. The State and Survey each contributed $400 per year to the program through fiscal year 1945. In fiscal year 1946, when greater funds became available through the Missouri River Basin Development Program, the State Geologist decided his contribution was no longer needed, and he withdrew from the cooperative program. Although cooperation was later restored, this was viewed at the time as a significant reversal attributable to the MRB program.

There are no other negative effects of this type in the record. Indirect evidence, however indicates the likelihood that in States where the program was large, participation by State agencies in cooperative water-resources investigations was less than it might have been otherwise.

On the positive side is the effect on the Water Resources Division of those hydrologists who served in the program early in their careers. It would be a long and impressive list of those whose first or early assignments were in the program and who later became the administrative or technical leaders of the Division. Program experiences contributed to the careers of engineers, geologists, chemists, and soil scientists who were later selected as district and branch chiefs, assistant regional and associate chief hydrologists, and supervisors of research programs of the Division. Even longer would be the list of those who became productive research hydrologists, staff members, and supervisors at several levels of the Division organization.

The reorganization of the Water Resources Division toward integration of its surface-water, ground-water, and water-quality activities might well have been hastened by program experiences. At the beginning of the program, Division participation was entirely by its autonomous branches. Each of the four branches planned, presented, defended, and operated its part of the program independently of (and perhaps in competition with) the other branches.

Collection of samples by Surface Water Branch personnel for the Quality of Water Branch and operation of gaging stations by Quality of Water Branch personnel for the Surface Water Branch in the

Missouri River basin were exceptions to the rule of independent branch operation. Samples of ground water were collected by Ground Water Branch staff, and it was not until the program was well underway that an agreement was reached that formalized coordination between the Ground Water and Quality of Water Branches in those projects where the quality of ground water was to be investigated. Memorandums written in the spring of 1954 discussed the need for joint planning, scheduling, and financing the work, and promulgated standards for treating and preserving samples, and making field determinations. A landmark feature of these memorandums was the groundwork laid for collaboration between the branches in jointly conducting the field work and preparing the reports. The expressed need for Quality of Water Branch participation in reports, conspicuous in the program, was a compelling influence in the emergence of the water-quality staff from its laboratory environment to the role of full participant in water-resources studies.

The advantages to the Water Resources Division, in terms of staff, management, and budgetary efficiencies, and to those who used the information of integrated water-resources activities became apparent early in the program. Experiences in the program were by no means the sole influences in the reorganization and integration of Division activities, but were factors that led to the several phases of Division reorganization in the 1950's and 1960's.

In the mid-1960's, river-basin planning came into vogue and the U.S. Geological Survey was asked to provide summaries of water-resources information in a format suitable for the preparation of a "framework plan" for development of water and related land resources of the Missouri River basin. Maps showing well yields, depth to ground water, saturated thickness of rocks, and chemical quality, and reports on flow characteristics of streams were prepared by the Water Resources Division and published by the Missouri River Basin Interagency Committee. These reports were the cornerstone of the water-resources analyses required for the planning effort and contributed significantly to the planning effort. Without the availability of information obtained for the program, the reports would have fallen short of meeting planning needs.

Then, in the mid-1970's, when national attention was given to the enormous coal deposits contained in the upper Missouri River basin, appropriations were made to the U.S. Geological Survey to determine the availability of water for coal development and to assess and predict the water-related environmental effects of large-scale coal mining. Again the water-resources information obtained for the MRB program provided a base on which to build the Coal-Hydrology Program. Particularly valuable were sediment data obtained during the early days of the program, but not obtained in later years as costs of detailed sediment records escalated.

The water-resources investigations conducted for the Missouri River Basin Development Program had an indirect, but beneficial effect on training of Water Resources Division hydrologists. In the early days of the program, Taylor recognized the need for staff training in quantitative ground-water hydrology and organized one of the first schools for hydrologists engaged in ground-water studies under the program. The school was held in Lincoln in 1951 and is considered the forerunner of ground-water short courses that were held in other locations in the Nation, and that later evolved into a major element of the U.S. Geological Survey's National Training Center established in Denver for all hydrologic disciplines.

The Missouri River Basin Development Program has passed into history, but the U.S. Geological Survey's participation in that program continues to benefit the community of hydrologic-information users not only within the basin but elsewhere. There remains a wealth of streamflow, ground-water and water-quality information for water-resources planners and administrators within the basin. Improved investigative and analytical techniques, data-processing systems, training, and even administrative improvements that are partly rooted in program experiences continue to pay dividends to those who rely on the U.S. Geological Survey for hydrologic data and interpretive analyses.

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APPENDIX A

U.S. GEOLOGICAL SURVEY's

"WATER PLANS FOR MISSOURI RIVER BASIN"

GEOLOGICAL SURVEY
WATER PLANS FOR MISSOURI RIVER BASIN

The plans of the Geological Survey for investigational work in the Missouri River Basin during 3 years of the post-war period provide for expansions of activities beyond current programs as follows:

	First year	Second year	Third year	Total
For installation of 129 new gaging stations, at an average cost of $1,500 per station	$67,500	$66,000	$60,000	$193,500
For operation of new stations, at $600 annually per station	27,000	53,400	77,400	157,800
For groundwater studies in regions where problems are most pressing; investigating the equivalent of about 30 counties (out of say 400 counties in the basin)	100,000	200,000	200,000	500,000
For quality of water studies, including both chemical quality with special reference to uses in agriculture and industry and to silt content in its relation to reservoir and channel capacities	98,000	75,000	75,000	248,000
For utilization studies related to problems in water power, navigation, irrigation, and range development and operation	50,000	50,000	50,000	150,000
Total	$342,500	$444,400	$462,400	$1,249,300

As an authorized Federal agency for making general investigations of the Nation's water resources, the Geological Survey makes surveys and reports that are basic to the development and utilization activities of all agencies, to the judication and administration of rights, and to the determination of equities. For these purposes the Survey measures the daily flow of surface streams; records fluctuations of lakes and reservoirs; investigates ground water to ascertain availability, depth, recharge, discharges, and storage; makes chemical analyses of both surface and ground water with special reference to their fitness for use in agriculture and industry and to their proper treatment for public and domestic water supplies, industrial processes and steam-boiler use; and prepares statistical and interpretative reports--all with view to furnishing reliable information that is essential as a basis for the full and best use of the water resources.

It serves also as adviser to the State Department in connection with international questions arising from the utilization and physical control of boundary waters.

The information collected and published by the Geological Survey is used by Federal, State, and municipal officials, in connection with administration, operation, and utilization; by engineers and superintendents in connection with planning, design, construction, and operation; by financiers in connection with the security of investments; and by lawyers and by courts in connection with titles, equities, and damages. Its work is financed in part by direct congressional appropriation, in part, by cooperative funds provided by States and municipalities and, in part, by funds furnished by other Federal agencies. Since the Missouri River Basin (17 1/2 percent of continental United States) is international and extends through wide ranges of latitude (10 degrees) and longitude (22 degrees) has great diversity of resources, both mineral and agricultural, its water problems are many, varied, and important. As precipitation is heaviest in the mountains, water is generally most abundant in the western part where there are many perennial surface streams. Problems related to its availability and use arise in all parts of the basin and are very acute in many sections of scant precipitation and few small surface streams.

The Survey's current program of water investigations in the Missouri River Basin is conducted in cooperation with all of the 10 States lying in whole or in part in the basin, and with other Federal bureaus and departments, notably, the Corps of Engineers, United States Army, the Office of Indian Affairs, and the State Department. Its plans, which contemplate expansions of the program along all lines of the Survey's activities related to water, in an attempt to meet the diverse and growing Federal, State, and local needs are set forth below, under four headings, "Surface water," Ground water," "Quality of water," and "Water utilization."

SURFACE WATER

Missouri River Basin.--Surface water is used largely in the Missouri River Basin in connection with irrigation, hydraulic power, and navigation. In the investigation of the quantity and availability of surface water, an expansion of the present program is planned to include a few additional gaging stations on the Missouri and its large tributaries and many new stations on small tributary streams that are valuable for irrigation, and on reservoirs, the stages of which are indices of the amounts of water in storage and of available reservoir capacities.

At the end of January 1944 the Geological Survey, in cooperation with other Federal agencies and State agencies, was operating 466 gaging stations in the Missouri River Basin, including 19 international stations. Some stations were being operated in each of the 10 States which lie wholly or partly in the basin. For a more complete coverage of the streams in the basin the establishment and operation of 129 additional stations is recommended. The distribution of the existing stations and of the additional stations among the principal areas of the basin and among the States is as follows:

Areas	Existing stations	Additional stations	States	Existing stations	Additional stations
Above Yellow-stone River	72	38	Montana	104	50
Yellowstone River	73	38	N. Dakota	16	5
Between Yellowstone and Platte Rivers	70	30	S. Dakota	26	18
Platte River and areas below to mouth	251	23	Wyoming	87	31
Total	466	129	Nebraska	75	18
			Minnesota	5	0
			Iowa	19	2
			Colorado	57	0
			Kansas	37	1
			Missouri	40	4
			Total	466	129

Estimated cost of additional gaging stations

Installation: 129 stations, at average cost of installation of $1,500 per station $193,500

Annual operation: 129 stations, at average cost of $600 per station $77,400

Souris River Basin

The Souris River Basin enters into the Missouri River problems because of the proposal to irrigate a large body of land in the Souris River Basin by means of water diverted from the Missouri River.

At the end of January 1944, eight gaging stations were being operated in the Souris River Basin. These include six discharge stations on the main river, a station for the determination of monthly gage heights and contents of Lake Darling, and a discharge station on Wintering River.

Stations near the eastern and western crossings of the United States and Canada boundary are operated as international gaging stations.

The principal tributary of Souris River in the United States appears to be Des Lacs River and it is suggested that a former gaging station on that stream in the vicinity of Foxholm be reestablished.

Sheyenne River Basin

The Sheyenne River enters into Missouri River problems because of the proposal to divert water from the Missouri River to Devils Lake, and to utilize the channel of Sheyenne River in the conduct of this water for a distance of 50 miles, more or less.

Sheyenne River rises in central North Dakota and joins Red River of the North in the vicinity of Fargo. Gaging stations were being operated at the end of January 1944 at three points: Sheyenne, Valley City, and West Fargo. An additional station is proposed for the upper part of the basin in the vicinity of Harvey, and within the part of the river that is proposed to be used for conducting Missouri River waters.

Devils Lake is in an inland basin of about 3,500 square miles lying north of Sheyenne River Basin. The area of the lake was reported as 115 square miles in 1883. From topographic maps made in 1928 the area was found to be 20 square miles. In 1940 the lake was 12 feet lower than in 1928.

GROUND WATER

Current need for ground-water study

Ground water is the chief source of supply in the Missouri River Basin for public water works, railroads, domestic supplies, and stock and farms. It is also used extensively for irrigation, air conditioning, and industrial purposes, and furnishes the fair weather flow of streams. In parts of the Basin the ground-water supply is considered inadequate to meet the increasing demands placed upon it; in other parts, however, the supply is ample for much increased development. The quantity and quality of the supply that can be developed at any one place in the basin is governed largely by the character, thickness, and areal extent of the geologic formations, proximity to areas in which water may enter or leave the formations, and amount of water available for recharging the formations. The formations tapped by wells, and from which springs issue, vary greatly in character, thickness, and areal extent over the basin, as do the other hydrologic factors that control the development and utilization of the ground water. The development to date has been chiefly unplanned and expedient owing to inadequate geologic and hydrologic records and imperfectly understood ground-water principles. There is urgent need for thorough systematic study of the occurrence of the ground water throughout the entire basin, and the inauguration of the systematic collection of water-supply records in order that the available supply may be put to optimum use. The necessity for such a study has been made apparent by; the diminution of the supplies obtained from wells in some places; by the difficulties encountered by cities, farmers, railroads, stock raisers and others in obtaining adequate supplies of good quality; by the large sums of money spent, often unnecessarily, in attempting to improve the supplies or to alleviate undesirable conditions produced by the construction of dams, irrigation canals, drainage ditches and other structures; by prolonged legal controversies over water rights; return flow from irrigated areas and the operation of well systems; and by the great demand for factual information on which to base estimates of the effects of ground-water conditions on the development of water projects.

The principal objective of the comprehensive ground-water study of the Missouri River Basin is the quantitative evaluation of ground-water recharge, discharge, and storage. Such study will furnish data for solving the multitude of problems that are controlled or affected in some degree by the occurrence of water below the surface. The study should be made systematically by counties and should include the collection of records of the quality of the water, pumpage from wells, fluctuations of water levels in wells, measurements of the gain in flow of streams that yield large quantities of water during fair weather, determination of direction and quantity of movement of the ground water, depth of the ground water below the land surface water-yielding properties of the formations and their thickness and areal extent, areas in which large quantities of ground water are used by vegetation, amount of rainfall penetration to the subterranean reservoirs, seepage from canals and reservoirs, and the mapping of areas in which artificial recharge may be practiced successfully. The evaluation of these factors will provide basic information for determining the effect of diversions from streams on the flow of these streams in their lower reaches, the trend of the ground-water levels in areas of heavy development and the perennial yield of the water-bearing formations, the effect of pumping from wells on the flow of streams, and the effect of the construction of dams, irrigation canals, reservoirs and drainage ditches on the level of the water table and on the flow of streams. To a large extent the future development of the Basin will depend on obtaining permanent and adequate supplies of good water. The results of the study will therefore be of great practical

and economic importance to the millions of residents in the Basin who must always depend largely upon wells and springs.

General ground-water conditions in the Basin

Region of glacial drift

The part of the Missouri River Basin lying in northern Montana, northern and eastern North Dakota, eastern South Dakota, eastern Nebraska and western Iowa, eastern Kansas and northern Missouri, is almost everywhere underlain by glacial drift. In places the drift is composed of poorly assorted mixtures of clay, silt, and boulders, that absorb water but transmit it very poorly. In other places the drift consists of assorted deposits of sand and gravel that both absorb and transmit water with ease. The sand and gravel deposits, which are the chief sources of supply for wells and springs, occur at the surface in only a few localities; most of these permeable deposits are buried beneath the surficial materials and are known only where penetrated by wells. These deposits furnish water supplies for many of the towns and farms in the drift region, especially in North Dakota and South Dakota where the deposits are the thickest. Because of the general lack of visual evidence of the existence of these permeable deposits, they have not been developed everywhere effectively. Many untapped deposits undoubtedly occur throughout the area and such deposits should be found and delineated by test drilling. At places the deposits can be artificially recharged by water from streams, reservoirs, and canals which, over a period of years, will result in a greatly increased ground-water supply that will increase and maintain the yield of wells and the fair weather flow of streams. Such recharge will doubtless occur in North Dakota with the construction of the Souris project. Where the sand and gravel deposits occur in extensive buried channels, the effects of artificial recharge may extend for long distances and, where geologic and hydrologic conditions are especially favorable, will result in increased artesian pressure and increased flow of wells.

Ancient lakes and rivers occupied parts of the drift area during glacial times, and in some of these places permeable deposits were laid down that now provide excellent sources of water supply. One such lake basin, Lake Dakota in the James River Basin in southeastern North Dakota, was found by the Geological Survey to be underlain by many feet of clean water-bearing sand that will supply adequate quantities of pure water for irrigation, industrial, and other uses. At the present time the basin is essentially undeveloped.

The drift area should be mapped geologically and hydrologically in such detail that each town will be provided with adequate data on the best nearby sources of water supply, the quality of the water, and the quantity from each source that will be available over a long period of use. Orderly development of the communities' water-supply systems can then be effected as the need arises.

Where permeable sand and gravel deposits occur in the valleys of perennial streams, such deposits constitute a large potential source of water supply. Properly constructed wells in such valleys may yield large quantities of water that in part may be replenished by the flow of streams. This method of utilization takes advantage of the filtering action of the permeable deposits and results also in providing relatively cool water in the summertime and relatively warm water in the wintertime. The success of such developments depends largely on locating the wells properly with respect to the infiltration reaches of the river and on the construction of suitable wells. The ground-water study will delimit the areas where developments of this kind are feasible and indicate the quantity of water that may be made available.

A part of the drift region in North Dakota, South Dakota, Iowa, and Nebraska is underlain by the Dakota sandstone, which is tapped by many deep wells. The Dakota sandstone has extensive areas of

artesian flow but the waters are highly mineralized at many places. In southeastern North Dakota the artesian pressure has declined more than 300 feet since the first wells were drilled to the Dakota sandstone in about 1890, but the flow is now believed to be approaching a balance with the recharge. The average flow per well has, however, decreased from about 20 gallons to only slightly more than 1 gallon a minute. There are in the area of artesian flow many so-called "wild wells," from which considerable water is wasted, and measures for controlling or stopping the flow of these wells should be developed by the investigation. Much of the water obtained from the wells tapping the Dakota sandstone at Sioux City is derived by seepage into the sandstone from the Missouri River. The investigation of the Basin will include further study of the Dakota sandstone in order that the water from it may be utilized to the fullest extent for beneficial purposes.

The drift in the lower part of the Missouri River Basin, in southeastern Nebraska, southwestern Iowa, northeastern Kansas, and northern Missouri, is at many places very thin and many of the ground-water supplies are obtained from alluvium in the valleys of the smaller streams. Some of these streams originally had tortuous courses and were subject to perennial floods. In an effort to reduce the flood hazard, the stream channels were straightened and deepened, in some places the alluvium was entirely excavated and the underlying hard rocks were exposed in the bottom of the channels. Although this lessened the frequency of floods in some valleys, it resulted in the draining away of much of the water that was stored in the alluvium with a result that town, farm, and railroad supplies and the fair weather flow of streams were made less reliable. The investigation will include a study of present and proposed drainage projects with a view of preventing the recurrence of such conditions, and the effecting of a compromise between protecting the water supply and alleviating poor drainage.

Montana and Black Hills Cretaceous region

Much of the Yellowstone River Basin in Montana and Wyoming, the part of North Dakota lying south and west of the Missouri River, and a part of northwestern South Dakota are underlain by the Lance and Fort Union formations. Fairly good water in quantities adequate for domestic and livestock supplies and small municipal supplies are generally obtained from strata or lenses of sand, gravel, and coal. These formations usually rest on Pierre shale, a thick, dense shale that yields no water, or only meager amounts generally of poor quality. Hence, locally, where the Fort Union and Lance are absent, or do not yield adequately, there is great difficulty in obtaining satisfactory supplies. Very few data are available on the ground water of this region and thorough study is greatly needed.

The region surrounding the Black Hills, including most of South Dakota west of the Missouri River and a strip of eastern Wyoming and northern Nebraska, is underlain by unproductive Cretaceous formations. The Pierre shale or shales of the White River group of formations occur at, or very close to, the land surface. The principal aquifer is the Dakota sandstone, which underlies the entire region except the Black Hills but it is several thousand feet below the surface in most localities. On the whole, ground-water supplies of this province are meager. Most municipal supplies in the region are of poor quality and of inadequate quantity. The water supply for some towns is hauled many miles.

Plateau region

The central parts of Montana and Wyoming consist of an arid to semiarid plateau region that is underlain by sedimentary formations, ranging in age from Paleozoic to Tertiary, not violently deformed but sufficiently warped and broken to produce a close relation between rock structure and the occurrence of ground water and to cause a rather rapid variation in ground-water conditions from place to place. On the whole, water supplies are not plentiful and not of very satisfactory quality. Where thick formations of nearly impervious material, such as shale, are at the surface, or where the plateau is greatly dissected, water

supplies are very scarce. Locally, however, sandstone aquifers are within reach of the drill and may yield very satisfactory supplies, in some places giving rise to flowing wells. Productive water-bearing sands and gravels, of Pleistocene or Recent age occur in some places, particularly in some of the stream valley. Only meager information is available on the productivity and reliability of the ground water in this region.

Great Plains region

The remainder of the Missouri drainage basin, consisting of most of Nebraska, northern Kansas, eastern Colorado, and eastern Wyoming, is underlain by Tertiary sands and gravels, that are exceptionally satisfactory for water supplies over extensive areas where underlie the smooth and almost uneroded plains. They yield large quantities of good water to relatively shallow wells. Most of the valleys of the rivers contain comparatively thick deposits of clean sand and gravel of Pleistocene or Recent age, that supply large quantities of good water to wells. On the whole, the Great Plains region is the most productive ground-water region in the Missouri drainage basin and at places much future development can be made. The sand hills area in central Nebraska constitutes one of the largest and most productive subterranean reservoirs in the United States. Except for sustaining the fair weather flow in the Elkhorn, Loup, and other rivers, the ground water in the sand hills is virtually unused. The Geological Survey has made several recent investigations of ground-water conditions in the Great Plains province. One of these covered the central Platte Valley, where irrigation with well water is increasing rapidly. Continued observations on ground-water levels carried on since 1930 indicate a general decline of several feet, but it is not known whether the perennial ground-water yield of the valley has now been reached. The study showed that the water-bearing sand and gravel of the valley may be artificially recharged if necessary, by water from Wood River or from the Platte River.

The dam and reservoir of the Central Nebraska public power and irrigation district is situated on the North Platte River in Keith County. Periodic observations on the water levels in wells are being made to determine the effect of storage of water in this reservoir on ground-water conditions in the county. An investigation in 1937 made by the Geological Survey showed that ground-water levels at places in Scott's Bluff County, Nebraska, have been raised as much as 150 feet as a result of the operation of the Pathfinder project. It also showed that a close relation exists between ground-water levels and return flow from irrigation and that many of the drainage and irrigation problems of the county can be alleviated to a large extent by the application of recognized ground-water principles. Another investigation made in 1938 in Box Butte County on the High Plains showed that this area is underlain by great thicknesses of saturated sand that will yield large quantities of water to wells. However, only a small amount of irrigation development has yet taken place.

Other areas in the Platte drainage basin should be given detailed study in order that the conditions in the Basin as a whole may be integrated with respect to water-supply utilization.

Much test drilling has been done in the valley of the Republican River in Nebraska, Kansas, and Colorado. Investigations have shown that at places there is ample water for considerable irrigation from wells, but that the most effective utilization of the water of the basin can be achieved by the combination of the ground-water and surface-water irrigation, depending upon the geographic and geologic conditions. Such combined use will prevent waterlogging of low-lying lands and the waste of water by undesirable vegetation.

Complex problems involving the relation of ground water and surface water exist in the South Platte Basin in Colorado, where extensive irrigation with water from wells has been made possible by the increase in ground-water storage, owing to surface-water irrigation. The use of ground water by plants has also increased, and the ground-water investigation should be directed toward determining to what extent

the water pumped from wells reduces the return flow and available water to downstream users and to what extent the water pumped is salvaged by reducing transpiration losses.

Methods of study.

The following procedure is proposed: The study can best be made by counties, and each such county should be given separate and special attention according to the nature of its ground-water problems. The county unit is a logical subdivision because it is easy to locate, and the movement of ground water is so slow--generally a few hundred to a few thousand feet a year--that conditions in each county may be considered and studied separately. First attention should be given to those counties in which critical ground-water problems now exist, or in which water-project developments will soon take place.

Collection of data

Test drilling.--The character, thickness, and areal extent of the water-bearing formations can best be ascertained by drilling small test holes. The Geological Survey, in cooperation with the Conservation and Survey Division of the University of Nebraska and the Kansas Geological Survey, has for several years been carrying on test drilling of this kind in Nebraska and Kansas. Data have thus been collected that are invaluable in determining ground-water conditions for the comprehensive study of the Missouri Basin. It will be desirable to purchase drilling rigs and to operate them continuously throughout the period of investigation. The character, thickness, and areal extent of the alluvium in the valleys of the streams will be determined and the location of permeable deposits beneath the uplands will also be determined. This method of exploration will be particularly valuable in the drift region, where geologic conditions cannot be ascertained by inspection and where the development of new water supplies is vital.
will also be determined. This method of exploration will be particularly valuable in the drift region, where geologic conditions cannot be ascertained by inspection and where the development of new water supplies is vital.

Pumping tests.--Pumping tests will be made wherever possible, usually on existing wells. The recent advancement in pumping-test methods makes possible the determination of the water-yielding properties of formations and provides practical means for determining well spacing, quantities of water to be expected from wells of different size, drawdown of the ground-water level, interference of one well with another, amount of water derived from flow of nearby streams, local geologic conditions affecting the occurrence of ground water, and the design of well fields.

Geologic correlation.--Geologists with ground-water experience will study and correlate the samples obtained from the test holes and outcrops of the formations. Such study will aid in planning further test drilling, in locating new supplies, and improving existing supplies.

Pumpage inventory.--Records will be obtained of the quantities of water withdrawn from wells throughout the basin in order that these data may be available for use in conjunction with studies of fluctuations of water level in determining the perennial yield of the formations. Records will be obtained from each town, irrigated area, railroad, and industrial plant and measures will be developed for obtaining continuing records of this kind for the future.

Water-level measurements.--In order to determine the trends of ground-water levels, and the changes in ground-water storage, an enlarged program of measurements of water levels in wells will be started and periodic observations will be made. The number and location of the observation wells in each county will depend upon the importance and complexity of the ground-water conditions. Some of the

wells will be equipped with automatic water-stage recorders. Other wells will be measured once a week, once a month, or only a few times a year. New observation wells will be placed in areas of heavy ground-water pumpage and in areas in which water-development projects are to be made. They will be established also near dams, reservoirs, irrigation canals, and drainage ditches in order to ascertain the effects of the operation of these structures on ground-water conditions. Observations of this kind are now being made in connection with the operation of the reservoir and canal system of the central Nebraska public power and irrigation district and the Loup River public power district.

Depth to water level.--The study will include an inventory of existing wells and information will be obtained on the size, depth, and diameter of the wells, the kind and size of pump and the use to which the water is put. Maps will be prepared, where feasible, showing lines of equal depths to water level.

Delimiting areas in which vegetation draws heavily on ground water.--Where ground water occurs at shallow depths, the roots of plants and trees extend to the capillary fringe or to the zone of saturation and they extract water in a manner similar to the pumping of a well. Large quantities of ground water are consumed in this manner in the Missouri River Basin, much of it by useless vegetation. Probably the greatest potential source of salvage of ground water lies in the reduction of vegetal uses that have little or no value, and the study should include the mapping areas with a view towards effecting measures for reducing this wastage of water. The tremendous use of ground water by vegetation is illustrated by the results of the investigation in the Central Platte Valley, to the effect that in a stretch of the valley of about 130 miles between Chapman and Gothenburg, the use of ground water by valueless plants during the period of the investigations amount to about 390,000 acre-feet a year. Similar conditions prevail at many other places in the basin, including localities where irrigation with surface water has raised the ground-water levels and has created new areas of vigorous plant growth.

Mapping areas favorable for artificial recharge.--The building up of ground-water storage through artificial recharge from reservoirs and irrigation canals is apparent in many places and the construction of new projects, such as the Souris project, will undoubtedly augment ground-water storage. In addition, the flood flows of some of the streams can be diverted in such a manner that there will be seepage into the subterranean reservoirs where geologic conditions are favorable. The study will include the mapping of such areas, especially where the present supply is meager or overdeveloped, or where it may be expected to become overdeveloped in the future. Artificial recharge may be effected in some of the cities through recharge wells in which water is fed into the water-bearing formation during certain seasons of the year in order that it will be available for use in the other seasons. The lowering of the water table along streams produces conditions favorable for artificial recharge in the sense that seepage is then induced from the streams into the subterranean reservoirs. The location of well fields near streams to take advantage of this source of water, including the filtering action of the sands and gravels and the more uniform temperature of the ground water, will undoubtedly prove to be the most logical solution for many water-supply problems of the basin. The ground-water study of the basin will include the mapping of stretches of the stream valleys that are favorable for this kind of ground-water development.

Interpretation of data and preparation of reports

The data gathered in the field study will be interpreted by competent engineers and geologists, and both the data and the interpretation will be presented in comprehensive county reports. These county reports will constitute an inventory of the ground-water resources of the Missouri River Basin. They should form a reference library of information on the subject that will be invaluable in future planning for all kinds of water development. The interpretation of the data will be directed toward specifying new

sources of supply for cities, railroads, farms, industries, and irrigation, and methods of improving the present supplies.

Estimates of cost

The collection of the data, the interpretation of these data, and the preparation of the county reports will be carried on simultaneously, in large part by the same group of geologists and engineers. It does not appear practical, therefore, to estimate the total cost of the comprehensive study on the basis of individual items. Moreover, the annual cost of the study will depend upon the number of counties in which investigations are made each year. The experience of the Geological Survey indicates that studies made in the detail outlined above require an average total expenditure of ten to fifteen thousand dollars per county, consideration being given to the fact that some counties will require a much larger expenditure whereas other counties will require less.

Quality of water

Adequate records of the chemical character of surface waters and of the amount of sediment transported by streams in the Missouri River Basin are indispensable for sound planning of the economic development of the basin. The following paragraphs describe briefly the needs and plans for comprehensive investigation of these two phases of hydrologic phenomena.

1. Agricultural and industrial quality of surface waters.--The successful operation of agricultural or industrial developments is dependent on adequate supplies of suitable water. Farm lands irrigated with large quantities of water have frequently been injured and sometimes ruined by the improper use of water, the chemical character of which was not known. Some crops are less tolerant to high proportions of certain mineral constituents than are other crops. Inasmuch as the drainage water from irrigated lands is more concentrated than the water applied to the land, it becomes increasingly important to know what chemical changes are taking place as the water is used over and over for downstream agricultural development. As irrigation increases in the Missouri River basin there will be an increasing demand for comprehensive records of the quality of the irrigation water.

Industrial development is even more dependent on the availability of sufficient quantities of water having desirable chemical characteristics. Certain industrial processes have rigid requirements as to the chemical composition of the water. Locations selected for these industries are frequently decided upon after comparing the cost of treating an unsuitable water in an otherwise desirable location with the cost of pumping a suitable water requiring little or no treatment in an undesirable location.

In order to decreases the losses from errors in allocation of waters for irrigation and in location of industrial plants, knowledge of the chemical character of the surface waters is needed. Past experience indicates that when a need for such information arises, there is insufficient time to obtain the needed data.

Some information on the chemical quality of surface waters in the Missouri River Basin was obtained in 1906-07, the results of which are published in Geological Survey Professional Paper 135, "The composition of the river and lake waters in the United States." So much agricultural and industrial development has taken place in the Basin since 1907, however, that the old analyses probably do not represent present conditions. Furthermore, the number of stations at which systematic information was obtained was far too small to give adequate coverage for the whole Basin.

The chemical quality of most surface waters is so variable through the year that single analyses may be of little value or may even be worse than none, unless full consideration is given to possible variations in composition. It has been found that, in general, analyses of 10-day composites of daily samples yield the normal minimum of information needed. For some streams sampling for many years is necessary, while for other streams sampling from 1 to 3 years may be adequate.

In order to make a comprehensive study of the quality of surface waters in the Missouri River Basin it is proposed to make a series of complete chemical analyses of composites of daily samples at 10 gaging stations the first year and at from 12 to 15 stations during the second and third years. In addition analyses would be made on samples collected less frequently at other stations in the Basin. It is estimated that the cost of operating these stations, including the costs of establishing and equipping a laboratory, would amount to $28,000 during the first year, and about $20,000 during each of the second and third years. In addition to the chemical analyses, daily temperatures of the surface water would be measured at each regular sampling station.

2. Sediment transportation.--The amount of sediment carried in most of the streams in the Missouri River [sic] is so great that it must be considered in determining the life of present and prospective reservoirs, in canalization of the river system in connection with inland waterways transportation, and in plans that relate to treatment of the waters for industrial and municipal use. The effective life of some existing reservoirs in the Basin appears likely to be much shorter than was originally anticipated on the basis of the inadequate information available as to the sediment loads carried by the streams on which the reservoirs are located.

Some studies of the sediment loads of streams in the Missouri River Basin have already been made by different agencies. For the most part, however, the studies were either fragmentary or were made at only a few points in the Basin.

In order that a systematic program may be initiated for the measurement of sediment loads of streams in the Missouri River Basin, it is proposed to collect samples at 24 established stream flow gaging stations. The samples would be collected from one to three or four times daily at these stations, depending on the characteristics of each stream. Analysis of each sample for total sediment content would be made and a representative number analyzed for mechanical composition at laboratories to be set up at central points within the Basin.

The estimated cost of purchasing the equipment, operating the sediment stations, analyzing the samples, and publishing the data obtained would be about $70,000 for the first year, and about $55,000 during each of the second and third years.

Water utilization

As already indicated, the program of the Geological Survey includes primarily the collection, compilation, and interpretation of basin information related to water, in ways that will contribute most effectively in general problems pertinent to the utilization of the water resources. These problems include those of administration by State, interstate, and Federal agencies and those of operation by governmental and private agencies. The desirable program is designed with foresight to assure that needs will be met as adequately as possible when and as, they arise. The program of the Geological Survey embraces also the interpretation of physical and economic information relative to water, incidental to the preparation by it of reports upon the best methods of utilizing the water resources.

An essential item of the program for the Missouri River Basin is the analysis and compilation of stream-flow records and related water information from the many reports and sources in which they are now scattered--some of which are no longer easily available, including revisions of records made in earlier years--into a group of reports suited to convenient and effective use in water problems. Such reports would contain information regarding storage, diversions, and types of water use. They would give authoritative historical data pertaining to the hydrologic evolution of the basin, for the consideration of questions about virgin flow and possible influences of climatic oscillations and works of man. Such information is a primary essential in comprehensive, long-range planning and in the adjudication of the conflicting interests of the several political subdivisions among which the water resources of the Missouri Basin must be apportioned.

In addition to the function of collection and compilation of basic data is that of interpretation and analysis with regard to the ways in which the water would be utilized. This function involves studies of specific methods of utilization, with such related surveys of sites and projects, including physical and economic aspects, as are necessary for evaluating the merits of different schemes of development. It includes investigations of the implications of the hydrologic data in respect to long or short-time trends that may be significant in operating and planning problems.

The advisory service rendered by the Geological Survey in connection with the soil and moisture conservation program of the Interior Department relates, in part, to the western portion of the Missouri RIver Basin. The activities concern all phases of water occurrences that are pertinent to erosion control, moisture conservation, and development of water supplies requisite to utilization of the western range, as related to lands under the jurisdiction of the Interior Department. The work is particularly essential in connection with projects of Departmental agencies which are planned for the period after the war.

For many years the Geological Survey has advised the State Department and International Joint Commission in the handling of international problems pertaining to waters along the boundary between the United States and Canada. It has collaborated with a similar Canadian investigating agency in the collection, compilation, and analysis of basic water data for the handling of international problems. The ramifications of plans for development of the waters of the Missouri Basin will quite certainly affect the flow of some of the streams crossing the Canadian boundary and thus will involve international questions. The Survey's program includes such activities as may be necessary to assure the handling of these questions through appropriate machinery and accepted procedures.

APPENDIX B

OFFICE DIRECTORY

OCTOBER 1, 1950

U.S. GEOLOGICAL SURVEY
Water Resources Division
510 Rudge-Guenzel Bldg.
Lincoln, Nebraska
October 1, 1950

OFFICE DIRECTORY

BRANCH	ADDRESS	TELEPHONE
Lincoln WRD Office — J.R. McLaughlin, Lincoln Chief Clerk		
Flick, Audrey T. McLaughlin, James R. Malheit, Mildred M. Miller, M. Winfield Stephens, Lucille M.	510 Rudge-Guenzel Bldg. Lincoln, Nebraska	2-7241, Ext. 267
GROUND WATER - Missouri Basin Hqs. — Geo. H. Taylor, Regional Engineer		
Lincoln		
Bentall, Ray Busch, Eldon A. Goss, Fern B. Hays, H. Charles Hornby, James S. Loerch, Leona G. McConnell, John W. Reed, Lester R. Rollf, Crystal J. Summers, Arlene P. Taylor, Geo. H. Wach, Andrew P.	507 Rudge-Guenzel Bldg. Lincoln, Nebraska	2-7241, Ext. 316
Lincoln Hydrologic Laboratory — A.I. Johnson, Materials Engineer		
Cheuvront, Maynard R. Johnson, Arnold I. Klug, Mervin L.	Room 10, Nebraska Hall University of Nebraska Lincoln, Nebraska	2-7631, Ext. 3248
Billings, Montana — F.A. Swenson, District Geologist		
Lorenz, Howard W. McMurtry, R. Gale Swenson, Frank A.	Room 318 P.O. Bldg. P.O. Box 839 Billings, Montana	9-2412

BRANCH	ADDRESS	TELEPHONE
GROUND WATER - Missouri Basin Hqs.—Continued		
Terry, Montana — F.A. Swenson, District Geologist		
Kohout, Francis A. Koopman, Francis C. Moulder, Edward A. Torrey, Alfred E.	P.O. Box 452 Terry, Montana	
Riverton, Wyoming --F.A. Swenson, District Geologist		
Hackett, O. Milton Morris, Donald A. Vanlier, Kenneth E.	Rm. 205 P.O. Bldg. P. O. Box 948	662-W
GROUND WATER - Nebraska		
Lincoln — Herbert A. Waite, District Geologist		
Brown, Roy S. Deffenbaugh, James L. Duncan, Earl A. Hughes, Ramona L. Keech, Charles F. Nelson, James W. Sanders, Bennie Schreurs, Raymond L. Svoboda, Gerald R. Unger, Hubert S., Jr. Waite, Herbert A.	508 Rudge-Guenzel Bldg. Lincoln, Nebraska	2-7241, Ext. 317
Ainsworth, Nebraska		
Cronin, James G. Newport, Thomas G. Trumm, Dean A.	Box 253 Ainsworth, Nebraska	74-W
Edgar, Nebraska		
Schnittker, Ferd G.	Box 282	None
Fullerton, Nebraska		
Sniegocki, Richard T.	Box 115	145 J
Loup City, Nebraska		
Brown, Delbert W.	Box 359	None

BRANCH	ADDRESS	TELEPHONE
GROUND WATER - Nebraska—Continued		
McCook, Nebraska		
Bradley, Edward	P.O. Box 277	None
QUALITY OF WATER — Paul C. Benedict, Regional Engineer		
Lincoln, Nebraska		2-7241
Adams, Fern A.	Room 509	Ext. 252
Barr, Willa M.	514	311
Benedict, Paul C.	509	252
Brennan, Robert	514	311
Brownell, Vincent E.	515	254
Busch, Robert D.	500	254
Davis, John R.	516	253
Durum, Walton H.	503	242
Gilfry, Willard R.	515	254
Greenstreet, Monna J.		
Gushard, Esther M.	516	253
Hembree, Charles H.	516	253
Hull, Lynn L.	513	311
Jochens, Eugene R.	503	242
Johnson, Edward L.	514	311
Kister, Lester R., Jr.	514	311
Langford, Russell H.	514	311
Matejka, Donald Q.	516	253
McKim, Donald R.	514	254
Meier, Edwin B.	516	253
* Neill, Everett D.		
Noel, John A.	514	311
Orth, Richard P.	513	311
Paulsen, Irene	509	252
Rainwater, Frank H.	513	311
Roberts, Bettye J.	516	253
Scherber, Floyd I.		
Swenson, Herbert A.	503	242
Thompson, Jack C.	503	242
Thrun, Robert W.	515	254
Tompkin, Harold L.	513	311
Vice, Raymond B.	516	253
Wark, John W.	516	253
Zabel, Carol J.	514	311

* Headquarters - Grand Island, Nebraska

BRANCH	ADDRESS	TELEPHONE
QUALITY OF WATER—Continued		
Ft. Collins, Colorado		
Albertson, Maurice L	Colorado A & M College Ft. Collins, Colorado	
Norton, Kansas — Don M. Culbertson, Hydraulic Engineer		
Albert, Calvin D. Archer, Jack G. Collier, Charles R. Culbertson, Don M. Hansen, Oluf R., Jr. Hicks, Jerry K. Piest, Robert F. Vague, Cleo E.	212 West Main P.O. Box 449 Norton, Kansas	6
Minneapolis, Minnesota — Byrnon C. Colby, Hydraulic Engineer		
Colby, Byrnon C. Johnson, Clyde O. Watts, George M.	St. Anthony Falls Hydr. Lab. Hennepin Island & 3rd Ave. SE	AT 6715 Ext. 433
St. Louis, Missouri		
Berning Robert F.	1004 Federal Bldg. St. Louis, Missouri	Main 8100 Ext. 235
Dickinson, North Dakota — E.J. Tripp, Hydraulic Engineer (SW)		
Asmus, Donald L. Rasmusson, Douglas E. Sloan, Darrell E.	050 3rd Ave. West Dickinson, North Dakota	6
Rapid City, South Dakota — Jay M. Stow, Chemist-in-Charge		
Adams, John E. Boschker, Andrew C. Gustafson, Arvo R. Howe, Harry M. Rogers, William C. Stow, Jay M. Tifft, Sheridan W.	State School of Mines Rapid City, South Dakota	4246
Riverton, Wyoming -- T.F. Hanley, Engineer-in-Charge		
Covington, Chester L. Obert, Charles F. Richardson, Everett V. Thompson, Melvin L.	Room 2 Post Office Bldg. Riverton, Wyoming	622W

BRANCH	ADDRESS	TELEPHONE
QUALITY OF WATER—Continued		
Worland, Wyoming — Thomas F. Hanley, Hydraulic Engineer		
Agee, Raymond W. Barnett, Marguerite E. Fabricius, Harold B. Hanly, Thomas F. Haushild, William L. Heidel, Sumner G. Kroll, Kenneth H. Lusby, Gregg C. Petri, Lester R. Reece, Gladys C. Ringen, Bruce H. (detailed)	Washakie County Courthouse Worland, Wyoming	107J
SURFACE WATER — Douglas D. Lewis, District Engineer		
Lincoln, Nebraska		
Blessum, Raymond J. Brenny, James B. Burns, Clarence V. Burmeister, Ivan L. Caughran, Gilbert W. Curtis, Russell E. (detailed) Ericson, Donald W. Ertz, Ione M. Furness, Lawton W. (detailed) Hungate, James D. Jolliff, Lillian A. Leeson, Elwood R. Lewis, Douglas D. McKinney, Robert N. Opocensky, Willard Phelps, Richard L. Philipsen, George E. Smith, Charles D. Van Dyke, Robert P.	511 Rudge-Guenzel Bldg. Lincoln, Nebraska Asst. District Engineer	2-7241 Ext. 244 Ext. 265 Ext. 244
Bridgeport, Nebraska		
Anthony, George	Bureau of Irrigation Office Box 1266	97
Cambridge, Nebraska -- Geo.L. Whitaker, Engineer-in-Charge		
Gilbert, M. Marjorie Hartley, Donald T. Henry, Alexander F. Walker, Patrick N. Whitaker, George L.	Junkers Building Cambridge, Nebraska	60

BRANCH	ADDRESS	TELEPHONE
SURFACE WATER—Continued		
Grand Island, Nebraska — Charles H. Carstens, Engineer-in-Charge		
Carstens, Charles H.	Air Base	3-600
Falk, Carl E.	Box 521	
Lind, James E.	Grand Island, Nebraska	
Rostvedt, Julian O.		
Valentine, Nebraska		
Maxwell G. Zellars	Resident Hydrographer	59-LJ
SW-Special Reports and Investigations — Roy E. Oltman, Hydraulic Engr.		
Oltman, Roy E.	512 Rudge-Guenzel Bldg.	2-7241
Rice, LaVerne L.	Lincoln, Nebraska	Ext. 245
Tracy, Hubert J. (detailed to Baton Rouge, La.)		

APPENDIX C-1

DEFINITION OF THE DUTIES AND RESPONSIBILITIES OF THE U.S. GEOLOGICAL SURVEY AND THE U.S. BUREAU OF RECLAMATION PERTAINING TO GROUND-WATER STUDIES UNDER THE MISSOURI BASIN PROGRAM

DEFINITION OF THE DUTIES AND RESPONSIBILITIES OF THE U.S. GEOLOGICAL SURVEY AND THE U.S. BUREAU OF RECLAMATION PERTAINING TO GROUND-WATER STUDIES UNDER THE MISSOURI BASIN PROGRAM

1. The following statements pertain especially to ground-water studies required under the Missouri Basin Program. Procedures now exist whereby the Geological Survey can, when requested by the Bureau of Reclamation and/or other governmental agencies and when adequate funds are provided, undertake ground-water studies required by those agencies.

2. The areas to be studied, the programs of investigations and their priority shall be determined by mutual agreement between the Geological Survey and the Bureau of Reclamation. These areas, programs and priorities are subject to the approval of the Interior Missouri Basin field Committee, and major changes shall not be made without the consent of that committee.

3. The ground-water studies made by the Geological Survey in connection with the Missouri Basin Program shall consist of one or more of the following in the order shown:

   a. General geologic and hydrologic studies as they pertain to the occurrence, storage, movement, recovery, discharge, recharge and quality of ground water and the basic data pertinent to potential drainage problems. These studies are to include collection and analysis of all available data that can be obtained without extensive test-hole drilling or other high cost operations; in some instances, preliminary test-hole drilling must be done in this general phase because of the absence of adequate field information. The work shall also includes preparation, and distribution to interested parties, of a report on each of the areas studied.

   b. Detailed studies with special reference to ground-water conditions as related to future drainage requirements and potential ground-water developments where such studies are considered necessary by the participating agencies. These detailed studies are to include the construction of the necessary test and observation holes, inventory of total discharges and withdrawals of ground water, correlation of water-bearing formations encountered in wells, detailed mapping of surficial geology and other work necessary to give a clear understanding of the geology and hydrology of the area under study.

   c. Continued collection of ground-water data and studies thereon as required by the Geological Survey and Bureau of Reclamation. These studies are to include especially the effects of irrigation and drainage upon the quality, quantity and recharge of ground water.

4. The above studies shall be conducted with the greatest possible coordination and cooperation at all levels between the Geological Survey and Bureau of Reclamation. Cooperation at field level is especially necessary; each agency shall assist the other to the greatest possible extent, particularly where the interchange of basic data and work by field personnel and equipment will result in the most rapid procurement of necessary data and in the lowest over-all cost.

5. The ground-water studies by the Geological Survey are to be limited to the procurement and interpretation of basic data.

6. All work pertaining to the location, design, construction, and operation of projects is the responsibility of the Bureau of Reclamation.

APPENDIX C-2

MEMORANDUM OF UNDERSTANDING

BETWEEN THE DIRECTOR OF THE GEOLOGICAL SURVEY

AND

THE COMMISSIONER OF THE BUREAU OF RECLAMATION

UNITED STATES
DEPARTMENT OF THE INTERIOR
MEMORANDUM OF UNDERSTANDING
BETWEEN THE DIRECTOR OF THE GEOLOGICAL SURVEY AND THE COMMISSIONER OF THE BUREAU OF RECLAMATION

relative to the

Coordination of Geologic Work Performed by the Geological Survey and the Bureau of Reclamation

1. Coordination of the geologic work performed respectively by the Geological Survey and the geologic units of the Bureau of Reclamation is desirable in the interests of both agencies and of the Department of the Interior and is necessary to assure the most expeditious joint procedure and the most useful over-all result, to prevent overlapping or omission of function, and to maintain the existing amicable cooperation of the two agencies so that their efforts shall be complementary and of mutual assistance.

2. In order to assure such coordination this memorandum defines the respective functions and responsibilities of the two agencies in the field of geology. The memorandum applies to all geologic procedures related to the activities or projects of the Bureau of Reclamation, but has no application to the nongeological activities of the Geological Survey nor to geological activities unrelated to the activities of the Bureau of Reclamation.

3. It is recognized that the geologic units of the two agencies have distinct fields of special interest and competence and, therefore, special functions which, although related, are distinct. The Geological Survey is concerned with all phases of basic and general geology and with the pure and applied geology of whole districts. The geological organization of the Bureau of Reclamation is concerned with the geology pertinent to the selection, acquisition, engineering study, construction and operation of specific engineering sites and projects and to the selection, testing and utilization of the required construction materials.

4. For activities within the field of basic, general geology, and of pure and applied geology of whole districts, the Geological Survey is pre-eminently qualified by reason of extensive past experience, special talent, appropriate organization, and precedent. Such activities shall be performed by the Geological Survey except for cooperative or joint activity as may be desirable in accordance with paragraphs 7 and 8, below.

5. In problems related to specific engineering sites, the geologic organization of the Bureau of Reclamation possesses the indispensable advantages of intimate and precise correlation of engineering and geologic procedures and viewpoints, coordinated facilities of specialized geological and engineering laboratories, and personnel experienced in the specific application of geology to engineering in accordance with Bureau of Reclamation administrative procedures, engineering standards, organizational framework, and past practical experience. In all matters pertaining to the immediate sites of Bureau of Reclamation engineering plans or structures (dams, reservoirs, canals, foundations, construction materials, etc.), which involve technical study, judgment, decision, or action by the Bureau of Reclamation, the geologic work shall be performed by its own geological organization, except for cooperative or joint activities which may be desirable in accordance with paragraphs 7 and 8, below.

6. The terms "basic, general geology" and "pure or applied geology of whole districts," which have been used to define the fields of responsibility of the Geological Survey, are meant to include aspects of geologic work such as the following: geologic mapping of large areas, detailed studies of stratigraphy

and correlation, regional ground water studies, regional studies of seismic conditions, problems of physiography, large scale problems of structural geology, economic resource studies, and special problems such as those relating to the erosional and deposition regime of streams, and matters pertaining to the geologic history of an area. Many of these aspects of geology, together with many other aspects which are also clearly "basic," "general," or applied to "whole district," may involve engineering geology. Such engineering geology is also an appropriate function and a proper responsibility of the Geological Survey. The Bureau of Reclamation shall be responsible through its own geological organization for geological and related laboratory procedures attendant on site selection and investigation, planning and design, construction, operation, and maintenance, together with the special legal, agricultural, economic and other problems such as those related to soils and arability which are within the normal sphere of Bureau of Reclamation operations, and including the procedures pertinent to the location, testing and selection of construction materials for specific Bureau projects.

7. The basic data obtained by the Geological Survey are indispensable to the Bureau of Reclamation in its specific engineering geology. Conversely, the data obtained by the Bureau of Reclamation through its studies of specific problems and sites may contribute helpfully to the Geological Survey's prosecution of general studies. Therefore, the two agencies jointly acknowledge the necessity for free and complete interchange of information relative to any problems of joint interest.

8. The cooperation and assistance of Geological Survey personnel has been and will continue to be of great value to the Bureau's specific engineering geology, as, for instance, in correlating the specific features of engineering sites with the general geology of an area. Conversely, the Bureau of Reclamation facilities, including the Petrographic and other engineering laboratories and specialized personnel, can contribute materially to many of the problems of the Geological Survey. It is understood that when studies by the Geological Survey would benefit by the use of the specialized field or laboratory facilities of the Bureau of Reclamation, they will be readily available on request to the fullest practicable extent and that when assistance by the Geological Survey would benefit Bureau of Reclamation activities, Geological Survey facilities will be similarly accessible to the Bureau of Reclamation.

9. This memorandum constitutes authorization of the field representatives of the Bureau of Reclamation and the Geological Survey to effect any arrangements which are compatible with the preceding paragraphs and with the administrative procedures of the two agencies. Such arrangements should be so made as to effect the maximum coordination of procedure with a minimum of administrative encumbrance.

GEOLOGICAL SURVEY
/s/ W.E. Wrather
Director

BUREAU OF RECLAMATION
/s/ H.W. Bashore
Commissioner

Approved:
/s/ Abe Fortas
Under Secretary of the Interior
Date November 30, 1945

APPENDIX C-3

PROCEDURES AND POLICY REGARDING GROUND-WATER INVESTIGATIONS, REGION 7, BUREAU OF RECLAMATION

UNITED STATES
DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Regional Office, Region 7
318 New Customhouse
Denver 2, Colorado

In Reply Refer to:
7-730

June 3, 1949.

To: District Manager, Casper, Wyoming Attention: C-162
District Manager, South Platte River District, Bldg.10,DFC
District Manager, McCook, Nebraska Attention: K-400
Area Engineer, Ainsworth, Nebraska Attention: H-100
Area Engineer, Grand Island, Nebraska Attention: G-700
Area Engineer, Pueblo, Colorado

From: Acting Director

Subject: Procedure and Policy Regarding Ground-Water Investigations, Region 7.

1. It has become increasingly evident that there is great need for a statement of ground-water policy to guide and coordinate work within Region 7. Accordingly, I am now establishing the policy as stated in the attached "Procedure and Policy Regarding Ground-Water Investigations, Region 7" dated May 20, 1949.

2. Any comments you may wish to offer will be appreciated.

/s/ W. E. Blomgren
W.E. Blomgren

Enclosure.

In quadruplicate.

CC-Commissioner, Wash., D.C., Attn: 700 (In quadruplicate)
-Reg. Dir., Billings, Mont., Attn: 6-100 (In quadruplicate)
-Chief Engineer, Denver, Colo. (In quadruplicate)
-Chief, Hydrology Div., Denver,Colo. (In quadruplicate)

Bureau of Reclamation, Region 7
Denver, Colorado
May 20, 1949

Procedure and Policy Regarding Ground-Water Investigations, Region 7

1. The following is prepared to outline the procedure and policy of Region 7 regarding ground-water investigations, with particular reference to cooperative work programs of the Bureau of Reclamation with the Geological Survey, both within the United States Department of the Interior.

Procedure

2. The Bureau of Reclamation shall be responsible for the collection and analysis of all basic ground water data relating to Reclamation Projects. However, it is the policy of Region 7 to utilize the services of the Ground-Water Branch of the Geological Survey to the greatest extent possible consistent with maximum efficiency and progress of Bureau of Reclamation work, in conformity with the Memorandum of Understanding between the two agencies. (see Par. 13).

3. The District and Area offices in Region 7 will anticipate, determine and program their requirements for ground-water studies. That type of work falling within the province of the Geological Survey (see Par. 14) will be outlined far enough in advance to permit the Geological Survey to budget, program, and complete the desired service with their own funds by the time it is required by the Bureau.

4. Ground-water programs to be assigned to the Geological Survey will be prepared by all field offices on Form OPC-PS-2, and will be accompanied with maps and narrative statements that clearly indicate the type and extent of work required by the Bureau of Reclamation. These programs will be submitted to the Regional Director for review and approval before incorporation in a formal request for services by the Geological Survey. It is essential that all proposed ground-water investigations recognize and incorporate the diverse interests and objectives of Drainage Engineering, Hydrology, Geology and Operation and Maintenance functions.

5. The type and degree of ground-water data requested from the Geological Survey shall be consistent with the use that is to be made of the data by the Bureau of Reclamation. Work should not be requested that exceeds in degree or areal extent the needs or objective of the Bureau of Reclamation. Reconnaissance information is generally sufficient in preparation of the Basin reports; detailed investigation may or may not be required in preparation of the Definite Plan Report.

6. Ground-water investigations undertaken directly by the District or Area offices in planning matters will be devised in accordance with the requirements and objectives of the particular engineering or other division that will utilize the results. The actual investigation will be undertaken directly by the field office, calling upon outside facilities for assistance to the extent necessary. Copies of programs for such work will be submitted to the Regional office for review and referral to other Reclamation offices that may be concerned, if necessary.

Types of Ground-Water Problems

7. All ground-water investigations shall be conducted with the greatest possible coordination and cooperation between the Geological Survey and Bureau of Reclamation. There will be free and complete interchange of basic data at all levels upon either formal or informal request, without referral to higher authorities.

8. Ground-water problems are arising with increasing frequency within Region 7, generally in regard to one or more of the following situations:

   (a) Location and selection of areas favorable to the development of pump irrigation projects.

   (b) Development and construction of pump irrigation projects involving detailed studies of ground-water yield, recharge, quality, permeability, etc.

   (c) Potential seepage that may affect the stability of proposed dams, reservoirs, and canals, and its effect on design and hydrological problems.

   (d) Potential or actual seepage from reservoirs, dams and canals which adversely affects a neighboring area by raising the ground-water table, thereby requiring provisions for drainage, lining, or other corrective measures.

   (e) Basic or historical ground-water data is commonly required in case of damage claims due to adverse effects on the ground-water table or on the quality of water.

   (f) Research or improvement of methods to obtain permeabilities of the heterogeneous types of aquifers commonly encountered.

   (g) Municipal ground-water supply.

   (h) Data to determine potential drainage problems on irrigable lands and information needed to determine extent of artificial drainage requirements.

9. It is evident that ground-water investigations are of concern to many Reclamation activities including, Planning, Design and Construction, Hydrology, Geology, Research and Operation and Maintenance. Because of the multiple purpose objective of most ground-water programs, it is essential that any investigation program evaluate and take into account such diverse objectives.

Available Facilities

10. Within the Bureau of Reclamation, Office of the Chief Engineer, the Drainage Engineering Division, the Dams Division and the Research and Geology Division all have ground-water or related technical specialists on their staffs. The Hydrology Division, Branch of Project Planning, also maintains ground-water specialists. All of the above divisions in addition to the appropriate divisions within the Region are available for consultation on ground-water problems in Region 7 and each is charged with technical control over ground-water investigations within their respective field.

11. As it is understood by this office, technical ground-water problems relating to design and construction matters, are the responsibility of the appropriate engineering division in the office of the Chief Engineer. Ground-water problems relating to water supply are the responsibility of the Hydrology Division. Ground-water specialists in all of the divisions are available for consultation and advice on Regional problems and may, when requested by the Regional Director, directly undertake special field assignments.

12. The Ground-Water Branch of the U.S. Geological Survey maintains a large staff of ground-water specialists actively engaged in basic ground-water studies over the entire United States. Their services

are available for Reclamation work to the extent that Reclamation requirements are anticipated and programmed by the District or Area offices in Region 7 and approved by the Regional Director.

Policy Regarding Cooperation with the Geological Survey

13. A "Memorandum of Understanding between the Director of the Geological Survey and the Commissioner of the Bureau of Reclamation relative to the coordination of geologic work performed by the Geological Survey and the Bureau of Reclamation", dated November 30, 1945, defined the respective fields of endeavor of the two agencies. The above memorandum indicates that fundamentally the Geological Survey is concerned with general and Regional ground-water studies, the Bureau of Reclamation with specific and local ground-water problems. It is believed that a convenient "yardstick" to distinguish between the two types of work is to ask the question: (1) Is the investigation directed primarily toward obtaining data for specific use during the design and construction of engineering structures? or (2) Is the investigation directed primarily toward the gathering of physical data for general use during the planning of any potential development? If the data being obtained is primarily for specific use in design, construction, or maintenance of projects or structures, it is not usually practical to divorce the investigation from the immediate supervision of the engineering unit in charge, the work being the responsibility of the Bureau of Reclamation. If the data being obtained is primarily for general or public use during the development of any plan, the ground-water work may, in many instances, be advantageously undertaken by the Geological Survey.

14. A "Definition of the duties and responsibilities of the U.S. Geological Survey and the U.S. Bureau of Reclamation pertaining to Ground-Water Studies under the Missouri Basin Program" was prepared by the Geological Survey after conferences in the Regional office, dated February 17, 1948. Such ground-water investigations, falling within the province of the Geological Survey by the Memorandum of Understanding of November 30, 1945, were classified into three groups: (a) General geologic and hydrologic studies, (b) Detailed studies, and (c) Continued collection of ground-water data. It has been found that the above portion of the "Definition" regarding the classification of types of studies has not been helpful in the devising of work programs. Too much emphasis has been placed on trying to define a general or detailed study rather than to devise required ground-water programs for referral to the Geological Survey. As stated in Par. 4, it is the policy of Region 7 that all cooperative ground-water programs shall include a self-explanatory narrative clearly stating the objective of the program and the extent and type of work required.

Attachments (2)

(1) Memorandum of Understanding between the Director of the Geological Survey and the Commissioner of the Bureau of Reclamation relative to the coordination of the geologic work performed by the Geological Survey and the Bureau of Reclamation, dated November 30, 1945.

(2) Definition of the Duties and Responsibilities of the U.S. Geological Survey and the U.S. Bureau of Reclamation pertaining to Ground-Water Studies under the Missouri Basin Program dated February 17, 1948.

APPENDIX D

CONCEPT OF THE MISSOURI BASIN PROGRAM OF THE GEOLOGICAL SURVEY

Concept of the Missouri Basin Program of the Geological Survey

The concept that is held of the Missouri Basin program of the Geological Survey has a vital bearing on the way it should be conducted.

One concept might be that the Survey's Missouri Basin program is identical with its regular National program as to (1) the permissible uses of the funds and (2) the objectives and nature of the work to be performed, so long as it is within the physical boundaries of the basin. If this is the correct view, the Survey should have full latitude to devise its program to best fulfill the over-all need for its information without giving preference to the needs of any single agency.

A second concept might be that the Missouri Basin program was intended by the Budget Bureau and the Congress to be a complement to the Survey's regular program and that it should be designed primarily to supply the basic information needed by the Interior agencies in developing the water and related land (including mineral) resources of the basin; and thereafter to meet the needs of other Federal agencies in this field as fully as practicable. As the Bureau of Reclamation's part in this program is considerably larger than that of the other Interior agencies, Reclamation's needs would warrant primary, but not sole, consideration.

No pronouncement by the Bureau of the Budget nor any act of the Congress specifically states which of these concepts is the correct one. There are, however, many indirect sources of evidence which tend to uphold the second concept. A few of these will be cited here.

Origin and development of program

The appropriations for fiscal years 1946-1954 for the Missouri Basin programs of the Bureau of Reclamation and the six participating Interior agencies (including the Geological Survey) have been made pursuant to the Flood Control Act of 1944, which authorized the water and related land development programs of the Bureau of Reclamation and the Corps of Engineers in the Missouri River Basin. The annual appropriations to the Bureau of Reclamation have carried an item designated "other Interior departmental agencies" under the heading "Missouri River Basin Project", and the Geological Survey has shared under that item through the allocation of funds by the Secretary of the Interior.

If the Survey's portion of that item were intended to be of the same nature and to serve the same purposes as its regular National program, the Missouri Basin funds would undoubtedly have been included in the Survey's regular budget and appropriation from the start.

Statements of purpose in Survey's annual budget presentations

In the annual budget statements for the Missouri Basin program which the Survey has furnished to the Bureau of Reclamation, it has been stated clearly that the first objective of the work was to supply information needed by the Bureau of Reclamation and other Interior agencies for their water and related land development programs. The benefits to other agencies was also pointed out, but Interior's needs were especially emphasized. This is true with respect to all phases of the Survey's work -- the topographic mapping, geologic and mineral resource surveys and mapping, and water resources investigations. Reference to the Survey's Annual budget presentations will verify this assertion.

Attitude of the office of the Secretary of the Interior

When the first MRB appropriation was received, the Secretary of the Interior required the Geological Survey to submit its proposed program for that year to the Bureau of Reclamation for approval before starting work on that program. The Bureau of Reclamation indicated that some of the proposed engineering geologic investigations were in areas where Reclamation's plans had already progressed so far that the geologic information for those places would come too late to benefit Reclamation. The Survey promptly shifted the locations of its proposed investigations to areas where the proposed reclamation work was farther off in the future.

In each year the Secretary's office has allocated the funds for "Other Interior departmental agencies" among the several Interior bureaus. It does not do this with the Survey's regular funds.

These facts imply that the Secretary's office holds the second concept regarding the nature of the MRB program.

Attitude of the Geological Survey and its Divisions

If the Survey's MRB funds were of the same nature as its regular funds and available for the same uses, there would seem to be no logical reason why the Conservation Division should not have been permitted to participate in the program in all four types of its work --all of which would contribute to the development of the natural resources of the basin. As the Survey permitted Conservation Division only to make river surveys desired by Reclamation, the Survey apparently held the second concept as to the applicability of the MRB funds.

In laying out their MRB programs each year, the Topographic and Water Resources Divisions have given primary consideration to the expressed needs of the Bureau of Reclamation, next the needs of other Interior agencies, and then those of other Federal agencies. The Geologic Division has conducted its engineering geologic investigations mostly in areas where it believed this would be of greatest benefit to Reclamation. As stated above, the Conservation division, when it participated in the MRB program, performed only work that was desired by Reclamation.

These facts indicate that the Survey's four Divisions feel that their primary obligation in the MRB program is to Reclamation.

Attitudes of the other participating Interior agencies

The other five Interior agencies which share with the Geological Survey the funds appropriated to Reclamation under the designation "Other Interior departmental agencies" also give first consideration to Reclamation's program in planning their own work under their MRB funds. They tie their work as closely as practicable to that of the Bureau of Reclamation. Even the Bureau of Mines does this in its minerals investigational program.

This indicates that these other Interior agencies also feel that their MRB funds (which come in the same manner and from the same source as the Survey's MRB funds) are not available for their many other types of work that are not related to the water and land development program. In other words, they apparently also hold the second concept as to the availability of their MRB funds.

Action of the Congress regarding FY 1955 appropriation

The Budget Bureau instructed the several Interior agencies to include their MRB needs for FY 1955 in their regular budget request rather than as an item in the budget of the Bureau of Reclamation. The Congress, however, refused to follow this plan, took the item for the MRB needs out of the Survey's regular budget, and transferred it back to the Bureau of Reclamation's budget with the similar MRB items of the five other participating Interior agencies. If the Congress had considered the Survey's MRB funds to be of the same nature and intended to serve the same purpose as its regular funds, the Congress obviously would not have refused to furnish the funds directly to the Survey under its direct appropriation.

Conclusion

All these sources of evidence indicate strongly that the primary purpose of the Geological Survey's Missouri Basin program is to provide basic information needed by the Interior agencies in planning, constructing, and operating works for developing the water and related land (including mineral) resources of the basin. As the Bureau of Reclamation has the largest part in Interior's development program, their needs should be given primary, but not sole, consideration. These investigations, nevertheless, are very useful for many other purposes and for carrying on the work of many other agencies -- Federal, State, and private -- in developing all the natural resources of the basin. The information collected contributes fully to the objectives of the Survey's National program.

Henry C. Beckman
July 28, 1954

APPENDIX E

WATER RESOURCES DIVISION STAFF, BY STATES, IN THE MISSOURI RIVER BASIN, JANUARY 1, 1953

COLORADO

SURFACE WATER BRANCH

District Office - Denver 2
Ph. BELmont 3-3611, Ext. 6419.

Bell,Francis M., Dist. Engr. - 13
Baily, J. Harold, Engr. - 12
Terry;, Jack M., Enagr. - 12
Eisenhuth, Harold P., Engr. - 11
Mesnier, Glennon N., Engr. - 11
Odell, Harold H., Engr. - 11
DePaulo, Augustine N., Engr. - 9
Essex, Keith S., Engr. - 9
Ham, Cavis B., Engr. - 9
Hodges, Edward B., Engr. - 9
Vaudrey, Walter C., Engr. - 9
Petsch, Harold E., Jr., Engr. - 5
McNutt, Margaret H., WAE, Engr-Aid - 6
Hinman, Lawrence E., Engr-Aid - 5
Hobbs, John H., Engr-Aid - 5
Ragsdale, Jess O., Engr-Aid - 5
Vieweg, B. Morgan, Engr-Aid - 5
Dyer, Robert E., WAE, Engr-Aid - 3
Shanks, James E., Engr-Aid - 4
Titus, Tom N., Engr-Aid - 4
Quinlan, M. W., Phy-Sci-Aid(Math.) - 5
Esterly, Nellie L., Clerk - 6
Larson, Loula M., Acct-Clk - 5
Coleman, Lucile, Clerk - 4
Kelly, Dorothy M., Clk-Steno. - 4
Newkirk, Eva B., Clk-Steno. - 3
Neal, Ruth M., Clk-Typist - 2

Area Office -Grand Junction
P.O. Box 551. 304 Main Street,
Rm 6, Phone 3214

Beaber, Howard C., Engr-in-chg. - 9
Whiteman, Russell E., Engr. - 9
Harris, Bill E., Engr. - 7
Hopper, Everett A., Engr-Aid - 7
Burch, Harold E., Engr-Aid - 5
Chaparro, Orlando M., Engr-Aid - 4
Freese, Mary, Clk-Steno. - 3

Riverton, Wyo. (See Wyo.)

Sheridan, Wyo. (See Wyo.)

Field Headquarters - Durango

Quigley, Alfred J., Jr., Engr. - 7

Field Headquarters - Fort Collins

Koloseus, Herman John, Engr. - 7

Field Headquarters - Lamar

Moor, Ross W., Engr-in-chg. - 9
Keliher, Charles L., Engr-Aid - 5

Durango (See N. Mex.)

McCoy, Orville, Engr-Aid - 5

Douglas, Wyo. (See Wyo.)

Kemmerer, Wyo. (See Wyo.)

Worland, Wyo. (See Wyo.)

GROUND WATER BRANCH

Office of Staff Geologist

Lohman, Stanley, W., Geol. - 13

District Office - Denver 2
Denver Federal Center.
Ph. BELmont 3-3611,
Ext. 546, 549.

McLaughlin, Thad, Dist. Geol.-12
Powell, William J., Geol. - 9
Burtis, Verle M., Engr-Aid - 6
Schooler, Ida Louise, Clerk - 5
Burnett, Helen S., Clk-Steno. -4
Junker, Doris M., WAE, Clk-Typt-2

Field Headquarters - Fort Morgan

MacNeill, Neil M., WAE, Engr. - 7

Field Headquarters - Holyoke

Cardwell, William D.E., Geol. - 9
Spiegel, Sidney J., Geol. - 7
Jenkins, Edward D., Engr. - 7

QUALITY OF WATER BRANCH

(See Regional Office in Nebraska for portion of State in Missouri River Basin; see Regional Office in Utah for Colorado River basin and District Office in New Mexico for balance of state.

Field Headquarters - Ft. Collins
(See Nebraska)

Albertson, Maurice L., WAE, Engr. - 12

TECHNICAL COORDINATION BRANCH

Office of Staff Engineer*

Denver - Denver Federal Center.
Ph. BELmont 3-3611, Ext. 201

Harbeck, G. Earl, Jr., Engr. - 12

* Represents Branch and Research Section in connection with water loss investigations and in inter Branch and Division Research.

Fort Collins, Denver**
c/o Col. A&M College, Ph. 1101, Ext. 109.

Rolfe, Benard N., Soil Scientist - 11

** Represents Research Section in connection with soils research.

KANSAS

SURFACE WATER BRANCH
Office of Staff Engineer*-Topeka

Spiegel, Jacob B., Engr. - 12

District Office - Topeka
305 Federal Bldg. Ph 3-3128

Leeson, Elwood R., Dist. Engr.-12
Brooks, Harold P., Engr. -11
Lennington, Lee R., Jr., Engr. -9
Klamm, Anthony T., Engr. Aid -7
Holliday, John P., Engr. -7
Rose, James D., Clerk - 5
Kreipe, Grace C., Clk-Steno.-4

Field Headquarters - Hays

Clemans, James W., Engr. - 7

Field Headquarters -Eureka

Marshall, Paul S., Engr. Aid -6

Field Headquarters - Liberal
(See Okla.)

Haddock, Charles R., Engr.Aid-6

GROUND WATER BRANCH

District Office -Lawrence
c/o University of Kans. Ph.852

Fishel, Vinton C., Dist.Engr.-12
Prescott, Glenn C., Geol. - 9
Wilson, W.W., Engr. Aid. -7
Mansfield, Bernita K., WAE, Cart-Dftsmn-4
Henderson, Betty L.G., Clk-Steno-4
Mason, Betty J., Clerk (Typ) -4
Godwin, Edyth L., WAE Clk-Typ-2

* Field Unit of Special Reports and Investigations Staff Section reports to Branch Chief.

Field Headquarters - Salina

Waterman, Willis D., Geologist - 7

QUALITY OF WATER BRANCH
(See Regional Office in Nebr.)*

Area Office - Norton
P.O. Box 429, 212 West Main St.
Phone 6

Culbertson, Don M., Engr-in-chg. -11
Guy, Harold P., Engr. -9
Albert, Calvin D., Soil Scientist -7
Berning, Robert F., MF, Chemist -5
Hicks, Jerry K., Engr-Aid -4
Mapes, Bobby E., Engr-Aid -3
Near, Charles R., Engr-Aid -3
Mathes, Alice A., Clk-Typist -1

* Except for portion of State in Arkansas River Basin for which see District Office in Oklahoma.

MONTANA

WATER RESOURCES DIVISION

Helena - 408 Federal Building
Water Resources Respresentative*

Heidel, Charles S., Engr. -12

* Acts as field representative of the Chief of Water Resources Division on matters pertaining to division of the waters of the St. Mary and Milk Rivers between Canada and the United States, and other international water problems.

SURFACE WATER BRANCH

District Office -Helena
P.O. Box 1696.
409 Federal Bldg.
Phone 2787.

Stermitz, Frank, Dist. Engr.-12
Goshorn, John D., Engr. -11
Anderson, Bennie A., Engr. -9
Blenkarn, Walter A., Engr. -9
Buswell, Grant W., Engr. -9
Bartells, John H., Engr. -7
Johnson, Melvin V., Engr. -7
Folsom, Orrin J., Engr-Aid -6
Schuller, R. Dale, Engr-Aid -6
Clark, Charlie H., MF, Engr-Aid -5
Lovely, Eugene O., Engr-Aid -5
Plunkett, Robert T., Engr-Aid-5
Aagaard, Fern Clair, Engr-Aid-4
Virag, Joseph M., Engr-Aid -4
Stermitz, Vincent J., Adm-Asst-7
Michels, William M., Acct-Clk -5

Area Office - Billings
P.O Box 383 333 Federal
Building. Phone 9-2412

Bekkedahl, Elmer H., Engr-in-chg. -9
Rennick, Kenneth B., Engr. -7
Swecker, Milton N., Engr. -7
Lounsbury, Stewart A., Engr-Aid -5
Noble, Margaret R., Clk-Steno-3

Area Office -Kalispell
P.O. Box 586, Adams Block
Phone 3026

Sollid, Allan S., Engr-in-chg-9
Benker, Rolland H., Engr. - 7
Dahlin, Warren Q., Engr. - 5

Field Headquarters - Bozeman

Boner, Fred C., Engr. - 7

Field Hradquarters - Fort Peck

Berwick, Vernon K., Engr-in-chg. - 7
McMilan, William L., Engr-Aid - 4

GROUND WATER BRANCH

District Office -Billings
P.O. Box 839 318 Federal Bldg.
Phone 9-2412

Swenson, Frank A., Dist. Geol. - 12

Field Headquarters -Bozeman

Hackett, O. Milton -Geologist - 9
McMurtrey, Robert G., Engr. - 7
Steinhilber, Walter L., Geol. - 7
Visher, Frank N., Geol. - 7

QUALITY OF WATER BRANCH

(See Regional Office in Nebraska for portion of State in Missouri River Basin; see Regional Office in Utah for balance of State.)

TECHNICAL COORDINATION BRANCH

Office of Staff Geologist*-Billings
P.O. Box 383 331 Fed. Bldg. 9-2412

Melin, Kenneth R., Engr. - 12
Hadley, Richard F., Geol. - 9

* Under the Office of Staff Geologist in Utah engages in soil and moisture conservation studies.

NEBRASKA

Address for all Lincoln offices:
Lincoln 8, 510 Rudge-Guenzel Bldg. PH. 2-7241, Ext.44 or 78.

WATER RESOURCESS DIVISION

Adm. Serv. Section - Lincoln

McLaughlin, James R., Adm. Asst.-7
Stephens, Lucille M., Acct-Clk. -5
Watson, Agnes M., Pers-Clk. Trne -3
Malhoit, Mildred M., Acct-Clk. -3
Miller, M. Winfield, Clk-Typ. -3
Flick, Audrey T., WAE, Clk-Typ -3

SURFACE WATER BRANCH

Office of Staff Engineer**

Oltman, Roy E., Engr. - 12
Meyer, Jean E., Secy. (Steno.) -4

**Field Unit of Special Reports and Investigations Staff Section for Missouri River Basin; reports to Branch Chief.

District Office -Lincoln
510 Rudge-Guenzel Building
Ph. 2-7241, Ext. 44 or 78

Lewis, Douglas D., Dist. Engr. -13
Anthony, George, Engr. -11
Caughran, Gilbert W., Engr. -11
Furness, Lawton W., Engr. -11
Beckman, Emil W., Engr. -9
Curtis, Russell E., Engr. -9
Philipsen, Geo. E., MF, Engr. -9
Benjamin, J. Philip, WAE, Engr. -7
Blessum, Raymond J., Engr. -7
Burmeister, Ivan L., Engr. -7
Pendleton, Alvin F., Jr., Engr. -7
Van Dyke, Robert P., MF, Engr. -7
Phelps, Richard L., MF, Engr. - 5
Flood, F. Dale, WAE, Engr-Aid - 5
Anderson, Jack A., Engr-Aid - 4
Smith, Charles D., WAE, Engr-Aid - 4
Joliff, Lillian A., Secy. (Steno.)-4
Eggert, Mabel M., Clk-Steno. - 4

Area Office - Cambridge
P.O. Box N. Junkers Bldg.
Phone 60

Whitaker, George L., Engr. - 11
Henry, Alexander F., Engr. - 7
Walker, Patrick N., Engr. - 7
Tomlin, Max E., Engr-Aid - 3
Gilbert, Marjorie M., Clk-Typist - 3

Area Office - Grand Island
P.O. Box 521, Air Base
Phone 3-600

Lind, James E., Engr. - 9
Hartley, Donald T., Engr-Aid - 7
Rostvedt, Julian O., Engr-Aid - 7
Morgan, Beverly S., Clk-Typist - 2

Field Headquarters - Ainsworth

Ericson, Donald W., Engr. - 7

Field Headquarters - Bridgeport

Burns, Clarence V., Engr. - 9

Field Headquarters - Valentine

Zellars, Maxwell G., Engr-Aid - 5

GROUND WATER BRANCH

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Lincoln - 510 Rudge-Guenzel Bldg.
Phone 2-7241, Ext. 47

Taylor, George H., Regional Engr.- 13
Bentall, Ray, Geologist - 11
Johnson, Arnold I., Engr. - 9
Klug, Mervin L., Engr. - 7
Busch, Fred E., Engr-Aid - 5
Wilson, William D., Engr-Aid -5
Barnell, Richard L.,WAE, Engr-Aid-4
Freemon, Lyman D., WAE, Engr-Aid -4
Kittle, Bernard W.,WAE, Engr-Aid -4
Weidler, M.E., WAE,Phy-Sci-Aid (Geol) - 3
Hornby, James S.,MF,(WAE)Engr-Aid-3
Kittle, Carl E.,WAE,Engr-Dftsmn -2
Sieg, Sue W., Secy. (Steno) - 4
Summers, Arlene P.,WAE,Clk-Typ -3
Loerch, Leona G., WAE, Clk-Typ - 3
Rollf, Crystal J., Clk-Typ - 3
Potter, Joanne F., Clk-Typ - 2

* Supervises ground-water investigations performed with funds from Missouri River Basin Program.

District Office -Lincoln
510 Rudge-Guenzel Bldg.
Ph 2-7241, Ext. 47

Keech, Charles F., Act. Dist. Engr. - 11
Johnson, Carlton Robert, Geol -9
Schreurs, Raymond L., Geol. - 7
Nelson, James W., Engr-Aid - 5
Duncan, Earl A., Engr-Aid - 4
Case, Ramona L., Clk-Steno - 3
Mace, Margaret N., Clk-Typ - 2

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Newport, Thomas G., Geologist - 7

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Chipps, George C., Engr-Aid - 5

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Regional Office

Lincoln - 510 Rudge-Guenzel Bldg.
Ph. 2-7241, Ext. 52

Benedict, Paul C., Regional Engr. -13
Swenson, Herbert A., Chemist -12
Colby, Bruce R., Engr. -12
Kreiss, Robert F., Engr. -12
Vice, Raymond B., Engr. -12
Johnson, Clyde O., Engr. -9
Matejka, Donald Q., Engr. -9
Heidel, Sumner G., Engr. -9
Krieger, Robert A., Chemist -9
Rainwater, Frank H., Chemist -9
Hembree, Charles H., Geol. -9
Brennan, Robert, Chemist -7
Jochens, Eugene R., Chemist -7
Kister, Lester R. Jr., Chemist -7
Langford, Russell H., Chemist -7
Zabel, Carol J., Chemist -7
Hubbell, David W., Engr. -7
Meier, Edwin Bruce, WAE, Engr. -7
Roach, Carl H., Geol. -7
Hull, Lynn L., Engr-Dftsmn -6
Beindorff, Arthur B., WAE, Chm. -5
Menke, Clarence G., Chem -5
Asmus, Donald L., MF, Engr. -5
Stevens, Herbert H., Jr., Engr -5
Mundorff, James C., Soil Scien -5
Tompkin, Harold L., Engr-Dftsmn -5
Barr, Willa M., Phy-Sci-Aid (chem)-5
Greenstreet, M.J., Phy-Sci-Aid(chem)-5
Delimont, Duane C., WAE, Engr-Aid -5
Prien, John D., Jr., WAE, Engr-Aid -5
Busch, Robert D., Engr-Aid -3
Copes, Donald F., Engr-Aid -3
Sandy, Roger D., WAE, Phy-Sci-Aid -1
Woten, Charles H., WAE, Phy-Sci-Aid -1
Gushard, Esther M., Edit-Clk. -4
Paulsen, Irene, Secy. (Steno) -4
Olson, Marylu, Clk-Steno -2
Rowlison, Ruth, Clk-Typist -2

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Minneapolis, Minn. (See Minn.)

St. Louis, Mo. (See Mo.)

Rapid City, S.D. (See S.D.)

Riverton, Wyo. (See Wyo.)

Worland, Wyo. (See Wyo.)

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Piest, Robert F., Engr. -7

Field Headquarters - Grand Island

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District Office -Bismarck
P.O.Box 750, Rm. 7 202-1/2
Third Street, Phone 139

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Monroe, Roy H., Engr. -11
McCabe, John A., Engr. -9
McCreery, Hugh C., Engr. -9
Nelson, Knute B., WAE, Engr. -9
Crosby, Orlo Adrian, Engr. -7
Pike, George M., Engr. -7
Eastman, John R., Engr-Aid -7
Glum, George, WAE, Engr-Aid -5
Jundt, Annabell M., Clerk -4
Schmidt, Della J., Clk-Steno -3

Area Office

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Field Headquarters

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Rapid City, S.D. (See S.D.)

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Schroeder, Elmer E., Engr -7
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GROUND WATER BRANCH

District Office - Grand Forks
University Station Ph. 4-7221

Akin, P. Donald, Dist. Engr. -12
Dennis, P. Eldon, WAE, Geol. -11
Aronow, Saul, WAE, Geol. -7
Paulson, Quentin F., Geol. -7
Powell, John E., Engr. -7

QUALITY OF WATER BRANCH

(See Regional Office in Nebr.)

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(See District Office in N.D.)

Area Office - Pierre
P.O. Box 216 207 Federal Bldg.
Phone 856

Darmer, Kenneth 1., Engr-in-chg. -11
Jamison, Gordon G., Engr. -9
Lamke, Robert D., Engr. -7
West, Robert E., Engr. -7
Stenstadvold, Eugene D., Engr. -7
Thoreson, Donald F., Engr-Aid -7
Curl, Albert W., Engr-Aid (Surv) -4
Peterson, Marie L., Clk-Typ -3
Stinson, Opal A., Clk-Typ -2

Field Headquarters - Pickstown

Dorman, Kenneth R., Engr-Aid -6

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Hedman, Ernest Robert, Engr. -7
McCollam, Archie A., Engr. -7

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Simmons, Clifton B., Geol. -9
Koopman, Francis C., Engr. -7
Vanlier, Kenneth E., Geol. -7
Stulik, Ronald S., Phy-Sci-Aid
(Geol) -4
Hanson, Emma V., Clerk -5

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(See Regional Office in Nebr.)

Area Office -Rapid City
c/o State School of Mines,
Ph. 4246.

Stow, Jay M., Chem-in-chg. -11
Orth, Richard P., Chem -9
Gustafson, Arvo R., Engr. -7
Ramsvick, Rolando J., Engr. -7
Sloan, Darrell E., Engr. -7
Howe, Harry M., MF, Engr. -5
Beyer, Thomas E., WAE,
Engr-Aid -4
Bump, James R., WAE, Phy-
Scien-Aid -1
Lees, Janet A., Clk-Typ -2

WYOMING

SURFACE WATER BRANCH

(See District Office in Colo.)

Area Office - Riverton
P.O. Box 948, P.O. Bldg.
Ph. 107-J

Petersen, Mervin S., Engr-in-chg-9
Smith, Roger I., Engr. -9
Meyer, Eric L., Engr-Aid -5
King, Tommie J., Engr-Aid d-4

Area Office -Sheridan
P.O. Box 948, P.O. Bldg.
Ph. 183-W

Haynes, G.L.,Jr., Engr-in-chg. -11
Ketcheson, Leslie R., Engr. -7
Custis, Thad W., Engr-Aid -3
Stohrer, Doris M., Clk-Steno. -3

Field Headquarters - Douglas

Hodges, Harold E., Engr-Aid -7

Field Headquarters - Kemmerer

Scott, Walter R., Engr. -9

Field Headquarters - Worland

Obert, Charles F., Engr-Aid -5
Amend, Donald R., Engr-Aid -3

GROUND WATER BRANCH

District Office -Cheyenne
Rm. 300, 2002 Capitol Avenue
Phone 8-8931, Ext. 37

Babcock, Horace M., Dist. Engr. -12
Rapp, John R., Geol. -7
McMahon, Natalie W., Clk-Typist -3

Area Office -Riverton
P.O.Box 948 204 Fed. Bldg.
Phone 622-W

Morris, Donald A., Geol-in-chg. -9
Moulder, Edward A., Engr. -9

Field Headquarters - Torrington

Bradley, Edward, Geologist -9
Bjorklund, Louis J., Engr. -9

QUALITY OF WATER BRANCH

(See Regional Office in Nebr.)

Area Office - Worland
1214 Big Horn Avenue
Ph. 107-J

Hanly, Thomas F., Engr-in-chg.-12
Petri, Lester R., Chem -7
Haushild, William L., Engr. -7
Lusby, Gregg C., Engr. -7
Ringen, Bruce H., Phy-Scien-Aid (Chem) -5
Brownell, Donna W., Phy-Scien-Aid -2
Barnett, Marguerite E., Clk-Typ -3
Reece, Gladys C., Laborer - C-3

Field Headquarters - Riverton

Richardson, Everett V., Engr-in-chg. -9
Williams, Robert C., Engr. -7

Field Headquarters -Buffalo

Covington, Chester L., Engr. -7

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APPENDIX F

INTERPRETATIVE REPORTS AUTHORED BY WATER RESOURCES DIVISION PERSONNEL FUNDED WHOLLY OR IN PART BY THE MISSOURI RIVER BASIN PROGRAM

Interpretive Reports of the Water Resources Division Funded Wholly or in Part by the MRB Program

COLORADO

Water-Supply Papers

1378 Geology and ground-water resources of the lower South Platte River valley between Hardin, Colorado, and Paxton, Nebraska, by L.J. Bjorklund and R.F. Brown, with a section on Chemical quality of the ground water, by H.A. Swenson. 1957.

1577 Ground-water geology and pump irrigation in Frenchman Creek basin above Palisade, Nebraska, by W.D.E. Cardwell and E.D. Jenkins, with a section on Chemical quality of the water, by E.R. Jochens and R.A. Krieger. 1963.

1658 Ground-water resources of the south Platte River basin in western Adams and southwestern Weld Counties, Colorado, by R.O. Smith, P.A. Schneider, Jr., and L.R. Petri. 1964.

1669-X Ground-water investigations in the lower Cache La Poudre River basin, Colorado, by L.A. Hershey and P.A. Schneider, Jr. 1964.

1809-L Reconnaissance of the ground-water resources in parts of Larimer, Logan, Morgan, Sedgwick, and Weld Counties, Colorado, by W.G. Weist, Jr., with a section on Chemical quality of the water, by Robert Brennan. 1965.

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9 Ground-water resources of parts of Weld, Logan, and Morgan Counties, Colorado, by L.J. Bjorklund, with a seciton on Chemical quality of the ground water by F.H. Rainwater. 1957.

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MONTANA

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1355 Geology and ground-water resources of the lower Yellowstone River valley, between Glendive and Sidney, Montana, by A.E. Torrey and F.A. Kohout, with a section on Chemical quality of the water by H.A. Swenson, 1956.

1360-C Geology and occurrence of ground water in the Townsend Valley, Montana, by H.W. Lorenz and R.G. McMurtrey, with a section on Chemical quality of the water, by H.A. Swenson. 1956.

1424 Ground-water factors affecting drainage in the First Division, Buffalo Rapids Irrigation Project, Prairie and Dawson Counties, Montana, by E.A. Moulder and F.A. Kohout, with a section on Chemical quality of the water, by E.R. Jochens, 1958.

1460-B Geology and ground-water resources of the Lower Marias irrigation project, Montana, by F.A. Swenson, with a section on Chemical quality of the ground water, by H.A. Swenson. 1957.

1482 Geology and ground-water resources of the Gallatin Valley, Gallatin County, Montana, by O.M. Hackett, F.N. Visher, R.G. McMurtrey, and W.L. Steinhilber, with a section on Surface-water resources, by Frank Stermitz and F.C. Boner, and a section on Chemical quality of the water, by R.A. Krieger. 1960.

1487 Geology and ground-water resources of the lower Little Bighorn River valley, Big Horn County, Montana, with special reference to the drainage of waterlogged lands, by E.A. Moulder, M.F. Klug, D.A. Morris, and F.A. Swenson, with a section on Chemical quality of the water, by R.A. Krieger. 1960.

1576-F Geology and hydrology of the Fort Belknap Indian Reservation, Montana, by D.C. Alverson. 1965.

1876 Geology and ground-water resources of the lower Bighorn Valley, Montana, by L.J. Hamilton and Q.F. Paulson. 1968.

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83 Geology and ground-water resources of the Helena Valley, Montana, by H.W. Lorenz and F.A. Swenson, with a section on Chemical quality of the water, by H.A. Swenson. 1951.

93 Ground-water resources of the lower Yellowstone River valley between Miles City and Glendive, Montana, by A.E. Torrey and F.A. Swenson, with a section on Chemical quality of the water, by H.A. Swenson. 1951.

170 Sedimentation and chemical quality of water in the Powder RIver drainage basin, Wyoming and Montana, by C.H. Hembree, B.R. Colby, H.A. Swenson, and J.R. Davis. 1952.

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HA-224 Availability of ground water from the alluvium along the Missouri River in the northeastern Montana, by W.B. Hopkins and J.R. Tilstra. 1966.

HA-468 Hydrology of the Northern Cheyenne Indian Reservation and adjacent areas, Montana, by W.B. Hopkins. 1973.

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WRI 76-40 Water-resources data for deep aquifers of eastern Montana, by W.B. Hopkins. 1976.

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Zimmerman, E.A., 1956, Preliminary report on the geology and ground-water resources of parts of Musselshell and Golden Valley Counties, Montana, with a section on Chemical quality of the water, by R.H. Langford.

NEBRASKA

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1258 Ground-water rsources in the Middle Loup division of the lower Platte River basin, Nebraska, by D.W. Brown, with a section on Chemical quality of the ground water, by F.H. Rainwater. 1955.

1327 Ground-water resources of the Prairie Creek unit of the lower Platte River basin, Nebraska, by R.T. Sniegocki, with a section on Chemical quality of ground water, by F.H. Rainwater. 1955.

1357 Computations of total sediment discharge, Niobrara River near Cody, Nebraska, by B.R. Colby and C.H. Hembree. 1955.

1358 Geology and ground-water resources of Buffalo County and adjacent areas, Nebraska, by R.L. Schreurs, with a section on Chemical quality of the ground water, by F.H. Rainwater. 1956.

1360-H Geology and ground-water hydrology of the valleys of the Republican and Frenchman Rivers, Nebraska, by Edward Bradley and C.R. Johnson. 1957.

1360-I Reconnaissance of the ground-water resources of the Elkhorn River basin above Pilger, Nebraska, by T.G. Newport, with a section on Chemical quality of the water, by R.A. Krieger. 1957. p. 715-754.

1368 Geology and ground-water resources of the upper Niobrara River basin, Nebraska and Wyoming, by Edward Bradley, with a section on Chemical quality of the ground water, by F.H. Rainwater. 1956.

1371 Ground-water resources of the Ainsworth unit, Cherry and Brown Counties, Nebraska, by J.C. Cronin and T.G. Newport, with a section on Chemical quality of the ground water, by R.A. Krieger. 1957.

1378 Geology and ground-water resources of the lower South Platte River valley between Hardin, Colorado, and Paxton, Nebraska, by L.J. Bjorklund and R.F. Brown, with a section on Chemical quality of the ground water, by H.A. Swenson. 1957.

1410 Geology and ground-water resources of the lower Lodgepole Creek drainage basin, Nebraska, by L.J. Bjorklund, with a section on Chemical quality of the water by E.R. Jochens. 1957.

1468 Geology and ground-water resources of Clay County, Nebraska, by C.F. Keech and V.H. Creeszen, with a section on Chemical quality of the water by F.H. Rainwater. 1959.

1474 Geology and ground-water resources of the Big Blue River basin above Crete, Nebraska, by C.R. Johnson and C.F. Keech, with a section on Chemical quality of the water, by Robert Brennan. 1959.

1476 Investigations of sediment transportation, Middle Loup River at Dunning, Nebraska, with application of data from turbulence flume, by D.W. Hubbell and D.Q. Matejka. 1959.

1489 Geology and ground water in the Platte-Republican Rivers watershed and the Little Blue River basin above Angus, Nebraska, by C.R. Johnson, with a section on Chemical quality of the ground water, by Robert Brennan, 1960.

1493 Geologic and ground-water reconnaissance of the Loup River drainage basin, Nebraska, by R.T. Sniegocki, with a section on Chemical quality of the water, by R.H. Langford. 1959.

1577 Ground-water geology and pump irrigation in Frenchman Creek basin above Palisade, Nebraska, by W.D.E. Cardwell and E.D. Jenkins. 1963.

1669-H Sedimentation and chemical quality of water in Salt Creek basin, Nebraska, by L.R. Kister and J.C. Mundorff. 1963. p. H1-H47.

1779-E Ground water conditions in the proposed water-fowl refuge area near Chapman, Nebraska, by C.F. Keech, with a section on Chemical quality of the water, by P.G. Rosene. 1964.

1779-H Ground water in Cedar Rapids division of lower Platte River basin, Nebraska, by J.B. Hyland and C.F. Keech. 1964.

1779-BB Ground-water resources of Mirage Flats, Nebraska, by C.F. Keech. 1964.

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422-D Channel patterns and terraces of the Loup River in Nebraska, by J.C. Brice. 1964.

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19 Progress report on the ground-water hydrology of the Republican and Frenchman River valleys, Nebraska, by H.A. Waite and others, with a section on The chemical quality of the ground water, by H.A. Swenson. 1948. 83 p. (See Water-Supply Paper 1360-H.)

20 Progress report on the geology and ground-water hydrology of the lower Platte River valley, Nebraska, by H.A. Waite and others, with a section on The chemical quality of the ground water, by H.A. Swenson. 1949. 211 p.

67 Progress report, investigations of fluvial sediments of the Niobrara River near Docy, Nebraska, by E.F. Serr 3d. 1950. 25 p.

107 Progress report, Chemical quality of the surface waters in the Loup River basin, Nebraska, by J.G. Connor. 1951. 15 p.

126 Ground-water conditions in the Dutch Flats area, Scotts Bluff and Sioux Counties, Nebraska, by H.M. Babcock and F.N. Visher, with a section in Chemical quality of the ground water, by W.H. Durum. 1951. 51 p.

139 Ground-water resources of the Wood River unit of the lower Platte River basin, Nebraska, by C.F. Keech. 1952. 96 p.

156 Reconnaissance of the geology and ground-water resources of the Pumpkin Creek area, Morrill and Banner Counties, Nebraska, by H.M. Babcock and F.N. Visher, with a section on The chemical quality of the ground water, by W.H. Durum. 1952. 30 p.

166 Ground water for irrigation in Box Butte, Nebraska by R.L. Nace, with a section on The chemical quality of the water, by W.H. Durum. 1953. 39 p.

205 Investigations of fluvial sediments of the Niobrara River near Valentine, Nebraska, by B.R. Colby, D.Q. Matejka, and D.W. Hubbell. 1953. 57 p.

406 Fluvial sediment in Whitehead watershed and Whitehead reservoirs, Nebraska, April 1955 to September 1956, by J.C. Mundorff and P.R. Jordan. 1958. 21 p.

470 Sediment discharge during floods in eastern Nebraska, by J.C. Mundorff. 1962. 8 p.

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HA-4 Configuration of the water table in Nebraska, by R.L. Schreurs. 1954. Scale 1:1,267,200.

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HA-12 Ground-water reconnaissance of the North Loup division of the lower Platte River basin, Nebraska, by C.F. Keech and M.P. Carlson. 1959.

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Kent, S.J., Engberg, R.A., and Ellis, M.J., 1981, Geohydrologic reconnaissance of the Crofton Unit, northeastern Nebraska: U.S. Geological Survey Water-Resources Investigations 81-58.

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NORTH DAKOTA

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1259 Geology and ground-water resources of the Fort Berthold Indian Reservation, North Dakota, by R.J. Dingman and E.D. Gordon, with a section on Chemical quality of the ground water, by H.A. Swenson. 1954.

1295 Chemical quality of surface waters in Devils Lake basin, North Dakota, by H.A. Swenson and B.R. Colby. 1955.

1769 Chemical quality of surface waters, and sedimentation in the Grand River drainage basin, North and South Dakota, by C.H. Hembree, R.A. Krieger, and P.R. Jordan. 1964.

1823 Sedimentation and chemical quality of surface water, Heart River basin, North Dakota, by M.L. Maderak. 1966.

1859-B Chemical quality of surface waters in Devils Lake basin, North Dakota, 1952-60, by H.T. Mitten, C.H. Scott, and P.G. Rosene. 1968.

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585-A Hydrologic investigations of prairie potholes in North Dakota, 1959-68, by W.S. Eisenlohr, Jr., and others. 1972.

585-B Evapotranspiration and the water budget of prairie potholes in North Dakota, by J.B. Shieflo. 1968.

585-C Ground-water hydrology of prairie potholes in North Dakota, by C.E. Sloan. 1972.

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37 Discharge and runoff in the Missouri River basin, by B.R. Colby and R.E. Oltman. 1948.

98 Trends in climate and in precipitation-runoff relation in the Missouri River basin, by R.E. Oltman and H.J. Tracy. 1951.

472 Current studies of the hydrology of prairie potholes, by J.B. Shjeflo and others. 1962.

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476 Ground-water resources of Benson and Pierce Counties, north-central North Dakota, by P.G. Randich. 1972.

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75-104 Ground-water availability in the Belcourt area, Rolette County, North Dakota, by P.G. Randich. 1975.

75-396 Results of aquifer testing in the Belcourt area, Rolette County, North Dakota, by P.G. Randich and G.E. Ghering. 1975.

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Part I, Geology, by C.G. Carlson. 1973.
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Part III, Ground-water resources, by P.G. Randich. 1976.

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Part I, Geology, by J.P. Bluemle. 1971.
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SOUTH DAKOTA

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APPENDIX G

DETAILS OF THE WATER RESOURCES DIVISION'S MISSOURI RIVER BASIN PROGRAM FISCAL-YEAR 1979

COLORADO FY 1979 MRB PROGRAM

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
Big Thompson R nr Drake, CO			$2,450			$2,450
Big Thompson R at mouth nr La Salle, CO			2,870			2,870
Cache La Poudre R at mouth of canyon nr Ft. Collins, CO			2,870			2,870
Cache La Poudre R nr Greeley, CO			2,870			2,870
Coal Creek nr Plainview, CO			2,870			2,870
Carter Lake nr Berthoud, CO			3,800			3,800
E. Portal Adams Tunnel nr Estes Park, CO			2,450			2,450
Horsetooth Res nr Ft. Collins, CO			3,800			3,800
Olympus Tunnel at Lake Estes, CO			3,430			3,430
St. Vrain C at mouth nr Platte-ville, CO			2,870			2,870
S. Platte R nr Kersey, CO			3,670			3,670
S. Platte R nr Weldona, CO			8,420			8,420
Boulder Cr at mouth	*	$2,710				2,710
Totals		$2,710	$42,370			$45,080

* Establishment of station is contingent on B of R paying $5,800 construction costs.

KANSAS FY 1979 MRB PROGRAM

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
N Fork Solomon R nr Portis, KS			$2,910			$2,910
Norton Res. effluent from conduit, KS			990			990
Smoky Hill R at Cedar Bluffs Res, KS			640			640
Smoky Hill R at New Cambria, KS		$3,650	160			3,810
Solomon R bl Glen Elder Dam, KS			2,890			2,890
S Fork Solomon R at Osborne, KS			2,460			2,460
S Fork Solomon R ab Woodston Div Dam, K	*	3,650	2,460			6,110
Totals		$7,300	$12,510			$19,810

* Addition of SW is contingent on B of R paying $5,500 construction costs.

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
Badger C nr Browning (2 sta.), MT (end 9-30-77)		$3,950	$150			$4,100
Beaverhead R nr Twin Bridges, MT (BR)		3,460	4,090			7,550
Bighole R nr Melrose, MT (BR)		3,460	150			3,610
Bighorn R at St. Xavier, MT (BR)			4,090			4,090
Big Muddy Creek (new station) (BIA) Funds from (BIA)	*	3,460				3,460
Birch C nr Valier, MT (BR)		3,460	4,090			7,550
Box Elder C nr Rocky Boy, MT		3,460	2,400			5,860
Fly C at Pompey's Pillar, MT (BR)		4,050	4,090			8,140
Little Bighorn R bl Pass C nr Wyola, MT		3,460				3,460
Little Bighorn R nr Hardin, MT			4,090			4,090
Little Bighorn R at State line nr Wyola, MT		3,460	150			3,610
Little People's C nr Hays, MT (BIA)		3,460	2,400			5,860
Marias R nr Shelby, MT (BR)		3,460	150			3,610
MF Judith R nr Judith Rg Sta., MT (BR)		3,460	150			3,610
Milk R at Juneberg Bridge nr Saco, MT (BR)			4,090			4,090
Missouri R bl Canyon Ferry Res, MT (BR)			4,090			4,090
Muddy C at Vaughn, MT (BR)		3,460	4,090	$7,800		15,350
Muddy C nr Vaughn, MT (BR)		3,460	4,090	7,800		15,350
Peoples C nr Hays, MT (BIA)		3,460	150			3,610

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
Powder R nr Locate, MT **						
Powder R nr Moorhead, MT**						
Pryor C at Pryor, MT		$3,460	$150			$3,610
Redwater C nr Vida, MT (BLM) **						
SF Judith R nr Utica, MT (BR)		3,460	150			3,610
Sun R bl Div Dam nr Augusta, MT (BR)		3,460	4,090			7,550
Sun R at Sims (BR)		3,460	150			3,610
Sun R at Vaughn, MT (BR)			4,090			4,090
Two Medicine C nr Browning (2 sta), MT (BIA)		3,950	150			4,100
Willow C nr Glasgow, MT		3,460	150			3,610
Yellowstone R nr Livingston, MT (BR)			4,090			4,090
Yellowstone R nr Miles City, MT (BR)			4,090			4,090
Totals		$74,230	$59,620	$15,600		$149,450
Miscellaneous Investigations						
(1) Review & publish reservoir data: Canyon Ferry, Tiber, Clark Canyon, Gibson, Piskun, Willow Creek, Fresno, & Nelson						770
(2) Missouri Breaks Sediment Program (BLM)				5,500		5,500
(3) Huntley Project Drain nr Worden, MT			4,090			4,090
Grand Total						$159,810

* BIA to pay construction costs
** To be funded by another program

NEBRASKA FY 1979 MRB PROGRAM

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
Blackbird C nr Meek, NE			$270			$270
Calamas R at Burwell, NE			2,770			2,770
Calamas R at Harrop, NE		$3,910				3,910
Cedar R nr Fullerton, NE		3,560	3,490			7,050
Dane C at Ord, NE			270			270
Eagle C nr Midway, NE			270			270
E Br Eagle C nr Midway, NE			270			270
Elkhorn R at Ewing, NE		3,560	150			3,710
Elkhorn R at Neligh, NE		3,560	150			3,710
Elkhorn R at Norfolk, NE		3,560	150			3,710
Elkhorn R at Waterloo, NE		4,150	3,090			7,240
Frenchman C at Culbertson, NE			1,620			1,620
Little Blue R nr DeWeese, NE		4,320	3,490			7,810
Little Blue R nr Hollenburg, NE			1,050			1,050
Long Pine C nr Riverview		4,150	2,120			6,270
Logan Creek nr Uehling, NE			150			150
Loup R nr Genoa, NE		4,900				4,900
Mid Loup R nr Comstock, NE			1,940			1,940
Mid Loup R nr Milburn, NE			2,180			2,180
Mid Loup R nr St. Paul, NE		6,190	1,350			7,540
Mira C at North Loup, NE			270			270

NEBRASKA FY 1979 MRB PROGRAM—Continued

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
Niobrara R nr Norden, NE		$3,560	$3,410			$6,970
Niobrara R nr Sparks, NE		3,750	150			3,900
Niobrara R nr Spencer, NE		3,960	150			4,110
N Loup R at Taylor, NE		3,920	3,410			7,330
N Loup R at St. Paul, NE		6,190	1,350			7,540
Platte R nr Duncan, NE (BR &FWL)		3,880	4,220			8,100
Platte R nr Grand Island, NE (BR & FWL)			4,740			4,740
Platte R nr Overton (N&S Chan), NE (BR & FWL)			5,310			5,310
Plum C nr Meadville		4,150	2,120			6,270
Redbird C nr Meek, NE			270			270
Republican R nr Orleans, NE			2,360			2,360
Republican R at Trenton, NE			1,000			1,000
S Loup R at St. Michaels, NE			1,350			1,350
Snake R ab Merritt Res, NE		4,010	150			4,160
Wood River at Riverdale, NE		1,050				1,050
Totals		$76,330	$55,040			$131,370
Investigations						
Review & publish reservoir data--McConaughy, Box Butte, Merritt, and Serman Reservoirs						1,090
Ainsworth Unit (return flows)		2,150	4,300			6.450

NEBRASKA FY 1979 MRB PROGRAM—Continued

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
Farwell Unit (return flows)		$2,150	$4,300			$6,450
Ground-Water Investigations						
Elkhorn Basin					4,500	4,500
Blue Division				5,020	10,600	15,620
O'Neill Unit			4,520		9,700	14,220
N Loup Division					6,300	6,300
Niobrara & Platte basins above sources of water supply						4,500
Prairie Bend Unit						9,600
Observation Well Replacement						0
Cedar Rapids Division						700
Mirage Flats Unit						2,400
Dropped from BR Request but FWL Requests Continuation						
Platte Valley - Central Platte Wildlife Refuge Mo. Meas. 19 wells						3,100
Recorder Wells						3,200
Platte R Stages - 4 sites						900
Total						$73,030
Grand Total						$210,400

NORTH DAKOTA FY 1979 MRB PROGRAM

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	To'als
Apple C nr Menoken (NBR)			$5,350	$1,840		$7,190
Big Coulee nr Churches Ferry, ND (BR)		$3,550	2,770			6,320
Cutbank C at N Lake Outlet, ND (FWS)		3,550				3,550
Cutbank C at Upham, ND (BR)		3,550	1,520			5,070
Deep R bl Cutbank C nr Upham, ND (BR)			4,100			4,100
Deep R nr Upham, ND (BR)		3,550				3,550
Devils Lake Chain, ND (BR & FWS)			8,080			8,080
E A Patterson Lk nr Dickinson, ND (BR)		550	870			1,420
Egg C nr Granville, ND (FWS)		3,550	710			4,260
James R at LaMoure, ND (BR)	$720		4,890	1,840		7,450
James R at ND-SD border, ND (BR)	720	890	4,100			5,710
James R nr Pingree (Depuy Marsh) (FWS)		700	1,170			1,870
Jamestown Res nr Jamestown, ND (BR)		1,770	1,170			2,940
Lake Tschida nr Glen Ullin, ND (BR)		550	870			1,420
Little Coulee nr Brinsmade, ND (FWS)		3,550	4,100			7,650
Missouri R at Garrison Dam, ND			0			0

NORTH DAKOTA FY 1979 MRB PROGRAM—Continued

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
Painted Woods C nr Wilton, ND (FWS)		$3,550				$3,550
Pilot Drain at Oakes, ND (BR)		3,550	4,890			8,440
Red R of the N bl Fargo, ND (BR)			1,910			1,910
Red R of the N at Halstad, MN, ND				$1,840		1,840
Red R of the N nr Hickson, ND (BR)		3,550	5,770	1,840		11,160
Cheyenne R nr Cooperstown, ND (BR)			4,100			4,100
Cheyene R at Harvey, ND (BR)		3,550	2,720			6,270
Cheyenne R at Lisbon, ND (BR)		3,550	4,100			7,650
Souris R nr Sherwood, ND (BR & FWS)			4,620			4,620
Souris R nr Verendrye, ND (BR)			4,100	1,840		5,940
Souris R nr Westhope, ND (BR)			0			0
Wild Rice R nr Abercrombie, ND (BR)			4,100	1,840		5,940
Wild Rice R nr Rutland, ND (FWS)		3,550				3,550
Wintering R nr Bergen, ND (FWS)		0	0			0
Wintering R nr Karlruhe (ABR)		2,510	2,770	1,840		7,120
Totals	$1,440	$49,570	$78,780	$12,880		$142,670
Investigations:						
Middle Souris Unit) Oakes Area)			12,720		2,530	15,250

NORTH DAKOTA FY 1979 MRB PROGRAM—Continued

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
J. Clark Salyer Refuge, ND (FWS, BIA) - 2 projects:						
1.) GW Study McHenry and Sheridan Cos. (FWL)					$2,790	$2,790
2) GW Study Bottinueau and Rolette Cos. (FWL & BIA)					5,280	5,280
Ft. Berthold Reservation (McKenzie Co) (BIA)					5,750	5,750
Warwick McVille Irrigation Area (BR)			$6,120		1,020	7,140
Total						$36,210
Grand Total						$178,880

SOUTH DAKOTA FY 1979 MRB PROGRAM

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
Belle Fourche R nr Sturgis, SD			$5,100			$5,100
Big Sioux R nr Dell Rapids, SD (BR)			4,060	$1,500		5,560
Cheyenne R bl Angostura Dam, SD (seasonal) (BR)			2,100			2,100
Cheyenne R nr Buffalo Gap, SD (BR)		$3,430	4,060			7,490
Cheyenne R nr Eagle Butte, SD (BIA)			8,000			8,000
Crow C nr Gann Valley, SD (BIA)		3,430	150			3,580
Enemy C nr Mitchell, SD (BR)		3,430	150			3,580
Grand R at Shadehill (BR)			2,100			2,100
Sidewood C nr Estelline, SD (BR)		3,430	150			3,580
Horse C nr Vale, SD (BR)		3,430	4,060			7,490
Inlet Canal nr Bell Fourche, SD (BR)			4,060			4,060
James R at Ashton, SD (BR)	$500	3,430	900			4,830
James R at Columbia, SD (BR)			4,060	1,400		5,460
James R at Huron, SD (BR)			4,060			4,060
James R nr Redfield, SD (BR)	500	3,430	900			4,830
Little White R nr Vetal, SD (BIA)		3,430	150			3,580
Medicine C nr Zell, SD (FWS)		3,430	150			3,580
Missouri R at Pierre, SD (BR)			4,060			4,060
Moccasin C nr Warner, SD (BR)		3,430	150			3,580

SOUTH DAKOTA FY 1979 MRB PROGRAM—Continued

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
Rapid C nr Farmingdale, SD (BR)		$3,430	$4,060			$7,490
Rapid C bl Pactola Dam, SD (BR)			4,060			4,060
Rosebud C NW of Rosebud Agency, SD (BIA)		3,430	150			3,580
Snake Creek nr Ashton, SD (BR)		3,430	150			3,580
Spring Creek nr Herreid (BR)			2,000			2,000
Grayhorse C nr Castlewood, SD (BR)		3,430	150			3,580
Turtle C nr Tulare, SD (FWS)		3,430	150			3,580
White Clay C ab Oglala Dam (BIA)		3,430	150			3,580
Wolf C nr Clayton, SD (BR)		3,430	150			3,580
Wolf C nr Ree Heights, SD (FWS)		3,430	150			3,580
Totals	$1,000	$61,740	$59,590	$2,900		$125,230
Investigations:						
Ground-Water Oahe Unit (Semi-annual water levels only (BR)						6,000
Review & publish data--Angostura, Deerfield, Orman, Pactola, and Shadehill Reservoirs (BR)						1,100
Highmore Canal observation wells (BR)						4,000
Totals						$11,100
Grand Total						$136,330

WYOMING FY 1979 MRB PROGRAM

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
Bates C nr Alcova, WY			$1,070			$1,070
Bighorn R at Kane, WY (BR)		$3,400	150	$4,490		8.040
Bitter C nr Garland, WY (BR)		3,400	4,030			7,430
Bull Lake C ab Bull Lake, WY		3,400	150			3.550
Casper C nr Casper, WY			2,500			2,500
Crow C nr Tipperary, WY		3,400	150			3.550
EF Wind R nr DuBois, WY		3,400	150	1,070		4,620
Fivemile Creek nr Shoshoni, WY (BR)				1,160		1,160
N. Platte R at Casper, WY (BR)			2,500			2,500
N Platte R at Mills, WY			2,500			2,500
N Platte R ab Pathfinder Res, WY			1,070			1,070
Ocean Drain bel Ocean Lake, WY (BR)		3,400	2,000			5,400
Sage C ab Sidon Canal, WY (BR)		3,400	4,030			7,430
Shoshone R bl Buffalo Bill Dam (BR)			730			730
Shoshone R nr Lovell, WY (BR)		3,400	4,030			7,430
S Fork Owl C bl Anchor, WY		3,400	150			3,550
S Fork Owl c nr Anchor, WY (BR)		3,400	150			3,550
SF Little Wind R ab Washakie Res		3,400	1,830			5,230

WYOMING FY 1979 MRB PROGRAM

Station	Constr.	Surface Water	Chem. or Bio. Quality	Sedi-ment	Ground water levels	Totals
Whistle C nr Garland, WY (BR)		$3,400	$4,030			$7,430
Totals		$40,800	$31,220	$6,720		$78,740
Investigations:						
Review & publish data--Lower Missouri Region: Alcova, Glendo, Guernsey, Pathfinder, Seminoe Res.						1,410
Review & publish data--Upper Missouri Region: Bow Lake, Anchor, Shoshone, Buffalo Bill, Boysen, Bighorn Res.						640
Biol. Monitoring & Trend Assessment-- Alcova, Seminoe, Pathfinder, and Glendo Res. ($7,692.50 each)						30,770
Total						$32,820
Grand Total						$111,560

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