A HISTORY

OF THE

Water Resources Branch

OF THE

United States Geological Survey

VOLUME 4
YEARS OF WORLD WAR II

JULY 1, 1939 TO JUNE 30, 1947

BY

ROBERT FOLLANSBEE

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YEARS OF WORLD WAR II

(1939-1947)

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Acknowledgments

The author wishes to make special acknowledgment to Carl G. Paulsen. His interest in the history caused him to suggest that it be carried through the war years, and make it possible for the author to carry out the work most advantageously. Acknowledgments are also due Nathan C. Grover, who, although retired, gave considerable time to reviewing the manuscript; also to many members of the Branch, too numerous to mention, for their wholehearted cooperation in furnishing most of the information on which the history is based.

YEARS OF WORLD WAR II (1939-1947)

This period extends from July 1, 1939, to June 30, 1947, and is called the years of World War II, although it was not until December 1941 that the United States entered the war which began in Europe in September 1939. By the beginning of the period, it was evident that this country might be drawn into the conflict and a rearmament program including the draft act, effective in September 1940, was started and prosecuted vigorously prior to December 1941, when the attack on Pearl Harbor forced us into the war. Although the war was not officially ended by June 1947, President Truman proclaimed the end of hostilities on December 31, 1946, thus terminating some of his war-time powers, and by further action terminated other war-time powers as of June 30, 1947.

This was a period during which the chief endeavor of the Branch was to keep its essential work on a fairly satisfactory basis in the face of the many handicaps to civilian activities caused by the war. To these handicaps were added increasing demands for more investigations. These demands which came from both cooperating States and Federal bureaus increased the total Branch funds from $3,060,000 in the fiscal year 1940 to $6,360,000 in the fiscal year 1947; and increased the full-time personnel from 513 to 1,043.

W. C. Mendenhall, the Survey's Director since December 22, 1930, retired February 27, 1943, after 48 years of service in the Survey. That year was a critical one for oil and Secretary Ickes was anxious to have an outstanding oil man head the Survey. In his search for the best man available, he requested a number of scientific societies to suggest lists of names. The list furnished by the National Academy of Sciences was headed by William E. Wrather, a consulting petroleum geologist. Dr. Wrather was offered the directorship and having accepted, was appointed Director May 7, 1943, the sixth to hold that position and the first since Major Powell to come to that position from outside the Survey.

For the Surface Water Division, every State was in cooperation with the Survey by the end of the period, and the number of gaging stations was increased from 4,164 with 3,000 recorders to 5,812 with 4,750 recorders. The number of district offices was increased from 37 to 41, with sub-district offices in addition.

For the Ground Water Division, as a result of the important role that ground water played in the many war establishments during the war years and the post-war expansion, all but seven States were in cooperation at the end of the period. The Division had so many requests for information from war-time establishments, that a large part of the personnel devoted considerable time to the special investigations required to obtain the desired information. The nationwide observation-well program was increased from about 5,500 to 9,200 wells, of which about 680 were equipped with water-stage recorders.

Increasing interest in the quality of both surface and ground water on the part of industry seeking new locations, during and after the war, resulted in more wide-spread cooperation with states seeking additional industrial plants. As a result of this more wide-spread state cooperation, it was possible to establish a number of laboratories in various parts of the country, and thus make a beginning in decentralization.

The Water Utilization Division broadened its activities by entering further into the field of interpretative studies, and in improving the analytical methods and techniques used in computing stream-flow records.

GENERAL ORGANIZATION

As a result of natural causes, there were more changes in the general organization than during any previous period. Carl G. Paulsen became acting chief of the Branch from the time of Nathan C. Grover's retirement, January 31, 1939, to October 17, 1939, when Glenn L. Parker was appointed Chief Hydraulic Engineer. At that time, Mr. Paulsen became Assistant Chief Hydraulic Engineer, a newly-created position which was made necessary by the greatly expanded work of the Branch. Mr. Parker died February 12, 1946, after nearly six and a half years as chief of the Branch and more than thirty-seven years in the Geological Survey. He had served for two years in Alaska and for twenty-eight years in the States of Washington and Oregon, of which twenty-six were in the position of the Survey's district engineer in the state of Washington. He came to chiefship therefore, after long field experience and with intimate knowledge of the functions and problems of the Geological Survey. His service as Chief Hydraulic Engineer, which fell wholly within this period, had to do largely with the difficult problems of war and of expansion of funds and personnel to meet war needs. These needs related to the availability of water for cantonments, hospitals, airfields, and other military establishments and for industrial plants engaged in producing military equipment and supplies. Such expansions included also great increases in cooperation with other Federal Bureaus, especially those having to do with war activities and to a lesser extent in cooperation with States. His administrative problems were therefore many and exacting. Mr. Paulsen succeeded him as Chief Hydraulic Engineer on March 1, 1946.

Throughout the period when Mr. Parker was Chief of the Branch, Mr. Paulsen served as Assistant Chief. He served also as Acting Chief of the Surface Water Division until April 19, 1940. Subsequent changes are described on page 26.

Under the war-time act 1/ authorizing the recall of personnel who had been retired, N. C. Grover was recalled August 20, 1942. At first, he divided his attention between Military Geology, a wartime division, and the work of the Branch. Within a few months, however, he had so many calls for work in the Branch that he had to give up his connection with the former group.

1/ Public 411, 77th Congress.

O. E. Meinzer continued as Chief of Division of Ground Water until retired for age, November 30, 1946, and was succeeded by A. N. Sayre. W. D. Collins continued as Chief of Quality of Water Division until retired for age, September 30, 1946, and was succeeded by S. K. Love. R. W. Davenport continued as Chief of Division of Water Utilization. The Division of Power Resources continued under direction of A. H. Horton until his death, March 4, 1945. The Division was discontinued March 31, 1945, and its functions transferred to the Division of Water Utilization.

Miss Helen Kiesel continued as Branch Chief Clerk.

APPROPRIATIONS

During the previous period, although the 50-50 cooperative principal was recognized by Congress, the Bureau of the Budget, and Congress itself could not believe that the States, during the depression years, would offer the amounts estimated by the Survey, and the resulting appropriations for several years were insufficient to meet in full the 50-50 cooperation offered by States and municipalities. The failure to meet such cooperation was also due in part, during the later years of that period, to the fact that before the year was over, State offerings were increased very considerably over the amounts estimated at the time of the Budget hearings. During those years, the Survey was reluctant to request deficiency appropriations.

However, during the war years, the psychology of Congress in making the collosal appropriations for the war effort was such that the relatively minor increases in appropriations requested by the Survey were granted. If later, those amounts proved to be inadequate to meet the States' cooperative offerings, the additional amounts needed were requested and were supplied in deficiency acts. That situation continued until the last year of the period when a new Congress controlled by the Republicans, elected on an economy program, refused to grant the full deficiency appropriation needed, and for the 1947 fiscal year, the Survey failed by 3 percent to meet full State cooperation.

The greater water-consciousness of the States with larger cooperative offerings, caused by the increase in the use of water, both surface and ground, needed by the tremendously expanded war industries, the plans for flood control by the Army Engineers, and the irrigation investigations by the Bureau of Reclamation in which the western States were deeply interested, were some of the causes of the increases in appropriations, particularly during the latter part of the period.

The following table shows the annual Branch appropriations, the amounts restricted to State cooperation, and the unrestricted remainder which was available for other purposes:

Annual Branch appropriations, amounts restricted to State cooperation, and remainder for other purposes:

Year	Branch Appropriation	Restricted to State Cooperation	Remainder for other purposes
1940	$1,143,000	$ 900,000	$243,000
1941	1,224,500	1,000,000	224,500
1942	1,285,500	1,000,000	285,000
1943	1,308,950	975,000	339,930
1944	1,436,700	1,008,700	428,000
1945	1,590,000	1,180,000	410,000
1946	2,116,900	1,620,000	496,900
1947	2,588,672	1,710,000	878,670

The "remainder for other purposes" has been segregated to emphasize the fact that the Survey has had to take on additional duties of a purely Federal character. During the previous period, the Federal-type work was confined largely to the maintenance of stations for the Colorado River compact and the beginning of [2] a network of Federal stations in other basins. During the present years, not only was the number of Federal stations increased, but stream-gaging requirements of the recently-negotiated Republican and Belle Fourche interstate compacts, and the International treaty with Mexico, all of which are described under the activities of the Surface Water Division, were factors which led to increases in the non-restricted items. Also, as the many requests from defense agencies for data on available water supplies in all parts of the country could not be handled properly on account of the small amount of non-cooperative funds, Congress increases those funds by $50,000 during 1942 and by $94,000 for the fiscal years 1943 to 1946, inclusive. During 1946, there was a nonrecurring item of $100,000 for post-war planning. Of the large increase in 1947, $263,000 was to pay a part of the cost of stations maintained for the Army Engineers ($175,000), the Bureau of Reclamation ($50,000), and TVA ($15,000), and for which those agencies had previously transferred funds. Although the $263,000 was only a small part of the funds transferred, it was hoped by the several agencies concerned that eventually Congress would appropriate directly to the Survey a major part of the funds needed to continue the Army Engineer, Bureau of Reclamation, and TVA stations instead of to those agencies for transfer. For starting investigations in Alaska, $14,000 was made available, and $37,500 for research, both in the 1947 fiscal year.

2/ pp. 9-10 (1928-1939)

The limitation on salaries in Washington was gradually increased as shown by the following annual amounts:

1940	$140,000	1944	$169,000
1941	140,000	1945	200,000
1942	140,000	1946	200,000
1943	170,000	1947	235,000

The salaries of personnel temporarily detailed to the Washington Office, although paid from field allotments, were charged against the limitation if the period exceeded five days.

COOPERATION

The growing importance of water-resources investigations and its public recognition is shown by the increased cooperative funds available during the period. The State and Municipal funds were practically on a 50-50 cooperative basis. The funds of other Federal bureaus could not be matched, but the marked increase in those funds were a measure of the growing importance of water resources records to the Federal government itself.

Annual cooperative State, Municipal, and Federal funds:

Year	State and Municipal	Federal	Total
1940	$ 914,688	$ 1,052,684	$1,967,372
1941	936,034	955,403	1,891,437
1942	1,008,951	941,843	1,950,794
1943	994,333	838,040	1,832,373
1944	1,108,733	926,261	2,034,994
1945	1,241,693	1,163,329	2,405,022
1946	1,603,752	1,300,285	2,904,037
1947	1,872,203	1,790,845	3,663,048

As there was no direct connection between the State and Federal funds, it was coincidental that they were in fairly close agreement.

WAR-TIME ACTIVITIES

Effect of Draft Act on Personnel

The "break-through" of the Nazis in the spring of 1940, after six months or more of the so-called "phony war" made it evident that there was grave danger that the United States would become involved in the war, and, to prepare for such probable action, Congress enacted the Draft Act, known as the "Selective Service and Training Act of 1940" which became effective September 16, 1940. 3/ Under

3/ Stat. L 54, pt. 1, 11.885 et seq.

that act, every male citizen between 21 and 36 years of age was required to present himself for registration, and become liable for training and service in the land or naval forces of the United States. Many of the Branch personnel were affected by that act, and as the tide of war rolled nearer and finally reached our shores, the depletion of personnel became more pronounced. Being red-blooded Americans, many did not wait for the draft but volunteered for service in the various armed forces; others holding reserve officer commissions, or having had previous training, received commissions; while still others, because of special qualifications, were drafted for special war-time activities. 4/

4/ p. 10.

The loss of so many experienced young men proved a serious problem for the Branch as at the same time, the work was increased considerably, partly as a result of various war activities, and replacements were urgently needed. The usual source from which personnel had been recruited, the Civil Service Commission lists of graduates of colleges, had dried up. Other sources had to be discovered and utilized. The work of some Federal agencies had been seriously curtailed and it was possible to obtain from them by transfer, engineers and engineering aids who for one reason or another were exempt from the draft. Although the employment of sub-professional grades had not heretofore been practiced, except in a few instances, the need for men was so great that such men were now used for routine work, particularly in the field.

War-Time Appointments - To meet the serious shortage of personnel of many agencies, and having few or no eligibles on its lists, the Civil Service Commission, acting under Executive Order, granted authority to the various agencies to obtain applications of persons who were believed to be qualified for the work required; the Commission rated the applications, and authorized appointments for those who received passing grades. Under Executive Order No. 9036, dated February 16, 1942, the Commission gave the agency concerned authority to make "war-time" appointments limited to the duration of the war and not to exceed six months thereafter, thereby deferring permanent appointments during the period while millions of citizens were in the military forces and war industries, and so were unable to compete for permanent appointments. So great was the need for personnel that a number of women were employed as engineering aids. A total of 617 "war-time" appointments was made.

Members of Branch personnel who entered military service were given military furloughs, and although many returned after the war, expanding personnel needs were not filled and many "war-time" appointees were retained. Realizing that in the not-distant future, the War would be officially declared ended, the Civil Service Commission, under Executive Order of February 1946, gave in the summer of 1946 when the great majority of service men had returned, a series of examinations for various grades, from which eligible lists for regular probational appointment were made. Many war-time appointees took the examinations and because of the experience gained in the Branch, were successful in them and were given probational appointments.

Effect of Restrictions

Use of cars. - Perhaps the most serious effect of restrictions imposed by the war was on the use of automobiles. Early in 1942, all automobile factories were converted to the production of war equipment, and no additional automobiles were manufactured. Thus, no new cars or trucks could be purchased and it was necessary to make the old cars last during the emergency. One of the first restrictions imposed was contained in an order from the Secretary [5]

5/ Order No. 1669, March 26, 1942.

which required that other means of transportation be used in all possible cases, that all automotive vehicles not absolutely essential be removed from active service immediately, and that the most effective use be made of vehicles remaining in active service. As a result of these restrictions, cars and trucks were operated very much longer than previously, and instead of being turned in when the distance traveled was 50,000 or 60,000 miles, and when the maintenance cost began to rise sharply, the vehicles were operated 100,000 miles or more with, of course, steeply mounting maintenance costs. Congress fortunately repealed the limit that could be spent on repairs on a car during any fiscal year.

Closely allied with the operation of cars was the consumption of gasoline and the use of tires. In 1941, when gasoline and rubber shortages were in the offing, the Secretary 6/ ordered that in the interest

6/ Order No. 1601, Aug. 15, 1941.

of conservation, no official cars should be driven in excess of 40 miles per hour. Some months later, upon learning that his order was being disregarded, the Secretary stated in a memorandum 7/ that infractions

7/ May 15, 1942.

would not be tolerated and violations brought to his attention would be dealt with summarily. With the prosecution of the war, the need to conserve tires became more critical and President Roosevelt appointed a committee headed by Bernard Baruch to study means of conserving rubber. That committee, known as the Rubber Survey Committee, made a report which was transmitted to Congress, August 6, 1942, and its recommendations were enacted into law soon afterward. The chief regulation affecting the Branch as well as all citizens was the speed limit of 35 miles per hour, which would achieve the greatest conservation of tires. Although many good citizens heeded that warning, many others failed to do so, and a year or two later the task of policing the highways against 35-mile violators became an impossibility, and that limit was generally ignored.

Not only was the use of cars restricted, but rationing of gasoline applicable to the entire population was an equally important factor. From May 15, 1942, in the East and December 1, 1942, in the West to Aguust 16, 1945, it was necessary to apply each quarter to the local rationing boards for coupons, without which gasoline could not be purchased. In applying for such coupons, it was necessary to estimate closely the mileage each car would be driven on official business. The estimated mileage was frequently reduced by the rationing boards in their infinite wisdom and coupons based on consumptive use of 15 miles per gallon, issued. If such coupons were found to be insufficient, it was usually possible to obtain additional coupons before the end of the quarter, but as this required convincing reasons, the tendency was to limit strictly the use of cars. In addition, the use of trucks, beginning November 15, 1942, required a certificate of necessity from the Office of Defense Transportation, which Office determined the mileage for gasoline, based chiefly on the amount requested in the application for certificate. This certificate had to be reviewed quarterly.

Perhaps as great a restriction as any on the use of cars was the rationing of tires. As a first step, the War Production Board, in July 1942, ordered an inventory of the number of new and used tires and tubes. This was followed by an order to turn over to that board, all tires in excess of 5 for each vehicle. Thereafter, as no new tires could be purchased on the open market, it was necessary to obtain replacements from the War Production Board, from the pool of tires previously surrendered. Tires sold to the Board originally, were sometimes repurchased at considerably higher prices.

Changes in hours per week. - Early in the war, the effect on Government personnel of the Draft Act, and other war activities, was such that the Secretary ordered as a war measure, a 44-hour week, beginning January 26, 1942. With the intensification of the war effort, the Secretary ordered a 48-hour week with no holidays, beginning January 2, 1943. After V-J Day, (Aug. 15, 1945), the Secretary reduced the work week to 40 hours, consisting of five 8-hour days, effective August 26 in Washington and September 9, 1945, in the field. The practical effect of the reduction was greater than the actual reduction in hours. Previously, it had been the rather general custom in the Branch, particularly in the field, to work long hours without regard to the actual number of hours per week and frequently work was continued on Sundays and holidays. However, with the 40-hour week, the tendency was to limit the hours of work, and when, on field trips, work was performed on Saturdays and Sundays, time off to compensate for such work was taken after returning to the office.

Increase in Salaries

After the work week was increased to 48 hours, Congress, by the Act of March 24, 1943, 8/ provided that all officially ordered

8/ Public 17, 78th Congress.

overtime in excess of 40 hours, should be paid for at one and a half times the regular rate, for the first $2980 of basic pay, the total compensation not to exceed $5,000. The overtime rate was in accordance with the rate established in industry as a spur to the war effort. That act was liberalized in 1945, by providing over-time pay for salaries in excess of $2980, at decreasing rates for the higher salaries. 9/ When the 40-hour week was established

9/ Public 106, 79th Congress, 1st Session.

and overtime abolished except in emergencies, Congress increased the base pay by amounts approximately equal to the previous over-time pay. As a result of the general increases granted industry by the Government early in 1946, Congress felt that Federal salaries were out of line, and increased all Federal salaries by 14 percent, effective July 1, 1946. 10/

10/ Public 390, 79th Congress, 2nd Session.

Limitation on number of personnel. -When Congress granted the 14 percent increase, it was with the proviso that the total number of employees in all civil departments should not exceed a definite number, that number to be substantially less than the number employed when the increase was granted. The Bureau of the Budget, each quarter set ceilings on the number of personnel each Federal agency could have.

Salaries outside continental United States. - The Brookhart Salary Act of July 3, 1930, had required the heads of executive departments and establishments to adjust the compensation of civilian field-service employees outside the continental United States unless such positions were expressly excepted by statute from the Classification Act of 1923. This requirement apparently had not been observed except by one or two agencies in Hiwaii where widely varying differentials had been applied. This procedure had resulted in what the Civil Service Commission described as "a chaotic situation for the various Federal agencies in Hawaii". Finally, in 1942, when Hawaii was a critical war center, the Civil Service Commission requested from the Comptroller General a decision regarding differential pay in order that the Hawaiian situation might be clarified. As a result of that decision, the Civil Service Commission on December 3, 1942, ruled[11] that it was permissible for the head of a Department or

11/ Circular 394.

Independent Establishment to fix salary differentials upon a percentage basis for employees serving at any point outside the States of the United States and the District of Columbia, the maximum differential being 25 percent. Accordingly, the Survey applied that differential to Hawaii and to Alaska.

Requests from war agencies

The many new establishments, both military and industrial, brought about by the war, posed many problems of available water supply to determine the best locations available, and the Survey was looked to for the answers. From July 1, 1941, to the end of the war, the number of requests received were:

Surface Water	10,053
Ground Water	3,250
Quality of Water	2,366
Total	15,669

The requests for surface-water data were largely for records or estimates of flow and in general, required but little additional field work. Similarly, requests for quality-of-water data could be answered by existing data and little field work was required. The requests for ground-water data were so varied and as they frequently required field investigations, a large part of the time of the ground-water offices in some parts of the country were devoted to those requests during the early years of the war. The investigations are described in some detail under the activities of that division.

The great number of requests threw such a burden on the Branch that Congress increased the non-cooperative funds by $50,000 for the fiscal year 1942 and by $94,000 for each of the fiscal years 1943 to 1946, inclusive.

In appreciation of the assistance received from the Survey, the Director of the Office of War Utilities of the War Production Board wrote the following letter to the Director of the Survey, Sept. 28, 1945:

"With the closing down of the Office of War Utilities, I want you to know how appreciative I am of the fine cooperation the Geological Survey gave to our Water Division throughout the period of the war emergency. Mr. Gowner, Director of that Division, has often told me of the invaluable consulting service received from members of your Washington staff and from your engineers in the field.

"The continuity of your records and the long experience of your staff was invaluable to the Water Division and permitted it to meet its immediate and pressing war problems with a minimum of staff and without duplication of effort.

"I sincerely hope the programs you are planning for expansion will be supported and carried out, for war conditions clearly indicated not only the extent to which our national economy is dependent on adequate water supply, but also the essentiality of the Survey's continuous accurate record of the country's water resources as the basis of their economic development and use."

Pig Iron Survey. - The production of steel was a vital factor in the war activities, and early in the war, much concern was felt by the War Production Board regarding the amount of pig iron available to the foundries, and whether such pig iron was being used exclusively for the war effort. Like some other war agencies, the Board did not have the necessary personnel to carry on the country-wide investigations needed, and as the Branch was anxious to further the war effort in every possible way and had a country-wide coverage of field offices, the Board on March 2, 1942, requested the Branch to undertake, at the Board's expense, a survey of some 3,200 foundries to determine the gross tonnage of pig iron used during December 1941, and the amount allocated for February 1942, also to determine whether priorities in the use of the pig iron were being observed strictly.

Lists of foundries and questionnaires were sent to each district, or other field office, together with numbered letters of authorization signed by an officer of the War Production Board, for each investigation. As soon as the lists and letters were received, the survey was started. Each foundry was visited and the necessary information obtained, being verified by the actual plant records. As soon as the information for each foundry was obtained, the completed questionnaire, signed both by the foundry official and the investigator, was mailed to the War Production Board. The foundries listed ranged from the largest where an investigation required a week or more to the smallest requiring only a short time to obtain the necessary information; others used scrap instead of pig iron and still others were no longer operating. About 2,400 foundries were actually investigated. The survey was completed within the allotted time at a total cost of $60,391.

Branch personnel in Military service

The Water Resources Branch furnished 246 of its personnel to the various branches of the military service. Owing to their special training a large majority were given commissions. One was commissioned as colonel, the highest rank for a reserve officer, and several were commissioned as lieutenant-colonel, one being an engineer who entered the Army as a private and attended Officer Candidate School. Many more were commissioned as major, captain, and lieutenant, with the corresponding naval rank for those who were in the Navy. A few retained their civilian status, being classed as specialists.

At the specific request of the War Department, ten geologists of the Ground Water Division were given commissions ranging from major to lieutenant, and assigned to water-supply battalions on headquarters' staffs overseas.

The complete list follows:

Aertker, Donald E.
Albert, C. Bruce
Anderson, Keith E.
Anderson, Orman K.
Anderson, Samuel G.
Armentrout, Warren R.
Augur, William T.
Babcock, Horace M.
Bach, W. Kenneth
Backe, Gordon J.
Baker, Roger C.
Barber, DeLoss H.
Barteldes, Otto E.
Batcheller, Jean E.
Beaber, Howard C.
Bennett, Robert Bruce
Bent, Paul C.
Berkowitz, Sidney A.
Beamer, Norman H.
Blake, Robert L.
Bodhaine, G. Lawrence
Bolon, Harry C.
Brewer, John Harold
Britton, James J.
Brown, Glen Francis
Brown, Irving L.
Brown, Russell H.
Burkebile, Frederick V.

Burkman, Grant A.
Busch, William F.
Cady, Richard C. 1/
Calkins, Myron D.
Carlson, Enos J.
Carns, Jack M.
Carstens, Charles H.
Carter, Roland W.
Cederstrom, D. J.
Colby, Byrnon C.
Colvin, Grattan C.
Conard, Raymond F.
Conover, Clyde S.
Constant, James A.
Cornelius, Quincy, C., Jr.
Cox, James B.
Cox, L. Theodore
Crane, Billy H.
Cross, William P.
Culler, Richard C.
Davies, David L., Jr.
DeWire, Harry A.
Dickstein, David D., Jr.
Dillon, Jack G.
Doll, Warwick L.
Dougherty, Donald F.
Dragnich, Stanley W.
Drake, Herbert E., Jr.
Drescher, William J.
Dunagin, Louis K.
Dunkle, William F.
Earhart, Charles E.
Ellis, Harold H.
Faehnle, David M.
Fellouris, John H.
Ferrin, Arthur J.
Fischback, Alexander A.
Fisher, Bernard
Fiske, Charles C.
Fleming, Dewitt P.
Fogarty, Donald J.
Foley, Frank C.
Folsom, Orrin J.
Ford, Paul G.
Fredericks, John C.
Gardner, Milton S.
Garner, Willie L.
Gerardi, Angelo P.
Glasier, Lloyd John
Goshorn, John D.
Graves, Rayfield W.
Griswold, Thomas N.
Griswold, William S.
Gunwaldsen, Ralph W.
Gurry, John W.
Hackmann, Glen N.
Hagensen, Carl Philip

Hale, Malcolm D.
Hall, Hatler F.
Hanks, Lawrence F.
Hannum, Curtis H.
Hanson, Archie J.
Harbeck, G. Earl, Jr.
Hardine, Kenneth L., Jr.
Harrell, Guy B., Jr.
Hassler, Milburn
Haynes, George L., Jr.
Henderson, Warren K.
Hennemuth, John R.
Henning, Norman E.
Hensley, Paul W.
Hickerson, Homer C.
Higgins, James J.
Hill, Herndon S.
Hodges, Edward B.
Homyk, Anthony, Jr.
Hulsing, Harry
Hunter, Hubert S.
Hurtgen, Donald C.
Ingles, James N.
Irelan, Burdge
Janda, Benjamin H.
Jenkins, Clifford T.
Jensen, Leon J.
Johnson, Thomas G.
Jones, Graham D.
Joseph, Irving
Jorgenson, Leonard N.
Kasner, Charlotte F.
Kizer, Lee E.
Kramsky, Meyer
Kroening, H. Frank
Lander, Frank T., Jr.
LaRocque, George A., Jr.
Leak, Howard S.
Leggette, Ralph M.
Lenfest, Leslie W.
Lewald, Charles E.
Lindholm, Curt F.
Loeltz, Omar J.
Lynn, Richard H.
McCabe, John A.
McCall, John E.
McCauley, Robert F.
McGowan, Jack
McKim, Robert L.
McLaughlin, James R.
Martin, Robert J., Jr.
Mayhew, William E.
Mathews, Elmer P.
Miller, Everett G.
Miller, Leonard W.
Miller, Mearle M.
Miller, Wallace T.

Mims, Benjamin L., Jr.
Molloy, John F., Jr.
Molloy, John J.
Moore, Samuel C.
Moore, W. James
Moulton, David R.
Murphy, Joseph A.
Murphy, William J., Jr.
Murphy, William M., Jr.
Murrow, Duncan C.
Nace, Raymond L.
Newcomb, Reuben C.
Odell, Harold H.
Ogata, Kent M.
Oltman, Roy E.
O'Neill, Vernon L.
Otton, Edmond G.
Patch, Marshall A.
Patterson, James L.
Paulsen, Wesley W.
Peck, Robert H.
Peirce, Earl H.
Pepper, Jack W.
Peracca, Americo R.
Perrey, Jospeh I.
Perry, Woodford J.
Peterson, Lee R.
Phillips, William N.
Porter, Livingstone, Jr.
Post, Arthur L.
Procter, Miles W.
Pynchon, Charles T.
Pree, Henry L., Jr.
Quarles, Thomas J.
Randall, Doris G.
Randolph, Burr H., Jr.
Rantz, Saul E.
Rasmussen, William C.
Reed, Albert L.
Reker, Carl C.
Revell, Russell W.
Ridgway, Lyle G.
Robinson, William H.
Rudd, Harold S.
Sanderson, Roy B.
Sandven, Hertel A.
Sayre, A. Nelson
Schaefer, Francis T.
Schaefer, Roland H. 1/
Schmickle, Robert D.
Schoerpner, Milton H.
Schoff, Stuart L.
Schreurs, Raymond L.
Schuller, R. Dale
Schwob, Harlan H.
Searcy, James K.
Seitsinger, Dan T.

Sexton, Harold J.
Shappy, Lillian R.
Shimasaki, William M.
Smith, Gerol B.
Sheaff, James L.
Silverman, Louis P.
Sittner, Walter T.
Slaughter, Marvin J.
Smith, Alvin L.
Smith, Harold L.
Smith, Robert J.
Smith, Rufus P.
Snell, Leonard J.
Spofford, James R.
Steacy, Robert E.
Stearns, Harold T.
Stephens, James W.
Stipp, John R.
Stockton, Herbert R.
Swenson, Herbert A.
Taylor, George C.
Taylor, George H.
Thomas, Harold E.
Thomas, Nathan O.
Thompson, Robert W., Jr.
Toth, Albert S.
Tracy, Hubert J.
Trisch, Donald L.
Wagar, John E.
Walker, Kenneth W.
Wandke, Alfred D.
Wann, Verlin M.
Warren, Moultrie A.
Wasylkiw, Myron A.
Weingartz, Larry W. 1/
Weinheimer, Thomas W.
Whitaker, Clair L.
Wiitala, Sulo W.
Williams, Adrian H.
Williams, Percy B.
Wilson, Alfonso
Wilson, Woodrow W.
Wollin, Ernest G.
Wood, Auburn E.
Woodward, Douglas R.
Workmaster, Frank N.
Youngquist, W. L.
Yates, Canipe B.

1/Deceased.

RAMSPECK ACT

During the years just preceding the war, the Administration had so limited in-grade promotions that only a very few could be granted. As the restrictions on such promotions were tightened each year, Federal employees made their grievances known in Congress, which enacted the Ramspect Act in 1941.12/ By this new act, the Classification Act of 1923 was amended to provide automatic promotions for employees on annual salaries who had not reached the maximum in their grades; for those whose efficiency ratings were less than very good, the increases were effective only until the middle salary for the grade was reached. The automatic increases occurred every 18 months for those whose increments were $100 per year or less, and every 30 months for those whose increments were $200 per year or greater.

12/Stat. L. 55, pt. 1, pp. 613-15.

In 1945, 13/ the automatic increases were made to apply to those employees whose current efficiency ratings were good or better, the increases to occur every 12 months for increments of $100, and every 18 months for increments of $200 per year or greater.

13/Public 106, 79th Congress, 1st Session.

AMENDMENT TO RETIREMENT ACT

In keeping with the liberal ideas of the Roosevelt administration, the Retirement Act was liberalized during the present period. The motive for such liberalization stemmed in large measure from those members of Congress who, having served many years, naturally desired retirement benefits for themselves, and also for the Congressional Committee employees, some of whom had also served many years. Accordingly, with that powerful incentive, legislation was enacted January 24, 1942, 14/ which liberalized the retirement provisions, making it possible for those who had reached the age of 60 and had served 30 years, to retire and receive half the highest salary during any five consecutive years of service. The original compulsory retirement at 70 was retained, as were the original methods of computing retirement benefits; which in some cases were more advantageous. Employee contributions to this retirement were increased from 3 1/2 to 5 percent. Immediately after the passage of the amended act, there was an outcry from the country against paying

14/Public 411, 77th Congress.

pensions to members of Congress, and the opposition was so strong that Congress quickly again amended the law by eliminating themselves from its benefits. In passing, it may be noted that in 1946, Congress enacted a law granting pensions to members of Congress.

EFFICIENCY RATINGS

Although efficiency ratings had been applied to positions in Washington since 1923, it was not until the present period that such ratings were extended to the field.

In 1913, Congress authorized the Civil Service Commission to set up a division of efficiency, but it was not until the passage of the Ramspeck Act in 1941, which made such action mandatory on the Executive Departments, that efficiency ratings were made. As the Executive Departments were considered to consist of personnel in Washington, as distinguished from the Field Service, the ratings previously had were not applied to the field personnel. However, the Ramspeck Act passed in 1941 required that efficiency ratings be applied to all positions, whether in the field or in Washington, in order that eligibles for automatic promotions could be determined. The fiscal year ending June 30, 1942, was the first year for which efficiency ratings were applied to all Survey personnel.

The application of efficiency ratings to the field personnel resulted in some changes in grades and positions.

WATER RESOURCES REVIEW

Early in the present period, the Branch increased its services to the public by starting the practice of issuing monthly summaries of water conditions, thus giving information on current trends. That action had its origin in a request from the White House, in a letter written by a Secretary to the President, dated July 27, 1939, addressed to the Secretaries of Agriculture and Interior, the Works Progress Administrator, and the Director of the Civilian Conservation Corps. The letter started:

> "The president has asked me to invite your attention to official and unofficial reports of the damage in the states affected by the present drought, damages to crops and timber lands and to the danger of low water supplies, said to be growing more acute daily.
>
> "The President asks that these conditions be most carefully observed and that the Federal Agencies be prepared in the event of an emergency, to render all possible assistance."

That letter was referred to the Division of Water Utilization where the desirability of issuing a monthly statement was recognized. The established procedure at that time required that all Survey publications must have editorial attention and review by the Administrative Geologist, and that time-consuming procedure thus involved was a bar to the prompt publication of monthly statements. However, W. B. Langbein, in January 1940, prepared a memorandum giving an outline of a proposed summary of all water conditions. So severe was the wide-spread drought at that time that it was necessary to request special information from several districts. In February, the district engineers were advised of the desirability of such action and of the values that would accrue to the public through a systematic study by the Survey of the march of hydrologic events, and regular prompt reports thereon. In that connection, the memorandum stated:

> The Survey's continuous records of stream-flow not only register faithfully climatic trends, but also serve many direct uses that are particularly affected whenever stream flow deviates widely from the mean.

It was proposed that each district select one or more stations, having stable control, unregulated flow, records of sufficient length to determine normal regimen, and what was of chief importance, the records from which could be transmitted promptly each month. To make the monthly summary feasible, it was necessary to obtain a special dispensation from the standard "editorial attention and review" requirement, and W. G. Hoyt, through his contacts with the Director's office, obtained such dispensation.15/ Thereafter, it was possible to make definite plans for monthly publication.

15/ Letter from W. B. Langbein to author.

To W. B. Langbein, under R. W. Davenport's direction, was given the job of working out the procedure and preparing the necessary forms, and on June 8, 1940, standard forms were sent to the district offices. The first "summary of stream-flow conditions" was issued for November 1940, and was based on the averages of 24 gaging stations. Texas, in keeping with its well-known characteristics, had "bigger and better floods" during that month and the results of 13 floods were included in that issue. About 350 copies of the summary were sent out to those who had requested information on stream flow. In the report for December, the map showing the percentage of normal stream flow was first introduced. Commenting on the first few issues, the Washington Office stated16/ that as shown by the many requests from organizations and individuals to be placed on the mailing list, the summaries seemed to be satisfying a popular need. Some of the requests came from persons who were apparently ignorant of the Survey's stream-gaging program which had been in operation for 50 years. The Defense agencies found that the summaries were particularly valuable to them as a basis for forecasting stream flow, and the Army Quarter-master General requested 200 copies of each future issue.

16/ Feb. 18, 1941.

In the fall of 1941, R. W. Davenport, at the time of a hearing before the International Joint Commission, discussed with officials of the Dominion Water and Power Bureau, the summary of stream-flow conditions and the definite need it was meeting, and suggested that the service might be extended to include the numerous streams along the international boundary of common interest to Canada and the United States.17/ This suggestion met with approval and arrangements were made to have the Canadian records sent directly to Washington, from the field. Records from 16 Canadian stations first appeared in the issue for May 1942. Commenting on the proposed inclusion of the Canadian records, J. C. Beebe of the Federal Power Commission stated that the contemplated inclusion of the Canadian records would be so

17/ Letter to Dominion Water & Power Bureau, Nov. 3, 1941.

valuable to the pulp and paper industry alone, that it would be worth the cost of the entire service. 18/

18/ Memo by W. G. Hoyt, Apr. 17, 1942

In June 1942, data on ground water were first included and in recognition of its broadened scope, the name of the publication was changed to "Water Resources Review". Until January 1943, the monthly releases had been handled by the Department's office of Information, but beginning at that time, the Review was sent out directly by the Branch, thus saving time.

By the end of the period, the number of stream-gaging records used had increased to about 130, and the well records to 55. The circulation had increased to 1,500, of which 150 copies went to Canada.

PECOS RIVER JOINT INVESTIGATION

The Pecos River is an interstate stream rising in the mountains east of Santa Fe and flowing south through eastern New Mexico and western Texas to its confluence with the Rio Grande, near Comstock, Texas. Characterizing the river basin, the National Resources Planning Board stated: 19/

19/ Regional Planning Part X, Pecos River Basin, June, 1942, p. VI.

> For its size, the basin of the Pecos River probably presents a greater aggregation of problems associated with land and water use than any other irrigated basin in the western United States. These involve both quantity and quality of water supplies, the problem of salinity being particularly acute; erosion and silting of reservoirs and channels; damage from floods; and interstate controversy over the use of the waters. There is an abundance of good land so that the limit of development is the availability of water of satisfactory quality. The use of the water of the river has been fully appropriated.

As will be shown, it is a basin in which the Federal interest is marked. As the basin has a scanty rainfall, agriculture is wholly dependent upon irrigation for which the water is obtained from both surface and ground sources. Early in its existence, the U. S. Reclamation Service took over from private interests the Carlsbad project; storage facilities were inadequate and in 1937 the Bureau of Reclamation constructed the Alamogordo Reservoir. In Texas, 10 independent projects were attempting to irrigate land from the Pecos River but serious water shortages and an increase of salinity rendered the river unfit for irrigation at times. By 1934, much land in those projects was no longer cultivated. As that was the beginning of the New Deal era of large scale loans and grants, the Red Bluff Water-Power Control District was organized for the purpose of constructing the Red Bluff Reservoir by means of a dam south of the New Mexico State line, which would be operated for the benefit of the surviving and consolidated independent irrigation districts. It was called a water-power control district as it was expected that the developed water power would ultimately liquidate the costs. The Reconstruction Finance Corporation purchased the bonds and the reservoir was constructed as a PWA project and was completed in 1936.

At times the Pecos River is subject to severe floods when the cities of Roswell and Carlsbad are inundated in part, as well as much agricultural land. The flood of May and June, 1937, was particularly severe, and as Congress in 1936 had declared the prevention of floods a Federal responsibility, there was a demand for Federal action, particularly as the Federal interests described previously were also affected.

Prior to World War I, potash, a strategic war mineral, had been obtained chiefly from Germany, but that war showed the necessity for developing a domestic supply. Some years later, large salt deposits were discovered in the Pecos Valley and in 1932, the U.S. Potash Company began the extraction of potash from them. During that process, large quantities of waste brine were deposited in an area having no visible outlet. Later, irrigators complained of increased salinity in the river water and brought suit. An investigation by the Survey showed that the salt was coming from a water-bearing formation and not from the wastes. 20/ Although that suit was dismissed, there re-

20/p. 333, (1928-1939).

mained the possibility of future suits, and to prevent possible interruption of a vital industry, further investigations were needed to determine possible sources of salinity.

Perhaps the greatest need was complete information relative to the water supply and its quality which must be available for the purpose of perfecting a compact between the states of New Mexico and Texas. A compact had been negotiated in 1925 but had not been ratified.

The Rio Grande Joint Investigation, which was made in 1936 under the sponsorship of the National Resources Committee, which later became the National Resources Planning Board, had pointed the way for a similar investigation on the Pecos, and while the efficient organization conducting the Rio Grande activity was still intact, it was thought by those interested that a similar investigation of the Pecos River should be undertaken. At the request of Secretary Ickes, the National Resources Committee called a meeting of all Federal, State, and local interests concerned, at El Paso, Texas, on March 20, 21, 1939, at which time it was unanimously agreed to undertake the Pecos River Joint Investigation. It was organized and carried out in cooperation with bureaus and services of the Agriculture, Interior, and War Departments, and funds for the Survey's portion of the investigation were provided by cooperation with the State officials of New Mexico and Texas and by contributions from the Bureau of Reclamation and the National Resources Planning Board.

The Rio Grande investigation had been carried on during one year. As previous investigations, chiefly by State agencies, had furnished much of the data needed, one year's further results were deemed sufficient. The Pecos investigation, however, had no such fund of accumulated information and so it was planned to cover two years. It was headed by Harlowe M. Stafford, engineer in charge, and Fred C. Scobey, associate engineer in charge, both employees of the National Resources Committee, with headquarters at Roswell, New Mexico. Field operations were started in July 1939, and continued through December 1940, and the final results were published by the National Resources Planning Board.

Available funds for the Survey's portion of the investigation were contributed as follows:

Survey	$ 30,000
State of New Mexico	30,000[1]
State of Texas	30,000[1]
Bureau of Reclamation	38,000[1]
National Resources Planning Board	23,000
Total	$ 151,000

1/ Regional Planning Part X, Pecos River Basin, p. 10; National Resources Planning Board, June 1942.

The investigations of each division are described under the general operations of that division in its portion of the Branch History.

GILA RIVER INVESTIGATIONS

The Gila River, like many other western streams, had been seriously over-appropriated for irrigation, and that situation was further complicated by the fact that the Indians on the San Carlos Reservation had prior rights to a large part of the flow. That priority was jeopardized by the use of water by the white settlers. In order to have the information needed to protect the Indian rights, the Indian Service in 1914 made an allotment to the Survey for the purpose of maintaining gaging stations on the Gila River and the diversions from it. The information thus obtained was expected to be used in an adjudication of the Indian rights. The investigation was discontinued in 1916, apparently for lack of funds; however, the river stations were continued by means of State cooperation, and beginning about 1921, Indian Service funds again became available and the operation of stations on the diversions was resumed. The Federal Court issued a consent decree as of January 1, 1936, and placed the administration of the decree under a Federal Water Commissioner. That official supplied the needed cooperative funds and the Indian Service funds were discontinued.

With the increase of settlement and the resulting need for additional irrigation, water therefor was obtained principally by pumping from wells, beginning about 1930. Because of extensive pumping, the Indian Service desired information which would enable that agency to determine the effect of upstream pumping from ground-water on the water flowing into the San Carlos Reservoir. To obtain the necessary information on the ground-water supply and its effect on the flow of the Gila, the Indian Service made allotments to the Survey, beginning with the fiscal year 1940.

At the same time, the Army Engineers were making a study of flood-control on the Gila and other streams, and wished to know the possible effect of flood water storage on the replenishment of the ground-water; also the amount of water wasted in the Safford Valley, and how much could be salvaged and by what means. Allotments were made to the Survey for a ground-water study. Those funds, together with the Indian Service funds, enabled the Ground Water Division of the Survey to make an extensive investigation beginning in October 1939.

The Gila River has dense growths of salt cedar (tamarisk) and other water-loving vegetation along its banks; the salt cedar requires large quantities of water which it obtains from the ground water close to the river or in part from the river itself. Salt cedars were just planted as shade trees at Clifton, Arizona, about 1908. This non-productive use of water was the greatest source of waste, and a determination of the losses due to it was an important phase of the investigation, which also included seepage measurements, well records, and analyses of the water. That investigation was discontinued in June 1942; the results failed to substantiate the large contribution of river water to the ground-water reservoir as believed by the Indian Service, but were sufficient for the needs of the Army Engineers. In a small way that investigation was also participated in, by the Quality of Water Division, as well as the Surface Water Division, which was maintaining the regular gaging stations.

The next investigation which in many respects was a continuation, was started in June 1943 as a war-time measure. The Phelps Dodge Corporation, one of the largest producers of copper, a mineral vital to the war effort, was in need of an additional water supply for its Morenci mine. The results of the 1939-42 investigation had shown considerable losses from the Gila River which might be stopped. In order to extend that study with a view to stopping losses and making available a larger supply of water for the Morenci plant, the Phelps Dodge Corporation requested the Defense Plant Corporation, a war-time agency of the Reconstruction Finance Corporation to arrange for an intensive study by the Survey of the Gila River Basin between Thatcher and the Calva gage, at the head of San Carlos Reservoir, a distance of 46 miles, and offered to reimburse the Defense Plant Corporation for the cost. The latter agency made the necessary arrangements and the investigation was started in June, 1943. It was on a more intensive scale than the previous one, requiring a larger share of participation by both the surface water and quality of water divisions and to coordinate the activities of the three divisions, the Chief Hydraulic Engineer set up an advisory committee consisting of C. S. Howard (Q), Chairman, J. H. Gardiner (S), and S. F. Turner (G), who appointed J. S. Gatewood as project engineer to coordinate the technical field work of the divisions. While the investigation was in progress, the Phelps Dodge Corporation was continuing its search elsewhere for an additional water supply and in 1944, entered into an agreement with the Salt River Valley Water Users, whereby the Corporation was to construct Horseshoe Dam forming a reservoir of 67,000 acre-feet capacity on Salt River, the reservoir to become a part of the Salt River project. In return, the Corporation was permitted to divert to the Gila Basin not to exceed 14,000 acre-feet annually up to a total of 250,000 acre-feet from Black River, a tributary of the Salt River.[21]

21/ Moody's Manual of Investments 1947, p. 1835.

The details of the investigations by each division are described under the activities of that division.

SOUTHEASTERN FLORIDA INVESTIGATION

The need for additional water supplies in the fast growing areas in the general vicinity of Miami, and protection against intrusion of salt water into the ground-water supplies in use, was first sponsored by the National Resources Planning Board, 22/ but that agency was unable to proceed with its proposed joint investigation. The investigation was made possible by cooperation with the city of Miami, Miami Beach, and Coral Gables, and later by Dade County. As all sources of possible supply were to be studied, basic hydrologic, geologic, and chemical data were required and the investigation was conducted by the Surface, Ground, and Quality of Water Divisions, working toward a common goal but each having its own personnel. There was but one agreement with the cooperative agencies. Indicative of the joint nature of the investigation, progress reports were prepared jointly by the three divisions.

22/ p. 82.

The details of the investigation are presented under the activities of each division in Florida.

BASIN REPORTS FOR BUREAU OF RECLAMATION

Before new construction work could be started by the Bureau of Reclamation, a report dealing with the engineering and economic feasibility of the project must be made to the President and to Congress, and authorization obtained, together with the required funds. The drought years of the nineteen-thirties had caused much hardship and heavy losses in parts of the Missouri River Basin, and to stabilize the economy of that region by conserving its water resources, the Bureau of Reclamation speeded up its study of multiple-purpose projects, including both irrigation and power, covering that portion of the Missouri Basin in the so-called irrigation states. In order that adequate data on the water resources would be available when required by the Bureau, the Survey contributed a statement covering the needs of all the divisions of the Branch. Owing to the short time available, that statement was prepared by the Washington Office. The Bureau's report to Congress was printed as Senate Document 191, 78th Congress, Second Session, April 1944.

Studies were being made by the Bureau throughout the irrigation states as a part of post-war planning, and reports for each of 15 major basins were scheduled. Although sponsored by the Bureau, the reports like that for the Missouri Basin were to be Departmental reports, and the Survey was expected to prepare for each report a statement covering the needs of the Branch to meet the obligations to furnish adequate water-resources data. In addition to existing programs, specific lists of additional gaging stations and costs of installation and annual maintenances were included, together with corresponding statements by the other divisions.

Under date of July 21, 1944, the preparation of the Survey's reports of the various basins was assigned to the field men of the different divisions, the chairman of each basin group, designated by the Washington Office, being responsible for assembling the report. During the preparation of the reports, the Survey representatives were expected to consult freely with the representative of the Bureau and other agencies concerned, and to furnish information in order that the Departmental report would be truly comprehensive. The reports were prepared and transmitted to the Bureau as requested. No other Basin report was presented to

Congress by the Department during the period, but a proposed program for the Colorado River Basin was issued by the Department in order that the proposed projects might be studied by the various State and Federal officials concerned.

The Missouri Basin report apparently resulted in the Missouri River Basin-Departmental Program, for which Congress made impressive appropriations in succeeding years.

The Colorado River report aroused the smouldering resentment of the lower basin states against the use of so much water by the upper basin states, although that amount was within the amount allotted by the Colorado River Compact. Comprising the difference of the two groups by modifications in the proposed program accounted for the delay in submitting the report to Congress.

MISSOURI RIVER BASIN-DEPARTMENTAL PROGRAM

Several years prior to the formulation of the Missouri River Basin-Departmental Program the Secretary's Office had felt that as most of the Interior Department agencies were concerned with water in one way or another, there should be some coordination of effort, and water resources committee, of which C. G. Paulsen was chairman and in which membership consisted of representatives from each agency, was informally organized on September 21, 1938. Although occasional meetings were held, very little was actually accomplished due largely to the urgency of matters pertaining directly to the war effort.

Beginning in the depression years of the thirties, the Bureau of Reclamation had started a general investigation in the western states to determine feasible irrigation projects. Reports on each basin were to be transmitted to Congress for approval of the recommended projects. The recurring floods of 1943, 1944, and 1945 in the Missouri Basin emphasized the need for a report on that basin and the Missouri Basin report was completed first. During its preparation, the other Interior agencies were called on to give their ideas regarding the program for the Missouri Basin. As a further step toward coordinating the views of the agencies, the Secretary on May 2, 1944, created a second Water Resources Committee with a representative from each agency and with Lee Muck of the Secretary's Office as chairman and W. G. Hoyt as executive secretary, a full time job, thus insuring action.

When the Missouri Basin report was published, it was apparent that the proposed plan was that of the Bureau and did not reflect the ideas of the other agencies. To remedy that defect, each agency was requested to submit estimates of cost of the investigations thought to be essential and to be made by it, and to fit into the general Bureau plan. The Bureau of Reclamation submitted these estimates for the fiscal year 1946 to the Bureau of the Budget, which recommended specific amounts for each Bureau, and after running the gauntlet of Congress, the resulting funds were allotted to the various bureaus by the Secretary's office. One of the first steps taken by the Survey to formulate its definite program was a meeting in Omaha, August 16, 1945, attended by representatives of all Survey Branches and by Bureau of Reclamation officials. August 16 was celebrated as "V-J Day" in Omaha. In passing, it may be stated that the resulting celebration closed nearly all restaurants and it was difficult to satisfy the inner man. Allocations to the Branch were made within a few weeks. The same procedure was followed for the 1947 fiscal year.

Division	1946	1947
Surface Water	$206,200	$177,650
Ground Water	125,000	120,300
Quality of Water	98,000	115,450
Water Utilization	25,000	16,900
Totals	$454,200	$430,300

Branch Field Office

As a result of this program, field offices of all four divisions were located at one point for the first time, making it possible to establish a branch field office. Lincoln, Nebraska, was selected as the field headquarters for ground water, quality of water, and water utilization; district offices for surface water and for ground water had previously been established there. With four separate offices in Lincoln, two located in the State Capital and two in a private office building, there was much confusion on the part of the public wishing Survey data, and as frequently happens, many inquiries were addressed to the wrong office, with resulting loss of time and annoyance on the part of the seekers for information before the right office was contacted. To remedy that situation, the division heads met on April 8, 1946, to consider ways and means. It was decided to hold what were to be termed Lincoln Staff Committee meetings at least monthly, the chairmanship to rotate between the division heads; a secretary to be appointed for a 6-month term from the combined personnel to record the minutes of the meetings and handle all branch-level correspondence. It was expected that the procurement of all supplies and equipment would be handled on the branch basis. Naturally the Washington Office favored the movement and to complete the unification, consolidated office space for all four divisions was obtained during August 1946, in the Rudge-Guenzel Building. It was then feasible to combine all routine administrative fiscal and procurement operations under one office; the clerical personnel consisting of a chief clerk and three assistants. The cost of operating the Branch Office is shared by the divisions on the basis that each division shall contribute in the proportion that its funds bear to the total funds of all divisions located in Lincoln. The Lincoln Staff Committee convenes as often as necessary to consider matters affecting all divisions. Correspondence regarding branch matters is handled by the staff secretary.

The activities of each division under the Missouri Basin Program are described under the various division headings.

RESEARCH

For a number of years, the Survey had submitted to the Bureau of the Budget, items for needed research by the Branch, the need being for research and development in relation to scientific techniques, instruments, and equipment. Until the fiscal year 1947, those items had failed either in that Bureau or in Congress. However, at last, in that year, Congress appropriated $37,000 for that purpose. To the Water Utilization Division was assigned formulation of the research program by the various divisions. The field offices were requested to suggest topics, and the suggestions received were turned over to the appropriate chief of division for consideration. As a result of the suggestions, the following allocation of research funds was made:

Surface Water Division	$12,500
Ground Water Division	18,000
Quality of Water Division	7,000
	$37,500

The program of each division is described under that division's activities.

Referring to the new opportunity for research, the Director stated at the Branch Conference in Montgomery, Alabama, 23/ that he conceived of research in the Branch as falling in three categories: (1) interpretation or determining the true significance of stream data; (2) devising better and more economical equipment--combining the entire technologic field for useful techniques; and (3) investigations into any phase of the hydrologic cycle, properly within the field of the Branch.

23/ Proceedings, Southern Branch Conference, December 5-7, 1946.

At the Carson City conference, the Chief Hydraulic Engineer stated 24/ that a Branch Research Committee had been established which would guide the programs to be started and carried on both in Washington, and in the field. It was expected that much help in the field of electronics and supersonics would be derived from close collaboration with other Branches of the Survey and with the Navy.

24/ Proceedings of the Western Conference, Sept. 18-20, 1946.

BRANCH CONFERENCES

During the previous periods, conferences of district engineers, from all the surface water districts were held in Washington with the exception of one in San Francisco in 1915, and one in Denver in 1917. Although the other divisions of the Branch were represented on the programs, the conferences were primarily for the purpose of gathering the district engineers in Washington to discuss technical and fiscal matters and related problems. The conferences lasted a full week, and the engineers were requested to arrive either before or remain after the conferences for personal discussion with the Director, the Chief Hydraulic Engineer, and others. The Ground Water and Quality of Water Divisions held their own conferences in Washington, whenever the problems of those divisions warranted. Thus, conferences during the previous periods were not true branch conferences.

War-time activities resulting in personnel shortages and travel and hotel restrictions, were not conducive to conferences; and it was not until 1945, that future conferences were considered. At that time, the members of the Ground Water Division in the far Western States requested the Chief Hydraulic Engineer to authorize a division conference sometime during 1946. That brought up the subject of future conferences; whether those should be confined to divisions or include the entire branch, and whether they should be regional or cover the entire country. The growth of the Branch made it impracticable to hold a general conference of the entire Branch in Washington, due both to the expense involved and the difficulty of obtaining accommodations for so large a number.

Before that point was fully decided, several members of the Ground Water Division in charge of field offices in the Northeast requested authority to hold a regional field conference. When the request was granted, the original plan was enlarged to include Ground Water and Surface Water personnel in New England, New York, New Jersey, Pennslyvania, Maryland, Delaware, Virginia, and West Virginia, the Quality of Water personnel in the Pennsylvania laboratory, and Washington Office representatives, including the Chief of the Branch, and Chiefs of Divisions or their representatives. Thus, the pattern for regional conferences participated in by all four divisions was set. August 6-8, 1946, was the time selected and H. C. Barksdale, in charge of ground-water investigation in New Jersey, was given charge of the arrangements. His chief concern was a suitable meeting place and the Y. M. C. A. camp at Downington, Pa., near Philadelphia, was found to be available and was selected. The conference was largely informal in character and was a farewell meeting for O. E. Meinzer, who was to retire in November. The success of the conference was not diminished by the almost continuous rain during the three-day period.

Remembering the request received the year before from the far West, and recognizing the value of and need for conferences in other sections of the country, four more regional conferences were decided upon to be held within the next year and to be attended by representatives of all divisions in each area. The Downington conference had emphasized one desirable advantage of regional conferences; the relatively short distances to be traveled made possible attendance of many more of the younger men than could have attended a general conference at any one point.

The Western states conference was held September 18-20, 1946, and covered Washington, Oregon, California, Idaho, Nevada, Utah, Arizona, and New Mexico. At the invitation of A. M. Smith, State Engineer of Nevada, the conference was held at Carson City, Nevada, T. W. Robinson, in charge of ground-water investigations in Nevada, was given charge of the local arrangements and was also chairman of the program committee, the other members being C. H. Canfield, C. S. Howard, and R. R. Woolley. Emphasizing the more formal character of that conference was a welcome by the Mayor, and as Carson City is the capitol, by the Acting Governor also. The Washington Office was represented by T. B. Nolan, Assistant Director, C. G. Paulsen, O. E. Meinzer, S. K. Love, and A. N. Sayre, the two latter soon to be appointed chiefs of their divisions. Each division was represented on the program, and in addition to the description of its general activities, by the chief of the division, the local men in charge of each project gave brief description of their activities. The time allotted to each description was 10 minutes with discussion limited to 5 minutes. The lighter side of the conference was represented by an open-air barbecue at Carson Hot Springs, a field trip to Steamboat Springs, Virginia City, and the famous Comstock Lode, and a dinner at the Indian School at Stewart. The total attendance was 82 which included cooperating officials of State and Federal agencies. The proceedings were compiled by T. W. Robinson and published in mimeograph form under the title "Proceedings of the Western Conference Water Resources Branch, Geological Survey, Carson City, Nevada, September 18-20, 1946."

The East Central Branch Conference was originally scheduled to be held in Columbus, but it was difficult to obtain the necessary hotel reservations, so Indianapolis was selected for the conference held November 7-9, 1946. It was a conference for those branch members in Indiana, Ohio, Illinois, Kentucky, Michigan, Wisconsin, Minnesota, Iowa, Missouri, and West Virginia. Possibly, because of the comparative nearness of Indianapolis to Washington, the Washington Office had 15 representatives, including the Director, Assistant Director, the present Chief of the Branch, the former Chief, Mr. Grover, and the chiefs of the divisions and representatives of other branches. The committee on arrangements and program consisted of D. M. Corbett and E. J. Schaefer, co-chairmen, F. F. Schrader, F. H. Klaer, Jr., O. H. Jeffers, J. I. Perrey, and W. R. Cross. The general arrangement was that of the Carson City conference, the chief difference being that more time was given to cooperating State officials, some of whom described the particular problems and needs of their states. The lighter side of the conference consisted of two dinner meetings for the cooperating State officials. The total attendance was 96. The proceedings were compiled by D. M. Corbett and published through the courtesy of C. H. Bechert, Director of the Indiana Department of Conservation, in mimeograph form under the title "Proceedings East Central Branch Conference of the Water Resources Branch, U. S. Geological Survey, Department of the Interior, November 7-9, 1946, Indianapolis, Indiana."

The Southern Branch conference for Branch personnel in North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, and Texas was scheduled to be held in Atlanta, December 5-7, 1946. Difficulty in obtaining hotel accomodations made it necessary to change to Montgomery, Alabama, D. H. Barber, Chairman, P. E. LaMoreaux and W. W. Hastings were appointed the committee on program and arrangements.

The Washington Office had 12 representatives, including the Director, Chief Hydraulic Engineer, chiefs of four divisions, and representatives of other branches. The program differed considerably from those of the previous conferences. There were brief remarks by cooperating officials of which 10 were present, but no papers by any, perhaps in keeping with the general plan which was few descriptions of regular routine activities, but instead, papers on particular technical problems and their solutions. Most of the papers called forth considerable discussion which was recorded in the proceedings. The entertainment featured an old-fashioned southern barbecue the first evening, followed by a talk by F. M. Bell on "Experiences in Japan", and a dinner the second evening. Although O. E. Meinzer had been retired, he attended the conferences and the dinner was virtually in his honor, after which he spoke on "Forty Years of Progress on Ground-Water Investigations." The total attendance was 131 and the program committee compiled the "Proceedings Southern Branch Conference of Water Resources Branch, U. S. Geological Survey, Department of the Interior, December 5-7, 1946, Montgomery, Alabama."

The final regional conference was held in Lincoln, Nebraska, April 9-12, 1947, for branch personnel in Montana, North Dakota, South Dakota, Wyoming, Colorado, Nebraska, and Kansas. As those states are situated largely in the Missouri Basin and as the Missouri

Basin Departmental Plan would have a prominent part in the conference, personnel from Iowa, Missouri, and Minnesota, situated partly in that basin, were also in attendance. The program committee consisted of G. H. Taylor, Chairman; H. C. Beckman, A. H. Tuttle, D. D. Lewis, P. C. Benedict, B. R. Colby, H. A. Waite, and P. E. Dennis; the arrangement committee consisted of B. R. Colby, Chairman, P. C. Benedict, C. V. Burns, D. D. Lewis, T. J. Schaefer, and H. A. Waite. Lincoln was chosen chiefly because it had a branch-level office with all four divisions represented. There were 19 representatives from other Survey branches. To complete his attendance at all the regional conferences, O. E. Meinzer, although he had retired, attended as a private citizen and gave a paper on "Forty Years of Progress in Ground-Water Investigations." Cooperating State and Federal agencies had 32 representatives. The program cover designed by the Lincoln Office contained a humorous sketch of the activities of each division. A somewhat crowded program had been arranged and to warn each speaker when his time was up, a large gong was sounded if he had failed heed the 5 second warning red light under his desk. One prominent member from Washington failed to heed the gong, but kept on until the continuous ringing of the gong drowned out his voice. The fourth day of the conference was reserved chiefly for discussions of administrative problems, and in that respect was reminiscent of the conferences in the previous periods when such discussions were an important feature of each conference. At the time the conference was being held, the Survey item for the next fiscal year had been heavily cut by the House, and the Senate had those items under consideration. To give the conference the latest information, Don McBride, Secretary-Manager of the National Reclamation Association, who was in close touch with the Congressional proceedings, came to Lincoln and reported to the conference. Many of the papers presented dealt with the Missouri Basin development under the Departmental Plan. That in turn was integrated with the so-called "Pick-Sloan" plan, the term applied to the general development program. W. S. Sloan of the Bureau of Reclamation described the Bureau's program under the plan and Gen. Pick was represented by Lt. Col. D. B. Freeman, who described the Army Engineers program. Representatives of the other Survey branches described their operations under the Missouri Basin-Departmental program. In addition to the morning and afternoon sessions, two dinner meetings were held. At one of the latter, Mr. and Mrs. Meinzer were presented with a sterling silver cream and sugar set by the ground-water personnel in the West Central states, and Mr. Meinzer, to enable him to locate ground water even more successfully in the future, was given a "water witch" (divining rod). For the benefit of the ladies, a tour of Lincoln was arranged one day, and a visit to Boys Town, a short distance out of Omaha, followed by a luncheon in Omaha. The total attendance was 222. Through the courtesy of Dr. Geo. E. Condra, Director Conservation and Survey Division, University of Nebraska, the proceedings were mimeographed under the title "Proceedings of the West-Central Branch Conference, Water Resources Branch, April 9-12, 1947, Lincoln, Nebraska."

SURFACE WATER DIVISION

Washington Office

Following Mr. Grover's retirement on January 31, 1939, C. G. Paulsen, in addition to acting as chief of the Branch until October 17, 1939, and assistant chief hydraulic engineer subsequently, continued the duties of chief of the Surface Water Division until April 29, 1940. At that time, R. G. Kasel was appointed acting chief and a year later chief, and served until his death, June 14, 1945. Again Mr. Paulsen took over the direction of the division, and with the help of other members of the Washington Office and some members from field offices called in for that purpose, continued the division's direction until September 17, 1946, when J. V. B. Wells was appointed chief. At the same time, in recognition of the great expansion of the division, A. H. Williams who had returned from his war service a short time previously, was assigned to the Washington Office and designated acting chief whenever the occasion arose. J. C. Hoyt continued as consultant until his retirement June 30, 1944, after 42 years of effective service in the Branch. With his retirement, one of the few remaining links with the old Hydrographic Branch under F. H. Newell was severed. In his early years of service, he did much by his writings and wide personal contacts with prominent engineers and others to make known the comparatively new science of stream-gaging as practiced by the Survey, and gave it recognition in engineering and governmental circles. His book, "River Discharge," written in collaboration with Mr. Grover, was the first text book on the subject and was widely used in engineering schools. Later, Mr. Hoyt devoted himself to the improvement of existing and development of new equipment, thereby increasing very greatly the accuracy of stream-gaging. The Branch certainly owes much to Mr. Hoyt for his energy and success in promoting the improvement of instruments, equipment, and methods during his long time of service. The improvement which he brought about is a fitting monument to his devotion to duty.

C. H. Pierce continued to receive most of the technical problems and prepared or revised technical reports. In 1940 and 1941, he supervised the tests on small-scale models [25]. Beginning in August 1941, he had charge of the Water Resources Bulletin, which had previously been the duty of H. F. Hill, Jr. During the latter part of the period, he revised the pamphlet "Equipment for river measurements--structures for cableways" which had last been issued in 1933. The revised pamphlet was not issued until September 1947.

Section of reports. - The section of reports which in earlier days had been known as the section of review, continued unchanged with B. J. Peterson as chief. In addition to the engineers detailed to it from the district offices, the following engineers constituted the regular staff:

M. C. Boyer	July 1, 1939 to Aug. 16, 1942
J. W. Gambrell	Dec. 17, 1941 to Apr. 18, 1943
D. L. Milliken	Jun. 18, 1943 to May 24, 1944
F. J. Flynn	Apr. 27, 1944 to June 30, 1947

Section of investigation. - G. C. Stevens continued in charge of the section of investigation, to which was referred inquiries of all types from various sources. During the early years of the period, the full time of the section was devoted to the special reports and inquiries regarding available water supplies for war industries and other war establishments. Many inquiries were "hush-hush" and did not mention the problem involved nor the use to be made of the water-supply. Answers to many inquiries, including informal advice, were made by telephone.

[25] p. 94.

Some inquiries were what may be termed "screw-ball", the outstanding one of that type being from a writer in California. That individual proposed to obtain an area of land 100 by 20 miles to demonstrate and absolutely prove that all theories relative to forestation and vegetation cover relative to flow of water are mere guesswork, being wrong in most cases. He needed gasoline to reach the various streams in the proposed area and asked the Survey for help in getting gasoline, stating

> No order to the OPA or any other such will do. Get me a paper that I can force immediate action with. Any official here will ball me all up with red tape until it is too late.

Needless to state, the Survey was unable to meet his request. Another "screw-ball" inquiry was as follows:

> "In any river, pond, pool, or water, there always has been what we may call surface water. What I would like to know is: Just what determines that; just what part of all water, whether in a lake, river, pond, or gold fish pool, shall be surface water. There is water from top to bottom. Some has to be bottom water and some in-between water and some just has to be water on top. What determines that? "

In a number of States, the highway departments had come to appreciate the value of stream-flow records in designing bridge openings and had cooperated with the Survey. It was believed that similar departments in other States might do likewise if the value of the work was called to their attention. Tate Dalrymple, who had been active in arranging highway department cooperation in Ohio, was selected in the fall of 1946 to coordinate the work of the various districts in cooperation with the highway departments. His duties led him to contact the district engineers, the State highway departments in the various districts, and to explain to them the value of the cooperative programs in other districts.

A. H. Frazier, who had been in charge of the development of smaller items of equipment was appointed chief of the Survey's Division of Field Equipment in July 1941, succeeding R. L. Atkinson who resigned.

Field

Just as there were more changes in the Washington Office than in the previous period, so were there more changes in the field organization. Three new districts with headquarters were created at Lincoln, Nebraska, in August 1941, at Baton Rouge, Louisiana, in September 1942, and at Bismarch, North Dakota, in October 1944, St. Louis, Missouri, in February 1946, each being previously a sub-division of a larger district; and at the end of the period, there were 41 districts, with sub-districts at Houghton and Lansing Michigan; Oklahoma City, Okla., Los Angeles, Calif., Pierre, S. Dak., Jackson, Miss., Carson City, Nev., and Logan, Utah. The number of gaging stations increased from 4,164 with 3,000 recorders to 5,812 with about 4,750 recorders.

The district engineers in 27 districts continued throughout the period, but in the remaining 14 districts, the following changes occurred:

District Office	Date	District Engineer	Succeeded by
Atlanta, Ga.	Sept. 1, 1941	F. M. Bell	M. T. Thomson
Charleston, W. Va.	Sept. 23, 1941	Wm. Kessler	H. M. Erskine
Charlottesville, Va.	Aug. 20, 1940	J. J. Dirzulaitis 1/	D. S. Wallace
Chattanooga, Tenn.	Sept. 1. 1941	C. E. McCashin 2/	F. M. Bell
College Park, Md.	Mar. 4, 1945	A. H. Horton 3/	V. R. Bennion
Columbus, Ohio	Sept. 11, 1945	C. V. Youngquist 4/	Tate Dalrymple(5/)
Indianapolis, Ind.	Sept. 14, 1945	H. E. Grosbach 6/	D. M. Corbett
Iowa City, Ia.	Apr. 20, 1940	R. G. Kasel	L. C. Crawford
Louisville, Ky.	Feb. 29, 1940	F. M. Veatch	J. V. B. Wells 7/
Ocala, Fla.	June 4, 1941	D. S. Wallace	G. E. Ferguson
Raleigh, N. C.	Apr. 30, 1947	E. D. Burchard 6/	E. B. Rice
Rolla, Mo.	Jan. 31, 1946	H. C. Beckman	H. C. Bolon
Salt Lake City, Utah	Sept. 16, 1942	A. B. Purton 2/	M. T. Wilson
Tacoma, Wash.	Oct. 16, 1939	G. L. Parker	F. M. Veatch

1/ Separated from service.
2/ Relieved of administrative duties due to physical disability.
3/ Deceased.
4/ Temporarily transferred to Ohio Water Resources Board.
5/ Succeeded by O. H. Jeffers, Sept. 1, 1946.
6/ Retired.
7/ Succeeded by F. F. Schrader, Sept. 16, 1946.

With the increase in the number of gaging stations and the resulting denser coverage, the number of sub-districts, sub-offices, and local residencies increased in greater proportion. At the end of the period, engineering personnel were stationed at 61 points, in addition to the 41 district offices.

Prior to World War II, with relatively few exceptions, the engineering positions had been held by graduates of engineering colleges. However, a considerable number of war-time appointees were to the grade of engineering aid, some of whom obtained later probational appointments. The military services had greatly reduced the ranks of the engineering students, with few graduating during the war years. Furthermore, under the G. I. Bill of Rights, returning engineers flocked to the engineering colleges for refresher courses or to expand their engineering education, with the result that few graduate engineers were available and those were snapped up by private industry, which was operating in high gear and could offer higher salaries than the Government. Under those conditions, the additional personnel required by the expanding program were of necessity obtained to some extent from the Civil Service Register of Engineering Aid (sub-professional grade), the requirements for which replaced a full engineering education by a certain amount of engineering experience. Referring to that situation, Mr. Wells made the following statement at the regional conference held in Lincoln: 26/

26/ Proceedings of the West-Central Conference, p. 26.

> At the present time, the ratio of engineers to sub-professionals is approximately two to one. Ade (A. H. Williams) and I have discussed this with many of our field offices, and I think that the general feeling, almost without exception, is that the sub-professionals are here to stay-- and rightly so. They have greatly assisted in

balancing our organization, relieving our older and more experienced professional people of routine field and office duties so that they can devote their energies to work that requires professional training.

Regional engineer. - Near the beginning of the period, the title of regional engineer came into use.

When cooperation with the Army Engineers was started in 1928, four Survey districts in the Missouri River Basin were involved and each district was submitting its own estimates of cost each year. About 1935, it appeared advisable to have one Survey engineer submit the combined estimates as it was believed that the Army Engineers preferred that procedure. As H. C. Beckman, in charge of the Rolla office, was most conveniently located to the Army Engineer offices concerned, and was actively engaged in cooperation, he was selected as the contact man for the Missouri River Basin. In 1939, in recognition of Mr. Beckman's widespread duties, his title was changed from District Engineer to Regional Engineer.

With the beginning of the Missouri River Basin-Departmental Program in August 1945, Mr. Beckman was appointed representative of the Water Resources Branch, as coordinator, and by the Secretary's order, represents the entire Survey on the Interior Department's Missouri Basin Field Committee. One of his chief duties is to keep in contact with the Bureau of Reclamation and the Army Engineers to learn their needs and help set up a program. Until January 1946, he continued in charge of the Rolla Office which until that time included the State of Kansas.

State Cooperation

During the period, the States of Rhode Island, Delaware, and South Dakota, in that order, entered into cooperation and as all the other States were already cooperating, that completed the list of the forty-eight States, plus the Territory of Hawaii.

State cooperation, which includes that of political sub-divisions, increased 82 percent as shown by the following annual amounts of such cooperation:

1940	$692,738	1944	$ 832,508
1941	702,375	1945	890,128
1942	762,120	1946	1,066,203
1943	768,051	1947	1,196,357

As would be expected, there were a number of reasons for such increases. Perhaps, the chief reason was that during the war years, many States had been unable to carry on many other activities due to war-time restrictions and had funds available to meet the needs for enlarged stream-gaging programs. The war industries in several states had caused at times water shortages and additional records were needed on which to plan for future expansion; either by such industries converted to peace-time uses or by attracting new industries to fill the void left by the closing of war-time industries. Expanding uses of water caused additional State agencies to cooperate for the purpose of obtaining records to meet their individual needs. Increasing attention to floods from areas of only a few square miles caused State Highway Departments to contribute funds. Creation of new districts with headquarters at State Capitols and closer contact with State officials, resulted in increased cooperation.

In several states, cooperation was increased to enable the Survey to maintain additional gaging stations needed by the Bureau of Reclamation in its intensive investigation in the so-called "arid states." Normal increase in existing programs with higher cost of operation also caused considerable increase.

The rate of increase depended somewhat upon the thoroughness with which the existing stream-gaging program in each state covered the state's streams. As an example, at the beginning of the period, the programs in the New England states and New Jersey were so thorough that the percentage of increase, about 23 percent, was smaller than for any other group of states.

With the end of hostilities, the total State cooperation was markedly increased. The reasons for the increase in each state are presented in the following pages which contain the details of cooperation. As cooperation was on a full 50-50 basis except during the 1947 fiscal year when 3 percent of Survey cooperative funds were held in abeyance, only the State cooperative amounts are shown. The amounts of cooperative State funds are taken from the official Survey records, and in a few instances may not include supplemental funds not covered by cooperative agreements.

Maine. - Cooperation with the State Public Utilities Commission continued on practically the same scale except for the last year when it was increased by $1,000.

Annual cooperative State funds available:

1940	$7,000	1944	$7,500
1941	7,000	1945	7,500
1942	7,500	1946	7,500
1943	7,500	1947	8,500

The increased cooperation was to meet the increased cost of operation.

New Hampshire. - Cooperation with the State Water Resources Board continued. For the fiscal year 1942 and 1943, the cooperation was increased to provide for the installation and operation of two additional stations.

Annual cooperative State funds available:

1940	$ 8,436	1944	$ 9,096
1941	8,124	1945	9,208
1942	11,250	1946	10,114
1943	10,575	1947	10,239

Vermont. - State cooperation continued during the period, but the official designation of the State agency was changed. The State Planning Board was organized to do certain work including a study of the State's water resources, and that board, instead of the Governor's office, became the cooperating agency in the fiscal year 1944. Later, the Planning Board was reorganized as the State Development Commission, with the same personnel and became the cooperative agency in the fiscal year 1946.

Annual cooperative State funds available:

Year	Governor's Office	Planning Board	Development Commission	Total
1940	$4,784			$4,784
1941	4,784			4,784
1942	4,760			4,760
1943	4,760			4,760
1944		$4,760		4,760
1945		6,260		6,260
1946			$6,260	6,260
1947			6,260	6,260

Massachusetts. - Cooperation with the Department of Public Works, Metropolitan District, Department of Public Health, and Metropolitan District Water Supply Commission, as described in the previous period, continued on substantially the same scale, with one exception. During the 1947 fiscal year, cooperation with the Department of Public Works was increased from $7,000 to $15,000 for the purpose of starting a program of 1 or 2 stations annually, on small streams having drainage areas of 2 to 5 square miles. This program had 2 objectives: (1) a study of the runoff for the design of culverts and bridge openings on small streams, and (2) the preparation of a special report on hydrology covering 2 or 3 years.

The only new cooperation was that with the State Department of Correction which covered the fiscal year 1940 only. On a farm operated by that agency, water was being pumped from a river for emergency use and cooperation in the operation of a gaging station nearby was arranged. At the end of the year, the Department decided that the record was not essential and discontinued the cooperation.

Annual cooperative funds available:

Year	Dept. Pub. Wks.	Met. Dist.	Dept. Pub. Health	Met. Dist. Water Sup. Comm.	Dept. Corr.	Total
1940	$ 7,000	$4,617	$ 3,625	$ 1,592	$ 250	$17,084
1941	8,000	4,675	2,457	1,242		16,374
1942	6,000	4,675	1,229	1,200		13,104
1943	6,000	4,677	1,375	1,200		13,252
1944	6,000	4,675	1,375	1,200		13,250
1945	7,000	4,735	1,512	1,500		14,747
1946	7,000	4,775	1,512	1,500		14,787
1947	15,000	5,400	1,750	1,650		23,800

Rhode Island. - The chief interest in Rhode Island's few streams relates to pollution from municipal and industrial wastes. As there was no information on either surface- or ground-water supplies, the Survey had discussed with State officials the desirability of a study of those resources. It was not until a change of State administration with a corresponding change in personnel of the Department of Public Works, that results were obtained. When the need for a water resources study was brought to the attention of the new Administration, an item for that purpose was placed successfully in the Department's budget. Cooperation began in the fiscal year 1941 in the amount of $5,500, for the purpose of installing and operating 7 stations. Subsequently, the amounts were reduced essentially to the amounts needed for operation, except that three additional stations were installed later.

Annual cooperative State funds available:

1941	$5,500	1945	$1,750
1942	1,750	1946	2,200
1943	1,750	1947	2,200
1944	1,750		

Connecticut. - Cooperation with the State Water Commission continued in practically the same amounts, except during the last three years when those amounts were increased on account of the higher cost of operation.

The cities of Hartford and New Britain continued their cooperation unchanged.

Annual cooperative State and municipal funds available:

Year	Water Comm.	Hartford	New Britain	Total
1940	$ 8,000	$ 450	$ 100	$ 8,550
1941	8,480	450	100	9,030
1942	7,800	450	100	8,350
1943	8,100	450	100	8,650
1944	8,240	450	100	8,790
1945	8,880	450	100	9,430
1946	9,000	450	100	9,550
1947	10,000	450	100	10,550

Referring to the cooperation, the State Water Commission in its Tenth Biennial Report for the years 1942-1944, stated 27/

27/ p.11, Tenth Biennial Report.

> The State Water Commission is most appreciative of the aid given by the director and staff members of the Stream Gaging Division of the Survey*** Their services have been of the highest order and the cheerful cooperation which has been extended to the State and its citizens in furnishing information is acknowledged with genuine pleasure.

New York. - Cooperation with the State Department of Conservation continued on a gradually decreasing scale as cooperation with other State agencies took on more of the stream gaging program. The State Water Power and Control Commission is a relatively small agency and the cooperative funds were such a large part of its total budget that the commission felt that the major cooperative program should go back to the Department of Public Works, where it properly belonged. The latter agency had been cooperating in a minor way and in the fiscal year 1942, became the chief cooperating State agency.

For many years, the State had been involved in litigation over the water levels of Lake George. The International Paper Company develops power between Lake George and Lake Champlain and at times, the owners of cottages on the shore of Lake George complained that the power company lowered the lake level too much. The problem was to determine the natural water line if the power dam were not in existence. Records of stage on Lake George had been maintained for many years, but there were no records of discharges at the outlet. To obtain that record, the Department of Law, beginning with the fiscal year 1943, cooperated with the Survey in establishing a gaging station which was located in the village of Ticonderoga. After the necessary records became available, the court specified that the lake level should be maintained between a certain range, based on the Survey records.

The special investigation on Long Island, which was started in the previous period, was extended to Suffolk County, the most eastern county on Long Island and to obtain the needed stream flow data, the Board of Supervisors of that county in the fiscal year 1942, entered into cooperation for the establishment and operation of two additional stations at first and other stations in each succeeding year. In addition to the formal cooperation, the County furnished some labor and materials for the construction of the stations.

Westchester County, an area of high class development, has a flood problem caused by small streams having steep gradients, and some years ago created the Westchester County Storm Water Control Survey to consider ways and means. The Army Engineers were requested to study a flood control program, but being unable to formulate plans without flood records, suggested that the Survey be contacted for such records. Accordingly, cooperation was effected in the fiscal year 1944 for the establishment and operation of six gaging stations, five being recorder installations. It may be noted that the first year's operation furnished valuable flood records, an exception to the general experience that floods are reluctant to occur after the installation of flood record stations.

Cooperation with the Buffalo Sewer Authority started in 1939 was for the purpose of maintaining 2 gaging stations on small streams entering Lake Erie close to the purposed extension of the sewer outlet. This was a short-lived program as the city personnel originally concerned entered the military forces and their successors, not being interested, discontinued the cooperation.

Cooperation with the city of Jamestown and the village of Lancaster was that of services in furnishing gage observers. The Washington Office objected to that type of cooperation and it was discontinued in the fiscal year 1946. In 1947, however, the Lancaster cooperation was resumed on a cash basis. Cooperation with the Oswegatchie River Improvement Commission was discontinued in 1944.

Cooperation started in the previous period with the City of New York, Board of Water Supply, Nassau County, Black River Regulating District, Hudson River Regulating District, Cities of Albany, Auburn, New York City Department of Water, Sewers, Gas and Electricity, continued during the period.

Annual cooperative State, County, and municipal funds available:

Year	Dept. of Cons.	Dept. Public Works	Water Power Cont. Comm.	Dept. of Law	Black River Reg. Dist.	Hudson River Reg. Dist.	Oswega-tchie Improv. Comm.	N. Y. Board Water Sup.
1940	$2,620	$ 2,906	$19,500		$1,863	$3,115	$ 50	$13,102
1941	2,620	2,596	23,800		1,613	2,755	50	14,893
1942	2,103	26,376			1,613	2,755	50	17,716
1943	560	34,814		$1,500	1,413	2,755	50	15,306
1944	655	35,663		763	1,443	2,755	50	15,240
1945	500	38,196		750	1,393	2,755		12,510
1946	750	40,424		750	1,468	2,505		13,060
1947	1,500	45,555		750	1,308	2,438		9,856

Cont'd.

Year	Nassau Co.	Suffolk Co.	Lancas-ter.	Buffalo Sewer Auth.	Auburn	Albany	N. Y. W. S.	Dept. G&E
1940	$1,500		$ 120	$ 500	$ 250	$ 272	$	202
1941	1,500		120	400	100	272		580
1942	1,500	$2,500	120	400	100	272		300
1943	1,500	600	120		100	272		300
1944	1,500	3,500	120		100	272		300
1945	1,500	4,000	120		100	272		300
1946	1,950	5,100			100	272		300
1947	2,250	6,750	225		100	272		300

Cont'd.

Year.	James-town.	West-Chester Co.	Total
1940	$ 132		$46,132
1941	132		51,431
1942	132		55,937
1943	132		59,422
1944	132	$8,583	71,076
1945	132	2,100	64,628
1946		2,100	68,779
1947		2,100	73,404

New Jersey.- Cooperation with the State Water Policy Commission continued during the period. In a reorganization, the Water Policy Commissio was taken into the Department of Conservation and during the last two fiscal years, the Department of Conservation became the cooperating agency, but this was just a change in name as the personnel directly concerned remained the same. The increased cooperation during the 1947 fiscal year was due chiefly to higher costs of operation. To complete the needed network of stations in the Delaware River Basin, 28/ the Water Policy Commission made

28/ p. 93.

a separate agreement during the fiscal year 1940 for the installation of three stations, the operation of which during succeeding years was a part of the regular stream-gaging program.

Cooperation with the North Jersey Water Supply Commission continued. That with the Delaware River Joint Toll Bridge Commission which had represented services for gage-height stations on the Delaware River was discontinued with the fiscal year 1942, as the Washington Office at the time was opposed to cooperation of that type.

Cooperation with the Passaic Valley Water Commission was started in 1947. That commission is the agency for the large cities in the joint operation of municipal water supplies in the Passaic Valley. The water supply is taxed under the State water code, and the amount of the tax depends upon the amount of water left in the stream below the point of diversion. There was no record of flow just below the diversion, the nearest record being that at a power plant some miles downstream. To determine more accurately the flow below the diversion, cooperation was arranged for the installation of a gaging station at that point.

Annual cooperative State funds available:

Year	Water Policy Comm.	Dept. of Cons.	N. Jersey Water Supply Commission	Delaware R. Bridge Commission	Passaic Valley	Total
1940	$17,700 1/		$ 2,000	$ 1,091		$20,791
1941	11,400		2,000	1,100		14,500
1942	12,500		2,000	600		15,100
1943	11,100		2,000			13,100
1944	11,600		2,000			13,600
1945	12,500		2,000			14,500
1946		$13,500	2,000			15,500
1947		18,000	2,700		$1,330	22,030

1/ Including a special allotment of $5,700 to complete network in Delaware River Basin.

Pennsylvania. - Cooperation with the State Department of Forests and Waters which was started in 1931 continued during the period, the annual amounts fluctuating between narrow limits except during the last three years, when they were increased on account of the rising costs of operation. The cities of Harrisburg and Bethlehem cooperated toward the maintenance of several gaging stations in connection with their water supplies:

Annual cooperative State funds available:

Year	Dept. Forests and Waters.	Harrisburg	Bethlehem	Total
1940	$ 30,000	$ 600	$ 1,000	$31,600
1941	29,000	600		29,600
1942	28,675	450	600	29,725
1943	27,675	350	450	28,475
1944	27,800	350	450	28,600
1945	30,000	350	450	30,800
1946	35,000	225	524	35,749
1947	35,000	225	500	35,725

Delaware. - When cooperation with Delaware was effected in 1943, the roster of the 48 states was complete. The need for water facts having become pressing in that state, V. R. Bennion, of the Maryland district, discussed the situation with the various Delaware State agencies and was referred to the Highway Department as being the agency most interested, and what was of greater importance, the agency having funds that might be made available for cooperation. That Department, in the absence of actual flood records, was using empirical flood formulae to determine the flood flows to be used in designing water-way openings. Mr. Bennion arranged therefore for a small amount of cooperation which was continued during the remainder of the period. During the fiscal year 1946, the cooperation was increased to permit the installation of an additional station. In passing, it may be noted that a short time after the establishment of several gaging stations, a flood occurred which had a unit runoff double that used previously in the formulae.29/

29/ Statement of M. R. Bennion to author.

In the fiscal year 1947, cooperation was arranged with the Newcastle County Soil Conservation District, the District's objective being the conservation of natural resources of the Brandywine Creek Basin which lies in both Pennsylvania and Delaware. The purpose of the cooperation was the installation and operation of a gaging station on Brandywine Creek and 8 rain gages, the records from which are to correlate the rainfall and runoff in the Brandywine Creek Basin.

Annual cooperative State and district funds available:

Year	State Highway Dept.	Newcastle County Soil Cons. Dist.	Total
1943	$ 300		$ 300
1944	1,200		1,200
1945	1,800		1,800
1946	3,000		3,000
1947	1,850	$4,500	6,350

Maryland. - Cooperation with the Maryland Geological Survey was continued. The State funds were augmented by contributions from the members of the Upper Potomac River Board for the maintenance of 5 stations near Cumberland. During the fiscal year 1944, the State Geologist having funds which he could not otherwise use due to war restrictions, increased his cooperation for the purpose of establishing 7 additional stations. The State and Survey furnished the funds for construction; and the cities and counties, the funds for operation during the remainder of the period. In 1946, the State Geologist obtained additional funds for the installation of 1 station and for the installation of recorders at the existing stations not so equipped.

The cities of Baltimore and Salisbury, and the Washington Suburban Sanitary District continued cooperation. The city of Annapolis and Anne Arundel County in which Annapolis is situated, both entered into cooperation for the purpose of determining the best additional water supplies available.

Annual cooperative State and municipal funds available:

Agency	1940	1941	1942	1943	1944	1945	1946	1947
State Geologist	$6,000	$6,000	$5,950	$5,950	$10,960	$8,300	$13,675	$9,150
Baltimore	900	900	900	900	900	1,525	1,650	1,800
Salisbury	200	200	200	200	200	225	250	275
Washington Suburban San. Dist.	600	650	875	875	875	1,450	2,250	1,800
Annapolis				800	200	200	250	275
Anne Arundel County					38	275	275	275
Totals.	$7,700	$7,750	$7,925	$8,725	$13,173	$11,975	$18,350	$13,575

Virginia. - Cooperation with the State Conservation Commission continued. D. G. Wallace became district engineer August 20, 1940, and soon afterward became interested in the water supplies of the small towns of the State. He visited every incorporated town, interviewed the town or city officials relative to the existing water supplies and their adequacy. Where additional supplies were needed, temporary gaging stations were installed where surface supplies could be obtained. In his capacity as Chief Engineer of the State Commission's Division of Water Resources and Power, he would offer advice to the small towns having no means of solving their water-supply problems. These contacts created additional interest in the State's water resources and the value of the Survey's investigations, and resulted in a gradual increase of the State cooperation.

The year 1941 was one of low flow and Wallace installed some gaging stations in the Coastal Plain and made what he termed "drought" measurements, believing that cities in that area might require additional water supplies. His belief was soon substantiated as within a short time, the great increase in war work in the Hampton Roads area made it necessary for both Newport News and Norfolk to seek larger additional supplies and to investigate both surface- and ground-water sources. In the meantime, cooperation was arranged with Newport News for the continuance of the temporary stations on the Chickahominy River and with Norfolk for the continuation of stations on the Blackwater and Nottaway Rivers. As a result of the records from those stations, the Federal Works Agency furnished some ten million dollars to obtain additional water supplies for the two cities.30/

30/ Letter from D. G. Wallace to author.

Just at the end of the period, cooperation was arranged with the city of Staunton for the operation of a gaging station on the North River above the city's dam, as a larger dam was to be constructed farther upstream.

Annual cooperative State and municipal funds available:

Year	Conservation Commission	Newport News	Norfolk	Staunton	Total
1940	$19,000				$19,000
1941	19,700				19,700
1942	19,485	$200	$400		20,085
1943	25,816	400	400		26,616
1944	21,500	400	400		22,300
1945	25,400	400	400		26,200
1946	28,560	800	400		29,700
1947	33,500	400	400	$100	34,400

North Carolina. - Cooperation with the State Department of Conservation and Development continued during the period. The severe flood of August 1940 damaged or destroyed about 40 gaging stations and to rehabilitate those stations, the State made a special allotment of $7,800 for the fiscal year 1941.

The Army Engineer cooperation was becoming increasingly important, and as Asheville was too far from the Army Engineer stations and headquarters, and also from the cooperating State officials in Raleigh, the Survey office was moved from Asheville to Raleigh in October 1943. With quarters adjacent to those of the State officials, the closer contact led to increased cooperation.

Annual cooperative State funds available:

1940	$12,505	1944	$17,000
1941	20,705	1945	17,500
1942	15,970	1946	17,500
1943	18,060	1947	22,500

South Carolina. - In addition to the State Highway Department, which continued its cooperation started in 1930, two other agencies, the Public Service Authority and the State Research, Planning, and Development Board, entered into cooperation during the present period.

In 1921, the Columbia Railway and Navigation Company obtained a permit and later a license from the recently-created Federal Power Commission to develop water power on the Cooper and Santee Rivers, but was unable to finance the project. To assure the development of the project which was needed for the industrial expansion of the state, the Legislature in 1934 created the Public Service Authority, the duties of which were defined as follows:31/

31/ Sec. 3, Act 887, Acts of 1934.

> The Public Service Authority shall have power to develop the Cooper River, the Santee River, and the Congaree River in this state, as instrumentalities of intrastate, interstate, and foreign commerce and navigation; to produce, distribute, and sell electric power; to reclaim and drain swampy and flooded lands; and to reforest the water sheds of rivers in this state; ***

The privately-owned power companies fought this legislation through the courts until 1938 when the act was declared constitutional. At its next session, the Legislature ratified the acquisition by the Public Service Authority of the license issued by the Federal Power Commission, and empowered the Authority to construct the project under the terms of the license.[32] Thereupon, the Public Service

32/ Act 179, Acts of 1939.

Authority started planning the project and later constructed it by means of a PWA loan and grant. Through the need for additional gaging stations and the service which the Survey could render,[33]

33/ P. 119.

A. E. Johnson arranged with the Authority for cooperation which began during the fiscal year 1944.

Realizing the need for post-war planning, the Legislature in 1944 created a commission to study, among other subjects, the peace-time economy and that body recommended to the Legislature the following year the consolidation of several existing State Boards. Following these recommendations, the Legislature in 1945 created the State Research, Planning, and Development Board. In connection with the industrial development of the state, the low-water flow of the rivers was of especial importance and to obtain such information at many points where complete records were not needed, the Board entered into cooperation in the fiscal year 1946. Another project under that cooperative agreement was the publication by the State of all South Carolina stream-flow records to be prepared by the Survey.

The cities of Spartansburg and Duncan each contributed to the maintenance of a gaging station.

Annual cooperative State and municipal funds available:

Year	Highway Dept.	Public Service Authority	Research, Plan. & Develop. Bd.	Spartansburg	Duncan	Total
1940	$ 5,000	$	$	$ 300	$250	$5,550
1941	5,000			300	250	5,550
1942	5,000			300	200	5,500
1943	5,000			300	150	5,450
1944	5,000	4,250		300	150	9,700
1945	5,000	3,600		300	150	9,050
1946	5,000	3,600	2,200	300		11,100
1947	5,000	3,600	2,625	325		11,550

Georgia. -Soon after cooperation was started in 1937, the name of the cooperating State agency was changed to the State Department of Natural Resources, and that in turn was changed to the Department of Mines, Minerals, and Geology in the fiscal year 1944. These changes caused by political changes in State administration, were chiefly in name and in the chief personnel, as the functions remained virtually the same.

In 1945, the Emory Field Station, a philanthropic agency operated by Emory University, began contributions to the State agency to enable the Survey to continue the maintenance of a number of gaging stations needed by the Field Station's investigations. $2,000 was contributed in 1945 and 1946 each, and $2,400 in 1947.

In the fiscal year 1946, M. T. Thomson showed the State officials that the amount per station allotted by the Army Engineers for the operation of their stations was so much higher than the average amount allotted for cooperative State stations, that the cooperation was increased by $3,000. In the fiscal year 1946, the Governor created the Agricultural and Industrial Development Board and that agency, faced with specific problems involving surface water, contributed $5,000 through the State agency. However, that contribution was later disallowed by the State Auditor.

In the fiscal year 1947, the State Highway Department contributed to the State cooperative agency $5,000 for the purpose of enabling the Survey to analyze flood conditions at selected bridge sites, and furnish data on the frequency and magnitude of floods, and the probable distribution of flow through the proposed bridge openings; the Survey's matching $5,000 to be used to study Georgia floods and prepare reports needed by the Department.

The State, cities, and towns were prosperous, and the smaller towns, depending almost wholly on ground water which would be inadequate for post-war growth which all anticipated, wished to develop surface supplies. These supplies were usually from small streams, where gaging stations would be required, and as the Development Board was interested in these problems, it was willing to contribute to the expansion of the stream-gaging program.

Annual cooperative State funds available:

1940	$8,000	1944	$ 9,700
1941	8,350	1945	11,700
1942	9,480	1946	14,700
1943	9,000	1947	20,100

Florida. - Cooperation with the State Road Department started in 1931, continued with a slight increase in funds during the last half of the period. The State Geological Survey, which had discontinued surface-water cooperation in 1931 in favor of the ground-water investigations, resumed full cooperation during the 1942 fiscal year, when its funds were increased, and continued during the remainder of the period.

The rapid increase in population, particularly in the larger cities, the discovery that irrigation is profitable to citrus growers, and the dry years of the present period which caused serious shortages in existing water supplies, created wide-spread interest in the state's water resources, and a willingness to increase State and County funds available for water resources investigations. In 1939, the city of Miami found that many of the wells furnishing the metropolitan area's supply were threatened by salt water encroachment, and requested the Survey to cooperate in a study of both surface and ground-water supplies. The survey entered into a 3-year program, including in the area studied, the Everglades and Lake Okeechobee, and at the conclusion of that program, the city realized the need for continuing observations on a reduced scale, and continued cooperation accordingly.

The data collected for the Miami program proved so valuable to the Everglades Drainage District that in 1943, that State agency entered into cooperation for the special object of determining in more detail the characteristics of the $50,000,000 network of drainage canals, and hence obtain better control of the water. As a by-product, the Army Engineers obtained sufficient data to design the comprehensive flood-control project which will bring needed relief to the district.

In connection with water supplies and pollution surveys, it was necessary to determine the quantities of water passing up and down the channels and along the coastal waterways during flood and ebb tides. Such special studies were made largely in cooperation with the State Board of Health and also with the city of Jacksonville. Various cities and counties cooperated in the operation of local stations.

One of the state's needs was for data in the small basins containing lakes used for citrus irrigation. To meet that need, the Governor and Cabinet in 1945 agreed to match with State Internal Improvement Board funds, money contributed by the counties and drainage districts, with the understanding that the combined fund would be matched by the Survey. By the end of the second year, about $16,000 was available.

Annual cooperative State and municipal funds available:

Agency	1940	1941	1942	1943	1944
State Road Dept.	$ 4,692	$4,500	$4,500	$4,500	$5,000
State Geological Sur.			500	1,000	1,000
State Board of Health				100	200
Miami	9,500	12,500	10,828	10,000	2,500
Everglades Drain. Dist.				1,875	3,750
Internal Imp. Fund					
Jacksonville	300	300	300	300	300
Tampa	200	200	200	200	400
St. Augustine	150	200	200	200	200
Daytona Beach			500	200	200
Fort Meyers				100	1,000
Lake Worth					450
Fort Pierce					200
Pinellas County					
Dade County					
Orlando Util. Comm.					200
State Hospital			200		
Perrey					
Total	$14,842	$17,700	$17,228	$18,475	$15,400

Cont'd

Agency	1945	1946	1947
State Road Dept.	$5,500	$5,750	$6,000
State Geological Sur.	500	3,000	3,000
State Bd. of Health	360	500	500
Miami	2,500	2,500	2,500
Everglades Drain. Dist.	5,000	5,000	6,000
Internal Imp. Fund		5,000	8,000
Jacksonville	550	550	300
Tampa	200	200	300
St. Augustine	200	200	200
Daytona Beach	200	200	
Fort Meyers	500	400	400
Lake Worth	275	150	
Fort Pierce	700	325	
Pinellas County	825	875	1,600
Dade County		1,000	2,750
Orlando Util. Comm.	200		
State Hospital			
Perrey			400
Totals	$17,560	$25,650	$31,950

Alabama. -Cooperation with the State Geologist continued at the same level during the period, except for two years when that official was in military service. His salary during that time was not used by the acting State Geologist and became available for an increase in the cooperative funds.

Annual cooperative State funds available:

1940	$7,500	1944	$ 7,500
1941	7,500	1945	10,000
1942	7,500	1946	8,125
1943	7,500	1947	7,500

Referring to the cooperative program, the State Geologist stated in his annual report for the year ending September 30, 1944:

> The cooperative water resources investigation has enabled the U. S. Geological Survey to better meet the many water problems in Alabama resulting from the war programs; and in so doing, has contributed much to the war effort. Present stream-flow data and continuous long-time records are useful to the Army, Navy, and war industry and are vital to any post-war planning. Information on the quantity and quality of available water is required by new industries which contemplate locating in Alabama.

Mississippi. - Cooperation with the State Geological Survey continued at $10,000 annually throughout the period.

Louisiana. - The Bureau of Statistics in the State Department of Conservation was the cooperating State Agency in theearly years of the period. The funds of that bureau were cut in the fiscal year 1942, and the cooperative funds correspondingly reduced. To make up for the reduction, the State Department of Highways contributed for that year. At that time, a new governor, Sam Jones, took office and he reorganized the State government by sponsoring a Department of Public Works in which would be centered all the engineering activities of the State. Thereafter, that Department became the cooperating agency. In 1944, the cooperation was increased to allow for some expansion of the program, and later increases were made on account of increased costs. These increases were arranged due chiefly to the efforts of the new district engineer, E. B. Rice.

Cooperation with the State University for the maintenance of 1 station on the campus for a special investigation was discontinued in 1942, when new construction work drowned out the station. At that time, the purpose for which the station was maintained had been accomplished.

Annual cooperative State funds available:

Year	Dept. Cons.	State Highway Dept.	Dept. Public Wks.	University	Total
1940	$ 10,000			$ 415	$10,415
1941	10,000			415	10,415
1942	7,500	$2,500		415	10,415
1943			$13,000		13,000
1944			16,500		16,500
1945			18,000		18,000
1946			20,000		20,000
1947			20,000		20,000

West Virginia. - After several unsuccessful attempts, the State Geologist succeeded in having an item for stream gaging included in his budget and beginning with the fiscal year 1940, he was able to cooperate to the extent of $3,200 annually. In the previous period without a specific item, he could only cooperate to the extent of $500. The state Public Service Commission, having no specific authority to cooperate, contributed $1,800 annually to pay the salary of a clerk for the Survey. The State Conservation Commission was interested in the flow of springs, chiefly in connection with the State fish hatcheries and during a dry summer, the Survey measured several times a number of springs, and the following year measured all of the many springs in the state. The Commission also wanted information on certain streams in connection with warm water hatcheries. Having located several streams that might be suitable, it was necessary to know the discharge, and realizing the help that the Survey could render, entered into cooperation during 1946 and 1947.

Mounting costs of operation and need for additional gaging stations for the study of pollution brought additional State agencies into the cooperative picture; the State Health Department was concerned with sewage pollution and the State Water Commission, with industrial wastes.

During the fiscal year 1943, the latter had a small amount available for cooperation; the next year, 1944, the State Health Department continued the cooperation as the Water Commission's funds were low and during 1945, the Water Commission was again able to provide the needed funds. For the last two years of the period, both agencies were financially able to continue cooperation. The

State Engineering Experiment Station and the city of Morgantown were interested in the flow of Deckers Creek in Morgantown, and beginning with the fiscal year 1946, cooperated for the purpose of installing and operating a station on that creek.

With the rejection of the Army Engineers' flood control plan for the Potomac River Basin, that agency curtailed its cooperative expenditures for stream-gaging, and to insure the operation of those stations until the State Legislation could provide funds for that purpose, the State Department of Agriculture cooperated to the extent of $1,000 during each of the fiscal years 1946 and 1947.

The Army Engineers had constructed a flood wall to protect the city of Huntington and upon its completion, turned it over to the city. The flow of Fourmile Creek has to be pumped through the wall and the city felt that in view of possible future litigation on backwater which might be caused by the creek, the gaging station which had been established in cooperation with the Army Engineers should be continued, and cooperation was effective during the last 3 years of the period.

Annual cooperative State funds available:

Agency	1940	1941	1942	1943	1944	1945	1946	1947
State Geol. Sur.	$3,200	$3,200	$3,200	$3,200	$3,200	$3,200	$3,200	$3,200
Pub. Serv. Comm.	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
Water Comm.				1,090		1,500	1,000	1,000
Health Dept.					1,500		2,500	1,500
Conserv. Comm.							1,500	3,200
Eng. Exp. Sta.							750	200
Dept. of Agric.							1,000	1,000
Huntington						300	300	300
	$5,000	$5,000	$5,000	$5,090	$6,500	$6,800	$12,050	$12,200

Kentucky

The State Department of Highways continued its cooperation, and found that one of the greatest needs was for records on small streams draining about 50 square miles, to serve as a guide for culvert design. Accordingly, the cooperation was increased to $10,000 in 1942 to cover a 6-station program. To provide for actual and anticipated increased cost of the stream-gaging program, that cooperation was increased in the 1947 fiscal year. In 1943, the State Department of Mines and Minerals desired the operation of 2 stations on the Dix River, the only Kentucky stream having power development, and began cooperation for that purpose. In 1945, Louisville and Jefferson County began cooperation for the purpose of obtaining records of 4 small streams in the county. These records gave the Planning and Zoning Commission needed data for studies of drainage and development for recreational purposes.

Annual cooperative State funds available:

Year	Dept. Highways.	Dept. M. & M.	Louisville & Jefferson Co.	Total
1940	$ 8,000			$ 8,000
1941	8,275			8,275
1942	10,500			10,500
1943	9,250	$ 800		10,050
1944	10,000	300		10,300
1945	10,000	1,700	$ 1,200	12,900
1946	10,000	550	900	11,450
1947	13,125	650	1,000	14,775

In 1945, a group of prominent educators and State officials conceived the idea of preparing for the use of the schools and also for the general public, a series of reports on Kentucky's resources, and to F. F. Schrader was assigned the preparation of a report on water. That report was published by the Bureau of School Service, College of Education, University of Kentucky, and reprinted by the Department of Mines and Minerals.[34] It contained a description of the hydrologic cycle, description of the streams and their uses, length and fall per mile of principal streams, a summary of stream flow records, and descriptions of outstanding floods. The ground-water areas were described in considerable detail.

34/ Series VIII, Reprint 10, 1946.

Tennessee. - Cooperation with the Department of Conservation's Division of Geology continued on practically the same scale throughout the period. As a large part of Tennessee is involved in the activities of the TVA with which the Survey has a separate agreement, the cooperation with the State was confined chiefly to Western Tennessee where no other funds were available, and to the smaller streams in the Tennessee and Cumberland River Basins with which the cooperating Federal agencies, TVA, and Army Engineers, were not concerned. In those basins, the State is interested primarily in the small streams which are sources for municipal water supplies and outlets for municipal sewage and industrial wastes.

Beginning in the fiscal year 1940, cooperation was arranged with the State Department of Public Health for the purpose of operating a gaging station on a highly-polluted small stream at Nashville. Although the records were discontinued when sufficient information was obtained, the cooperation was continued as a token contribution to the general stream-gaging program, which contributes much helpful information to the Department of Public Health.

Cooperation with the city of Knoxville was started during the fiscal year 1945 for the purpose of operating two gaging stations on First Creek, a small stream subject to periodic damaging floods in Knoxville. Until the completion of flood-control works, the stream-flow records are used in forecasting floods, in connection with the rainfall records from several city-operated rain gages. The records are furnished to the TVA forecasting sections which predict crest stages on the stream in Knoxville. These forecasts have saved the city large amounts of money previously spent in unnecessary moving of families from areas subject to inundation, and the city officials are well-pleased with the cooperation.[35]

35/ Letter from F. M. Bell to author.

Annual cooperative State and municipal funds available:

Year	Dept. of Conservation	Dept. of Public Health	Knoxville	Total
1940	$ 9,000	$ 400	$	$ 9,400
1941	10,600	400		11,000
1942	9,350	400		9,750
1943	8,200	400		8,600
1944	9,000	400		9,400
1945	9,000	400	200	9,600
1946	9,500	400	400	10,300
1947	9,500	400	400	10,300

Ohio. - During the war years, Ohio's very large industrial enterprises, among the largest in the United States, were expanded to meet the war demands. The chief industries were the manufacture and fabrication of steel and rubber, and the development of electric power by steam; each required large quantities of water. A measure of the quantities used is given by C. V. Youngquist,[36] who states that during 1945, the Youngstown Sheet and Tube Co. used by pumping in the Youngstown district, 95,303,710,000 gallons of water, equal to a continuous flow of 400 second-feet; the annual generation of electric power by steam requiring 80 gallons per kw is 15 billion kwh, equal to a continuous flow of 5,100 second-feet. These water requirements caused water shortages at certain times, and to provide for future expansion, the industrial interests desired additional investigations of the state's water resources, and as shown by the increased State funds made available, the State Legislature realized the need for additional State support.

36/ Ohio's Water Resources: Ohio State University Studies, Engineering Series, Vol. XV, No. 1, May 1946, p. 7.

Cooperation with the State Cooperative Topographic Survey continued during the period, except during 1941 when the State Division of Conservation and Natural Resources contributed funds for the installation of artificial controls at four existing stations; the controls forming pools for recreation and fish propagation. Cooperation with the Muskingum Watershed Conservancy District, ceased with the fiscal year 1940 as the Army Engineers took over the flood prevention work in that area, and subsequent cooperation was with the latter agency. Cooperation with Miami Conservancy District also continued.

During the fiscal years 1942 and 1943, the Mahoning Valley Sanitary District again cooperated. Those were critical years for the water supply for the Youngstown steel district, and it was necessary to regulate by the amount of inflow the water released from the storage reservoirs. This required a Survey resident engineer to measure all inflow and report each day what the release should be, and the District cooperated in the maintenance of the resident engineer. District cooperation was not necessary subsequent to 1943 as the Army Engineers operated the reservoirs and paid a part of the cost of the Survey's activities.

In 1941, the State Chamber of Commerce, industrial leaders, and Federal officials interested in water, held a meeting to discuss the growing water problems. A committee of 65 members was appointed to study the problem, and that committee recommended the creation of a water supply agency to emphasize the investigation of ground-water as well as surface-water supplies. The State Water Supply Board was created in 1941, and began cooperation on a small program of 5 stations in the Grand River Basin, for the purpose of investigating the possible storage of water for industrial use in Northeastern Ohio by means of a canal from the Ohio River. In the fiscal year 1946, the cooperation was increased to provide for the construction of 3 additional stations in the Akron area, for the benefit of the rubber industry.

Realizing that greater powers than those vested in the Water Supply Board should be given to a State agency, the Legislature created the Water Resources Board, succeeding the Water Supply Board, effective October 2, 1945. Its duties were "to study and report the facts of water uses and resources".37/ C. V. Youngquist had been on

37/ Idem p. 3.

the original committee and was requested by the newly-created Board to become Chief Engineer for at least two years, and outline a program of action. He was given a w. a. e. appointment in the Survey and became Chief Engineer of the Water Resources Board. In outlining the program to the author, Mr. Youngquist stated that he endeavored to cover all phases of hydrology in one program. The Surface Water cooperation which began in the fiscal year 1946, included analyses of flood frequencies and special flood studies showing relation between rainfall and runoff.

In 1945, a new bridge engineer in the State Department of Highways was concerned with the size of bridge openings on small streams and came to the Survey for information. Tate Dalrymple prepared a report on stream and bridge openings and as a result, cooperation was started in the fiscal year 1946. The chief purpose was the establishment of stations on very small streams for the proper design of culvert openings. By the end of the period, 14 stations had been installed on drainage areas ranging from 0.3 to 10 square miles.38/

38/ Tate Dalrymple: Application of Hydrologic Data to Bridge and Culvert Design. (Unpublished.)

Cooperation with the State University for two years was for the purpose of analyzing water samples which were obtained in connection with the stream-gaging program. Cooperation with the cities of Columbus, Van Wert, Canton, and Springfield was for the purpose of maintaining gaging stations needed in investigation of surface-water supplies; cooperation with the Lucas County Sanitary District was for the maintenance of 2 gaging stations for the study of waste disposal.

Annual amount of cooperative State and municipal funds available:

Agency	1940	1941 1/	1942	1943	1944
Topographic Survey	$ 5,000	$ 5,700	$ 8,400	$ 8,400	$13,867
Miami Cons. Dist.	5,000	5,000	5,000	3,500	3,500
Muskingum Dist.	2,966				
Water Supply Board			2,650	1,650	1,250
Water Resources Board					
Highway Dept.					
State University		600	300		
Mahoning Valley District			1,400	1,330	
Cities	550	550	950	1,550	1,150
Lucas County					
	$13,516	$11,850	$18,700	$16,430	$19,767

Cont'd

Agency	1945	1946	1947
Topographic Survey	$13,183	$12,500	$12,500
Miami Cons. Dist.	3,500	3,500	3,500
Muskingum Dist.			
Water Supply Board	1,250	5,700	625
Water Resources Board		7,000	7,600
Highway Dept.		7,500	7,500
State University			
Mahoning Valley District			
Cities	900	1,550	1,500
Lucas County	518	518	518
	$19,351	$38,268	$33,743

1/ State Division of Conservation and Natural Resources.

Indiana. - Cooperation with the Department of Public Works continued through the fiscal year 1941. In January 1941, the State Assembly abolished the Department of Public Works which consisted of the State Highway Commission and the Department of Conservation, and set up those agencies independently, effective July 1, 1941. Thereafter, separate cooperative agreements were signed which continued until June 30, 1943. The first legislative act authorizing the Department of Conservation to cooperate with the Survey was enacted in 1943. By its terms, $15,000 per year was to be available for a 10-year period; in addition, an emergency fund of $2,000 for use before June 30, 1943, was made available. In that act, no distinction was made between surface- and ground-water investigations as both were contemplated. Before the agreement was signed, the Director of the Department of Conservation insisted that those investigations which had previously been carried on independently by the Surface and Ground Water Divisions, under agreements with separate State agencies, be consolidated under one Survey representative, who was D. M. Corbett in charge of the Surface Water investigation. By so doing, some duplication of work and administrative expense would be avoided. Since July 1, 1943, only one cooperative agreement has been in effect, even though the Department of Public Health, Highway Commission, several cities and utilities contribute to the Conservation Department, in aid of the investigations. Pollution is a serious problem and the Department of Health must know the concentration of pollution in the streams. It takes its own samples and must know the stream flow to determine the concentration. The State decides upon the division of funds between the surface- and ground-water investigations.39/

39/ Letter from D. M. Corbett to author.

Referring to the consolidation of surface- and ground-water investigations, C. H. Bechert, Director, Water Resources Division, Conservation Department, stated at the Branch conference in Indianapolis, Nov. 7-9, 1947: 40/

40/ Proceedings p. 34.

> Almost three and one half years have elapsed since our expanded water resources program has been put into effect. We feel that while our set-up with the Survey may be unique in some respects, it has paid dividends in increased efficiency, a well balanced program, and a high quality of work.

During 1940 and 1941, Indianapolis contributed to the maintenance of one gaging station in connection with its municipal water supply.

Like many other states, Indiana came to realize during the war years, the importance of its water resources to heavy industry and during the last two years, the funds were greatly increased.

Annual cooperative State and municipal funds available:

Year	Dept. Public Wks.	Dept. Conservation	Hwy. Comm.	Indianapolis	Total
1940	$ 5,700			$ 300	$ 6,000
1941	8,250			250	8,500
1942		$ 3,464	$ 4,950		8,414
1943		7,910	5,400		13,310
1944		18,678			18,678
1945		17,900			17,900
1946		26,275			26,275
1947		34,175			34,175

Illinois. - Cooperation with the State Water Survey, a division of the Department of Registration and Education, continued on the same level during the period. At the end of the previous period, cooperation with the Division of Waterways in the Department of Public Works and Buildings had been resumed and was continued at a fairly uniform rate until the last two years of the period. The Division of Waterways wished to have on file complete information on each small basin in the State, including unit hydrographs and duration curves, and increased the cooperation during the 1946 fiscal year for that purpose. The same agency under the leadership of Col. Hill, a retired Army Engineer, was preparing a post-war stream-gaging program which included the development of a network of small basin stations. The Survey was interested in that program and for the fiscal year 1947, the cooperative funds were increased to $26,100 for the purpose of installing stations on small streams.

Cooperation with the East Side Levee and Sanitary District was started in 1940 fiscal year and continued during the period. It was the purpose of this cooperation to maintain a station on a drainage basin of five square miles in the Mississippi River bottom lands. The soil is such that in dry seasons, it cracks open and no runoff occurs; in the rainy season, the cracks disappear and runoff occurs. The District wished to know how much runoff could be expected from that type of soil.

Annual cooperative State funds available:

Year	State Water Survey	Div. of Waterways	East Side L. & S. Dist.	Total
1940	$10,000	$ 6,500	$ 148	$16,648
1941	10,000	7,500	368	17,768
1942	10,000	5,000	144	15,144
1943	10,000	5,000	150	15,150
1944	10,000	5,000	113	15,113
1945	10,000	5,000	90	15,090
1946	10,000	9,100	150	19,250
1947	10,000	26,100	200	36,300

Michigan. - Cooperation with the Stream Control Commission started in 1932, on the basis that the Commission would perform the field work and the Survey would supervise the field work and compute the records, continued during the period. In October 1941, the Commission proposed to reduce its activities from 32 to 16 gaging stations and to reduce the State contribution from $4,000 to $2,000 annually. As a result of this deplorable situation, as D. M. Corbett phrases it, 41/ a committee of faculty members of the University of Michigan's engineering school, headed by Dean Ivan Crawford, called on the Governor for a cash contribution of $4,500 annually, to maintain the existing stations. Of this amount, the Conservation Department and the Highway Department each contributed half, and the Stream Control Commission decided to continue its cooperation in the amount of $3,000 annually. As a result, no stations were discontinued.

41/ Letter to author.

Early in 1942, the Fish Division of the Department of Conservation, through the State Geological Survey contributed another $7,500 to expand the water resources investigation on other streams and some of the major lakes.

With the end of the war and the lifting of travel restrictions, Michigan, nearly surrounded by the Great Lakes and containing some 11,000 inland lakes, became such a favorite tourist center that the tourist industry has become second only to the automobile industry. The lakes naturally were the chief attraction, and the presence of so many visitors resulted in a very material increase in property values along the lake shores. That brought into prominence the controversy over the conflicting interests of the lake resort and property owners, and those of the neighboring muck-land farmers. The former group wishes to have the lakes maintained at high level to keep the marshy shores covered, and maintain a constant depth not only for fish spawning beds, but to afford access to the boat wells; the latter group, conversely, wishes to see the spring floods and high water removed from its lands as soon as possible in order that a start might be made in growing crops. This conflict became so serious that a solution is sought by thorough geologic and engineering studies.

Also, Michigan is a poorly-drained state due to the nature of the glacial deposits, resulting in many small drainage basins, in a majority of which, problems of drainage, flood control, and pollution of surface water supplies occur. To furnish the answer to these problems, complete stream flow data are necessary.42/

42/ Eddy, G. E., State Geologist; Water Resources Investigational Program; Proc. East-Central Branch Conference, Nov. 7-9, 1946, Indianapolis.

In the Northern Peninsula, there is a need for increased employment and that in turn depends upon additional power, much of which can be hydropower, and as existing stream flow records are very few, many additional stations are needed.43/

43/ Noecker, M., Development of Water Resources in the Northern Peninsula of Michigan; Proc. East-Central Branch Conference, pp. 45-46.

To meet the various needs for additional stream flow records, the Department of Conservation began cooperation in 1942, increasing the funds the following year. The urgency of the needs was reflected in the very substantial increase during the last three years. Funds provided by the Legislature were augmented by power company contributions to the Conservation Department.

Cooperation with the Department of Conservation was for "water-resources investigation", and one agreement covering both surface- and ground-water cooperation was signed. D. M. Corbett was the Survey's representative and the funds were allotted to the two divisions in consultation with the cooperating State officials.

Annual cooperative State funds available:

Year	Stream Cont. Comm.	Highway Dept.	Dept. Cons.	Total
1940	$ 4,000			$ 4,000
1941	4,000			4,000
1942	3,500	$ 2,250	$ 8,000	13,750
1943	3,000	2,250	12,500	17,750
1944	3,000	2,250	12,250	17,500
1945	3,000	2,250	21,625	26,875
1946	3,500	2,250	20,559	26,309
1947	2,000	2,500	28,425	32,925

Wisconsin. - Cooperation with the Public Service Commission continued at substantially the same level until the last year of the period when it was increased slightly on account of the increased cost of operation. The State Statutory Committee on Water Pollution became during the last few years simply the Committee on Water Pollution, by dropping the "State Statutory", as being unnecessary and really meaningless. It is a committee consisting of personnel from the Public Service Commission, the Department of Health, and the State Engineer, concerned chiefly with State buildings, all interested in pollution. The Committee has no budget but has authority to accept contributions from water users for the purpose of cooperation with the Survey.

Annual cooperative State funds available:

Year	Public Service Comm.	Committee on Water Pollution	Total
1940	$7,400	$ 1,000	$ 8,400
1941	6,800	1,450	8,250
1942	6,800	1,375	8,175
1943	6,800	1,363	8,163
1944	6,800	1,463	8,263
1945	7,500	1,388	8,888
1946	7,500	1,390	8,890
1947	8,500	1,740	10,240

Minnesota. -Past experience with drainage in Minnesota had been such that it became unpopular in the state and when early in the period, a reorganization was effected to bring into one agency the design and construction pertaining to water resources development, the Division of Drainage and Water became the Division of Water Resources and Engineering. Therefore, beginning with the fiscal year 1942, cooperation was with that agency. Prior to that time, efforts to increase the cooperative funds met with little result, despite the fact that, as P. R. Speer, the district engineer who had come from the Albany district in 1939, told the author, the district was trying to do a $15,000 job with only $6,000. By the time of the reorganization, the State had become more water conscious as a result of the recent drought years, and the reorganized agency was able to obtain substantially larger State funds, and these were gradually increased.

To develop new industries on the iron ranges in Northeastern Minnesota and thus stabilize its economy, which had been hard hit during the depression years, the State had created the Iron Range Rehabilitation Commission which was supported by a State tax on iron ore. The development of new industries created new water problems, and the commission became interested in the development of storage on the small streams of that region which is on the divide separating the Mississippi, Hudson Bay, and Great Lakes Drainages. For the purpose of installing and operating 5 stations, the Rehabilitation Commission proposed to transfer funds to the Division of Water Resources and Drainage, and the stations equipped with staff-gages were installed in the 1943 fiscal year. Later, it was decided the transfer of funds could not be made and the Division of Water Resources and Engineering increased its cooperation that year to cover the new stations. In the next fiscal year, 1944, a cooperative agreement was made with the Rehabilitation Commission itself for $3,230 to equip the 5 stations with recorders. Subsequent cooperation covered the operation of these stations.

The State Highway Department and the city of Winona had a flood problem, including several bridges, over Gilmore Creek. The Highway Department was working on a flood control plan which required records of peak discharges, and began cooperation in the fiscal year 1944 for the maintenance of the Gilmore Creek station.

During the war years, canning and packing house wastes in Austin caused a serious pollution problem on Cedar River. That is an interstate stream and communities farther downstream in Iowa were concerned with the stream pollution. The State Board of Health was working on the problem and in order to have the necessary streamflow data, the city of Austin, beginning in the fiscal year 1945, cooperated for the purpose of having the Survey install and operate a station on Cedar River.

Annual cooperative State funds available:

Year	Div. Drain. & Water	Div. Water Res. & Engr.	Iron Range Rehab. Comm.	Hwy. Dept.	Austin	Total
1940	$ 6,250					$6,250
1941	6,975					6,975
1942		$ 12,073				12,073
1943		12,550				12,550
1944		12,645	$ 3,230	$ 200		16,075
1945		13,550	1,250	250	$740	15,790
1946		15,370	1,250	250	220	17,090
1947		15,245	1,250	250	220	16,965

Iowa. - Cooperation with the State Geological Survey was increased during the period. This was due at first to the fact that the Legislature at the beginning of the period made a direct appropriation to that agency for stream-gaging, and that action increased the State Geological Survey's interest in the work with the result that more of its own funds were contributed. At the same time, the other State agencies, which in the previous period had contributed funds, requested the State Geological Survey to use every means to increase the funds. As an aid, state-wide interest was increased by the issuance of two State reports, one a summary of yearly and flood flows from 1873 to 1940, and the other the complete records for the years 1941 and 1942. Largely, as a result of the Soil Conservation Service's work in Iowa, there was a rather wide-spread interest in sediment in the streams, particularly in connection with lake silting, and for the fiscal year 1944, the cooperative amount was increased to provide for the collection of sediment samples at 4 gaging stations, and at some miscellaneous points.

As the increase in cooperative funds to include sediment records was the first cooperative money for sediment studies in the United States,[44]

44/ Statement of P.C. Benedict to author.

the immediate reason for such action should be noted. An application to the Federal Power Commission for the development of power on Cedar River involved the building of a dam on that stream. In a court hearing on the application, those opposed claimed that the pool formed by the dam would become filled with silt. This hearing created considerable interest and the Governor was receptive to an increase in the State funds for the sediment studies.

The State Institute of Hydraulic Research continued its cooperation, the funds coming not only from its own resources, but also from contributions received from a dozen cities as part payment for the maintenance of stations in which they were especially interested; under State Law, certain restrictions were placed on sewage treatment plants with respect to river discharge.

The State Conservation Commission, through its biological division of fish and game was interested chiefly in lake levels and, wishing also to be identified with the general stream-gaging program, gradually increased its cooperation.

Annual cooperative State funds available:

Year	State Geological Survey	Institute Hydraulic Research	State Conservation Commission	Total
1940	$ 4,500	$4,000	$ 300	$ 8,800
1941	4,467	4,100	300	8,867
1942	5,670	5,877	300	11,847
1943	5,670	4,805	750	11,225
1944	8,420	3,600	950	12,970
1945	10,895	3,100	750	15,745
1946	11,150	5,000	1,000	17,150
1947	11,150	5,000	1,500	17,650

Missouri. - Cooperation with the State Geologist (Missouri State Geological Survey and Water Resources) continued in slightly increasing amounts, until the last two years of the period when a new State Geologist obtained an increased appropriation on account of the increased cost of operation.

During the previous period, the State Highway Commission had cooperated in services in the collection of flood records on small streams but during this period, the Commission contributed cash to enable the Survey to obtain such records.

The Conservation Commission was interested in flood records from typically small streams in the Meramec River Basin and cooperated in that work during 1944 and 1945.

Annual cooperative State funds available:

Year	State Geologist	State Highway Commission	Conservation Commission	Total
1940	$ 10,600	$ 650		$ 11,250
1941	10,500	750		11,250
1942	11,450	510		11,960
1943	11,570	550		12,120
1944	12,550	500	$ 300	13,350
1945	12,485	270	300	13,055
1946	20,510	270		20,780
1947	18,007	300		18,307

Arkansas. - Several changes in the cooperating State agencies occurred during the period. The State Geologist lost interest in surface-water investigations and his contributions were reduced. He resigned in 1943. At the same time, the rationing of gasoline had so reduced the revenues of the State Highway Commission, the chief cooperating agency, that its contributions stopped in 1943. A new State Geologist was much more interested in the State's water resources and obtained sufficient funds not only to continue the annual contribution formerly made by the Highway Commission, but to increase it by $1,000.

In the fiscal year 1942, the State Flood Control Commission, which had been created to be the contact agency with the Army Engineers in flood control plans, began cooperation and continued through 1945. A new governor, in an economy program consolidated several existing departments, including the State Geological Survey and the Flood Control Commission, into the Resources and Development Commission. That Commission was the cooperating agency during the remainder of the period. The city of Fort Smith contributed to the maintenance of a gaging station during the first year, but thereafter that station was made a part of the regular State cooperative program.

Annual cooperative State funds available:

Agency	1940	1941	1942	1943	1944
State Geologist	$ 800	$ 850	$ 250	$ 250	$8,500
State Highway Comm.	7,500	7,500	7,500	7,500	
State Flood Cont. Comm.			750	1,500	750
Resources & Develop. Bd.					
Fort Smith	250				
Total	$8,550	$8,350	$ 8,500	$9,250	$ 9,250

Cont'd

Agency	1945	1946	1947
State Geologist	$ 8,500		
State Highway Comm.			
State Flood Cont. Comm.	750		
Resources & Develop. Bd.		$10,000	$10,000
Fort Smith			
Total	$9,250	$ 10,000	$10,000

North Dakota. - During the period, the cooperating State agency changed from the State Engineer to the State Water Conservation Commission, but that was a change of name only. The State Engineer was also the Chief Engineer of the Conservation Commission which had been created about 1937, as a result of the drought years. As State Engineer, he had no funds as all funds were appropriated to the Commission, but continued to sign as State Engineer as formerly. Finally, in the fiscal year 1946, the State Engineer signed the cooperative agreement as Chief Engineer of the Conservation Commission, and thereafter that agency was the official cooperator.

Annual cooperative State funds available:

1940	$1,540	1944	$4,000
1941	1,300	1945	5,800
1942	1,750	1946	7,500
1943	2,500	1947	7,500

The increase in cooperative funds in 1946 was due to the fact that with the establishment of a district office in Bismarck, additional interest was created, resulting in the increase indicated.

With the increase in cooperative funds in 1945 and the beginning of cooperation in South Dakota at the same time, a district comprising those two states was created. R. E. Marsh, district engineer, opened the district office at Bismarck, October 16, 1944.

South Dakota. - Attempts had been made by State officials at various times to obtain State funds for cooperation in stream-gaging but without success as the Legislature, reflecting the attitude of the citizens, was not water-minded. However, in the fiscal year 1944, a new Governor became convinced that in the proposed development of the Missouri Basin, then coming actively into the picture, the State should help in the study of its water resources. Having no specific appropriation for that purpose, he decided that a number of State agencies should contribute from their general funds, and as the work would be done in cooperation with the U. S. Geological Survey, it seemed logical to him that the State Geological Survey should be designated as the cooperating State agency. Accordingly, that agency, the Highway Department, and the Department of Game, Fish, and Parks, each contributed equal amounts for the fiscal years 1944 and 1945. For 1946 and 1947, the Legislature made an appropriation to the State Geological Survey for stream-gaging. Beginning with the fiscal year 1946, the Department of Game, Fish, and Parks wished to make a study of stream-bed losses in six streams originating in the Black Hills and cooperation for that purpose was effected. Those streams flow out of the granite across limestone outcrops for distances ranging from 1 to 6 miles, then through granite before reaching the flood plain.

With cooperation assured in South Dakota and increased cooperation in North Dakota, a district comprising both states was created in October 1944, with the district office in Bismarck, North Dakota, and a sub-office for South Dakota in Pierre, South Dakota. W. M. Littlefield, who had been in charge of the South Dakota stations from headquarters in Rolla, when those stations were a part of the Rolla District, continued in charge of the South Dakota stations, and moved to Pierre.

Annual cooperative State funds available:

Year	State Geological Survey	Dept. Game, Fish and Parks	Total
1944	$ 2,490	$	$2,490
1945	2,400		2,400
1946	4,000	4,480	8,480
1947	4,000	3,600	7,600

Nebraska. - During the first two years, cooperation with the State Engineer gradually decreased. In July 1941, when a new State Engineer had been appointed, C. G. Paulsen arranged for a material increase in State cooperation and for the establishment of a district office in Lincoln. Thus, Nebraska became a separate district. Cooperative funds were increased from $12,500 to $20,000 and a district office was established in Lincoln in August 1941, with H. C. Bolon as district engineer, succeeded by D. D. Lewis, May 8, 1942, when Mr. Bolon entered military service. During 1946 and 1947, the cooperative funds were increased to provide for some expansion, the relatively small amount of the State's cost of the North Platte River investigation[45] and to meet the increased cost of operation.

[45] p. 170.

Annual cooperative State funds available:

1940	$14,000	1944	$20,000
1941	12,500	1945	20,000
1942	20,000	1946	25,775
1943	19,000	1947	25,775

Kansas. - Cooperation with the State Board of Agriculture continued. In the fiscal years 1942 and 1943, the funds were increased to permit the establishment of 3 additional stations in 1942 and 2 in 1943; in 1947, the addition was due to the increase in costs.

Annual cooperative State Funds available:

1940	$6,600	1944	$8,750
1941	7,000	1945	8,250
1942	8,800	1946	8,250
1943	9,250	1947	10,300

Oklahoma. - Cooperation with the Oklahoma Planning and Resources Board continued unchanged in amount during the first four years of the period. It was then felt that something should be done to make the people of Oklahoma more water conscious, and both the State and the Survey increased the cooperation during the next two years. During 1944, supplementary funds were made available for the purpose of preparing a report summarizing all data then available on the water resources of the State and making interpretations of them. This report was prepared by the Branch and published by the State under the title "Oklahoma Water" and was given wide distribution. The cooperative funds for the last two years of the period were substantially increased.

The Grand River Dam Authority, a State agency, and also a Federal Power Commission licensee, cooperated with the Survey in the installation and maintenance of four stations required by the Federal Power Commission license. November 21, 1941, under Presidential Order 8944, the Grand River Dam Authority was taken over by the Federal Works Agency, which supplied funds for the continued operation of those stations until the creation of the Southwestern Power Authority by Secretarial Order in the fiscal year 1946, made that agency the successor of the Federal Works Agency. The power plant was returned to the Grand River Dam Authority, September 1, 1946. That agency paid the entire cost of maintenance during the remainder of the period.

Cooperation with Oklahoma City continued during the period and when a second station was added, the cooperative amount was increased. Cooperation with the city of Mountain Park for the purpose of maintaining one gaging station was in effect during the last two years.

Annual cooperative State and municipal funds available:

Agency	1940	1941	1942	1943	1944
Planning and Resources Bd.	$12,780	$12,780	$12,780	$12,780	$15,280
Grand River Dam Authority	2,500	1,750	782		
Oklahoma City	250	250	250	250	250
City of Mountain Park					
	$15,530	$14,780	$13,812	$13,030	$15,530

Cont'd

Agency	1945	1946	1947
Planning and Resources Bd.	$14,780	$17,500	$17,500
Grand River Dam Authority			2,910
Oklahoma City	500	500	500
City of Mountain Park		500	400
	$15,280	$18,500	$21,310

Texas. - The many army establishments and war industries which came into existence during the war years, with accompanying great increase in the use of water, made Texans more water conscious than ever. During the latter years of the period, there was a wide-spread desire for new industries to fill the void left at the end of hostilities, and an important aid to the accomplishment of that desire was a more complete knowledge of the available water resources. As a result, the funds made available to the State Board of Water Engineers were very considerably increased during the last two years. The available state funds consisted of moneys appropriated by the Legislature and contributions from counties, cities, districts, and other agencies interested in particular problems.

The Red Bluff District was vitally interested in the Pecos River Joint Investigation and contributed to its support during the investigation, and continued afterward to support the maintenance of Pecos River gaging stations. The upper Guadalupe Authority created under state law for the investigation and development of the upper Guadalupe River contributed money for the establishment of two gaging stations. Those stations were subsequently maintained as a part of the general stream-gaging program.

The Bureau of Reclamation obtained from the Nueces River Conservation and Reclamation District, funds for the establishment of 2 gaging stations. The Survey expected that additional funds would be provided for the maintenance of those stations, but that expectation was not realized, and the stations were maintained as a part of the regular program. The Pecos River Compact Commission, a Texas agency, created to negotiate with New Mexico, an inter-state compact for the equitable division of Pecos River waters, made a contribution one year to continue certain stations which would otherwise have been dropped. The city of Dallas contributed funds for the installation of a recorder on Lake Dallas, the source of the city water supply.

Annual cooperative funds available:

Agency	1940	1941	1942	1943	1944
Bd. Water Engrs.	$25,000	$31,000	$34,000	$30,000	$28,000
Red Bluff Dist.	7,600	2,700	900	900	900
Upper Guadalupe Authority		1,416			
Neuces River Dist.				1,800	
Pecos River Compact Comm.					2,000
Dallas				500	
Total	$32,600	$35,116	$34,900	$33,200	$30,900

Cont'd

Agency	1945	1946	1947
Bd. Water Engrs.	$31,000	$45,000	$56,000
Red Bluff Dist.	900	900	900
Upper Guadalupe Authority			
Nueces River Dist.			
Pecos River Compact Comm.			
Dallas			
Total	$31,900	$45,900	$56,900

Montana. - Cooperation with the State Engineer and with the Water Conservation Board continued.

Until the fiscal year 1942, the Survey had been operating a considerable number of so-called state stations which had been established in 1909 by the State Hydrographer, 46/ and for which no specific allotment was made, the costs being charged to available funds. However, by 1942, the precedent of charging other agencies for the operation of specific gaging stations had become established, and a charge was made for the "State stations." During 1944 and 1945, State funds were insufficient to pay that cost, and the Survey continued their operation from other funds. During 1946 and 1947, to compensate for that cost, and to pay the cooperative cost of two additional stations, the State Engineer increased the cooperative funds.

46/ Follansbee, Robert, History of the Water Resources Branch to June 30, 1919, p. 206.

The Water Conservation Board cooperation continued in varying amounts, depending upon the funds available.

In 1939, the city of Bozeman was discharging its sewage into East Gallatin River and became interested in the flow of the river, as water users downstream threatened court action. Accordingtly, the city cooperated for the purpose of establishing and maintaining a station at Bozeman to determine the actual flow. In passing, it may be stated that when it became known that the Survey was measuring the

East Gallatin River, the threatened law suit failed to materialize -- so much for Survey prestige.

Annual cooperative State and municipal funds available:

Year	State Engineer	Water Cons. Bd.	Bozeman	Total
1940	$ 9,000	$ 5,800	$ 350	$ 15,150
1941	9,000	7,500	160	16,660
1942	14,675	5,500	160	20,335
1943	13,300	5,500	160	18,960
1944	9,000	3,500	160	12,660
1945	9,000	4,650	160	13,810
1946	18,000	7,000	160	25,160
1947	18,000	8,000	240	26,240

Wyoming. - Cooperation with the State Engineer which had been resumed in 1915 after a lapse of several years continued during the period. The special North Platte River investigation, 47/ which was 47/p.170 started in May 1946, accounted for the slight increase during 1947.

The Legislature in 1939 consolidated the State Planning Board and the State Water Conservation Board into the State Planning and Water Conservation Board. The consolidated Board, unlike the predecessor Water Conservation Board which had made its own investigations, decided that it could better achieve its goal by cooperating with existing Federal agencies in their studies of irrigation possibilities. The Bureau of Reclamation was making a statewide investigation and was maintaining a number of gaging stations in the Green River Basin. At the beginning of the period, the Bureau desired to turn these stations over to the Geological Survey, and in order to finance the transfer, the State Planning and Water Conservation Board contributed $600 to the State Engineer's cooperative fund for that purpose.

In the fall of 1940, toward the end of the State's biennium, the author was informed, perhaps by accident or perhaps by design, that the Board had an unexpended balance for which it had no apparent use. Realizing the need for additional gaging stations to aid the Bureau of Reclamation's investigations, the author made up a list of stations and proposed cooperation to the extent of the unexpended balance. This suggestion was received favorably but had to be acted upon formally by the Board, at its next meeting which was held in Great Falls, Montana, at the time of the National Reclamation Association meeting. The author was requested to be present to explain the proposed cooperation and it thus came about that it was necessary to journey to another state from that with which the proposed cooperation was effected. The Board acted formally upon the proposal and allotted $4,200, most of which was expended that fall in the construction of the new stations.

During the next 4 years, the funds of the Board were drastically curtailed, but a small amount of cooperation was effected each year except 1944, particularly for the purpose of maintaining existing stations, and in 1943, to enable the Survey to take over several additional stations in the Green River Basin which the Bureau of Reclamation had recently installed, and was operating.

In the fall of 1944, the Wyoming Reclamation Association, keenly interested in additional irrigation, sponsored a movement to obtain a large appropriation to be devoted to planning for post-war development. As one item, the author suggested to the association an extensive program of additional gaging stations needed by the Bureau of Reclamation. The 1945 session of the Legislature, at the Governor's request, made to the State Planning and Water Conservation Board, a special appropriation of $40,000 to be used in cooperation with the Bureau of Reclamation and the Geological Survey. In April 1945, the Board, with the approval of the Bureau of Reclamation, allotted to the Survey for the biennium, $29,000 to be used to establish additional stations needed by the Bureau and to supplement the State Engineer's funds in the maintenance of existing stations, including those Wyoming stations being maintained by the Bear River investigations.48/

48/ p. 89.

Annual cooperative State funds available:

Year	State Engineer	State Planning & Water Conservation Bd.	Total
1940	$ 10,600	$	$ 10,600
1941	10,500	4,200	14,700
1942	10,500	1,650	12,150
1943	10,000	1,650	11,650
1944	10,533		10,533
1945	10,200	4,500	14,700
1946	10,275	11,000	21,275
1947	12,500	8,000	20,500

In addition, the following allotments, which include contributions by Lincoln and Uinta Counties, were made for the Bear River investigation:

1944	$4,066	1946	$5,590
1945	5,825	1947	4,886

Colorado. - The regular stream-gaging program was continued in cooperation with the State Engineer. Beginning in the 1942 fiscal year, a supplemental program was started in cooperation with the Colorado Water Conservation Board.

The highest part of the Rocky Mountains being located in Colorado, the headwaters of four major western interstate streams rise within its borders and with irrigation needs in all the states calling for more water than was available within the basins of the interstate streams, serious conflicts had arisen. Before 1937, the engineering features of such conflicts had been under the jurisdiction of the State Engineer, together with the administrative duties of administering the water decrees within the state.

To separate the interstate features from the administrative duties, the Legislature in 1937 created the Colorado Water Conservation Board.49/ The duties of the Board are to cooperate with the Attorney General in all matters relating to interstate suits concerning the surface waters and compile all necessary data for

49/ Chap. 265, Session Laws of Colorado, 1937.

that purpose, also to promote the conservation of the water resources in order to secure the greatest utilization of such waters, and the utmost prevention of floods. In these and other duties, the Board is authorized to cooperate with Federal agencies.

Early in the period, the Bureau of Reclamation needed a very considerable number of additional stations in connection with their project investigations, and desired the Survey to operate those stations after the Bureau made the installations. However, as no funds were to be provided for operation, the Survey could not agree to that proposal, and the Bureau of Reclamation maintained the new stations, rather under protest. The number of such stations gradually increased, and in the fiscal year 1942, the Bureau, anxious to get out of the business of stream-gaging, suggested to the Water Conservation Board that cooperation be effected with the Survey in order that the Bureau stations be taken over by the Survey. By that time, the Water Conservation Board was deeply interested in the Bureau's projects and wished to assist the investigations. The Board was also checking the plans, and needed the records from the new stations. The Board felt that as the Bureau of Reclamation stations were not being maintained according to Survey standards, the records were not directly comparable and not being published in the Water Supply Papers, were not readily available. Also, the Bureau of Reclamation stations were to be maintained for a few years only, in connection with specific investigations, and were considered merely to supplement the regular stream-gaging program maintained in cooperation with the State Engineer. 50/ The Bureau's proposal was made at an opportune time and cooperation became effective. The number of new stations gradually increased and the cooperative funds were increased accordingly.

50/ Statement of A. C. Stiefel to author.

Annual cooperative State funds available:

Year	State Engr.	State Water Conservation Board	Total
1940	$29,000		$29,000
1941	27,600		27,600
1942	29,000	$ 5,000	34,000
1943	26,800	6,500	33,300
1944	27,000	6,500	33,500
1945	26,250	6,300	32,550
1946	25,000	7,500	32,500
1947	25,000	8,500	33,500

New Mexico. - Cooperation continued with the State Engineer, under two separate agreements, one with the State Engineer and the other one with the State Engineer as Secretary of the Interstate Stream Commission. The first agreement which continued practically unchanged in amount, was for the purpose of carrying on the regular stream-gaging program. The second agreement was to finance special investigations on interstate streams, as the need arose. For the first two years, that agreement was increased to cover the State's share of the Pecos River Joint Investigation, the field work of which was completed in 1941, and beginning in 1940, it paid for the stream-gaging required by the Rio Grande Compact, and beginning in the 1945 fiscal year, the added stream-gaging required by the Costillo Creek Compact; the increase in 1948 was to take care of increased costs.

Cooperation with the State Highway Engineer was started in the fiscal year 1941, as an indirect result of the flood of 1941 on the Rio Grande. After that flood, Berkeley Johnson obtained from the Highway Planning Survey, a list of 40 sites at which new bridges were to be constructed. He then asked the bridge engineer what flood information he needed at those sites. The latter replied that he wanted to know how high the flood stages would be, what the velocities and amount of scour would be. On being told that gaging stations at those sites would give the needed information, the bridge engineer became interested in cooperation. At some of the 12 sites in which the Highway Department was interested, gaging stations were in operation. A cooperative program covering 5 new stations was arranged, and continued during the period.

In the fiscal year 1946, the County Commissioners and the County Planning Board were making a study of the water resources of Colfax County of which Raton is the county seat, and the Survey was called upon to determine whether sufficient information for the entire county existed. As surface and ground water, and the qualify of water were involved, Berkeley Johnson, C. V. Theis, and C. S. Howard went to Raton, and after making preliminary investigations, decided that additional information was needed and cooperative agreements with all three divisions were made. Six gaging stations were installed and operated under that agreement. As the Bureau of Reclamation was interested, that agency financed construction of 2 of the 6 stations.

Annual cooperative State and county funds available:

Year	State Engineer	Inter-State Streams Comm.	State High-Way Engineer	Colfax County	Total
1940	$16,000	$ 4,175			$20,175
1941	16,000	9,100			25,100
1942	16,000	8,150	$ 2,550		26,700
1943	15,000	9,150	2,000		26,150
1944	15,000	9,150	2,200		26,350
1945	16,200	10,950	2,200		29,350
1946	15,000	10,950	2,200	$2,100	30,250
1947	15,000	15,950	2,200	1,500	34,650

Note. - From 1942 to 1947, the Inter-state Streams Commissioner's funds shown include supplemental funds not matched by Survey funds.

Idaho. - Cooperation with the Department of Reclamation as in former years was divided between the Boise and Idaho Falls district offices, chiefly on the basis of the number of cooperative gaging stations operated by each.

Annual cooperative State funds available:

Year	Boise	Idaho Falls	Total
1940	$18,000	$ 7,000	$25,000
1941	15,683	7,220	22,903
1942	16,850	7,450	24,300
1943	18,020	7,450	25,470
1944	13,500 1/	7,450	20,950
1945	16,500	7,450	23,950
1946	17,200	7,750	24,950
1947	18,500	7,750	26,250

1/ Includes $1,000 allotted prior to July 1, 1943, for the Bear River investigations.

With the start of the Bear River investigations July 1, 1943, the following additional cooperative funds became available to meet Idaho's share of that expense:

1944	$3,467	1946	$4,000
1945	3,800	1947	4,000

During the fiscal year 1944, cooperation in the amount of $700 was effective with the Emmet Irrigation District for the purpose of installing a water-stage recorder on Payette Lake, as the result of a controversy between the water users and owners of summer cottages at the lake over the allowable amount of storage in the lake. The operation of that station was included in the regular cooperative program.

Utah. - Cooperation with the State Engineer started in 1904 with the payment of a few observers' salaries, continued. Prior to the fiscal year 1942, the cooperative program included only the larger streams of the state. The State Engineer was operating independently some gaging stations on small streams and the Bureau of Reclamation in cooperation with the State Engineer, was maintaining some stations as part of an investigation of small reservoir projects. Early in the fiscal year 1942, the cooperative program was enlarged to cover all the stream gaging in the state, and the cooperative funds were almost doubled for the purpose of installing and operating additional Colorado River Basin stations needed by the Bureau of Reclamation in connection with studies of the Central Utah project and for stations to show Utah's contribution to the Colorado River. The Upper Basin States were attempting to divide the waters allocated by the Colorado River Compact 51/ to the Upper Basin as a unit, and the State of Utah needed

51/ p. 99 (1919-1928).

additional information to determine its contributions of the water supply to the Colorado River. In the fiscal year 1947, the cooperative funds were again substantially increased for that purpose.

Annual cooperative State funds available for regular program:

1940	$10,000	1944	$14,312
1941	10,000	1945	15,435
1942	16,000	1946	27,290
1943	17,750	1947	42,218

With the start of the Bear River investigations July 1, 1943, the following additional cooperative funds became available to meet Utah's share of their costs:

1944	$3,355
1945	3,771
1946	4,000
1947	3,701

Nevada. - Cooperation with the State Engineer continued in the amount of $1,500 annually until the fiscal year 1944. The Nevada Agricultural College was maintaining for the Humboldt River Water Users, and for the State Engineer's office, a number of stations needed for snow surveys and stream-flow forecasting, the expense being borne chiefly by the latter two agencies. It was thought desirable by all concerned that the stream gaging in the State should be coordinated and advantage taken of the Survey's experience and technical personnel and thus eliminate duplication of effort and reduce expenses. Accordingly, in July 1943, all the work was placed under the Survey's supervision and $1,650 annual contribution of the Humboldt Water Users transferred to the State Engineer to increase the State's cooperative funds, together with additional funds made available by the State Engineer. During the last two years of the period, the funds were increased chiefly to meet the higher operation costs.

Annual cooperative State funds available:

1940	$1,500	1944	$3,850
1941	1,500	1945	4,350
1942	1,500	1946	5,625
1943	1,500	1947	5,625

Arizona. - In 1942, the Governor wished to consolidate in the office of the State Land Commissioner the duties of the State Water Commissioner and operate the land and water departments as a unit. This would result in economy of operation under a man who was very familiar with the State's problems. Accordingly, the State Legislature effected that consolidation, 52/ and the State Land Commissioner became the cooperating official in the fiscal year 1944.

52/ Chapter 28, Laws of 1942.

The Salt River Valley Water Users Association continued cooperation in the maintenance of the stations in that region.

Maricopa County Municipal District No. 1 is an irrigation district operating Lake Pleasant Dam on the Agua Fria River. In that connection, it keeps records of the reservoir and of the river below the dam. The district desired a station above the dam and cooperation was arranged in the fiscal year 1941, whereby the Survey established and operated the station above the reservoir and cooperated in the maintenance of two existing stations.

Cooperation with the San Carlos District which started in the fiscal year 1942, was an outgrowth of cooperation with the Gila River Water Commissioner of the Federal Court. That official desired reports at 10-day intervals for a number of stations that increased to 15, and contributed $1,500 annually. Other water users also wanted those reports until the number of copies reached 20, and it was felt that cooperative funds should be increased to $2,400, and the San Carlos District became the cooperating agency.

Cooperation with Gila Valley Irrigation District was started in the fiscal year 1946. When the Phelps Dodge Corporation decided to obtain an additional supply of water outside the Gila River Basin,[53] it diverted water from Black River, a tributary of Salt River and by means of a pump and pipe line, transported it to Willow Creek, a headwater stream of the Gila River. At the same time, an arrangement was made with the Gila Valley Irrigation District whereby the latter would use the Black River water, in lieu of an equal amount of Gila River water to be used by the copper company at its Morenci plant. In that agreement, the stipulation was made that the Survey or any other Federal agency was to measure the water.

53/ p. 18.

Annual cooperative State funds available:

Agency	1940	1941	1942	1943	1944
State Water Comm.	$15,000	$15,000	$10,000	$10,000	
State Land Comm.					$10,000
Salt River Valley Water Users Assoc.	5,500	5,500	6,000	3,000	4,000
San Carlos Dist.			2,400	2,400	2,400
Maricopa County Dist.		300	500	500	500
Gila Valley Irr. Dist.					
Total	$20,500	$20,800	$18,900	$15,900	$16,900

Cont'd

Agency	1945	1946	1947
State Water Comm.			
State Land Comm.	$10,000	$15,000	$15,000
Salt River Valley Water Users Assoc.	4,000	5,000	5,000
San Carlos Dist.	2,400	2,400	2,400
Maricopa County Dist.	500	500	500
Gila Valley Irr. Dist.		2,500	4,250
Total	$16,900	$25,400	$27,150

Washington. - Cooperation with the State Department of Conservation and Development, continued with a slight increase until the fiscal year 1946. In that year, the new director of that Department felt that the small streams program started by the Departments of Fisheries and Game in the fiscal year 1943 should be added to the Department's cooperative program and increased the cooperation accordingly; also in 1947, some of the Department's unallocated funds were added to the cooperative agreement, accounting for the large increase that year.

For some years, the salmon industry had been declining and in the fiscal year 1943, the Department of Fisheries, which was concerned with commercial fish only, became critical of the water rights in western Washington, and needed stream flow records to determine whether appropriators were leaving sufficient water in the streams for the fish; the streams were being dried up and were being dammed which prevented the fish from reaching their spawning grounds. The Department of Game which was concerned with the "game" fish had much the same problem and the two agencies began cooperation with the Survey to initiate what was known as the small streams program.

Cooperation with Seattle was increased beginning with the fiscal year 1944 when snow surveys which required the construction of shelter cabins and stocking them with supplies, were added to the cooperative program; and the city's hydrographer, who had performed much of the field work was no longer available, making it necessary for the Survey to perform all field work. Cooperation with Tacoma was increased during 1942 as the construction of a dam drowned out two stations making it necessary to establish two new ones, one above and the other below the reservoir. The gradual increase during the later years was due to increased cost of operation.

At the beginning of the period, cooperation was started with Bellingham. That city controls Lake Whatcom as a reservoir and its operation antagonized the residents along the lake shore by the changes in lake level, and those along the creek below the reservoir who had small garden tracts, and who believed that the operation of the control gates subjected the garden tracts to either drought or flooding. Many law suits resulted and to obtain official records of lake levels and creek discharge for future suits, the city began cooperation July 1, 1939. Cooperation with Skagit and Whatcom Counties, the cities of Aberdeen and Everett, and the Inter-County River Improvement Commission continued practically unchanged except for some temporary increases to cover additional gaging stations.

Cooperation with Columbia County and the Walla Walla County Planning Board was started in the fiscal year 1941. The Bureau of Reclamation desired to make a study of the possibilities for supplemental water supplies for irrigation in those counties and needed additional stream flow records. To obtain the additional records, the two counties began cooperation with the Survey. Cooperation with Snohomish County was effective during the fiscal year 1941 for the purpose of obtaining miscellaneous measurements needed in connection with flood-control studies. During 1944 and 1945, the Board of Commissioners of Pierce County cooperated for the purpose of protecting a gaging station with 200 feet of log revetment. Also, the Skagit County Public Utility District cooperated for the purpose of increasing the small streams program.

Beginning with the fiscal year 1945, cooperation was started with two additional State agencies. The State Department of Highways desired the establishment of additional stations and operation of a gaging station for flood records in connection with the proposed construction of two bridges on Nooksack River; also a study of flood frequencies in the state. The State Capitol Commission was proposing to convert into a fresh water lake a stream entering the tidal basin adjacent to the capitol grounds, and needed records on that stream. That same year cooperation was also started with Bremerton and Waterville for the purpose of studying possible sources of municipal supplies and in the 1946 fiscal year, cooperation was started with Cosmopolis for the same purpose.

Cooperation with a number of private interests was effective through the Department of Conservation and Development, the custodian of such cooperative funds. Prior to 1945, that procedure had no legal authority, but in 1945, the Legislature authorized such action by creating the "stream-gaging trust fund" for that purpose.

Annual cooperative State and municipal funds available:

Year	Dept. Cons. & Develop.	Seattle	Tacoma	Bellingham	Inter-Co. River Imp.	Skagit Co.
1940	$ 10,468	$ 3,487	$ 1,230	$ 2,200	$ 200	$ 200
1941	11,329	4,368	1,470	250	225	225
1942	12,378	2,525	9,100	250	225	225
1943	12,396	2,771	2,660	175	225	225
1944	14,184	7,100	4,730	200	225	1,225
1945	17,614	6,750	4,110	475	1,485	725
1946	33,724	10,660	5,840	300	375	225
1947	65,650	11,175	8,820	300	450	250

Year	Whatcom Co.	Aberdeen	Everett	Columbia Co.	Walla Walla Co.
1940	$ 185	$ 230	$ 175	$	$
1941	200	230	250	40	150
1942		230	250	200	700
1943	100	230	225	200	700
1944	200	450	225	225	750
1945	225	230	225	225	750
1946	225	230	225	225	750
1947	250	750	300	300	850

Year	State Dept. Fisheries.	State Dept. Game	Pierce Co.	Skagit Co. PUD	State Dept. Highways	State Capito Comm.
1940						
1941						
1942	$ 300					
1943	500	$ 300				
1944	3,700	1,000	$ 200	$ 1,000		
1945	6,200	6,000	200	500	$ 500	$ 950
1946	2,150				700	225
1947	950	1,500			1,600	

Year	Bremerton	Waterville	Cosmopolis	Snohomish Co.	Total
1940					$ 18,375
1941				$ 400	19,137
1942					26,383
1943					20,707
1944					35,414
1945	$ 1,200	$ 100			48,464
1946	3,000	150	$ 580		59,584
1947	1,500		450		95,095

Oregon. - Cooperation with the State Engineer continued practically unchanged, as did that with the cities of Portland and McMinnville. In the fiscal year 1942, the Bureau of Reclamation was studying the irrigation possibilities on Walla Walla River, an interstate stream, and a station was needed near the State line to show the quantities of water passing from Oregon and available for use in Washington. To aid that work, the Umatilla County Court started cooperation to help in the maintenance of that station which was installed at the expense of the Bureau of Reclamation.

For some years, the city of Eugene had a Federal Power Commission permit and application for license to develop water power on the McKenzie River and was paying the cost of the maintenance of a gaging station operated by the Survey. In the fiscal year 1945, the city withdrew its application for license, but wishing to have the gaging station continued, cooperated with the Survey for that purpose. The net result was that whereas previously it paid the entire cost of the maintenance under the terms of its permit, it now paid only a half, the Survey matching the cooperative funds.

The city of Corvallis obtains its water supply from Rock Creek, and in planning for future growth, needed information on the flow in case storage would become necessary. Cooperation was started during the fiscal year 1946.

Annual cooperative State and municipal funds available:

Year	State Engr.	Portland	McMinnville	Umatilla Co. Court	Eugene
1940	$24,850	$ 400	$ 300		
1941	25,750	400	225		
1942	24,250	400	225	$ 125	
1943	24,750	400	225	125	
1944	24,750	275	165	125	
1945	23,750	300	175	125	$ 175
1946	26,000	300	200	150	175
1947	26,000	350	200	150	175

Cont'd

Year	Corvallis	Total
1940		$25,550
1941		26,375
1942		25,000
1943		25,500
1944		25,315
1945		24,525
1946	$ 250	27,075
1947	200	27,075

California. - Cooperation with the California Department of Public Works continued, being gradually increased during the latter half of the period to cover the increasing cost of operation. Cooperation with the San Francisco Public Utilities Commission, East Bay Municipal Utilities District, Santa Clara Valley Water Conservation

District, Los Angeles County (flood control), Orange County, Ventura County, Metropolitan Water District (for Tucson Office), and the Cities of Lodi and Santa Cruz continued during the period, the reasons for such cooperation having been described in a previous period. With the City of San Diego, the cooperation was practically the same except during 1947 when it was increased for the purpose of establishing two additional stations and installing a recorder at a third station. Cooperation with the City of San Luis Obispo was discontinued with the fiscal year 1941, when a new city administration was opposed to it. Stanford University discontinued cooperation with the fiscal year 1941 when Hetch Hetchy water became available, making it unnecessary to continue plans for a reservoir and for the gaging station maintained in that connection.

Cooperation with the City of Santa Barbara for the purpose of maintaining stations on Santa Ynez River in connection with the Gibralta Reservoir was chiefly one of evaluated services and that type of cooperation was reduced during the period. Santa Barbara County desired an investigation of its water resources and in the 1941 fiscal year cooperated with the Ground Water Division. After that investigation was started, A. M. Piper informed the County that to make a complete water resources inventory, it would be necessary to have a number of additional gaging stations and suggested cooperation with the Surface Water Division. That suggestion was acted upon and cooperation was started in the fiscal year 1942.

The severe floods of March 1938 resulted in increased cooperation in Southern California. Cooperation with San Bernardino County was increased very materially during the fiscal years 1942 to 1946. The County had set up a flood control district and the latter wished to have a hydrologic study of the possibility and magnitude of floods in the mountainous section of the county, as a basis for planning flood control and conservation measures. The County increased the cooperative funds for that purpose. Riverside County created the Riverside Control and Water Conservation District in 1947; the chief engineer inspected the Survey's San Bernardino report and desired a similar one for Riverside County. Cooperation was increased during 1947 for that purpose.

The Orange County Water District created to take care of water rights, wished to know the evapo-transpiration losses by heavy native vegetation in the canyon section of the Santa Ana River below the Prado flood control reservoir, constructed in 1940 by the Army Engineers. This was of considerable importance to two large canals diverting water below the canyon, and cooperation was started in the fiscal year 1944 to finance the necessary investigation.

The Imperial Irrigation District was maintaining a number of stations in connection with the diversion to the all American Canal, and to enable the Survey to make check measurements and compute the records, cooperation became effective with the Tucson Office during the last two years of the period.

Annual cooperative State, County, and municipal funds available:

Agency	1940	1941	1942	1943	1944
Dept. Public Works	$ 32,000	$29,000	$29,500	$27,473	$33,580
East Bay Municipal Utility Dist.	1,000	1,000	1,000	700	800
San Francisco Public Utilities Comm. 1/	4,000	4,000	4,000	4,000	3,750
Santa Clara Valley Water Cons. Dist.	600	600	600	500	1,100
City of Lodi	1,200	1,000	1,000	700	800
Los Angeles County (flood control)	2,600	2,600	2,600	2,600	2,600
City of Santa Barbara	3,000	3,000	1,500	1,150	1,500
Santa Barbara County			4,700	2,600	5,250
Ventura County	1,000	1,000	1,000	1,000	1,000
Santa Cruz	150	150	150	150	150
Metropolitan Water Dist.	5,000	5,000	5,000	5,000	5,000
Orange County Flood Control Dist.	3,000	3,000	3,000	3,000	3,333
Orange County Water Dist.					750
Riverside County	1,000	1,000	1,000	1,000	1,000
San Bernardino County	1,000	1,000	4,700	5,820	6,000
City of San Diego	1,800	1,800	2,000	1,600	1,800
Stanford University	300	500			
City of San Luis Obispo	100				
Imperial Irrigation Dist.	-				
Totals	$ 57,750	$54,650	$61,250	$57,293	$68,413

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Agency	1945	1946	1947
Dept. Public Works	$33,580	$40,000	$50,000
East Bay Municipal Utility Dist.	1,000	1,000	1,000
San Francisco Public Utilities Comm. 1/	3,550	3,800	4,600
Santa Clara Valley Water Cons. Dist.	800	800	800
City of Lodi	800	800	800
Los Angeles County (flood control)	2,600	2,600	2,600
City of Santa Barbara	1,500	1,500	1,500
Santa Barbara County	5,000	4,250	6,500
Ventura County	1,200	1,200	1,200
Santa Cruz	150	150	150
Metropolitan Water Dist.	5,000	5,000	5,000
Orange County Flood Control Dist.	4,000	4,000	4,000
Orange County Water Dist.	1,250	1,500	1,750
Riverside County	1,300	1,300	4,300
San Bernardino County	6,500	6,000	1,000
City of San Diego	2,000	2,000	3,100
Stanford University			
City of San Luis Obispo			
Imperial Irrigation Dist.		150	150
Totals	$70,230	$76,050	$88,450

1/ These funds for the maintenance of Hetch Hetchy stations were not matched, as the Raker Act granting San Francisco the right to the use of those streams specified that the entire cost of operating the necessary gaging stations should be borne by San Francisco.

Hawaii. - Cooperation with the Commissioner of Public Lands continued in somewhat larger amounts than during the previous period, and due chiefly to higher costs of operation, the amounts were further increased during the last two years.

Annual cooperative funds available:

1940	$32,000	1944	$31,950
1941	32,000	1945	32,000
1942	30,150	1946	36,307
1943	27,150	1947	36,868

Although there was no financial cooperation with municipalities, Hilo maintained the trails and provided an assistant when the Survey engineer visited the stations, and sometimes provided transportation. The Board of Water Supply Engineers of Honolulu made some inspections and measurements at gaging stations which, in the previous period, had been built by means of funds furnished by that agency. Also, the use of the city shops was made available and assistance rendered by shop employees.

The integration of the Survey with that of the Territorial Division of Hydrography, which had been in effect since the beginning of cooperation, continued, the Survey district engineer being also the chief hydrographer of the Division of Hydrography. An outline of the duties of the combined organization is given in the Annual Report of the Governor of Hawaii for the fiscal year 1947, as follows:

> The Division of Hydrography, in cooperation with the Geological Survey, U.S. Dept. of the Interior, collected data on the flow of owned water, planned future developments for irrigation, investigated sources of domestic and public water supply, analyzed flood control conditions, and made studies to discover the location and conditions of occurrence of ground water and the quantities available for development.

Federal Cooperation

Of the Federal agencies transferring funds to the Survey during the previous period, the Public Works Administration and the National Resources Planning Board passed out of existence during the present period, and the Department of Agriculture, through the Soil Conservation Service, discontinued cooperation. New agencies entering the picture were the Bonneville Power Administration, Southwestern Power administration, Federal Works Agency, War Production Board, Office of Land Utilization, and Defense Plant Corporation. The Public Health Service cooperated during 1947. Cooperation continued with the Army Engineers, State Department, TVA, Bureau of Reclamation, Indian Service, Fish and Wildlife Service, Federal Power Commission, and Weather Bureau.

As a result of the Flood Control Act of 1936, the Army Engineers required many more gaging stations and made available much larger amounts than previously. The Bureau of Reclamation, during the latter part of the period, expanded its investigations greatly and called upon the Survey for many additional stations.

The total Federal (non-Survey) cooperative funds expended annually by the Survey for surface-water investigations were:

1940	$992,084	1944	$ 824,462
1941	876,829	1945	1,085,008
1942	867,018	1946	991,739
1943	790,078	1947	1,431,936

Army Engineers. - The effect of the long range flood control act approved June 28, 1938, 54/ on the Survey work required by the Army Engineers was felt to a certain extent during the fiscal year 1939, but its full effect was not apparent until the present period. This is shown by the annual amount of Army Engineers funds available, which includes funds for the last two years of the previous period for comparison.

54/ p. 64 (1928-1939).

1938	$ 84,204	1943	$632,393
1939	255,392	1944	688,836
1940	737,480	1945	872,680
1941	671,941	1946	599,598
1942	636,349	1947	736,968

The increases during 1944 and 1945 were due to the construction of a large number of stations established during those years. For a number of years, the Survey had endeavored to obtain in the annual appropriation acts, an item covering at least a part of the cost of operating the Army Engineer stations with the thought that the funds should be appropriated directly to the Survey instead of to the Army Engineers, and then transferred to the Survey. Finally, for the fiscal year 1947, Congress appropriated $175,000 or half the amount requested. Before applying those funds to the amount previously requested for transfer, a conference with representatives of the Office of Chief of Engineers was held. Funds transferred by the Army Engineers were not available for expenditures in the District of Columbia, and the Washington Office could not be reimbursed for the considerable additional work resulting from the cooperative Army Engineer program. The cost of that additional work had to be absorbed by other funds. To remedy the situation, it was agreed that of the $175,000 appropriated for Army Engineer work, $34,725 should be reserved not only to meet such additional cost, but also a part of the cost of developing special equipment for measuring large streams in that program. Consequently, the amount of funds requested for transfer were reduced by $140,275.

As a result of the increased funds, the number of Army Engineer stations operated by the Survey was increased from 501 in 1939 to 1,492 in 1947. The policy of contributing Survey funds to the cost of installing and operating the stations, thus making it a truly cooperative program, was continued. The percentage of such cooperation depended upon the financial ability of each district.

The following list shows the number of Army Engineer stations operated by each district June 30, 1947:

Albany	55	Denver	12	Raleigh	34
Atlanta	50	Fort Smith	29	Rolla	58
Augusta	3	Harrisburg	91	St. Paul	51
Austin	65	Hartford	1	St. Louis	4
Baton Rouge	24	Helena	20	Salt Lake City	9
Bismarck	36	Indianapolis	39	San Francisco	44
Boise	22	Iowa City	56	Santa Fe	12
Boston	43	Jackson	39	Tacoma	28
Charleston	75	Lincoln	6	Topeka	33
Charlottesville	83	Louisville	71	Trenton	2
Chattanooga	18	Madison	32	Tucson	4
College Park	27	Montgomery	33	Urbana	63
Columbia	21	Ocala	39		
Columbus	122	Portland	38	Total	1492

In addition, records for about 85 stations maintained by the Army Engineers were reviewed by the Survey and published. In addition, there were 35 stage stations having no discharge records.

The additional stations were selected primarily for their value in flood studies and later, flood-prevention projects, and the number in each district was determined not only by the streams requiring flood protection but also by the degree of state-wide coverage of streams by means of the State-cooperative programs. In those districts having comprehensive State cooperative programs, the need for additional stations was very much less than it was in the districts where such programs were inadequate. A comparatively few stations temporary in character were established for the purpose of revising the studies made for the "308" reports. A majority of the stations in the Boise District were for that purpose.

The increase from 35 to 122 stations in the Columbus District occurred chiefly in the Muskingum River Basin and was due to the fact that the Army Engineers took over from the Muskingum Watershed Conservancy District, the District's flood-control program, including 38 gaging stations which had been primarily maintained by the Survey in cooperation with the Conservancy District. Additional stations were established in connection with that flood-control program.

The disastrous floods in the Ohio River Basin climaxed by that of January 1937, had caused the Army Engineers to plan an extensive system of flood-control and for that purpose, the Army Engineer stations in Pennsylvania were increased from 24 to 91, practically all the increase being in the Ohio River Basin. Emphasis was naturally placed on flood measurements and in order to reach the stations quickly, the Survey established a large sub-office in Pittsburgh having about 8 engineering personnel. In addition to the stations listed, 23 stations were maintained for short periods in connection with special reports that were being made by the Army Engineers.

A notable contribution by direct expenditure of funds, was contracting for the 3,200-foot I-beam on the underside of the railroad bridge across the Mississippi River at Thebes, Ill., 55/ from

55/ p. 154.

which the cable car was suspended. Under war-time conditions, the cost of that installation was about $10,000.

Another contribution not included in the transfer of funds to the Washington Office was that by the Seattle Army Engineer Office to the Tacoma District. In 1946, the Army Engineers were revising their "308" report on the Columbia River and desired the installation of 50 special staff gages, their stages were tied to two regular gaging stations, and by that means, rating curves were prepared for the staff gages. A total of $1,700 was transferred for that purpose.

In general, all work was performed by the Survey. The most notable exception was in the Ohio River Basin, where under the cooperative agreement, the Army Engineers performed the field work on the main stem stations, except above Lock 13 near Belaire, Ohio, where the Survey's Pittsburgh Office performed the field as well as office work, and on the stations located near the mouths of the principal tributaries. The records however were computed by the Survey. The Ohio River is subject to serious floods and as the Army Engineers desire numerous discharge measurements during every major flood, that agency wished to have available, when needed, engineers trained in flood measurements. During the 1947 fiscal year, curtailment of the Army Engineer flood-control funds made it necessary to suspend field work at a number of the stations and the Survey performed the field work, though on a more modest scale.

Another exception was in the southern Gulf states where 21 stations were maintained by the Army Engineers, the records for which were later reviewed by the Survey; that number was reduced from 31 during the period. In that area, the Army Engineers had maintained in previous years 42 stations which had been discontinued and for which records had not been computed. In the spring of 1944, 17 of the stations in operation had the base data for several years and Gail A. Hathway, special assistant to the Chief of Engineers, wished to have the Survey compute, if possible, those records together with the records for 42 discontinued stations. For that purpose, a special allotment of $75 per station year was made and as 185 station years were finally computed, the amount transferred was $13,932.[56] There must have been some slight miscalculation as 185 station years at $75 amounts to $13,875. In Oklahoma, 35 stations and a relatively few stations in other districts were maintained by the Army Engineers, the records for which were reviewed by the Survey. In Arkansas, 12 stations and in Kansas, 11 stations were operated by the Army Engineers in order that experienced personnel would be available for additional flood measurements when needed.

Soon after the beginning of the enlarged program in which much of the field work in the Ohio River Basin would be performed by the Army Engineers, who had been developing equipment for flood measurements on the Ohio River somewhat similar to that of the Survey, it was thought advisable that each agency should become familiar with the special equipment of the other. Accordingly, a cooperative arrangement between the Chief of Engineers and the Director of the Survey was made whereby the Army Engineers' Cincinnati District Office and the Survey's Columbus Office were designated to prepare descriptions of the field equipment of both agencies, with especial

56/ Statement of D.H. Barber to author.

reference to new or modified devices of both agencies. Such descriptions adequately illustrated were published in 1940 by the Cincinnati District under the title "Descriptive Pamphlet on Stream Gaging Equipment." Experiments with various types of equipment were continued, and the results were published as "Supplement to Descriptive Pamphlet on Stream Gaging Equipment in August 1942."

Mississippi River Commission: The Mississippi River Commission is an autonomous agency under the Chief of Engineers, charged with the planning for navigation and flood control of the Mississippi River below the Ohio. The actual engineering work required is performed by the Army Engineers who have a division office and three district offices in that area. The division engineer is ex-officio the president of the Commission. During the major flood of January 1937, the Commission became interested in the records of the Survey's Vicksburg station, and requested daily discharges at that point, and also at a station to be installed on the Atchafalaya River at Krotz Springs, La.

During the early part of the present period, the Commission continued that cooperation which had included the maintenance of stage records at the New Orleans station. In 1944, the cooperation was discontinued as the Commission decided that its own stations at Vicksburg and near Krotz Springs gave sufficient information. The support of the New Orleans station was also discontinued.

Annual cooperative funds available:

1940	$4,000
1941	4,000
1942	4,670
1943	4,975
1944	2,717

It may be stated in passing that the Army Engineers during the 1947 fiscal year, with the approval of the Mississippi River Commission, resumed cooperation at the Krotz Springs and New Orleans stations.

<u>State Department</u>. - Most of the cooperation with the State Department was through the International Joint Commission in the operation of the gaging stations along the northern boundary west of the Great Lakes and of the tributaries to the boundary waters. During the period, the number of international gaging stations increased from 53 to 73. The completion of the Grand Coulee Dam caused backwater at the International Boundary and it was necessary to establish a station at the boundary; also a station on the lake at Grand Coulee Dam. A station on Skagit River near Hope was made an international station as the city of Seattle proposed to back water from its Ross Reservoir across the international boundary. The bulk of the increase was in Saskatchewan where increased development in the Battle Creek and Frenchman Creek Basins made it necessary to add in that Province the additional stations.

In addition to the international stations, the State Department funds, known as "Waterways Treaty funds" were used to support 37 stations at which gage heights only were obtained. Those were chiefly for the purpose of measuring the change in slope at the stations affected by backwater.

The field allotments to the districts for the operation of the gaging stations described were as follows:

1940	$36,600	1944	$41,800
1941	38,150	1945	48,085
1942	39,800	1946	53,200
1943	39,700	1947	51,900

For the auxilliary gage installation on the Columbia at the interna-tional boundary, it was necessary to install a 6x6-foot shelter on rock badly seamed. Additional funds were provided as follows:

1942	$9,996
1943	1,354

Under the international treaty with Mexico, effective April 18, 1945, the gaging station on the Rio Grande near San Marcial, N. Mex. was transferred from the International Boundary and Water Commission to the Survey July 1, 1946, and the State Department provided $4,300 for the fiscal year 1947, as it was necessary to keep a resident engineer there for the frequent measurements required.

Bureau of Reclamation. - During the first two years of the period, the Bureau of Reclamation contributed to the Pecos River Joint Investigation $38,000, of which $27,200 was allotted to the Surface Water Division. During the entire period, the Bureau was making comprehensive investigations of irrigation possibilities and as the cost of such possibilities was prohibitive for irrigation alone, it was necessary to consider other uses also, making the investigations those of multiple-purpose projects. For some years, the Bureau in some states where State and Survey funds were insufficient for the purpose, carried on its own stream gaging program of new stations. It did, however, transfer to the Survey funds for the maintenance of a few stations of particular importance. The maintenance of its own stations proved to be unsatisfactory, and during the last three fiscal years, the Bureau transferred funds to the Survey for the maintenance of practically all additional stations in which it was interested, and as many of the stations had been installed on a temporary basis, funds were also transferred to enable the Survey to rehabilitate them and bring them up to Survey standards. During the last two years, the funds transferred included those for the maintenance of the 125 gaging stations in the Missouri River Basin-Departmental Plan.

At the end of the period, 393 stations which included the 125 stations, were being wholly or partially supported by Bureau of Reclamation funds.

The annual funds available:

1940	$14,200	1944	$ 6,933
1941	15,643	1945	76,465
1942	3,485	1946	262,766
1943	9,317	1947	538,959

In addition to the Bureau funds available during 1947, Congress increased the Survey's appropriation by $50,000 to apply to the expense of maintaining stations for the Bureau.

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Tennessee Valley Authority. - Cooperation which had been effective since the creation of the Tennessee Valley Authority in 1933, continued. During the period, there was no definite basis on which funds were requested, further than the general understanding that sufficient funds would be available to cover not only TVA's share of the maintenance of the regular gaging stations, but also of special work requested from time to time. In 1933, 100 gaging stations were supported wholly or in part by TVA, but that number was gradually increased until on June 30, 1947, there were 155 stations of which 93 were in the Chattanooga District, 53 in the Raleigh District and 9 in the Charlottesville district. The reservoir stations were not included.

Annual cooperative funds:

1940	$102,000	1944	$ 59,500
1941	51,000	1945	62,500
1942	55,000	1946	60,560
1943	57,000	1947	80,000

The large increase during 1940 was due to a large WPA construction program for which TVA provided about $50,000 for materials, supplies, tools, etc. The increase in 1947 was to provide for increased cost of operation.[57]

[57] Letter from F. M. Bell to author.

Department of Agriculture. - Both the Soil Conservation Service and the Flood Control Coordinating Committee contributed funds for the continuation of the sediment projects started during the previous period.[58] Most of the projects were discontinued in

[58] p. 81, 89 (1928-1939).

1940 but the Boise River Watershed project was continued until November 1941, and the Little Tallahatchie project, until September 1942. The combined funds of the two agencies available were:

1940	$69,700
1941	72,100
1942	45,977
1943	22,075
1944	775

A very considerable amount was carried over from year to year, and was not used. The exact amounts used each year are not available at this time.

Weather Bureau. - Except during the last year of the period, direct cooperation with the Weather Bureau was limited to checking the Bureau's river gages in a few districts; in addition, the Weather Bureau furnished gage-height records to several districts. During the last year, however, under a cooperative agreement with the Survey and Army Engineers, the Weather Bureau contributed $4,500 toward the cost of installing recorders on the Ohio River at Cincinnati and Portsmouth. At both points, the Weather Bureau was particularly interested in the records for flood forecasts.

The Cincinnati installation replaced a gage in a power plant which required a long intake that not only became inoperative at frequent intervals, but on account of drawdown, the well readings were not a true index of the river stages. At several conferences between the Survey, Army Engineers, and Weather Bureau in 1945, it was agreed that a new station should be installed adjacent to the suspension bridge between Cincinnati and Covington. The estimate cost was $7,500 and each agency agreed to furnish a third. It was a year or more later when the installation was completed and costs had increased so greatly that each agency contributed an additional $1,000. A description of the concrete installation having an over-all height of 99 feet is given on Pages 132-133.

The Portsmouth installation was that of a key Weather Bureau station, but one in which the Survey had no direct interest, as under the present main Ohio river station program, it does not benefit the Survey, except from the standpoint of public and cooperative relations.59/

59/ Letter from F. F. Schrader to author.

Following the flood of March 1945, the local American Legion Post started an agitation to have an adequate recording gage at Portsmouth, as several gages had been used in the previous years and the correlation of their records was somewhat uncertain. Following several conferences between interested agencies, it was agreed that the Weather Bureau, Army Engineers, and the city of Portsmouth would each contribute up to $1,000, and the Survey would make the installation; any additional funds needed would be supplied by the City. As the installation was made in the fall of 1947, it is beyond the scope of this history, but it may be stated in passing that a galvanized pipe well 72 feet high was installed near a pier of the suspension toll bridge.

Annual cooperative funds:

1942	$ 448
1943	20
1944	133
1945	176
1947	4,500

Fish and Wildlife Service. - Under the President's second reorganization plan, the Biological Survey was transferred to the Department of the Interior from the Department of Agriculture, and the Bureau of Fisheries from the Department of Commerce July 1, 1939, One year later under the third reorganization plan, the two were consolidated into the Fish and Wildlife Service.

During the previous period, the Biological Survey had transferred funds to the Survey for the purpose of maintaining gaging stations on the Souris River Basin, N. Dak., the Malheur Refuge in Oregon, the Seney Migratory Bird Refuge in northern Michigan, and on the headwaters of the South Fork White River in South Dakota. Of the four projects, three were continued, but the White River Project was discontinued September 30, 1940. By that time, the difficulties with the power company 60/ had been settled out of court

60/ p. 89 (1928-1939).

and there was no further need for the records.

Two new projects were started during the latter part of the period. The Fish and Wildlife Service desired to establish a wildlife refuge in a swampy area bordering Parker River in Massachusetts. As that project would interfere with duck hunting and was opposed by local and State interests, a representative of the Secretary made an investigation. At that time, H. B. Kinnison pointed out the uncertainty as to whether the proposed storage of more water in the refuge would be a help or a hindrance to the water power at a snuff mill located farther downstream. To settle that point, funds were provided in October 1945 for the installation and maintenance of a gaging station on Parker River.

The Fish and Wildlife Service was purchasing water from the Bureau of Reclamation for the fish in the Yakima River Basin, and in 1946 requested the Survey to operate two temporary stations during the irrigation season for the purpose of checking the amount of water delivered.

Annual allotments for the projects:

1940	$6,000	1944	$2,165
1941	3,800	1945	2,194
1942	3,838	1946	5,123
1943	2,200	1947	3,225

National Park Service. - Cooperation with the National Park Service for the maintenance of a gaging station on Rock Creek in the District of Columbia continued.

Annual allotments for the purpose:

1940	$350	1944	$338
1941	350	1945	400
1942	350	1946	498
1943	350	1947	600

In addition, there was cooperation in services, consisting in furnishing gage observers at 6 stations in Yellowstone National Park.

Indian Service. - At the beginning of the period, the chief work for the Indian Service was the continued operation of some 80 stations on ditches serving Indian lands in the Rio Grande Basin in New Mexico. In the fiscal year 1943, the annual funds were reduced from $15,000 to $3,000, and the number of stations reduced to 25. Subsequently, the amount was increased slightly each year. The 5 stations being maintained on the Crow Reservation, Montana, became a part of the Missouri River Basin-Departmental Program during the 1947 fiscal year.

The Indian Service purchased water from the Bureau of Reclamation for use on the Yakima Reservation, and to check the amount of water delivered, 6 gaging stations were maintained during the period. Beginning in May 1944, the Survey operated during the irrigation season a gaging station on the Palo Reservation. Four stations were maintained on the Shoshone Reservation, Nevada.

Annual expenditure of funds were:

1940	$20,050	1944	$ 6,200
1941	17,750	1945	6,200
1942	17,750	1946	6,500
1943	5,850	1947	9,400

Federal Power Commission. - The Survey's functions in connection with the Federal Power Commission[61] continued unchanged

61/ p. 97 (1919-1928)

except that near the end of the 1947 fiscal year, most of the supervision of project operation was transferred from the Water Resources Branch to the Conservation Branch. In general, such supervision was limited to power projects situated on public lands outside the forests, and as the Conservation Branch was charged with the classification of public lands, that Branch was the logical agency to exercise such supervision. When the Federal Power Commission began to issue permits and licenses about 1920, the Conservation Branch had no field offices and for convenience and economy of operation, the supervision of projects was delegated to the district offices of the Surface Water Division. However, with the establishment of field offices by the Conservation Branch, it was logical to transfer the supervision of projects to those offices. The supervision of stream gaging remained with the Surface Water Division.

Annual expenditures of Federal Power Commission funds for field expenses chargeable to supervision of projects:

1940	$350	1944	$153
1941	431	1945	259
1942	264	1946	68
1943	195		

The law creating the Federal Power Commission prohibited other agencies from charging it for services rendered.

The amounts expended by permittees and licensees in the maintenance of more than 300 stations under Survey supervision were:

1940	$25,000 1/	1944	$27,366
1941	23,631	1945	35,865
1942	19,556	1946	31,007
1943	25,059	1947	36,566

1/ Estimated

National Resources Planning Board. - The National Resources Committee was an agency created by Executive Order in the early days of the Franklin D. Roosevelt Administration and was financed by grants from PWA. It did not rest on congressional authority and when PWA funds were approaching exhaustion near the end of the previous period, an attempt was made to obtain a direct appropriation from Congress. As there was considerable opposition in Congress to the overall-planning which touched many phases of American life, the Committee was merged with the Federal Employment Stabilization Office which had been created by Congress, and the merger became the National Resources Planning Board on June 7, 1939. Opposition continued, and finally Congress declined to continue the appropriation for that agency and it was discontinued June 30, 1942, except for a small sum to wind up its affairs during the next fiscal year.

In March 1939, a joint investigation of the Pecos River modelled on the Rio Grande Joint Investigation of 1936, was started by the National Resources Committee and was completed in 1942.[62]

62/ p. 15.

In the fall of 1939, a general plan for the Joint Investigation of Southeastern Florida water resources, to be sponsored by the National Resources Planning Board was discussed with various Federal agencies.

The need for the investigation was shown by Alex Orr, mayor of Miami, who was much concerned with the encroachment of salt water resulting from the heavy pumping to meet the rapidly increasing demand for water in the southeastern part of Florida. He contacted the National Resources Planning Board in Washington, and that agency referred him to the Survey for the purpose of discussing the situation; it was decided that an investigation was needed. Unlike the previous joint investigations to which the National Resources Committee had contributed substantially from PWA funds, the Planning Board, not having access to such funds, was unable to make a contribution but offered to furnish a coordinator for the efforts of the various agencies to be engaged in the joint effort. The Survey offered to match State or local funds in the investigation of the surface and ground waters and their quality. As State agencies were unable to raise all the funds needed, Mr. Orr stated that he would raise the money locally. The city of Miami was the chief contributor and cooperative work was started in the fiscal year 1940. The Planning Board furnished the services of a coordinator at first, which indicated that other Federal agencies were beginning other phases of the joint investigation. But the Planning Board's funds were exhausted after a few months and thereafter, the Natural Resources Planning Board dropped out of the picture, and the water resources investigation was continued on a cooperative basis between the Survey and the local communities. The details as described under the activities of the various divisions in Florida.

During the period, the funds contributed by the Planning Board were for the Pecos River Joint Investigation only and the amounts allocated to the Surface Water Division were as follows:

1940	$ 6,054
1941	11,508[1]
1942	923

1/ Estimated.

Public Works Administration. - In the 1942 fiscal year, the Public Works Administration made a final allotment to the Survey, of which $3,950 was used by the Santa fe District.

Bonneville Power Administration. - The Bonneville Power Administration was created by Act of Congress approved August 20, 1937,[63] as a provisional agency set up for the transmission and

63/ 50 pt. 1, Stat. L. 732.

scale of Columbia River hydro-electric power from the Bonneville Dam, then nearing completion. During parts of the fiscal years 1942 and 1943, that agency desired, particularly during low water, daily records of the stage and flow of the Columbia and Snake Rivers in connection with the operation of the Bonneville Power and arranged with the Tacoma District to furnish current records twice monthly. The Power Administration also installed telemark recorders at the Dalles and Trinidad stations. In 1945, funds were provided for the establishment of stations on the Columbia River near Umatilla and on the Snake River near Pasco. The station at Umatilla was attached to piling at the Standard Oil Company's dock and when the telephone company was requested to connect the telemark with its lines, the request was refused on the grounds that an explosion might possibly occur if wastage of oil at the unloading dock coincided with a telephone call to the telemark. Therefore, the Umatilla telemark was not used. The Power Administration itself installed telemark recorders at these stations. In accordance with the agreement, the Survey, for the Pasco station, maintained the low-water rating curve up to 30,000 second-feet, and furnished a list of mean daily gage heights, but not the daily discharges.

With the installation of telemark recorders, the power load dispatcher at Vancouver could call up the telemark stations several times a day and obtain the stage automatically; then by means of the rating curves, he could determine the discharge for the next few days and operate the Bonneville plant much more efficiently.

Annual amount of available funds:

1942	$ 224	1945	$5,600
1943	500	1946	606
1944	50	1947	750

The Umatilla station was operated by the Portland District and the Pasco station by the Tacoma District.

Southwestern Power Administration. - As a war measure to insure power for the vital aluminum works in Arkansas, the Secretary of the Interior created on August 31, 1943, the Southwestern Power Administration for the purpose of unifying the control of the power plants at the Grand River Dam, the Norfolk Dam, and the Denison Dam, and marketing the power. Of these, only the Grand River Dam in Oklahoma concerns this history.

On November 21, 1941, a special representative of the Federal Works administration, had taken over the operation of the Grand River Dam on November 21, 1941, as a war measure and when the Southwestern Power Administration was created, the same representative was continued. From November 21, 1941, until September 1, 1946, when the Grand River Dam was returned to the Grand River Dam authority, a State agency, the cost of operating the four gaging stations required by the FPC license was paid either by the Federal Works Agency or the Southwestern Power Administration, from the dam's power revenues. The records show that from July 1, 1945, to September 1, 1946, the funds were provided in the name of the Southwestern Power Administration as follows:

1946	$2,820
1947	463

Federal Works Agency. - The Federal Works Agency was created by the reorganization plan No. 1 made effective July 1, 1939. In it were grouped the Public Roads Administration, Public Buildings Administration, Public Works Administration, and a number of smaller agencies.

The Grand River Dam Authority, a State agency and also a Federal Power Commission licensee, was taken over by the Federal Works Agency on November 21, 1941, and operated the Authority until the fiscal year 1946, when the Southwestern Power Authority was created for that purpose. Four gaging stations were being maintained, and the Federal Works Agency furnished funds for the operation of those stations as follows:

1942	$1,224	1944	$2,579
1943	2,413	1945	2,949

Defense Plant Corporation. - The Defense Plant Corporation, a war-time agency of the Reconstruction Finance Corporation, acted as agent for the Phelps-Dodge Corporation in financing the second Gila River investigation.64/

64/ p. 18.

The funds allotted to the Surface Water Division for that investigation were:

1944	$27,922
1945	22,171

War Production Board. - To pay the cost of the pig-iron survey requested by the War Production Board on March 2, 1942,65/ the following funds were transferred to the Survey:

65/ p. 10.

1942	$47,440	1943	$12,951

Public Health Service. - In the spring of 1947, the Public Health Service selected the Emory University Field Station as an outpost to describe as soon as possible any entrance into the United States of typical malaria or similar diseases, and during the remainder of the period paid a part of the salary and expense of the engineer who had been maintaining the general hydrologic program at the Field Station since September 1942.66/

66/ p. 121.

The amount contributed was $871.

Federal Stations

During the previous period, the Federal stations supported wholly by funds appropriated to the Survey for that purpose had been known as "Federal-type stations,"67/ but during the war years, and in keeping with the rush of events, "type" was dropped and they became known as Federal stations.

67/ p. 10 (1928-1939).

Congress continued sympathetic and during each of the first two years of the present period increased the amounts for that purpose, but thereafter granted no furher increases until 1947. As the war drew toward its close, more and more thought was given to post-war planning, in which the Survey records were essential to both the Army Engineers and the Bureau of Reclamation, the two Federal agencies chiefly concerned with water. At the same time, the cost of operating existing stations was increasing to such an extent that it was feared State cooperation might not increase sufficiently to make it possible to continue the operation of some cooperative stations needed, particularly as the needs of the States were concerned with many streams in which the Federal interest was not paramount.

Therefore, the Survey formulated a long-range plan having a goal of 1,000 Federal stations forming a net work to be known as base stations, permanently equipped and to be continued indefinitely. For 1947, the increase of $68,200 was included in the Budget estimate, and Congress was so strongly committed to post-war planning that not $68,200 but $79,800 increase was appropriated.

The following table shows the annual amounts appropriated for Federal stations and the number of such stations:

Year	Appropriation	Number of stations
1940	$ 106,000	188
1941	112,500	189
1942	112,500	191
1943	112,500	191
1944	112,500	191
1945	112,500	191
1946	112,500	191
1947	211,000	218

Interstate Compact Requirements

In a previous period, the Colorado River Compact[68] had

68/ P. 99 (1919-1928).

directed the Survey "to cooperate to promote the systematic determination and coordination of the facts as to flow. To secure the ascertainment and publication of the annual flow for the Colorado River at Lee Ferry."[69] Under that authority, Congress had appropriated

69/ Art. V.

funds for the establishment and operation of stations required. Such appropriations continued in the amount of $50 annually until the fiscal year 1947 when more intensive studies showed the need for additional gaging stations and the amount was increased to $105,000. As a matter of passing interest, it may be stated that Arizona which had refused to sign the Colorado River Compact originally, finally did so during the present period while the treaty with Mexico[70] was

70/ p. 87.

being negotiated.

At the end of the previous period and during the present one, four additional interstate compacts having stream-gaging requirements became effective; the Rio Grande, Republican River, Belle Fourche River, and Costillo Creek.

The Rio Grande Compact, which had been the ultimate goal of the Rio Grande Joint Investigation, 71/ was negotiated by the states of

71/ p. 78 (1928-1939).

Colorado, New Mexico, and Texas, and was consented to by Congress and signed by the President May 31, 1939. To administer the compact, the governor of each state appointed a Commissioner for that state, the three officials forming the Rio Grande Compact Commission; the Federal government appointed Berkeley Johnson, the Survey's district engineer in Santa Fe, as the Federal representative who was chairman of the Commission, but in accordance with the Federal policy of neutrality, had no vote. The Commission was required to have maintained and operated 12 gaging stations at specified points, in order that the terms of the compact in allocating the water supply between the three states should be fulfilled. Some of those stations had been maintained for some years by the Survey and its State-cooperating agencies, and those stations were named in the compact as USGS stations. There was no requirement that the compact stations should be maintained by the Survey, nor were special funds provided for that purpose, and the stations continued to be operated by the Colorado and New Mexico Survey Districts in which the required stations were situated.

The dry years of the nineteen thirties had shown the need for more extensive irrigation in the Republican River Basin, lying in Colorado, Kansas, and Nebraska, and the disastrous flood of May and June 1935 had shown the even greater need for flood control. As a result, the Bureau of Reclamation began making an investigation of the water resources looking toward their development, and the Army Engineers began studies of flood prevention. The normal flow of the upper river was as usual over-appropriated and to settle the conflicting claims of the three states, a division of the water supply was needed, before plans for additional irrigation, including storage could be decided upon. The Governors of the three states met December 22, 1939, to discuss the need for a compact and as a result, each Governor appointed a state commissioner, the three forming the Republican River Compact Commission. As the Survey was actively engaged in maintaining in the Republican River Basin in the three states, gaging stations, the records of which would play an important role in determining the water supply allocations to each state, the Federal representative selected was Glenn L. Parker. A compact was finally negotiated and approved by Congress May 26, 1943. The compact set forth at great length, the amounts allocated to each state and the tributary sources from which such allocations were to come. Perhaps, following the precedent set by the Colorado River Compact, and also by the important role that stream-gaging records would play in the operation of the compact, the Survey was directed to "collaborate with the officials of the States charged with the administration of this compact in the execution of the duty of such officials in the collection, correlation, and publication of water facts necessary for the proper administration of this Compact." 72/ To enable the Survey to perform its

72/ Art. IX.

duty of collecting and publishing the records from 18 gaging stations required, the Survey inserted in its estimates for the fiscal year 1945 and succeeding years, an item for the operation of those stations. The following annual amounts were made available:

1945	$25,000
1946	25,000
1947	27,500

The Belle Fourche River rises in eastern Wyoming and flows into South Dakota where it joins the Cheyenne River. Water rights had been acquired in both states and the citizens of South Dakota wished to have a compact allocating the available water supply between the two states, in order that an assured supply might be used to the best advantage in future planning; Wyoming also wished to have a definite amount reserved for its use in future development. Accordingly, each State appointed commissioners and negotiated a compact which was approved by Congress February 26, 1944.73/ The Compact contained the same requirement of the Survey as that contained in the Republican River Compact, and directly taken from that compact. A gaging station at the State line was required and an item for the establishment and maintenance of that station was inserted in the Survey's estimate for the fiscal year 1947. The amount of $2,700 was made available.

73/ Public 236, 78th Cong. 2nd Sess.

Costillo Creek, a small tributary of the Rio Grande, arises in Colorado and crosses the Colorado-New Mexico State lines three times before entering the Rio Grande in New Mexico. A compact approved by Congress June 11, 1946, provided for the maintenance of twelve gaging stations to furnish the data necessary for administration. In that connection, the Compact contained the by now usual direction to the Survey to collaborate in the collection and publication of the stream-flow records. When the Compact was approved, it was too late to obtain Federal funds for the operation of the gaging stations during the remainder of the present period.

International Treaty with Mexico

Irrigation from the Colorado River in Mexico, just south of the California-Mexico International line, had been active for many years and the amount of water utilized has been steadily increasing. To assure both countries an equitable division of Colorado River water, the United States proposed a treaty covering that river. The Mexican Government was more concerned about a division of the water of the Rio Grande in view of the rapid expansion of irrigation on the American side of the lower Rio Grande Valley, and desired that the proposed treaty cover both the Colorado River and the Rio Grande. A treaty, which also included the Tiajuana River, the third international stream, was negotiated and ratified by both countries. The protocol of exchange of ratifications was signed in Washington, February 3, 1944, and the Senate ratified the treaty and protocol April 18, 1945.

In addition to dividing the waters of the international streams, the treaty stipulated that the jurisdiction of the International Boundary Commission should be confined to works on or along the boundary and to those devoted exclusively to the performance of treaty functions. Heretofore, the American section of the International Boundary Commission had maintained since 1931 the San Marcial gaging station on the Rio

Grande, which measures the inflow into the Elephant Butte Reservoir that was built partly to insure delivery of 60,000 acre-feet annually to Mexico. In view of the treaty's limitation on the Commission's field of operation, an agreement between the State and Interior Departments was reached whereby the Survey was to operate the San Marcial station and the State Department was to join with the Interior Department in explaining to the Bureau of the Budget and to Congress the reason for the transfer of that station, and the need for funds for the relatively expensive operations which required several discharge measurements weekly. The Survey item for the fiscal year 1947 included $4,300 for the San Marcial station and it was transferred to the Survey on July 1, 1946.

During the period, no additional work on the Colorado River came to the Survey. The agreement mentioned previously provided that the Survey was to continue the operation of the Yuma station, but that additional stations below that point were to be installed and operated by the International Boundary Commission. Neither did the Survey have any additional work in Tiajuana Basin as it was already maintaining a number of gaging stations in cooperation with the city of San Diego.

Missouri River Basin-Departmental Program

During the period covered by this history, 125 gaging stations were authorized, distributed as follows:

Montana	36	South Dakota	13
Wyoming	18	Nebraska	22
Colorado	10	Kansas	13
North Dakota	13	Total	125

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

Pecos River Joint Investigation[74]

74/ p. 15.

Although the agreement for the investigation was signed in February 1939, funds did not become available until July of the new fiscal year and field work was started in August. As this was an interstate project, the Santa Fe district established headquarters at Roswell with three engineers, and the Austin district had headquarters at Pecos, Texas, with two engineers.

To obtain records of stream flow and storage of the Pecos River, its tributaries, diversions, wastes, drains, and reservoirs, from the headwaters in New Mexico to a point below the irrigated lands in Texas, a valley distance of about 400 miles, 104 stations were established which with existing stations made a total of 132 stations. Of that number, 20 were at pumping plants where records of performance were kept and the pumps rated by current meter. In addition, a series of seepage measurements in the Toyah Creek and Comache Creek Basins were made. The field work was terminated December 1940, at which time most of the additional stations were discontinued. A few stations for which the records had lasting value were made a part of the regular stream-gaging programs. The computed records were furnished to the Planning Board engineer in charge of the investigation. In addition to its cash contribution 75/

75/ p. 17.

the Bureau of Reclamation furnished a number of records connected with the Carlsbad project, and the Army Engineers paid for the installation of a station on the Pecos River needed for flood studies.

Funds available for the surface-water phase of the investigation were about:

	State	Survey
New Mexico	$5,000	$5,000
Texas	10,000	10,000

Of the total contributions by the Natural Resources Planning Board and the Bureau of Reclamation, the exact amounts devoted to this phase of the investigation are not available but it probably was about one-third.

Bear River Investigation

Bear River is an extremely inter-state stream. It rises in Utah, flows into Wyoming, again into Utah, back into Wyoming, then into Idaho, and finally into Utah and discharges into Great Salt Lake. It is highly developed and like most western rivers, its water supply is insufficient at all times for the demands upon it.

In 1939, a dry year, there was trouble in administration and the Idaho water users threatened to file suit against the Wyoming and Utah users. To avoid such a suit, which would be expensive and long-drawn out, as all interstate water suits are, the State Engineers of the three States decided to appoint a committee of water-users to work with the State Water Commissioners until such time as a Compact Commission could be appointed and a compact negotiated. The water-users committee was appointed in 1940 to make a survey of Bear River and determine the best method of administration.

That same year, the Bureau of Reclamation was making a basin-wide investigation of all irrigation possibilities which was started in 1938, and at a meeting of water-users held in Evanston, Wyoming, July 17, that agency explained the various possible projects, and stated that from 750,000 to 1,000,000 acre-feet of water was wasted into Great Salt Lake annually, or enough to irrigate 250,000 acres additonal.76/ Before definite plans for new projects could be made,

76/ Letter from L. C. Bishop, State Engineer of Wyoming, to author.

the Bureau felt that the conflicting rights of the water-users in the three states should be settled by the States. That required complete information regarding the actual diversions in each state as well as the water supply available at various points.

In 1941, the State Engineers of the three states, as an aid to the water-users committee appointed the previous year, agreed to make inturn measurements of the diversions from Bear River, especially above Bear Lake inlet. These series of measurements were started early in May and continued with some breaks until the latter part of October. As the river was measured at various points as well as all diversions and inflows, it was possible to determine gains and losses in various sections of the river. Thus for the first time, information regarding actual diversions and river gains and losses for the river above Bear Lake outlet, a few miles below the inlet, was available.

During these measurements, it became apparent to the engineers making the measurements that additional gaging stations were required to obtain more complete data and in the fall of 1941, the Denver District of the Survey installed for Wyoming two additional stations on Bear River, and in the spring of 1942, the Boise District installed for Idaho a station on Thomas Fork, and the Salt Lake District for the State of Utah established the station on Bear River near Woodruff. Those stations became a part of the regular stream-gaging program.

To consider the work for 1942, a meeting was held in the office of the Utah State Engineer in January 1942, at which the three State Engineers, representatives of the Bureau of Reclamation, and the Survey's district engineers of the three districts concerned were in attendance. At that time, the Bureau of Reclamation announced that it had employed Thomas Curtis, an experienced hydrographer, to make measurements of the principal diversions and some additional measurements at the Survey's river stations; also establish additional so-called development stations in order that a clearer picture of the diversions and the gains and losses might be obtained. It was proposed that the States and Survey share with the Bureau the cost of that season's work, the Bureau itself offering to pay a quarter of the entire cost. The States were unable to pay a share of the cost and as the Survey could make funds available only by cooperating with the States, it also could put up no funds. However, the Survey and States, under existing agreements, could carry on their regular programs in the Bear River Basin. The Bureau agreed to carry the burden until the next sessions of the State Legislatures could appropriate funds for that purpose. To coordinate the work, Reid Jerman, for the Bureau of Reclamation, and A. B. Purton, for the Survey, were appointed co-directors of the investigation.

To negotiate a compact, when sufficient information was available, each State appointed compact commissioners, and those commissioners held a meeting in Rock Springs, Wyoming, June 7, 1943, to organize the work for that year. By that time, the legislatures had provided additional funds and the States and Survey were in a position to share in the over-all costs. That meeting was attended by C. G. Paulsen and the three district engineers concerned. The Bureau of Reclamation announced that a successor to that agency's hydrographer would have to be chosen, and that definite arrangements should be made to fix responsibility for the work and to finance by all agencies interested, an adequate investigation of the entire basin. At Mr. Paulsen's suggestion, it was decided that all hydrometric data be handled under one agency, and that one-half the necessary funds be contributed by the States and Survey together (on a 50-50 basis), one-quarter by the water users, and one-quarter by the Bureau of Reclamation. It was further decided that a project engineer was to be selected by the Survey and that all personnel-- Survey, State, Water users, and Bureau of Reclamation--engaged on that investigation were to report directly to the project engineer; in other words, a separate organization was to be created. W. V. Iorns, of the Salt Lake Office, was appointed project engineer July 1, 1943, and headquarters were established at Logan, Utah, with an engineering personnel of five, together with seasonal employees and the necessary clerical staff. The three district engineers and the Bureau of Reclamation engineer in charge of the Utah investigations, with T. R. Newell, chairman, acted as an advisory committee to the project engineer. During the period, at least one meeting of the committee was held each year to consider the project engineer's progress reports and future plans, and settle any points of policy or procedure which might arise. Its functions were purely advisory, as full responsibility rested with the project engineer.

In the divisions of costs, much of that supplied by the water users for the work was evaluated services of water commissioners and others engaged directly in compiling records, and also depreciation on equipment furnished by the various agencies. As these items were elastic and caused considerable argument, and as the actual cash by the States, Survey, and Bureau was about equal, a new agreement was entered into September 21, 1945, whereby the Survey, Bureau, and the three States as a unit were each to contribute $12,000 annually, making a total of $36,000. Thereafter the evaluated services were not matched.

The first year, 79 base and development stations were maintained, together with 443 additional stream and canal stations in the basin, and substantially the same stations were maintained during 1944 and 1945.

For the 1946 irrigation season, it was decided that diversion records on tributary streams, except Smith's Fork, be discontinued and with some other changes that reduced the number of base and development stations to 70, and miscellaneous gaging stations on canals and tributaries to about 150, and 10 stations on tributaries below diversions.

When the investigation was started there was no definite time limit for it, and to clarify that situation, the three State engineers on November 13, 1944, decided that the existing program should be continued until such time as the State Engineers decided that sufficient data for compact purposes had been collected.

For the use of State and Federal officials and the water users concerned, the following reports were published:

Bear River Hydrometric Data Report 1943
Bear River Hydrometric Data Report 1944
Bear River Hydrometric Data Report 1945
Bear River Hydrometric Data Report 1946

In 1945, the Compact Commissioners began to consider the kind of compact to be negotiated. Before that could be decided upon, it was necessary to have an analysis of the data being collected, and the State Engineers requested the Director to enlarge Mr. Iorns' authority for that purpose as the latter was best qualified to make that study. That would require additional funds, and November 26, 1946, the Director advised the Commissioner of Reclamation that $3,000 additional would be needed for studies for the compact, and the latter authorized the expenditure of that amount from the funds appropriated to the Survey for Bureau of Reclamation work. Authorization for Mr. Iorns to make the technical studies needed for the compact was given February 6, 1947.

The following engineering assistants were employed on the Bear River investigations:

B. S. Robison	July 1, 1943 to June 30, 1947
I. V. Goslin	Sept. 17, 1943 to Mar. 15, 1946
C. F. Wilcomb	May. 16, 1945 to Feb. 15, 1946
M. S. Peterson	Feb. 25, 1946 to June 30, 1947
A. B. Harris	June 1, 1946 to June 30, 1947
W. N. Jibson	July 15, 1946 to June 30, 1947

There were several Bureau of Reclamation employees assigned to the Logan Office. In addition, there were a number of employees engaged during irrigation seasons only.

Available funds

Year	Combined States	Survey	Bureau of Reclamation	Eval. Dept., etc.	Total
1944	$10,788	$10,288	$ 10,168	$ 10,893	$42,137
1945	13,396	10,657	11,683	10,893	46,629
1946	13,590	13,200	12,030	10,900	49,720
1947	12,587	11,781	15,000 1/	11,600	50,968

1/ Of this amount, $13,500 was charged to the Survey's account of funds appropriated to the Survey for work performed for the Bureau.

Mr. Iorns' extra work with students is described under the activities of the Salt Lake City District.

Incodel

Incodel, the official abbreviation of "The Interstate Commission on the Delaware River Basin," was an outgrowth of the Interstate suit brought by the State of New Jersey against the State of New York and the city of New York, with the Commonwealth of Pennsylvania Intervenor. 77/

77/ Supreme Court of the United States, October, 1930, No. 16, Original May 4, 1941.

The city of New York wished to increase its water supply by diverting water from the Delaware River, an interstate stream, and tried to negotiate a compact with New Jersey and Pennsylvania for that purpose. Being unsuccessful, the city started construction on the proposed diversion, and was sued by New Jersey, with Pennsylvania as intervenor. The decision of the Supreme Court permitted the city to divert water, subject to two restrictions: The first was related to the flow at Port Jervis, New York, where the river leaves New York and flows between New Jersey and Pennsylvania, and where the Survey had a gaging station; the second was applied at Trenton, New Jersey, and was related to the salt-water barrier in the river at Philadelphia and farther downstream, and involved the Survey's gaging station at Trenton, the lowest station on the river and just above tide-water influence. When the flow at Port Jervis is less than 1,535 second-feet, and at Trenton less than 3,400 second-feet, the city shall release from the storage reservoirs sufficient water to increase the flow to those volumes, except under certain conditions.

A diversion of the proposed magnitude from the Delaware River requires years to complete and in the meantime, the Delaware River Basin States of New York, New Jersey, Pennsylvania, and Delaware agreed to act harmoniously toward the goal of planning the development of the basin more advantageously and thus forestall another TVA. Each State created a commission on Inter-state cooperation, consisting of a State senator, a member of the House of Representatives, a member of the Governor's cabinet, an official of the State Planning Board, and a delegate at large. The four commissions about 1939 jointly organized Incodel, the primary objective of which[78/] has been, is, and will continue to be, to promote governmental cooperation and to coordinate all projects for the development, improvement and protection of the Delaware River Valley. Headquarters were established in Philadelphia with an executive secretary.

78/ Incodel, a report on its activities and accomplishments, July 1, 1944, to June 20, 1945, Philadelphia, Pa.

One of Incodel's first activities was a study of the streamflow records in the basin, during which that agency consulted with the Survey's district engineers in New York, New Jersey, and Pennsylvania. To complete a satisfactory network of stations in the basin, Incodel decided that three additional stations, all in New Jersey, were needed and recommended that the State provide funds for their installation and maintenance.[79/] The records for all stations on the Delaware River Basin were furnished to Incodel for use in studying conditions in the drainage basin before the diversion was completed.

79/ p. 34.

Improvement in equipment

The effects of shortages both in personnel and materials during the war years were not conducive to improvement in existing equipment or development of new equipment. However, the need for power equipment for flood measurements of large rivers led to the development of a battery-operated reel and the construction of a limited number.

In 1938, the Columbus Office devised an electrically-driven reel and crane to obtain better discharge measurements under difficult measuring conditions, with a minimum expenditure of physical energy. Unlike other power-driven equipment, the electrically driven reel was small, compact, and light. The reel and crane were mounted at the right of a four-wheel truck 30"x48", equipped with 6-inch rubber wheels. The reel was the standard type E reel with an electric motor mounted on the right end in place of the conventional crank. The 110-volt AC or DC motor developed one horsepower under continuous operation or two horsepower under a fifteen-minute rating. From tests with the reel, a 100-pound weight was raised 4.2 feet per second; a 200-pound weight, 3.8 feet per second, the heaviest weight for which the reel was designed.[80/]

80/ Water Resources Bull., May 1939, p. 386 et seq.

During 1942 and 1943, further work was devoted to an electrically driven reel, now called a "battery-operated reel," which could be used with all standard cranes and gaging cars, and with either type B or type E reels, by placing a sprocket on the reel shaft. An incentive to the work at that time was doubtless the receipt of pictures taken by the Army Engineers' Vicksburg Office while experimenting with battery-operated reels.

As would be expected, many changes were made in the first Survey model, resulting in a unit that appeared to be satisfactory, and in 1942, 6 units were assembled for field tests, both by the Survey and by the Army Engineers. The starting motor was mounted on a frame, clamped to the crane underneath the reel. The power was furnished by a 170-ampere-hour 6-volt lead-acid storage battery.81/

81/ Water Resources Bull., Aug. 1942, pp. 123-127.

The battery-operated reel proved to be satisfactory, and there were more calls for it than the Columbus Office could supply, owing to the shortage of materials. As a result, the Baton Rouge and Iowa City Districts each developed a somewhat similar battery-operated reel. For the description of a power-operated unit of somewhat different type devised by the Austin District82/.

82/ p. 164.

Flood reports

Unlike the previous period, which was marked by a large number of major floods affecting several states, there were few major floods during the present period. Although there were many moderate floods, most of them covered relatively small areas and as those areas were usually within a single state, the ensuing investigations were made by the district affected and the resulting reports published either as water-supply papers or State publications. Wide-spread storms in August 1940 caused floods on many streams in the southeastern states and the Water Utilization Division planned and supervised the investigation which was made by the six districts affected.83/

83/ P. 390.

Studies in National Hydraulic Laboratory

When full-scale models of artificial controls were tested in 1934-5 in the flume of the National Hydraulic Laboratory, the available water supply limited the head on the models to about 0.8 foot. It was expected that tests would be made on small-scale models, permitting higher heads, but it was not until 1940 and 1941 in the present period that those tests were made.

Several small-scale models on various scales were made and tested under maximum heads which corresponded to 3.5 feet for the Trenton prototype, and 3.0 feet for the Columbus prototype. This extension of head was very helpful in studying the behavior of those types of control under higher discharges.84/

84/ Water Resources Bull. Feb. 1947, pp. 56-57.

In addition, calibration tests were made on small-scale models of several small dams used as gaging stations in the Trenton District. Assisting the Laboratory staff in the tests were C. H. Pierce, A. D. Ash, and E. J. Kennedy. The results were analyzed by Mr. Pierce.

The Los Angeles Office had developed a control differing materially from those of the Trenton and Columbus types, and had equipped a considerable number of gaging stations with it. In the fall of 1939, a small-scale model was constructed and tested by Messrs. Pierce and Ash, the tests being made between October and December. The results were furnished the Los Angeles Office.

Purchase of Gaging Station Sites

Taking a long-range view, the Washington office visualized a situation whereby a change of land ownership might make it necessary to move a gaging station, even if the site occuped were the best available. To avoid such a possibility, which would be of rare occurence, the Survey desired authority to purchase gaging station sites, and also permanent easements; the latter would eliminate the necessity for annual renewals in those cases where it was necessary to lease land for gaging stations. Accordingly, a bill was introduced into the Senate in 1942, and the Senate committee on Public Lands, while holding hearings in Glenwood Springs, Colorado, in September of that year, on various bills affecting Public Lands, included the Survey's bill. The author was requested to represent the Survey at that hearing and explain the purpose of the fill. The hearing on the bill was held under most favorable circumstances; Senator Pat McCarran of Nevada, Chairman of the Committee, in calling attention to the bill, stated that he had a very friendly feeling for the Survey, remembering when a schoolboy, having the job of reading a staff-gage in Nevada and thereby earning a most welcome $10 per month. Practically no opposition to the bill was shown at the hearing, and December 24, 1942, a law was enacted 85/ authorizing the Survey

85/ 56 Stat. I, 1086, 43 U.S.C. Sup. III, Sec. 36b.

to acquire not to exceed 10 acres for a single site, when funds were later appropriated for that purpose. The budget estimate for the fiscal year 1944 had already been approved by the Bureau of the Budget, and it was too late to include an item for purchasing sites that year. It was not until the fiscal year 1946 that favorable action was obtained. Because of the difficulty of obtaining an additional item for that purpose, it was proposed to change the language of the stream-gaging so as to allow payment to be made for such sites as a part of the regular expenses of the Branch up to a total of $35,000. That ceiling limit was reduced by the Bureau of the Budget to $10,000 for the purchase of sites and rights-of-way, and with that change, Congress gave the necessary authority.

During the remainder of the period, it was not necessary to purchase gaging station sites, but a hundred or more easements were purchased for small sums, at sites previously having annual right-of-way agreements.

Snow Surveys

During the present period, more attention was given to snow surveys. The first snow surveys by the Survey were started in 1922 by the Helena district in Glacier National Park, in connection with the International agreement on the waters of the St. Mary and Milk Rivers. Six snow courses were visited early in May each year. One course was discontinued in 1927 as being unsatisfactory but the remaining 5 courses continued to be measured early in May by engineers of the Survey and of the Dominion Water and Power Bureau of Calgary, Alberta. In 1934, the Army Engineers became interested in the snow survey work and requested the Survey to establish courses on the head-water basins of the Missouri River. Twenty courses were established which were measured monthly from January to May, inclusive. That number had been reduced to 14 in 1949. Antedating the Montana surveys by two years, the cooperating State agency in Maine had started snow surveys and those surveys became a part of the cooperative program. In the winter of 1937-38, largely as a result of the 1937 floods where melting snow was an important factor, snow surveys were started in New England and New York, 50 courses in the former and 200 courses in the latter district. The Hartford district started snow surveys in 1941, measuring at 21 points.

With snow surveys being made in the northeastern states, there was a community of interest in that subject and following the precedent set by the Western Snow Conference, E. S. Cullings, chief engineer of the Black River Regulating District of Watertown, N. Y. called a meeting of interested individuals and agencies, Federal, State, and private corporations, on September 16, 1940. To form a medium for the exchange of information and ideas related to snow measurements, and other snow problems, the Eastern Snow Conference was organized. That conference, through occasional meetings, did much to increase the interest in snow surveys. Results of snow surveys made by the various members of the Eastern Snow Conference were furnished the Albany Office of the Weather Bureau and were published at the end of each season.

In the Pacific Northwest, the Portland district for the Soil Conservation Service had started in 1937 readings at 8 snow courses near gaging stations. The Tacoma Office started readings at 16 snow courses in 1943-44. In general, the snow courses were visited about 3 times during the winter.

Research Projects

Early in the fiscal year 1947, when research funds became available, a committee consisting of F. M. Bell, C. H. Pierce, and J. V. B. Wells was appointed to recommend projects. It was decided that for the 1947 funds, the projects should be divided between pure hydraulic research and development of equipment, and that the objectives of the program were (1) improvement of accuracy of streamflow records, and (2) reduction in the cost of obtaining them.

Five major projects were selected, three in hydraulic research, and two on equipment.

Upper Columbia Snow Laboratory. - In the summer of 1945, the Army Engineers and Weather Bureau began the installation of the necessary equipment in the Middle Fork of the Flathead River Basin, along the continental divide in Montana for the purpose of determining the hydro-meteorological relations. The Army Engineers at that time requested the advice of Helena District in the selection of sites for two gaging stations and the proper equipment. The stations were established, one being equipped with an artificial control. In the fall of 1946, arrangements were made whereby the Survey was to perform some of the field work, and compile the stream-flow records. S. E. Rantz was detailed to the Processing and Analysis Section maintained at Sacramento. The stream-flow records were computed in considerable detail; during periods of snow melt and open-water periods of marked fluctuations, the records were computed on the hourly basis. That investigation came within the scope of the research program and $800 of research funds were allotted to it. Previously, the Survey's work had been on a repay basis.

Electronic method applicable to stream gaging. - A graduate student at the Utah State Agricultural College at Logan, Utah, V. E. Hansen, in connection with his thesis, was studying methods of measuring electronically the hydrostatic pressure head, and as that showed possibilities for use in stream gaging, Mr. Hansen's project was adopted and $500 allotted to him. To eliminate intakes and the troubles inherent in those in muddy streams, Mr. Hansen proposed to locate an electronic pickup on the bed of the stream and connect it with the recorder by means of a transmission line following the contour of the bank. The immediate objective of the investigation, as outlined by Mr. Hansen, was to develop an electronic pickup unit that would measure hydrostatic pressures. By so doing, friction and inertia inherent in present float and mechanical devices in use would be reduced to a minimum. By having the pressure affect an electronic circuit, it could easily be superimposed on a carrier wave for long-distance transmission to a central receiving station. Upon the completion of the project in the spring of 1947, a report of the results was transmitted to Washington by Mr. Iorns, who was in close touch with the project. He commented as follows:

> Mr. Hansen is to be commended on his accomplishments in the short period of research on this problem. From the results obtained, *** it is indicated that a suitable electronic measuring device can be constructed and it is recommended that additional research and development work be carried forward on this project.

It was apparent that much more intensive investigation would be required before it became a practical device for the determination of gage height.

An investigation of the backwater profile for steady flow in prismatic channels. - A contract was entered into with the University of Illinois for the continuation and broadening of a research project started in 1944 in the fluid mechanics and hydraulics laboratory by two Survey engineers, E. G. Barron and W. D. Mitchell, as a thesis for a graduate degree. The project involved the determination of certain factors pertaining to the operation of slope gaging stations in order that the computed profile could be compared with the actual profile. An artificial channel, rectangular in cross section, had been constructed, having cross sections varying in roughness and also in area due to overflow. Originally, two of the cross sections had been investigated. The present agreement provided for the investigation of 5 additional cross sections. In addition to the research funds, the University and the Urbana District both contributed funds. The latter loaned needed equipment and Survey engineers made more than 100 current meter measurements to check the flow in the channel. The Water Utilization Division gave helpful advice and criticism. The laboratory work was completed, but from the preliminary analysis, it appeared that further analytical work was needed before the full benefits of the project could be realized. The results of the investigation were published by the University of Illinois as Bulletin Vol. 46, No. 51, March 1949.

Development of snowmobile. - The increase in the number of gaging stations at high altitudes and in isolated locations, and the greater emphasis being placed on winter and early spring records, made it highly desirable that a small snowmobile suitable for Survey work be developed. G. D. Clyde, Chief, Division of Irrigation and Water Conservation, Soil Conservation Service, with headquarters at Logan, Utah, was much interested in snowmobiles for snow survey work and during the war, helped the Army develop a light test model and operated one of them on test runs under mountain conditions. During the spring and fall of 1946, V. W. Iorns, whose headquarters were also at Logan, discussed snowmobiles with Mr. Clyde and was shown some movie film of the Army machine in operation. Mr. Paulsen at a later date also saw the film and was so favorably impressed that he suggested as a research project the development of a similar machine, working in cooperation with the Soil Conservation Service. An informal agreement was made with the Soil Conservation Service whereby Willis Barrett, engineer of that agency, was in charge of the project and Emmett Divine, a machinist, was employed by the Survey to work with Mr. Barrett. Two snowmobiles were being built, one for each agency, and the fabrication and assembly were made with the help, at times, of student machinists and welders. The basic designs were the result of suggestions of Messrs. Clyde, Iorns, Barrett, and Divine. Shortly after the end of the period, the Survey snowmobile was completed and ready for testing.

Branch equipment shop in Columbus. - Toward the end of the fiscal year, the remainder of the research funds available to the Division were used to purchase shop tools to assist in equipping the Branch equipment shop at Columbus.

Summary of district operations

A summary of the operations of each district in sufficient detail to present a fairly complete picture is given. Attention is called to the fact that the terminal dates of personnel in one district may not, in some instances, coincide with the initial date of duty of the same personnel transferred to another district; the accrued leave may be included in the terminal date, while initial date is always that of entrance on duty. Only personnel holding Survey appointments are listed.

Attention is also called to the section on State Cooperation which contains the details of such cooperation, including the reasons for it.

Augusta, Me. - The number of stations was increased from 38 with 37 recorders in 1939, to 49 with 48 recorders in 1947. The chief increase was made during 1941 and 1942 as a result of Army Engineers and other Federal cooperation. During 1938, the Agusta Office established 4 stations and in 1941, the Boston Office established 1 station in New Hampshire near the Maine border; since 1939, the Boston Office has provided funds for half the cost of the operation of the 5 stations by the Augusta District since the records were of interest to both Maine and New Hampshire. In addition to the gaging stations, evaporation records were maintained on Moosehead Lake and Cobbosseecontee Stream at Gardiner, the latter being discontinued in 1942. Although powerhouse records computed by power companies continued to be received as they had been for many years, only three records were published during the period as the others were not considered sufficiently accurate.

To meet the need for records from very small drainage areas, a need felt by many of the districts, a station was established in 1945 on Gales Brook near Parkman having a drainage area of less than one square mile; in contrast, the next smallest drainage area measured by an existing station was one of 76 square miles. It was planned to establish other stations in comparable areas in different parts of the district.

Snow surveys, which were first started by the State Water Power Commission in 1920, were continued as a part of the cooperative program, about 40 points being measured in February, March, and April; each year a map showing the water equivalent as of March 1 was prepared and sent to those interested. The measurements of observation wells for the Ground Water Division was started in 1939 with one well and increased to 5 wells in 1942. The preparation of duration curves, resumed during the previous period, was continued.

The Public Utilities Commission was interested in water power and early in the period, the district office spent considerable time bringing down to date the census of developed and undeveloped water power made by the State in 1928.

In spite of war-time restrictions, a certain amount of repair work was performed, that at one station taking an unusual turn: The station on Sebec River at Sebec was rebuilt in 1942 and to save an annual rental fee of $25 exacted by the owner of the land, the station was relocated at the opposite bank where no rental was involved.

The winter of 1941-42 was one of unusually low flow and at the station on the Aroostock River at Washburn, the intake was frozen for a distance of 270 feet, making the well gage heights worthless. It was a period of serious power shortage and a knowledge of the actual discharge was of great importance, and a portable steam-thawing outfit was rented and the intake thawed by introducing the steam to the intake through a garden hose. The intake was thawed out in 9 hours but subsequently froze again. No further attempt was made to thaw the intake until Spring, but as records of discharge were required, to obtain that information, gage heights were taken twice daily with outside gage and weekly measurements were taken with current meter for 10 weeks, beginning in January. As the use of automobiles was restricted, it was necessary for the engineer to make the trip to the station by train. That meant leaving about 1:00 a.m., if the train was on time, and arriving at Presque Isle about noon where a power company employee furnished transportation to the station. The returning train arrived at Augusta about midnight, also if on time. That 23-hour work day repeated weekly constitutes a Branch record.

M. R. Stackpole continued as district engineer and had the following Civil Service engineering assistants:

Name	Period
P. J. Sheehy	July 1, 1939 to Feb. 9, 1941
W. J. Sanders	Feb. 1940 to Nov. 20, 1940
K. B. Young	Feb. 7, 1941 to June 30, 1947
C. H. Minehan	Apr. 1, 1941 to July 11, 1941
G. S. Hayes	July 21, 1941 to Oct. 1946
J. H. Hartwell, Jr.	Sep. 11, 1941 to Dec. 1, 1941
R. A. Morill, Jr.	Dec. 31, 1946 to June 30, 1947

Lura G. McLain was district clerk.

Boston, Mass. - In addition to the states of Massachusetts, New Hampshire, and Vermont, which comprised the Boston District during the previous period, cooperation with the State of Rhode Island started in the fiscal year 1941, added that state to the district. The number of stations increased from 97 in 1939 to 149 in 1947, 145 being equipped with recorders. The 149 stations were located as follows: Massachusetts, 54; New Hampshire, 45; Vermont, 39; Rhode Island, 10; Connecticut, 1. The increase was due to larger State and Federal funds. The Army Engineers' flood studies were just getting under way in New England at the beginning of the period, and to aid these studies, the number of Army Engineer stations were increased from 2 to 43, some of which were stations previously maintained on the State-cooperative programs. Cooperation with Rhode Island added 10 stations. All but 5 New Hampshire stations operated by the Augusta District for the Boston District, were maintained directly by the Boston Office. Long-distance recorders were established at three Army Engineer stations, two being immediately below flood-control dams, and the third on an index stream entering the river just below one of the dams. During the first 18 months, 34 stations were established, all in concrete structures. A number of artificial controls were built at these stations.

Early in the period, the Boston District developed the design and construction of the steel "h" columns for the support of cableways. The columns have entirely surplanted the "a" frames for cable supports on new structures in the district and are now being used in other districts. They were a part of the development of structures for gaging stations in which the use of wood was entirely eliminated with the exception of the instrument shelf.

For work in the field, the district was divided into 7 areas, and an engineer was assigned to each who was responsible for the operation and maintenance, development of rating curves, and for the elimination of lost record. Records of lost record by areas were posted monthly. This produced competition which helped to lower the amount of lost record in the district. About half the records were computed by means of the integrator as power regulation made that action necessary.

In 1940, at the request of the Department of Public Works, the Survey made an investigation and study of backwater conditions on Millers River during floods and suggested channel changes to improve those conditions. The plan was put into effect by the State, and proved to be successful. Also at this time, at the request of the Commonwealth of Massachusetts, a study recognized as the first of its kind was undertaken to develop a means of determining the magnitude of floods of various frequencies on both gaged and ungaged areas in Massachusetts. The Kinnison-Colby flood flow formulas[86] for Massachusetts resulted from this work and have since been widely used in the hydraulic design of bridges, culverts, and dams in the region for which this work is applicable.

86/ Proceedings A.S.C.E., March 1944, p. 267.

Severe floods on the headwaters of the Connecticut River occuring June 14-15, 1942 and June 15-16, 1943, did considerable damage, much of which was believed by the residents to be due to the Pittsburgh reservoir. As the State desired reports, investigations of both floods were made. The first flood was caused by a rainfall of more than 9 inches in 12 hours; the second was caused by a cloudburst-type storm which was probably the most severe within the memory of the oldest inhabitants. The resulting floods in New Hampshire and Quebec were the greatest on record. Investigations and reports of both floods were made by district personnel, and the reports published in the journal of the Boston Society of Engineers, Vol. XXX, Nos. 1 and 4.

Beginning in October 1942, the district began the publication of a monthly Water Bulletin, as a result of several factors; the previous year had been extremely dry and water power was deficient; industry was increasing rapidly in preparation for war, and in 1942 the power deficiency became acute. Requests for information regarding the water supply were so numerous that the monthly publication was started. Each issue contained the average precipitation for the district, stream flow for selected stations showing runoff as depth in inches and also percent of normal, storage in major reservoirs, and a statement by the Ground Water Division on groundwater levels. The January, February, and March issues contained the results of snow surveys collected not only by the Survey but by other agencies. The bulletin was sent to the Army Engineers, the Weather Bureau, and others in New England interested in the water supply; at the end of the period, there was a mailing list of 107.

Like other northern districts, the Boston District had trouble with frozen intakes during periods of low flow accompanying extreme cold weather, and during the winter of 1943-44, a portable steamer used by paper hangers for removing wall paper was purchased. By its use, a 2 1/2 - inch intake was thawed at the rate of one foot in three minutes. The success of the steamer led to its use by some other districts, at least by the Denver District to the author's knowledge.

In the spring of 1944, the station on Lake Winnipesaukee Outlet at Lakeport, New Hampshire was reestablished. As the release of water is controlled by gates, there is no constant stage-discharge relation. To replace the one-point continuous method obtained for a short time during the previous period, a Keeler deflector meter and a Stevens duplex recorder were installed to avoid the constant attention required by the current meter.87/ Its operation

87/ Water Resources Bulletin August 10, 1945, p. 126.

during the remainder of the period was entirely satisfactory.

Readings at least three times a winter on the 50 snow courses started during the previous period were continued. The results, together with those for the Albany District, formed a report by the Eastern Snow Conference and were published by the Weather Bureau in Albany.

During the last year of the period, as a result of increased cooperative funds for that purpose, a beginning was made on a program to establish in Massachusetts each year one or two stations on small streams draining area from 2 to 5 square miles. Two stations equipped with recorders and concrete controls were established, and to make the station records of greater value, a rainfall station and an observation well gage were also established in each basin. Also, as a result of the increased funds, the preparation of a special report on the hydrology of Massachusetts was started. It was planned to publish these data in two volumes, one the compilation of records and the other their analyses.

To rid himself of the ubiquitous small boy while making a bridge measurement of Millers River at Erving in 1942, George Anthony thought he had solved the problem of subsiding the boy with ten cents to stay away. Thereafter, the precedent having been set, he had to continue the subsidy during succeeding measurements. Moreover, when another engineer appeared later, the price was forced up to fifteen cents. The ultimate outcome is unknown to the author.

H. B. Kinnison continued as district engineer and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
G. K. Wood	July 1, 1939 to June 30, 1947	
C. L. Muntz	July 1, 1939 to Apr. 1, 1940	
C. E. Knox	July 1, 1939 to Oct. 1941	
	May 14, 1946 to June 30, 1947	
W. L. Isherwood, Jr.	July 1, 1939 to Apr. 17, 1942	
M. A. Patch	July 1, 1939 to Mar. 22, 1941	1/
J. W. Gurry	July 1, 1939 to Jan. 1941	1/
M. T. Thomson	July 1, 1939 to Aug. 31, 1941	
M. A. Benson	July 1, 1939 to June, 1943	
F. J. Flynn	July 1, 1939 to Apr. 26, 1944	
A. M. Moore	July 1, 1939 to June 30, 1947	
D. L. Milliken	July 1, 1939 to Feb. 1943	
A. F. McVarish	July 1, 1939 to Feb. 2, 1940	
R. J. Greer	July 1, 1939 to Feb. 15, 1943	
L. J. Keefe	Oct. 19, 1938 to June 19, 1940	
W. P. Somers	Aug. 16, 1939 to June 30, 1947	
W. R. Williams	July 1, 1939 to Oct. 1941	
B. R. Colby	May 22, 1940 to Mar. 18, 1943	
W. S. Daniels	June 18, 1940 to June 30, 1947	
L. W. Lenfest	Sep. 23, 1940 to Sep. 8, 1943	
C. C. McDonald	Nov. 1, 1941 to Mar. 21, 1946	

Name (Cont'd)	Period	Military Furlough
K. M. Kelley	Oct. 1941 to June 30, 1947	
George Anthony	Mar. 1, 1941 to Apr. 9, 1943	
D. J. Fogarty	Aug. 25, 1941 to June 30, 1947	May 1945 to Mar. 1946
H. N. Halberg	Mar. 7, 1941 to Nov. 29, 1944	
J. H. Hartwell	Sep. 11, 1941 to June 30, 1947	
C. H. Minehan	July 12, 1941 to June 30, 1947	
W. C. Schaller, Jr.	Jan. 3, 1941 to Feb. 1, 1943	
D. W. Van Tuyl	June 18, 1942 to Jan. 3, 1946	
Miss L. A. Swallow	Dec. 21, 1942 to June 30, 1947	
E. L. Burke	May 1, 1941 to June 30, 1947	
F. B. Cook	Jan. 2, 1947 to June 30, 1947	
L. E. Newcomb, Jr.	July 8, 1946 to June 30, 1947	
G. H. Searles	July 16, 1945 to June 30, 1947	
R. E. Steacy	Feb. 25, 1946 to June 30, 1947	
A. R. Brown, Jr.	May 6, 1946 to Oct. 22, 1946	
A. C. Capaldi	Feb. 25, 1946 to Apr. 21, 1946	
M. H. Coolidge	Apr. 17, 1946 to June 30, 1947	
J. V. Bagley	Sep. 20, 1945 to June 30, 1947	
G. A. Miller	Feb. 12, 1945 to June 30, 1947	
D. P. Preece	July 12, 1943 to June 30, 1947	
R. W. Tucker	June 14, 1943 to June 30, 1947	
N. C. G. Patev	Oct. 21, 1946 to June 30, 1947	
H. E. Linden	June 20, 1944 to Jan. 25, 1946	
R. C. Cutter	June 20, 1945 to Sep. 26, 1945	
O. W. Hartwell, Jr.	Oct. 12, 1945 to June 26, 1946	Deceased.

1/ Military furlough; did not return to district.

Miss Eleanor P. Harrington (Mrs. Lowell) was district clerk until November 1, 1943, when she was succeeded by Miss Evelyn M. Crowley.

Hartford, Conn. - During the period, the number of stations increased from 33 to 38, and in addition, the city of Waterbury, beginning in 1935, furnished records of Shepaug River at Woodville. As many Connecticut streams are artifically regulated, recorders are essential, and 36 stations were so equipped in 1947.

A station worthy of special mention is that on the Connecticut River at Bodkin Rock, at the head of the "Narrows" just above tide water, established January 1, 1947, for the Army Engineers. Bodkin Rock marked the supposed control for a stretch of river known as the Hartford Pool, extending 30 miles upstream. That stretch was an important factor in the Connecticut River flood-control system, designed to protect a thickly settled and heavily industrialized area, and a record of the discharge from the pool was essential. As Mr. Bigwood writes, 88/

88/ Letter to author.

"Determination of the stage-discharge relation anywhere in the pool is complicated by the storage factor, inherent in deeply pooled stretches of stream channels. Therefore, accurate computations of the flood discharge in the pool required accurate knowledge of inflow and storage, or outflow and storage in relation to stage. The storage was determined from a number of valley cross sections obtained by the Army Engineers." That was an uncertain round-about way of obtaining results, and it was decided to establish a gaging station at the Narrows, where the storage factor would be presumably small. Until it was determined by the records at the new station as well as records of inflow, change in valley storage, and other factors, that Bodkin Rock was the actual control, that station was installed with slope-gage equipment. Discharge measurements were made from a highway bridge 100 feet above the river at high stages with 35-foot depths, and the tag settings on the meter cable were made by means of field glasses. During rises above the tidal influence, the discharge measurements were referred to the Hartford gage 30 miles upstream and the daily discharge computed by that means. No attempt was made to compute records during periods of tidal influence.

Beginning in 1941, temporary gages were maintained on 2 streams near Bristol for intermittent flood-flow observations in connection with a study of flood characteristics by the Commission.

A number of special flood investigations were made at the request of the Water Commission. One was a short field investigation and office analyses of a storm of June 24-25, 1944, in the Bolton Lakes area; a second investigation was that of floods in the upper Housatanic River Basin June 18, 1945. A hurricane storm of September 1944, during which the precipitation was 6 to 8 inches, resulted in less than 1 inch of runoff, due to its occurrence after a long dry period.

Beginning June 1, 1943, to supplement in greater detail the Water Resources Review, a typewritten report entitled "Monthly Water Resources Review and Outlook for Connecticut" was sent to twenty agencies and individuals interested. Regarding its use, Mr. Bigwood writes:89/ "The newspapers and radio give the release varying cover, depending on its 'newsiness', I expect." It contained for the entire state, a statement regarding the monthly runoff in terms of the 30-year record on Quinibaug River at Jewett City as the index, and the trend of ground-water levels in several key observation wells. A forecase called "outlook" for runoff during the following month, based on both current stream flow and ground-water levels, was made for normal precipitation, and also for negligible precipitation. For the Connecticut River Basin as a whole, the statement prepared by the Boston District for its Water Bulletin90/ was included, as being of much interest to residents of Connecticut.

89/ Letter to author.

90/ p. 101.

Beginning with the winter of 1941, snow measurements were made at 21 points, three times each winter.

B. L. Bigwood continued as district engineer and had the following Civil Service technical assistants:

Name	Period
L. W. Furness	July 1, 1939 to May 1, 1944
M. P. Thomas	July 1, 1939 to June 30, 1947
J. H. Ehrich	July 1, 1939 to Dec. 30, 1939
L. W. Lenfest	Sep. 15, 1939 to Sep. 23, 1940
T. J. Irza	Feb. 8, 1940 to June 30, 1947
W. L. Isherwood, Jr.	May 6, 1944, to June 30, 1947

Mrs. E. K. Flood was the district clerk.

Albany, N. Y. - During the period, the number of stations increased from 154 to 197, practically all being equipped with recorders. The increase was due chiefly to the flood investigations of the Army Engineers, as New York State streams were subject to severe floods. During the present period, such floods occurred in the Susquehanna Basin in March and April 1940; the Delaware Basin in May 1942, being the second-highest known; in the Allegheny Basin July 3, 1942, being the highest in about 40 years; in the Mohawk Basin in October 1945, the highest known; and the Chemung Basin May 1946, the highest since 1903. The Survey investigated those floods and prepared typewritten or mimeographed reports for local distribution.

For more efficient operation, as well as ability to reach stations quickly, two additional sub-offices were established. During the previous period, the Binghamton office had been established where the Army Engineers had an office. In 1942, the latter office was moved to Syracuse, and the Survey office was moved to Ithaca, a more central location. The Ellenville office remained unchanged; in January 1944, an office was established at Jamaica to give close attention to the exacting work connected with the Long Island investigation;[91]

91/ p. 185 (1928-1939).

and in September 1944, a sub-office was established in the Albany office, but with its own personnel. The reason for the latter action was to separate the operations of gaging stations from the administrative functions of the district office; A. H. Harrington, the district engineer, spent most of his time visiting the various sub-offices, and it was necessary to have a district office personnel to give its entire time to the heavy administrative work. That personnel, in addition to the district engineer, consisted of H. W. Fear, principal assistant and Miss A. D. Buchanan, district clerk. In addition to the administrative work, Mr. Harrington personally reviewed all stream flow records before transmitting them to Washington. Each sub-office was in charge of an engineer P-4, with an office engineer P-3 grade, several other engineers, and 1 or 2 clerks; each office was responsible for the field and office work in its area and kept its own accounts. An allotment for each office was set up at the beginning of each fiscal year; the entire available funds were distributed and assessments were then made to pay the cost of operating the district office.

To maintain the high standards of accuracy for which the district was noted, each engineer carried two meters, and each shelter contained a copy of the rating curve for that station; the engineer was required to compute the measurement as soon as made and compare it with the curve. If it differed by more than a few percent, a second measurement was made at a different section, using the second meter. Needless to add, the stations in New York state have fairly permanent controls.

To keep the feeling of district unity essential to morale, a monthly publication entitled "Gage House Gossip" started in January 1942, was published monthly, each sub-office taking turns in preparing the material which was furnished by all the offices; a striking feature of each number was the cover designed by those artistically inclined. The district office mimeographed and circulated each issue, and furnished a cover if the sub-office ran out of ideas.

The special study showing the effect of reforestation on stream flow started in 1932 and was continued unchanged, the report covering the results to be written at a later date. The intensive study of Long Island water resources started in 1936 was continued and enlarged in 1942 by the establishment of two additional stations each year in cooperation with Suffolk county. That study was an integral part of and concurrent with the study of the ground-water resources.

The "New York State Cooperative Survey" started in the winter of 1937-38 was continued, records being received from about 200 snow courses. In addition, to the immediate uses by the cooperators in connection with storage and releases, the snow-survey reports were used extensively by various railroads, particularly the New York Central in connection with plans for maintaining continuous operations during periods of flood from melting snows. Also, some large distributors of fuel oil and gasoline used the records in planning winter storage facilities.

In 1943, as a result of cooperation with Westchester County, 5 water-stage recorders were to be established in a high-class residential district, and the county authorities had their architect design the structures which would have a more esthetic appeal than the standard Survey structures. Those were the days when authorization for materials was to be obtained from the WPB. The Survey's application was referred to Washington where it was only one of many applications, and the war ended before action was taken. In the meantime, by means unknown to the author, the materials were obtained and with the help of the County which furnished some labor, the stations were installed. A sixth station equipped with a staff gage was also established.

The Army Engineers had set up a flood-warning system for an emergency program whereby its engineers in various parts of the state telegraphed to headquarters river stages and weather data. During the spring months, and at other specified times, Survey observers at certain stations, reported daily the river stage and weather data, to the Army Engineer employee in the area affected.

After the organization of Incodel, 92/ records from all stations in the Delaware River Basin were forwarded regularly to that agency's office in Philadelphia.

92/ p. 92.

During the nineteen-twenties, contacts had been established with engineering students at Rensselaer and Cornell by means of nearby gaging stations, the operation of which was explained to the students. Such contacts were gradually increased during the ensuing years until at the end of the period, it had become an annual event at the engineering colleges for Survey engineers to describe the Survey's work to hydraulic classes in the morning, and give a field demonstration at a nearby gaging station in the afternoon, the students performing much of the field work. That program was carried out at Rensselaer, Cornell, Union, Manhattan, New York University, and Clarkson. The latter contact was made late in the period when Mr. Harrington as a vice president of the American Society of Civil Engineers went to Clarkson to address the student chapter of the society. Following that visit, he was requested to include Clarkson in the list of colleges to be visited annually.

A unique method of rating a gaging station was devised by F. F. LeFever on the Lake George outlet at Ticonderoga, where severe backwater conditions prevented the use of standard methods. It was discovered that a well-defined relation between turbine-gate openings and discharge existed, regardless of backwater conditions. A weekly recorder mounted on a shelf was attached to the generator-turbine hookup, to record the movement of the quadrant on the gate-opening mechanism. Later, 13 discharge measurements, covering a gate-opening range from

Name	Period	Military Furlough
T. R. MacKay	Jan. 15, 1941 to Oct. 10, 1944	
W. J. Hickey	Mar. 18, 1941 to Aug. 24, 1946	
F. F. LeFever	Mar. 21, 1941, to June 30, 1947	
R. J. Martin, Jr.	Apr. 1, 1941 to June 30, 1947	
I. S. Levine	Apr. 7, 1941 to June 30, 1947	
H. D. Brice	July 1, 1941 to June 30, 1947	
G. R. Ayer	Aug. 6, 1941 to June 30, 1947	
C. L. Whitaker	Sep. 19, 1941 to June 30, 1947	
C. W. Reck	Oct. 1, 1941 to June 30, 1947	
R. M. Sawyer	Oct. 26, 1941 to June 30, 1947	
C. E. Knox	Oct. 30, 1941 to May 13, 1946	
M. H. Schoerpner	July 6, 1942 to Aug. 31, 1943	Sep. 1, 1943 to Sep. 12, 19
L. W. Lenfest	Sep. 8, 1942 to June 30, 1947	/Deceased./
J. H. O'Keefe	Sep. 16, 1942 to June 30, 1947	
B. A. Plusnin	Oct. 1, 1942 to Jan. 8, 1944	
J. E. Wagar	Oct. 16, 1942 to June 30, 1947	
I. R. Leonard	Apr. 8, 1943 to June 30, 1947	
F. R. Heartz	Feb. 8, 1944 to Dec. 19, 1944	
J. F. Molloy, Jr.	Feb. 28, 1944 to Apr. 19, 1944	
W. A. Currier	July 17, 1944 to Mar. 27, 1945	
E. A. Tefft	Oct. 9, 1944 to June 30, 1947	
A. E. Voloshin	Nov. 1, 1944 to Mar. 15, 1945	
G. E. Johnson	Dec. 19, 1944 to Aug. 14, 1945	
M. W. Groves	Jan. 15, 1946 to June 30, 1947	
W. L. Carr	Jan. 27, 1946 to Feb. 27, 1946	
B. Dunn	Feb. 18, 1946 to June 30, 1947	
R. F. Johnson	Feb. 25, 1946 to Mar. 8, 1947	
C. G. Johnson, Jr.	Apr. 4, 1946 to June 30, 1947	
C. H. Hardison	June 3, 1946 to June 30, 1947	
A. S. Toth	Oct. 15, 1946 to June 30, 1947	
O. P. Hunt	Feb. 18, 1946 to June 30, 1947	

1/ On assignment to Japan and Korea, December 1945 to June 1946, to Alaska August to November 1946.

Miss A. D. Buchanan was district clerk.

Trenton, N. J. - During the period, the number of gaging stations decreased from 80 with 54 recorders to 76, all equipped with recorders. The decrease in numbers was more apparent than real as early in the period, 12 stage stations on the Delaware River in cooperation with the Delaware River Joint Toll Bridge Commission, were discontinued. Five stations were established during the first year or so, including three to complete the network in the Delaware River Basin. A few additional changes accounted for the net decrease of 4 stations.

Some time after the station on the Delaware River at Montague was established in 1940, a comparison of its records with those of the Delaware at Port Jervis, N. Y., 9 miles upstream, indicated an unusually large inflow between the two. To determine whether the apparent discrepancy was due to errors in the records or to an actual large increase in flow, an investigation was made during unusually low flow in 1943. All small tributary inflows were measured and those showed about the same surface runoff per square mile as other streams in the general vicinity, thus shedding no light on the problem. This suggested that the unaccounted-for gain was from ground water, and measurements of the Delaware and Neversink Rivers were made at several intermediate points; the gain appeared to be in two sections, one in the main river some distance below Port Jervis, and the other in the Neversink River which enters at Port Jervis. In September 1944, a year later, a series of surface and bottom temperature measurements at 500-foot intervals in the Neversink River between the lowest gaging station and the mouth, a distance of 9 miles was made; the temperatures were the same except in one mile-long stretch where the bottom temperatures, being colder, indicated inflow from ground water. Cold weather interrupted a similar test on the mainstream and no further investigation was made during the period.

One of the two Army Engineer stations in the district had three recording gages. It was the station on the Pompton River at Pompton Plains where the river is divided by an island and has, in each channel, a concrete dam without gates or flash boards with a recorder just above each dam. A major flood showed that the dams were submerged, and in order to obtain extreme high-water records, a third recorder was installed 4 miles downstream; that site was used only during extreme high water as at lower stages, the control for low discharge was poor.

One of the most important stations in the district was the Delaware River at Trenton, located a short distance above tidal influence. The records were used in connection with the so-called "salt-water barrier" in the vicinity of Philadelphia. A study made by the State of Pennsylvania had shown that the position of the barrier was definitely related to the flow at Trenton, about 35 miles upstream; the lower the flow, the farther upstream was the barrier's position. Many industries from Philadelphia downstream use large quantities of river water, and during low water when the salt-water barrier moves up-stream, it is necessary to treat the river water for its salinity. That is an expensive operation and advance notice of the flow at Trenton is of great value in determining when it will be necessary to start treating the river water. In 1944, the Trenton Office began the practice during the low-water season, of sending daily reports to a small number of industries. Since 1931, a record of the daily flow has been sent to a number of companies at the end of each month. The number has increased to about one dozen. During the last two years, the Army Engineers contributed a small amount to help defray the cost of keeping the record up to date and furnishing it monthly to the Army Engineers' Philadelphia Office.

A severe flood on Oldman's Creek near Woodstown in September 1940 destroyed a gaging station under unusual circumstances. A concrete shelter was located at the upstream side of a concrete bridge . During the flood, which had a peak discharge of 8,100 second-feet or 1,500 second-feet per square mile, the bridge acted as a funnel, causing a scour ranging from 2 to 10 feet at the gage, causing the gage shelter, some 20 feet in height, to disappear. The shelter was never found and the assumption was that it toppled into the hole caused by scour and was covered by gravel upon the subsidence of the flood.

A human-interest item was noted in connection with the operation of the "Hatch Act." A woman observer, in signing the required affidavit, made a note on her affidavit stating that the only organization to which she belonged was the Methodist Church.

O. W. Hartwell continued as district engineer and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
Otto Lauterhahn	July 1, 1939 to June 30, 1947	
E. G. Barron	July 1, 1939 to July 19, 1939	
R. W. Thompson, Jr.	July 1, 1939 to Mar. 1942 1/	
Everett Miller	July 1, 1939 to June 30, 1947	Feb. 1941 to Nov. 1945
R. H. Tice	July 1, 1939 to July 1941	
Helen P. Stidworthy	July 1, 1939 to June 30, 1947	
A. C. Lendo	Sep. 7, 1939 to Dec. 3, 1946	
W. E. F. Mayhew	Oct. 10, 1941 to Nov. 9, 1942 1/	
W. C. Schaller, Jr.	May 27, 1942 to Aug. 1, 1942	
J. M. Ludlow	Sep. 1, 1942 to June 30, 1947	
R. J. Greer	Feb. 15, 1943 to Apr. 26, 1944	
W. T. Sittner	Mar. 1, 1943 to June 30, 1947	May 1944 to June 1946
C. P. Parkinson	Aug. 14, 1944 to Nov. 18, 1945	
E. L. Beaumont	Oct. 23, 1939, to June 30, 1947	
R. G. Macomber	Mar. 4, 1946 to June 30, 1947	
G. S. Hayes	Oct. 8, 1946 to June 30, 1947	

1/ Military furlough; did not return to district.

Harrisburg, Pa. - The importance of flood studies and flood forecasting was perhaps the chief factor in increasing the number of gaging stations from 109 to 157 during the period. After the disastrous floods of March 1936, the Army Engineers made intensive studies, particularly of the Ohio River Basin above Pittsburgh, and as a result of those studies, the number of cooperative Army Engineers' stations was increased from 24 to 91, the chief increase occurring in 1941. In addition, about 23 special stations were operated for the Army Engineers' special investigations and reports; one group, located at proposed reservoirs, being stage stations, in connection with existing stations; and another group where stage and discharge data were furnished, but no records were computed. With so many stations in the western part of the state, the sub-office established at Pittsburgh in 1938 became increasingly important, and its engineering personnel was increased to 7 in order to operate about 75 stations, as flash floods made it necessary to reach the stations as quickly as possible. Included in the stations maintained, were 4 on the Ohio River as far downstream as Lock 13 near Bellaire, Ohio.

The type of construction used was cinder or concrete block. Although there were no notable structures, two were unusual in that reinforcing rods were placed both horizontally and vertically, as the blocks were laid; the reason being that both installations were in deep excavations made in loose fill.

Early in the period, the Federal-State/Flood Forecasting Service 94/ began to function with headquarters for the Susquehanna River Basin at Harrisburg and for the upper Ohio River Basin at Pittsburgh. As melting snow is one of the chief causes of the winter and spring floods, a system of snow measurements was included in the program. Daily reports of stream flow and precipitation for key stations were received at the headquarters, and for a greater number of stations when

94/ p. 191 (1928-1939).

critical conditions were developing. To avoid interruption to telephone and telegraph communication during floods, the State-owned high-frequency radio network was used in transmitting the reports, many of which came from State Forestry employees. Later, the forecasting network was expanded to cover the entire state. The importance of the flood-forecasting service was evidenced by the fact that almost every year serious flood damage occurred somewhere in the state. As a corollary, almost every engineer who remained a year or two in the district, obtained valuable flood-work experience.

Two outstanding floods were investigated during the period. During the floods of May 1942 in the Delaware and Lackawanna River Basins, the Schuylkill River at Reading was the third highest since 1757, the Lehigh River the second highest in 156 years of record, and the Lackawanna River the highest remembered. Peak discharges were obtained not only at all gaging stations but by means of slope-area measurements, flow over spillways and through contracted openings, at about 40 other points. The Albany and Trenton Districts furnished the data for their states. The results, together with records of precipitation, and elevations of all major floods in the area were given in a report that was published by the Pennsylvania Department of Forests and Waters.95/

95/ The Floods of May 1942 in the Delaware and Lackawanna River Basins, 1942.

The flood of July 1942 in the upper Allegheny River and Sinnemahoning Creek Basins was the highest ever recorded on the upper reaches of the Allegheny and Clarion Rivers. A similar investigation was made, including determination of peak discharges at some 50 points where there were no gaging stations. The results were also published by the Department of Forests and Waters.96/

96/ The flood of July 1942 in the Upper Allegheny River and Sinnemahoning Creek Basins, 1943.

For many years, there had been requests from industries regarding the temperatures of the surface streams available for industrial use, as well as their quality, and when cooperation between the State and the Quality of Water Division became effective July 1, 1944, the need for temperatures was increased. Beginning in October 1944, and continuing for one year, the gage observers were equipped with thermometers and read the temperatures at about weekly intervals, and the surface water personnel made temperature readings whenever discharge measurements were made. Miscellaneous temperature readings were made both on streams and springs. The results of the temperature readings, together with certain long-time records maintained by power companies, were published by the Department of Forests and Waters.97/

97/ Temperatures of Natural Waters in Penn., 1946.

When the quality of water investigations were started, spot samples were obtained at every gaging station during the low flows of that summer.

The office work of the Harrisburg District was of greater scope than in most districts. As an aid to engineers, a card index of all sea-level bench marks in the state was arranged by counties;

flood profiles of the greatest floods in every basin of 500 square miles or greater were developed; many studies were made for the State Water and Power Resources Board to which applications to develop water supplies through storage or otherwise, were made.

From February 25 to March 2, 1946, the Annual Sportman's Show was held at the Commercial Museum in Philadelphia. The various State agencies, including the Department of Forests and Waters, were invited to furnish exhibits. As this show afforded an opportunity to obtain desirable publicity, the Survey arranged an exhibit which consisted of a metal tank containing water in which a water-stage recorder, a type A, and a pygmy meter were operating. Other pieces of equipment were set up on the floor, and pictures of gaging stations and discharge measurements in the making lined the wall. The exhibit was placed in a prominent position just inside the museum entrance, and was well attended.

During the period, J. W. Mangan, who continued as district engineer and Chief of the State Division of Hydrography, was instrumental in starting cooperation with the State in both ground-water and quality-of-water investigations.

Civil Service engineering assistants were:

Name	Period	Military Furlough
F. L. LeMert	July 1, 1939 to June 30, 1947	
J. V. B. Wells	July 1, 1939 to Mar. 5, 1940	
S. E. Rantz	July 1, 1939 to Feb. 9, 1940	
George Weber, Jr.	July 1, 1939 to Apr. 15, 1941	
R. C. Culler	July 1, 1939 to July 25, 1946	Jan. 2, 1943 to Nov. 20, 1943
H. M. Erskine	July 1, 1939 to Sep. 24, 1941	
P. B. Williams	July 1, 1939 to Mar. 28, 1947	Feb. 13, 1942 to Dec. 2, 1945
R. W. Leonard	Sep. 6, 1939 to Nov. 16, 1941	
John Horton	Oct. 16, 1939 to June 30, 1947	
R. S. Lord	Apr. 15, 1940 to July 19, 1944	
J. A. Murphy	Apr. 24, 1940 to Feb. 9, 1942 1/	
A. S. Toth	May 15, 1940 to Sep. 16, 1946	June 2, 1945 to Apr. 14, 1946
J. R. McLaughlin	Sep. 16, 1940 to June 30, 1947	April 16, 1941 to Mar. 1, 1946
K. I. Kollar	Oct. 1, 1940 to Oct. 9, 1941	
C. J. Rossow	May 13, 1940 to June 30, 1947	
S. B. Koks	Mar. 1, 1941 to Sep. 19, 1944	
R. E. Fish	Nov. 17, 1941 to June 30, 1947	
F. N. Hansen	Oct. 14, 1941 to June 30, 1947	
David Barton	June 16, 1941 to June 30, 1947	
E. A. Burti	Dec. 1, 1941 to June 30, 1947	
J. R. Hennemuth	Dec. 16, 1941 to ~~Aug.~~ 29, 1945 1/	
A. L. Smith	Apr. 6, 1942 to Feb. 4, 1943 1/	
H. A. DeWire	Aug. 5, 1942 to Jan. 27, 1944 1/	
R. K. Middleton	Dec. 2, 1942 to Oct. 10, 1944	
R. W. Reichle	Apr. 2, 1942 to June 30, 1947	
L. W. Weingartz	May 16, 1942 to Dec. 15, 1943 1/	Deceased
R. J. Greer	Jan. 10, 1944 to May 12, 1944	
I. A. Heckmiller	Sep. 5, 1944 to June 30, 1947	
S. E. Craighead	Jan. 8, 1945 to June 30, 1947	
R. E. Bartoo	Jan. 8, 1945 to June 30, 1947	
G. E. Terney	Jan. 23, 1945 to Oct. 20, 1945	

Cont'd

Name	Period	Military Furlough
H. S. Rudd	Feb. 4, 1946 to Oct. 4, 1946	
W. W. Machin	May 7, 1946 to Apr. 18, 1947	
W. C. Vaundrey	Oct. 4, 1946 to June 30, 1947	

1/ Military furlough; did not return to district.

College Park, Md. - The Middle Atlantic States District became the College Park District when the headquarters were moved from Washington to College Park, Md., on the campus of the Maryland Agricultural College June 5, 1940. That change was made chiefly to relieve the crowded condition in the Washington Office. During the period, the district area was increased by the State of Delaware when cooperation with that state became effective in the spring of 1943. On July 1, 1945, the 10 stations on the Potomac River Basin in West Virginia operated for the Charleston District were transferred to that district.

The number of gaging stations increased from 40 with 32 recorders in 1939 to 61 with 59 recorders in 1947. Of the 61 stations, 45 were in Maryland, 9 in Delaware, 3 in West Virginia, and 2 each in Pennsylvania and the District of Columbia. The Army Engineers gradually increased their support from 3 to 27 stations in connection with their flood studies. Those are included in the 61 stations.

At the gaging station on Christina River at Cooch Bridge, Del., it was necessary to use a bulldozer to lower the channel and construct an artificial control in order to avoid backwater from a mill dam. During 1944, the records of all stations in the Potomac River Basin, and the remaining Maryland records comprising in all, 11,900 station-month records, equivalent to about 990 years, the longest being that of the Potomac River at Point of Rocks, since 1895, were compiled by the Survey and published by the State Department of Geology, Mines and Water Resources.98/

98/ Bull. 1, 1944.

With the beginning of cooperation in Delaware, 7 gaging stations were installed in the spring of 1943, two being at the sites of stations maintained by the Harrisburg District for a few years during the previous period.99/ An additional station was established the following year. One of the stations near Wilmington was on Shellpot Creek, draining an area of 7 square miles; that vicinity was changed from a rural to an urban area with a corresponding change in runoff characteristics, and a knowledge of that change in small areas was desired. Near the close of the period in 1947, cooperation with the New Castle County Soil Conservation District, in the Brandywine Valley, of which 85 percent was in Pennsylvania, and the remainder in Delaware, resulted in the installation and operation of 1 stream gaging station and 8 recording rain gages.

99/ p. 190 (1928-1939).

A. H. Horton continued as district engineer until his death March 4, 1945. He was succeeded by V. R. Bennion. Other Civil Service Engineering assistants were:

Name	Period
A. D. Ash	July 1, 1939 to Sep. 25, 1941
L. B. Pierce	July 1, 1939 to Feb. 20, 1945
G. E. Ferguson	July 1, 1939 to Oct. 25, 1940
E. J. Kennedy	July 1, 1939 to Dec. 10, 1946
Harold Cladny	July 1, 1939 to July 15, 1939
D. B. Bogart	Oct. 5, 1939 to Sept. 24, 1941
F. H. Amul	Jan. 4, 1940 to Feb. 18, 1941
Mrs. M. A. Dahlquist	May 6, 1940 to Nov. 1, 1940
Mrs. M. L. Keith	Oct. 21, 1940 to Oct. 16, 1944
W. R. Williams	Sept. 22, 1941 to Feb. 26, 1943
Miss E. M. Wilson	Oct. 21, 1942 to Sept. 28, 1945
L. A. Gennell	Sept. 27, 1943 to Apr. 21, 1945
O. M. Davis, Jr.	Jan. 24, 1945 to June 30, 1947
K. L. Kollar	Feb. 1, 1945 to June 16, 1945
Mrs. C. V. Lee	Feb. 26, 1945 to June 30, 1947
P. W. Brewer	Apr. 16, 1945 to June 30, 1947
Mrs. M. R. Steffen	Oct. 29, 1945 to June 30, 1947
James Thomas, Jr.	Apr. 4, 1946 to June 30, 1947
R. O. R. Martin	Apr. 5, 1946 to June 30, 1947
D. F. Dougherty	Nov. 8, 1946 to June 30, 1947
L. T. Loomis	Feb. 25, 1947 to Nov. 18, 1947

There were no military furloughs.

Charlottesville, Va. - The number of gaging stations was increased from 91 of which 85 were equipped with recorders, to 152 of which 109 were equipped with recorders. The increase was made possible by additional Army Engineer funds which increased the number of statinns so supported from 15 to 83, of which some were existing stations, and by practically doubling of the State appropriation.

In order to operate more satisfactorily the stations on streams in southwest Virginia, a sub-office was established at Marion on July 19, 1942. This office operated stations in which both the Army Engineers and TVA were interested, the latter stations being increased from 7 to 10. As of June 1947, 31 stations were operated by the Marion sub-office. A second sub-office was maintained for a short time at Danville, Virginia, in 1942, but was closed for lack of personnel when the engineer in charge was given military furlough. All stations except those in southwest Virginia were then maintained from the main office in Charlottesville.

In the establishment of new stations, it was the district policy to make temporary timber or pipe-well installations for recorders, or non-recording installations at first, and if the sites proved to be satisfactory, permanent concrete structures were installed later.

During the drought year 1941, about 250 miscellaneous measurements were made; so small was the flow of many streams that pygmy meters, tanks, and portable Parshall flumes were used.

The flood of August 1940, because of its severity and the damage caused, entailed considerable extra field and office work, especially as everyone interested, and that included a great many, wanted the flood records at the earliest possible date. The stages were so much greater than the range of the rating curves that it was necessary to make many slope-area measurements of the peak discharges. The concrete structure on the Roanoke River at Brookneal was destroyed by the flood and a new site upstream was selected where the station would not be washed out. After excavation had started, it was discovered that it was necessary to dynamite 20 feet of solid rock; only hand drills were available and four months were spent on that job, and another concrete gage house on Falling River near Brookneal. More slope-area measurements were made after the flood of October 1942, and several after the flood of 1944. The October 1942 flood was the highest known in parts of the Shenandoah and Rappahannock River Basins.

During the war years, because of the many Army and Navy establishments and also basic industry supplying war-time needs, the Charlottesville District prepared much more than the average reports of other districts on water supply. Many of the reports required the establishment of temporary gaging stations, where cities or towns needed additional water supplies. In the highly important military area of Hampton Roads, an investigation for additional water supply required the establishment of 4 gaging stations, 2 being equipped with recorders. The data furnished aided the decision by the Public Works Agency to build pipe lines and a low dam, at a cost of ten million dollars, for a largely increased water supply for the Newport News and Norfolk areas.

During the spring of 1944, the practice of taking the temperature of the water whenever a discharge measurement was made was started. That came about by the many requests from industrial concerns seeking locations where water supplies and water temperature were suitable.

Largely as a result of the increased interest in stream-flow records, the compilation of Virginia records made in 1927 and published by the State, was brought up to date, and those for the period 1927 to 1942 were published in 1944 by the Virginia Conservation Commission as a series of four bulletins containing records of daily stage as well as discharge. As frequently happens when later information becomes available, it was necessary to revise some of the older records.

In September 1946, the Army Engineers requested the Survey to obtain data on the variation in velocity during the ebb and flow of the tide through the Lynnhaven Inlet. Lynnhaven Bay is famous for its oysters, and siltation and shifting sand bars had destroyed a large part of the oyster beds, and was constantly changing the navigation channels. Four motor boats, with a boatman for each, were furnished by the Army Engineers and the Survey furnished 2 engineers for each of the 3 boats, and a single engineer for the fourth. September 11 was selected, the forecast for which was for minimum wind and rain. Two sections were selected, one about 300 feet wide on Long Creek and the other across Lynnhaven Inlet a distance of 2,200 feet. Velocity measurements for vertical-velocity curves at each site were made as continuously as possible through a 14-hour period from about 2 a.m. to 6 p.m. An extra boat, manned by the Army Engineers, made the rounds to relieve some of the men occasionally for short rest periods, and what was of equal importance, supplying refreshments. In addition to the district engineer, 8 engineers from the district office participated in the measurements. Velocities ranged from 0 to 3.5 feet per second, and depths were as much as 14 feet.

During the summer of 1947, an inventory of the major reservoirs in the state was made by O. D. Mussey. As no previous inventory had been made, it was necessary to obtain the information from the owners. The compilation of the replies showed 35 reservoirs exceeding 1,000 acre-feet capacity, the oldest having been constructed about 1780 and five others before the Civil War. The results were published by the Virginia Conservation Commission.[100]

100/ Major storage reservoirs of Virginia, Bull. 9, 1948.

J. J. Dirzulaitis continued as district engineer until August 20, 1940, when F. F. Schrader was appointed as Acting District Engineer for a short period, followed by D. S. Wallace as Acting District Engineer until June 1941, at which time he was appointed District Engineer. Other Civil Service engineering personnel were:

Name	Period	Military Furlough
F. F. Schrader	July 1, 1939 to Jan. 10, 1942	
A. R. Green	July 1, 1939 to June 30, 1947	
T. F. Hanly	July 1, 1939 to May 18, 1946	
O. D. Mussey	July 1, 1939 to June 30, 1947	
T. W. Edwards	July 1, 1939 to Jan. 15, 1940	
R. D. Schmickle	Oct. 27, 1941 to June 17, 1942	June 18, 1942 to Dec. 13, 1945
R. E. Curtis	Mar. 26, 1941 to June 30, 1947	
J. S. Cragwall, Jr.	May 19, 1941 to June 30, 1947	
B. L. Mims, Jr.	Aug. 21, 1941 to Feb. 4, 1946	Feb. 23, 1942 to Nov. 4, 1945
R. H. Tice	Sep. 8, 1941 to June 30, 1947	
G. C. Colvin	Mar. 23, 1942 to Feb. 28, 1947	Sep. 14, 1942 to Dec. 10, 1945
S. G. Anderson	July 20, 1942 to June 30, 1947	Apr. 19, 1944 to Dec. 3, 1945
C. H. Hannum	Feb. 9, 1942 to June 30, 1947	Sep. 10, 1943 to May 19, 1946
H. M. Tuttle	July 1, 1942 to May 31, 1945	
W. E. Patten	Jan. 28, 1943 to Nov. 24, 1946	
E. H. Ogilvie	June 19, 1944 to June 30, 1947	
Mrs. V. W. James	Sep. 11, 1944 to June 3, 1947	
Mrs. E. T. Abrams	Aug. 28, 1944 to June 30, 1947	
J. L. Smith	Nov. 2, 1944 to June 3, 1945	
B. Y. Canipe	Jan. 21, 1944 to Jan. 5, 1945	
G. M. Thayer	Sep. 24, 1945 to June 30, 1947	

Raleigh, N. C. - The Raleigh District expanded its activities from the operation of 103 to 134 stations, of which 129 were equipped with recorders. The increase was due chiefly to the flood-control study being carried on both by the Army Engineers and the Soil Conservation Service, 30 stations having been established during the first 18 months of the period and some discontinued within a few years. That study was intensified because of the severe flood of August 1940. During the fiscal year 1942, at the request of TVA, 10 stations were established by the Raleigh District in the Hiwassee River Basin in Georgia. Including those stations, the Raleigh District operated 53 TVA stations.

The 1940 flood was a hurricane flood covering the western part of the state and causing record runoff in a drought year, so severe was the flood that half a dozen stations were destroyed. The top of the shelter on the Roanoke River at Roanoke Rapids was submerged in spite of its having been raised 6 feet before the flood; afterward it was raised an additional 6 feet; the cableway had a 900-foot center span, supported by A-frames; so much drift caught on the cable that it ripped out the concrete anchorages, uprooting a 6-inch tree in the process. The A-frames were later replaced by steel towers, and a 600-foot span added on one side and 500-foot span on the other, making a total span of 2,300 feet. Following that flood, the district made an intensive investigation which is described on Page 390.

In the Coastal Plain, the river slopes are flat and the flood plain is usually heavily timbered; as a result, the flood flows are seriously retarded resulting in an average range in stage of about 15 feet. Where bridge sites are suitable, those were utilized for discharge measurements, but at other stations, it was necessary to erect cableways. In order to measure the over-flow through heavy timber, it was necessary to clear a space from 40 to 80 feet wide under the cableway, through the overflow areas. At 8 stations where the overflow was an important part of the discharge, the length of the cleared space ranged from 500 to 2,200 feet, and to keep down the fast-growing brush and trees, the clearing had to be done annually.

Cableways over navigable streams caused special problems; on the Cape Fear River at Lock No. 3, where the cable was supported on towers 30 and 40 feet high, a winch was installed behind the anchorage and hooked onto the cable in front of the turnbuckle, thus making it possible to lower the cable for passing boats. The personnel at the lock lowered the cable when necessary.

To make readily available to the public all hydrologic data in the Cape Fear River Basin, the Survey and Weather Bureau collaborated in the compilation of the records of both agencies. The Survey's data for 20 gaging stations were presented in mean discharge in million gallons per day (showing the influence and interest of water works men in the records), description of ground-water investigations with accompanying data, and chemical analyses. The report was published by the State in 1947.

The district office was moved from Asheville to Raleigh in October, 1943,[101] and Asheville not only remained a sub-office but

101/ p. 38.

had its own sub-office at Bryson City to operate the stations in the western part of the State. In the center of the Piedmont region, a sub-office was established at Statesville, near the close of the period. The sub-office at High Point, established for that investigation,[102]

102/ p. 196 (1928-1939).

was continued until March 31, 1944.

E. D. Burchard continued as district engineer until his retirement April 30, 1947, when J. L. Lamson became acting district engineer. Other Civil Service engineering personnel were:

Name	Period	Military Furlough
E. B. Hodges	July 1, 1939 to June 30, 1947	
J. W. Gambrell	July 1, 1939 to Dec. 17, 1941	
K. A. Mac Kichan	July 1, 1939 to Dec. 9, 1941	
V. W. Rupp	July 1, 1939 to Jan. 1, 1940	
R. W. Leonard	July 1, 1939 to Sep. 5, 1939 Nov. 19, 1941 to Dec. 21, 1945	
P. G. Ford	Nov. 27, 1939 to June 30, 1947	Sep. 8, 1942 to Jan. 15, 1946
J. L. French	Jan. 10, 1940 to June 39, 1942	
G. E. Harbeck, Jr.	Apr. 3, 1940 to Jan. 5, 1946	Feb. 19, 1943 to Jan. 1, 1946
H. S. Rudd	May 27, 1940 to Dec. 30, 1940 1/	
R. H. Peck	June 13, 1940 to June 30, 1947	Nov. 28, 1940 to Dec. 3, 1945
J. M. Terry	Aug. 27, 1940 to Oct. 7, 1943	
R. J. Smith	Apr. 11, 1941 to June 30, 1947	Jan. 25, 1943 to July 9, 1946
H. A. Taylor	Aug. 7, 1941 to June 30, 1947	
E. G. Wollin	Oct. 29, 1941 to June 30, 1947	Nov. 27, 1942 to June 26, 1946
R. W. Gunwaldsen	Nov. 10, 1941 to Jan. 1, 1942	
H. C. Creasman	Nov. 18, 1941 to Apr. 10, 1944	
R. B. Vice	Dec. 15, 1941 to June 10, 1946	
J. R. S. Hill	Apr. 16, 1942 to Jan. 31, 1943	
J. W. Hankins	May 1, 1942, to Mar. 8, 1944	
R. Y. Canipe	May 25, 1942 to Feb. 24, 1943 1/	
Margy G. Bean	Jan. 1, 1943 to July 31, 1944	
A. J. Taylor	May 24, 1943 to Nov. 15, 1943	
D. C. Murrow	Mar. 16, 1943 to June 30, 1947	Mar. 22, 1944 to Oct. 7, 1946
H. A. Whitman	Sep. 1, 1943 to June 30, 1947	
W. R. Eaton	Oct. 18, 1943 to June 30, 1947	
W. T. Utter	July 24, 1944 to Dec., 1945	
H. A. Ballard	Sep. 1, 1944 to June 30, 1947	
A. B. Goodwin	Jan. 17, 1945 to June 30, 1947	
L. D. Stephenson	Apr. 7, 1945 to Dec. 10, 1945	
H. A. Carlson	July 1, 1945 to June 30, 1947	
F. P. Barnes	Jan. 27, 1947 to June 13, 1947	

1/ Military furlough; did not return to district

Mrs. Effie T. Workman was district clerk until January 1, 1944, when she was succeeded by M. V. Harrington.

Columbia, S. C. - Additional cooperation with the Army Engineers, most of which occurred early in the period, was chiefly responsible for the increase in the number of gaging stations from 33 to 54, of which 50 were equipped with recorders. To meet the needs of the Army Engineers so far as possible, about 80 percent of the stations were connected with sea level datum.

Continuing the close contacts with the State Highway Department, the Survey furnished the Department with data on river stages at times of flood, and correlated those stages with the Weather Bureau forecasts. Also, the Highway Department continued to submit bridge plans for the District Engineer's examination of the flood openings. One plan was for a bridge across the 19,000-foot flood plain of the Wateree River, where gaging station records indicated that a bridge opening of 4,200 feet would be sufficient, and the remaining distance could be earth fill.

The wide-spread flood of August 1940,[103] reached stages considerably above previous measurements, and coordinating the investigation by neighboring districts, the Columbia District made flood surveys to determine the peak discharges at points not covered by discharge measurements, and prepared a report on the flood for all district stations.

103/ p. 390.

An unusual cooperative program was that with the Public Service Authority started in the fiscal year 1944. The Public Service Authority was beginning the operation of the Santee-Cooper development, which combines hydro-power, navigation, and in less degree, flood control on the lower Santee River. It was important that the Authority have flood data at upstream stations in order to operate the spillway gates of the large reservoirs and prevent water waste; at other times, stream flood records were required in connection with the generation of power, and the conservation of low water. Soon after the system was placed in operation, a flood occurred during which A. E. Johnson furnished the Authority stream flow records from upstream stations; that information proved its value, and at a subsequent conference, the value of continuous upstream records was demonstrated. As a result of the ensuing cooperation, the Survey furnished a daily report 6 times a week, giving the discharge of the upstream gaging stations, the stages of the reservoirs, and the rainfall and weather forecasts, as furnished by the Weather Bureau.

In the Coastal Plain, the streams meander within a heavily timbered swamp area from one to five miles in width, and as station controls are practically non-existent, the most desirable sites for gaging stations are at bluffs. Use was made of an airplane for reconnaissance when the trees were bare by means of which not only were the bluff sections located but all available roads and trails were noted for use during construction. In the Piedmont section, where the streams have alternate pools and riffles, the use of an airplane was also found advantageous, as shown by the following incident: A station was desired in a twenty-mile reach of the Tyger River, and an engineer spent 3 days making local inquiries and exploring, but found no riffles; then two engineers spent a day descending the river in a motor boat, with a third man in a car following along the nearest highway; finally, a site was selected. Later, by use of an airplane, the same information was obtained in fifteen minutes.[104]

104/ Water Resources Bull., Aug. 1944, p. 124.

The contacts with the civil engineering students at the University of South Carolina started during the previous period,[105] were continued with satisfactory results, both to the students and the Survey.

105/ p. 198 (1928-1939).

A. E. Johnson continued as district engineer, and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
J. M. Terry	July 1, 1939 to Oct. 6, 1940	
L. B. Yarger	July 1, 1939 to June 30, 1947	
F. W. Wagener	July 1, 1939 to June 30, 1947	
H. L. Smith	Oct. 4, 1940 to Mar. 1, 1943 1/	
W. W. Evett	Oct. 4, 1943 to June 30, 1947	

Cont'd

Name	Period	Military Furlough
J. M. Carns	Mar. 1, 1943 to Apr. 13, 1943	
L. L. Finley	Apr. 16, 1943 to June 30, 1947	
W. T. Utter	Dec. 10, 1945 to June 30, 1947	

[1] Military furlough; did not return to district.

Mrs. L. P. Knox was district clerk.

Atlanta, Ga. - The number of gaging stations was increased from 64 with 40 recorders in 1939 to 92 with 77 recorders in 1947, the greatest increase occurring in the first year when the Army Engineers supplemented the State program by furnishing funds for 15 stations. This cooperation was increased during the period as the Army Engineers, requiring additional records for flood-control projects associated with the serious power shortage, and for 3 multiple-purpose reservoirs being placed under construction, contributed additional funds towards the maintenance of existing stations with the result that by the end of the period, 50 stations were supported wholly or in part by that agency.

Serious deficiencies in water resources information in connection with water supply for military establishments and defense industries were immediately apparent in the beginning of the war effort. Military establishment sites were often selected by high authorities on the assumption that water supply and streams for sewage disposal were readily available. As a result, the Army Engineers charged with construction of camps and air fields frequently demanded minimum flow information on streams for which no records were available. On one occasion, the local Army Engineer Office called the Survey and stated that Washington was on the phone and wanted immediately information regarding the minimum flow of certain small streams. To meet this situation as soon as possible, the district made spot measurements in October 1942 at 117 sites on small, unregulated, representative streams, chiefly in the Piedmont Plateau, supplemented in the following year by additional spot measurements in adjacent provinces. Fifteen index stations, equipped with staff gages, were established to supplement existing permanent gaging stations. The drainage areas were measured and the low-water flow per square mile computed for each stream that had been measured. By hydrographic comparison, using the permanent gaging stations and the emergency index stations, the minimum flow for 1942 and the drought year 1941, were computed. When these results were studied, a general pattern of low-water yields was indicated, from which reasonably accurate determinations of minimum flows could be made for any small stream in North Georgia. Maps showing the result of this study were distributed to the Army and defense agencies, with the result that requests for information dropped from a dozen or more per month to practically none.

While this investigation and study were in the nature of a wartime emergency task, the results were of permanent value to serve the needs of many small towns in Georgia requiring expanded water facilities for municipal or industrial use. Subsequent investigation on specific streams showed that the estimates could be verified with a high order of accuracy, provided the geologic characteristics of the region were properly considered.

Cooperation with Emory University Field Station for the purpose of investigating hydrologic factors related to malaria control had started informally in 1937 when a number of gaging stations, which were selected by the Survey, were installed and equipped with staff gages and operated by Field Station personnel. In 1942, the Field Station installed water stage recorders at 5 stations and planned to continue their operation; however, the draft boards took all but one man from the staff, so their organization was disbanded in September 1942. The operation of the gaging stations was then undertaken by the Survey, who employed the one remaining man. He devoted a part of his time to those stations during the remainder of the period, except during the last four months when, to meet the need of the Public Health Service,[106] he devoted practically all his time to the Field Station investigation.

106/ p. 84.

In 1945, E. L. Hendricks was detailed to the Field Station to study the data collected on the hydrologic program including, besides the gaging stations' records, ground water observations at 89 wells; pond level records on 19 ponds; an evaporation station; and rainfall, temperature and humidity gages. Early in the investigation, it was established that as the ponds, which were of primary interest to the malaria problem, had impervious bottoms, and were not effected by ground water levels, the ground water phase of the investigation was terminated.

In 1944, 7 gaging stations were established for the Army Engineers who were revising the 308 Report of the Altamaha River Basin. In the fiscal year 1946, as a result of increased State cooperative funds for the purpose of investigating small streams, many sites were investigated, plans prepared for new stations, and equipment purchased. However, with a change in the political picture in the state, it appeared inadvisable to proceed with the installations; a wise decision, as later the State Auditor reduced the appropriation by $5,000.

In the spring of 1946, Tate Dalrymple, who was on the Washington Office staff as liaison member for State Highway Departments, contacted the State Bridge Engineer and found that he was concerned with a complex stream flow condition at a particular bridge site. Mr. Dalrymple, with the assistance of M. R. Williams, analyzed the situation and furnished a solution. As a result, several other similar problems were referred to the Survey, and the State Highway Department in the fiscal year 1947, began cooperation with the Survey.

During the period, two sub-offices were maintained, one at Camilla during a part of 1942 and 1943, and the other at Newton from July 1945 to the end of the period; both in connection with the Emory University Field Station and other gaging stations in the southern part of the state.

F. M. Bell was district engineer until September 1, 1941, when he was transferred to the Chattanooga District and was succeeded by M. T. Thomson. Other Civil Service engineering personnel were:

Name	Period	Military Furlough
J. L. French	July 1, 1939 to Dec. 31, 1949	
R. F. Conard	July 1, 1939 to Arp. 18, 1941 1/	
J. M. Carns	July 1, 1939 to Feb. 2, 1947	Apr. 16, 1943 to Dec. 31,19
M. R. Williams	July 1, 1939 to Nov. 18, 1945 2/	
	June 8, 1946 to June 2, 1947	
L. K. Dunagin	Jan. 2, 1940 to Sep. 20, 1942 1/	
A. F. McVarish	Jan. 3, 1940 to Mar. 9, 1944	
O. K. Anderson	Nov. 20, 1940 to Mar. 27, 1942 1/	
S. A. Berkowitz	Oct. 20, 1941 to June 6, 1942 1/	
E. L. Hendricks	Feb. 28, 1942 to June 30, 1947	
L. R. Mills, Jr.	May 22, 1942 to June 30, 1947	
J. F. Gibson	Sep. 1942 to Mar. 6, 1943	
Mrs. H. H. Bell	Oct. 20, 1942 to Mar. 31, 1944	
C. M. Bunch	Sep. 2, 1943 to June 30, 1947	
T. L. Davis	Feb. 4, 1944 to Oct. 15, 1945	
C. M. Sellers	Mar. 26, 1944 to June 30, 1944	
W. H. Cone, Jr.	May 1, 1944 to Feb. 28, 1947	
G. T. Condrey, Jr.	Nov. 8, 1944 to June 30, 1947	
D. Carlton	Mar. 19, 1946 to July 31, 1946	
A. N. Cameron	May 3, 1946 to June 30, 1947	
J. E. Heatherly	Mar. 10, 1947 to June 30, 1947	

1/ Military furlough; did not return to district.
2/ Temporary detail to Japan.

Mrs. Effie T. Workman was district clerk until January 1940, Miss Gladys Boulton February 1940 to May 1943, and Miss A. L. Cain during the remainder of the period.

Ocala, Fla. - At the beginning of the period, cooperation with the city of Miami for the purpose of searching for an additional water supply increased the number of gaging stations on canals in the Lake Okeechobee and Everglades area by 20 during the first year, and that with the Everglades Drainage District by 10 in 1942. Cooperation with the Internal Improvement Fund resulted in the establishment of 15 regular stations and 7 stage stations, chiefly on small streams, during the last 2 years. The Army Engineer stations were increased from 18 to 39. These various increases together with a few stations established in cooperation with cities and counties, increased the number of stations from 56 at the beginning of the period to 111 at the end of the period, of which 59 were equipped with recorders. There were also 78 stage stations where the flatness of the topography made it impracticable to measure the discharges. Their value was due to the fact that the stage recorded represented the water elevation over a somewhat extensive area.

The cooperative programs with the city of Miami and with the Everglades Drainage District, brought about field work in the Everglades, a region unlike any other in the United States. Conditions were totally different and a somewhat detailed account of the unusual problems and how they were solved appears warranted.

The Miami program required a study of the rainfall and runoff of the Everglades area tributary to the Miami area itself for the purpose of evaluating the surface-water supplies available. Besides the gaging stations, it was necessary to supplement existing rainfall stations with 18 additional stations and 4 evaporation stations, installed and operated by the Survey.

The gaging stations were located chiefly on the canals draining the Everglades, with a few entering Lake Okeechobee, the records from which were needed to coordinate the studies of the Ground Water and Quality of Water Divisions in the investigation of an additional water supply. The studies of surface and ground water were intimately related as water passed readily between the channels and the adjacent ground.

At several stations, no stage-discharge relation existed; during periods of heavy rainfall, water from adjacent cultivated areas is pumped through the canals and into Lake Okeechobee, and during periods of light rainfall, the water is pumped from the canals for irrigation. As the stage in the lake is very nearly the same as that at the canal stations, the flow in the canals may change each day, not only in amount but also in direction. To determine the variations in velocity and direction, observers read twice a day not only the stage, but also made at a given point in each canal a float measurement. Whenever a discharge measurement was made, the velocity at that given point was also determined. From the area of the cross section, the mean velocity was determined from the point velocity, and the discharge computed.[107]

107/ Water Resources Bull., Nov. 1941 p. 174.

One of the most pressing needs was a determination of the flow of the tide-affected Miami Canal which enters Miami River 3 1/2 miles above its mouth. A recorder was installed at the city's water plant 4 miles above the mouth of the canal, the datum being sea level. A tide station consisting of a recorder in a concrete well was located in Biscayne Bay into which the Miami River flows. The stage at the canal station was constantly changing with the tide and with it, the discharge of the canal.

Determination of the canal discharge was made either by hourly measurements during the tide-cycle of 12 hours and 26 minutes, if the minimum discharge was less than 200 second-feet, or by a pair of measurements, one at maximum discharge and the other a minimum discharge if the minimum was greater than 200 second-feet. As the mean-cycle elevation of Biscayne Bay is not constant, there was no simple discharge relation at the gaging station, and a three dimension tide-correction method was devised by C. C. Yonkers.[108]

108/ Water Resources Bull., May 1944, pp. 79-82.

Each month, the Everglades Drainage District was furnished with a statement of water-supply conditions and with special reports on seepage measurements and flood crest profiles and other related subjects. The data collected proved so valuable to the Everglades Drainage District that cooperation with that agency began in the fiscal year 1943. Like that with the city of Miami, the program required stations chiefly on the canals.

Aside from the changes in levels, the measurement of the canal flow was made more difficult by the heavy covering of water hyacinth and other aquatic plants in many places. During the previous period, it had been necessary to make float measurements at some stations, 109/

109/ p. 201 (1928-1939).

but during the present, measuring sections were cleared either by mechanical or chemical means. A submarine weed-cutting saw was used on some small streams and canals. By means of a boat the saw was stretched across the canal, and allowed to sink near the bottom; men on each bank operated the saw, alternately pulling it back and forth and slowly moving upstream, and were able to clear a section 75 feet long, 40 feet wide and 10 feet deep, in about 15 minutes. 110/

110/ Water Resources Bull., Aug. 1944, p. 132.

Although satisfactory, that method was too expensive to be used generally. The Everglades Drainage District used on its canals a chemical spray applied at first from a plane but later from a boat.

Beginning in November 1945, a sea plane was used in reaching some stations in swamp-bordered inter-connected lakes and river reaches in the Kissimmee River Basin, as the loose sand roads were either too wet or too dry for ordinary use. Formerly, it was necesary to use either a car or boat from the main highway and then frequently, swim to the station as the shelters were some distance from the gently-sloping shore line; the plane landed in the water and taxied to the shelters. Seven stations were visited in half a day as compared with about 2 days by car and boat. 111/

111/ Water Resources Bull., Feb. 1946, p. 7.

A number of special studies of the amount of flow during a tidal cycle on several coastal streams were carried on in cooperation with the Army Engineers, in connection with harbor and other navigation studies and with the State Board of Health and the city of Jacksonville in connection with pollution studies. The methods used were similar to those used in the St. Johns River at Jacksonville in May 1945, where two recording gages were placed 7 miles apart. At a given point in the cross section, velocity measurements were made at frequent intervals as an index to the variations in discharge of the river. Four discharge measurements, 2 during flood tide and 2 during ebb tide, were made by 4 engineers working simultaneously from the bridge station, each measuring one-quarter of the flood. By means of these measurements, and the index of the variation of flow from the point velocity measurements, the total discharge during the 12 hours 26 minutes of tidal cycle was computed. Samples of chloride and suspended sediment were collected.

When cooperation with the Florida Geological Survey was resumed in the fiscal year 1942, it included the measurement of springs, lakes, and sink holes. The lakes selected for measurement were those at which lowering of water levels when analyzed with evaporation records, indicated a possible recharge to the underlying limestone formations. Continuous records of 6 springs started in the previous period, were maintained and periodic measurements of other springs were made. Florida has many sink holes containing water and the depth of those holes was an attraction to the tourists. As bait to enhance that attraction, owners of the sink holes were prone to exaggerate the depths to fantastic figures. The measurement of the depths by the Survey frequently proved the falsity of those claims. However, three sink holes were found to have depths of 167, 175, and 208 feet, respectively.[112]

112/ Water Resources Bull., Aug. 1943, p. 118.

In commenting on the unusual conditions in Florida, Mr. Ferguson stated that it isn't every state where sea cows knock the float cables off the recorders.

D.S. Wallace was district engineer until June 2, 1941, when he was transferred to the Charlottesville district and was succeeded by G.E. Ferguson, who had been in the district since October 29, 1940. Civil Service engineering assistants were:

Name	Period	Military Furlough
E.L. Hendricks	July 1, 1939 to Feb. 26, 1942	
B.P. Slater	July 1, 1939 to Jan. 21, 1942	
H.H. Cooper, Jr.	July 1, 1939 to Dec. 31, 1939	
T.G. Johnson	Dec. 1, 1939 to Aug. 15, 1946	July 9, 1942 to Apr. 14, 1946
J.W. Pepper	Nov. 28, 1939 to July 9, 1946 1/	
C.C. Yonkers	Oct. 11, 1940 to June 30, 1947	
J.M. Busalacchi	Jan. 4, 1940 to Sep. 29, 1943	
G.B. Harrell, Jr.	Jan. 2, 1940 to Sep. 30, 1947	June 9, 1942 to Mar. 18, 1946
C.W. Lingham	Nov. 25, 1940 to June 30, 1947	
J.A. McCabe	June 8, 1940 to June 30, 1947	Apr. 23, 1943 to July 19, 1946
G.C. Goddard, Jr.	Sep. 8, 1941 to June 30, 1947	
R.L. Taylor	Mar. 8, 1941 to June 30, 1947	
D.B. Bogart	Sep. 27, 1941 to June 30, 1947	
J.C. Berkenbosch	Aug. 21, 1942 to June 30, 1947	
M.S. Gardner	Oct. 10, 1942 to June 30, 1947	May 2, 1944 to Jan. 21, 1946
R.C. Heath	Nov. 24, 1942 to June 30, 1947	
Miss H.M. Lisenby	Dec. 21, 1942 to Nov. 2, 1945	
T.H. Simons	Oct. 1, 1945 to June 30, 1947	
A.R. Corbett	Apr. 12, 1946 to June 30, 1947	
W.R. Kidd, Jr.	Jan. 14, 1943 to July 15, 1946	

1/ Military furlough; did not return to district

Montgomery, Ala. - At the beginning of the period, the Montgomery District comprised the states of Alabama, Mississippi, and Louisiana, except for those areas in the Tennessee River Basin in northern Alabama and a small section in the northeast corner of Mississippi where the stations were maintained by the Chattonooga District. Louisiana became a separate district in 1942, and the activities for the entire period are described under the Baton Rouge District. Stations in Mississippi were operated by an office located in Jackson, Miss., which computed the records, kept its own financial accounts, and maintained cooperative relations; in 1946, that office became virtually independent and actually independent June 1, 1947. D.H. Barber was district engineer until called into military service for a year's training November 1, 1940, and H.C. Bolon was acting district engineer until August 21, 1941, when he became district engineer of the newly created Lincoln, Nebraska District. E.B. Rice became acting district engineer and administered the district from the Jacskon Office until October 21, 1941, when Mr. Barber returned from training and remained until January 12, 1942, when he entered the Army. Mr. Rice was again acting district engineer from January 13, 1942, to February 10, 1946, when Mr. Barber returned and remained as district engineer until retirement June 1, 1947. M. R. Williams succeeded him. Beginning October 14, 1944, Mr. Rice administered the district from Baton Rouge and C. H. Hardison was in charge of the Alabama operations.

As the activities in Mississippi are described under the Jackson office, only the Alabama activities are here described.

The number of gaging stations was increased from 44 to 75, of which 67 were equipped with recorders. A large part of the increase was due to additional Army Engineer cooperation whereby the number of stations was increased from 14 to 33. Although no sub-offices were maintained, the state was divided into three sections and an assistant engineer placed in responsible charge of each.

Low-water flow was of particular value in Alabama and during a period of extreme low water in 1941, many miscellaneous measurements of small streams were made. The drainage areas were also measured and the discharge per square mile determined.

The Montgomery office began in January 1941 to send out monthly statements entitled "Surface Water Conditions and Outlook for Alabama," based chiefly on the flow of two index stations. The storage in Lake Martin, having a capacity of 1,622,000 acre-feet was also included. The runoff outlook for the following month was for the most probable, and smallest probable, mean flow, depending on the precipitation. Twenty-four copies were sent to all interested State Departments, district engineers in adjacent states, and others interested.

From February 1943 to April 1944, available State funds made it possible to establish 10 stations at strategic points on streams having drainage areas ranging from 24 to 318 square miles. As their continuation depended upon future funds, the stations were equipped with staff or wire-weight gages. Although low-water flow was the chief reason for their installation, the stations were maintained during the entire 14-month period; thereafter, 8 of them became a part of the regular program and the remainder were discontinued.

Requests for information regarding water temperatures were being received and to answer those requests, water temperatures were read in connection with the regular discharge measurements beginning in October 1943.

As a result of increased cooperation with the Army Engineers in 1944,113/ a number of additional stations were established, and back records for stations previously maintained by that agency were computed.

113/ p. 75.

In 1944, a study of the natural water losses from selected drainage basins was made, the losses being taken as the difference between the average precipitation and the runoff from a basin in a given period. The purpose of the study was to draw "inferences" from the rainfall records prior to the beginning of the stream flow records. The results were published by the Geological Survey of Alabama as Bulletin 56, 1945.

Toward the end of the period, the State Highway Department began the practice of requesting flood frequency studies on streams where new bridges were being designed. Another request for a flood study was that made by the city of Mobile about 1945 for a stream on which no records existed. That resulted in the development of a unit hydrograph.

The following Civil Service engineering assistants were employed in Alabama during the period:

Name	Period	Military Furlough
S. C. Moore	July 1, 1939 to June 30, 1947	Apr. 25, 1943 to Aug. 11, 1944
W. S. Daniels	July 1, 1939 to June 24, 1940	
C. H. Hardison	July 1, 1939 to May 8, 1946	
E. I. Clancy	July 1, 1939 to Sept. 29, 1940	
W. C. Griffin	July 1, 1939 to June 30, 1947	
P. J. Mathis	Nov. 14, 1939 to Oct. 22, 1941	
E. J. Taylor	Nov. 21, 1939 to Aug. 31, 1942	
R. W. Carter	Oct. 9, 1940 to June 30, 1947	June 8, 1945 to Apr. 9, 1946
H. E. Drake, Jr.	Aug. 28, 1941 to July 17, 1942 1/	
J. J. Button	June 1942 to Jan. 13, 1944 1/	
N. J. Lusczynski	Apr. 7, 1944 to Aug. 6, 1946	
W. N. Phillips	Oct. 3, 1944 to June 30, 1947	May 16, 1945 to Nov. 17, 1946
L. B. Peirce	Feb. 24, 1945 to June 30, 1947	

1/ Military furlough; did not return to district.

Jackson, Miss. - Although Mississippi was a part of the Montgomery District, it was operated as a separate unit, and after D. H. Barber's return from military furlough in 1946, it became virtually independent; the only connection being the inclusion of the monthly reports with those of the district. E. R. Rice was in charge of the Mississippi work until he became acting district engineer of the Montgomery district and was succeeded by I. E. Anderson March 26, 1942, who remained during the rest of the period.

The number of stations was increased from 54 in 1939 with 36 recorders to 70 in 1947, 48 being equipped with recorders. Much of the increase came during the first year or so. In the year previous to the present period, the State cooperation had been greatly increased and large sums of WPA and PWA funds were made available for construction, much of which was performed in the first year of present period when 18 stations were established. In 1942, 6 stations were added, 5 in cooperation with the Forest Service, which in connection with the work of the Flood Control Coordinating Committee, desired to start a project in the Homochitto and Buffalo Bayou Basin, similar to that on the Little Tallahatchie River.114/ Work on this project was sus-

114/ p. 90 (1928-1939).

pended a few months later on account of the war and was not resumed. Increased cooperation with the Army Engineers in 1944 made it possible to establish additional stations subsequently. That cooperation required the computation of back records for stations maintained by the Army Engineers,115/ and the making of check measurements in the

115/ p. 75.

future. As several of those stations were situated in the upper Tombigbee Basin, and as the Survey was maintaining a number of stations in that part of the state, a sub-office was maintained at Tupelo from May

1944 to June 1946 for the purpose of computing the Army Engineer records and performing the necessary field work.

During the low-water period of 1942, spot measurements of small streams were made in connection with the regular field work. Some time later, it became the practice to take water temperatures throughout the year at the regular stations and also when spot measurements were made. That procedure was followed, though man-power shortage made it necessary to reduce the number of measurements. The information was of especial value to the Fish and Game Commission.

When the Mississippi River Commission cooperation was discontinued in 1944,[116] it was no longer possible to maintain a resident engineer

116/ p. 76.

at Vicksburg, and thereafter an engineer from Jackson visited Vicksburg and measured the Mississippi River weekly. In making the measurements, 200- and 300-pound weights were used on a single wire. Although 500-pound weights were available, they were not being used as a suitable wire to suspend them could not be obtained. The Army Engineers were measuring four times a week at their own station one-fourth mile downstream, working from a power launch, and since the fall of 1945, using a fathometer which was found to indicate soundings accurate to 0.1 foot. A comparison between the Survey and Army Engineer measurements showed that the Army Engineers took four times as many soundings and about a quarter as many velocity determinations, each for 5-minute intervals. Comparison between 18 simultaneous pairs of measurements by the two agencies showed average agreements within 3 percent. All measurements were used in the joint computation of the records.[117]

117/ Water Resources Bull., May 1947, p. 112.

The power-operated crane and reel at the Vicksburg station was sent to Fort Smith during the flood of April 1943,[118] and at other times was

118/ p. 156.

loaned to other districts for special investigations.

The personnel of the Jackson office was very civic-minded, 5 of 6 engineers were members of the Junior Chamber of Commerce, 2 being directors and 3 participated in all war drives.

The Jackson Office had the following Civil Service engineering personnel:

Name		
J.K. Searcy	July 1, 1939 to June 30, 1947	(Nov. 26, 1940 to Nov. 24, 1941) (Aug. 24, 1942 to Dec. 11, 1945)
D.F. Dougherty	July 1, 1939 to Aug. 29, 1942 1/	
N.O. Thomas	July 1, 1939 to June 30, 1947	June 19, 1943 to Apr. 18, 1946
F.J. Mahoney	July 1, 1939 to Feb. 15, 1940	
D.L. Davies, Jr.	Nov. 17, 1939 to Oct. 21, 1942 1/	
S.A. Berkowitz	Nov. 21, 1939 to Oct. 18, 1941	
G.C. Calvin	Dec. 4, 1939 to Mar. 24, 1942	
K.I. Darmer	Apr. 6, 1940 to Oct. 29, 1946	
J.D. Shell	Nov. 16, 1940 to Feb. 1946	
A.E. Hulme	Mar. 10, 1941 to Dec. 1942	
I.E. Anderson	Sep. 19, 1941 to June 30, 1947	
E.L. Grimes	Nov. 1942 to June 30, 1947	Aug. 1, 1946 to June 30, 1947

1/ Military furlough; did not return to district.

Baton Rouge, La. - Louisiana remained a part of the Montgomery District until September 21, 1942, as during that time, political uncertainty regarding State cooperation might have forced curtailment of the work. However, with a new State administration and the growing demand for records, together with the increasing State cooperation, it was felt that the stream-gaging program had become firmly established, and Louisiana became a separate district. Except for making the financial arrangements with cooperating agencies, it was virtually a separate district before the change.

R. C. Marsh, who had been in charge of the Louisiana work, became district engineer, and remained until October 1944, when he was transfered to the newly-created Bismarck District. E. B. Rice, who succeeded him, was also acting district engineer of the Montgomery District until February 10, 1946.

During the period, the number of gaging stations was gradually increased from 28 to 63, the additional stations being due chiefly to the increased State cooperation, and in lesser degree, to the increase in Army Engineer stations from 18 to 24. Because of the flat slopes, 12 stations had auxilliary slope gages. Of the 63 stations, 24 were equipped with recorders. State cooperation which began in the 1939 fiscal year led to the rapid establishment of gaging stations but even though aided by a WPA project, it was possible to install only a small number of recorders. The drying up of WPA funds and a little later the war-time restrictions limited construction seriously. Consequently, recorders were installed only at stations having rapid fluctuations of stage. Many streams are of the bayou type and do not fluctuate rapidly, making it possible to obtain fairly satisfactory records with non-recording gages.

To meet the wide range of conditions from sluggish low flows to high flood flows, each field man carried 4 meters; a pygmy, a slow velocity meter in the best possible condition, and two standard meters, one of which was used for rough work during floods. At 5 stations, the flow was so sluggish during low water that boats were used to find the least bad measuring section. The streams have wide flood plains and during floods, it was necessary to measure the over-flow by means of boats; the district owned 3 boats with outboard motors, and rented others when needed. Four battery-operated cranes and reels were available for high water measurements. One flood measurement was notable. It was made on the Red River at Coushatta in April 1945, where it was necessary to measure the overflow along the main U.S. highway for a distance of 7 miles before reaching the station, and in addition to the main channel itself. Much of the overflow, which was from 2 to 10 feet deep, was ponded but in some sections, it was flowing either at sharp angles or parallel to the highway; telephone poles were used for section markings and depending upon the flow, the sections were from 200 to 1,000 feet wide. Two men in a boat measured the overflow. Two men with power equipment measured the main channel from the bridge. The measurement required 10 hours, after which it was necessary to spend the night over a filling station in Clarence which was 4 feet under water. To that unusual experience was added one still more unusual: A foxhound had been rescued from the flood and placed in the filling station; as she had a litter of pups during the night, it was up to the marooned engineers to find food for the new arrivals.

Records of stage were obtained on the Mississippi River at Baton Rouge and below New Orleans, as the Army Engineers desired continuous records of stage at strategic points to determine instantaneous river profiles. As the growing of rice needs irrigation at certain periods, water was diverted from one small drainage basin to another, and a number of stations were established to show the available supply.

A side light on field conditions is shed by a placard observed by the author in the reptile division of the State Museum of Natural History in New Orleans, bearing the statement that there are 26 varieties of snakes in Louisiana, of which 6 are poisonous.

In addition to the district engineer, the district had the following Civil Service engineering assistants:

Name	Period	Military Furlough
E. H. Orleman	July 1, 1939 to Nove. 5, 1941	
F. B. Sessums	July 1, 1939 to Nov. 24, 1945	
W. S. Daniels	Aug. 26, 1939 to June 24, 1940	
C. L. Muntz	July 29, 1940 to June 5, 1943	
A. E. Hulme	Mar. 10, 1941 to Dec. 26, 1941	
	Feb. 18, 1943 to Nov. 17, 1944	
J. M. Garrett	Mar. 10, 1941 to July 30, 1941	
G. C. Calvin	Dec. 26, 1941 to Mar. 23, 1942	
E. J. Taylor	Dec. 26, 1941 to June 30, 1947	
R. P. Smith	July 1, 1942 to June 30, 1947	Feb. 13, 1944 to May 6, 1946
D. R. Aertker	Oct. 10, 1942 to June 30, 1947	May 27, 1943 to Mar. 18, 1946
J. L. Price	Nov. 2, 1942 to Feb. 15, 1943	
Miss R. I. Cowan	Jan. 9, 1943 to Nove. 15, 1943	
J. W. Gambrell	June 1, 1943 to June 30, 1947	
F. F. Foil, Sr.	June 1, 1943 to July 23, 1943	
L. J. Daigre	Sep. 4, 1944 to June 30, 1947	
P. E. Chambers	Dec. 1, 1944 to Mar. 22, 1945	
J. D. Boswell	Oct. 23, 1945 to Mar. 1, 1947	
J. R. Gardner	Nov. 5, 1945 to June 30, 1947	
H. J. Tracy	Jan. 1, 1946 to June 30, 1947	
J. D. Shell	Feb. 25, 1946 to June 30, 1947	
D. F. Dougherty	Mar. 20, 1946 to June 28, 1946	
J. E. Edwards	Apr. 12, 1946 to June 7, 1946	

There were five district clerks during the period:

Miss C. H. Ness	July 1, 1939 to Apr. 26, 1942
Miss M. L. Karns	May 25, 1942 to Oct. 29, 1942
Mrs. E. H. Taylor	Oct. 3, 1942 to Jan. 5, 1946
Mrs. Mae Eastwood	Jan. 6, 1946 to Feb. 5, 1946
Mrs. M. K. Hodge	Feb. 6, 1946 to June 30, 1947

Charleston, W. Va. - In 1939, there were 54 stations with 35 recorders in the Charleston District and in 1947, 96 stations with 87 recorders. That increase was due largely to additional Army Engineer cooperation which increased the number of stations partially supported by them from 41 to 75. Most of this increase occurred during the first two years as the records from the existing stations were insufficient for the Army Engineers' comprehensive flood-control program, particularly in the Ohio River Basin. A few new stations were established nearly every year as the result of additional State and municipal cooperation. The College Park District had been operating 10 West Virginia stations in the Potomac River Basin, but beginning July 1, 1945, those were transfered to the Charleston District. For economical and more effective operation, a sub-office was established at Elkins December 2, 1940, for the operation of stations in the eastern and northern sections of the state. Its program gradually developed until at the end of the period, about 40 stations were being operated, and most of the records were computed also. From October 9, 1941, to May 23, 1943, a sub-office was maintained at Hinton. The Army Engineers requested that action be taken to permit more extensive field work in the extreme southern section of the state at a number of stations directly connected with the Bluestone Dam, which was in the early construction stage at that time.

During the period, there were a number of cloudburst-floods, the most notable occurring August 4-5, 1943, in the north-central section of the state. That flood was caused by a rainfall which was as much as 15 inches in 2 hours. Numerous special measurements were made following the flood and a report was prepared for publication as a water-supply paper.

In 1943, a program of low-water spot measurements at numerous points where such information was of value in connection with water supply and waste disposal but where it was not economically possible to maintain stations, was started. About the same time, it became the practice during the warmer months to measure water temperatures when measurements were made, and also to obtain daily temperatures from power companies, water companies, and other interested agencies at some 30 or more stations.

An investigation of the principal springs was made during the summer and fall of 1945; all springs having a discharge of 100 gallons per minute or greater, numbering 208, were visited and measured in the summer and the more important were measured again in the fall. During the search for the larger springs, 135 smaller springs were located and measured. Two recorders were maintained on representative large springs during the investigation.

William Kessler was district engineer until September 23, 1941, when he was succeeded by H. M. Erskine and became associate engineer. Other Civil Service engineering personnel were:

Name	Period	Military Furlough
L. B. Holland	July 1, 1939 to June 30, 1947	
H. A Taylor	July 1, 1939 to Aug. 5, 1941	
H. A. Weggel	July 1, 1939 to July 31, 1940	
J. H. Fellouris	May 14, 1940 to Aug. 11, 1941 [1]	
V. R. Bennion	July 19, 1940 to Oct. 17, 1941	
M. A. Wayne	Nov. 25, 1940 to June 10, 1946	July 13, 1944 to Apr. 30, 1946
K. L. Kollar	Oct. 9, 1941 to Jan. 31, 1945	
K. A. MacKichan	Oct. 20, 1941 to June 30, 1947	
C. P. Hagensen	Jan. 27, 1942 to May 20, 1942 [1]	
W. F. Sigler	July 1, 1943 to July 26, 1946	
J. D. Lilly	Jan. 1, 1945 to Jan. 10, 1947	

Cont'd

Name	Period	Military Furlough
Leon Rock	Nov. 5, 1945 to Dec. 7, 1946	
W.H. Truslow, Jr.	Nov. 30, 1945 to May 1, 1946	
W.D. Pickering	Dec. 5, 1945 to June 17, 1946	
H.G. Hinson	Jan. 2, 1946 to June 30, 1947	
H.C. Hickerson	Sep. 30, 1946 to June 30, 1947	
Hymen Carp	Dec. 2, 1946 to June 30, 1947	

1/ Military furlough; did not return to district.

Louisville, Ky. - In addition to stations operated in Kentucky, the Louisville District maintained four stations in Illinois and Indiana, and nine stations on the main stem of Ohio River. Field work for these nine main-stem stations was performed mainly by the Army Engineers with most office work and part of the field work by the Survey. The total number of stations in the district was increased from 50 to 93 during the period with an increase in recorders from 15 to 64. The greatest increase occurred during the first two years when 23 additional stations were installed. Practically all of the other additional stations, about 20, were established prior to and including 1944, about half of these in cooperation with the Army Engineers and the balance, all on small streams, in cooperation with the Highway Department and City of Louisville and Jefferson County. In 1939 the Army Engineers cooperated in the operation of 50 stations and in 1947, this support had increased to 71 stations.

Most of the large group of stations established in the first two years of the period were equipped with recorders, some including cableways, and this extensive construction program was made possible by the WPA project, which was initiated during the previous period and continued until June 1941. Under that program, selection of station sites, preparation of plans and estimates were made by the Survey, but the actual construction was performed by four crews, each consisting of a foreman and laborers under general Survey supervision. The foremen were selected from among former hydrographic field assistants in other Survey districts, and were experienced in this type of construction. Of the some 50 individual gaging-station projects in the 2 1/2 year WPA program, 44 gage-well structures either pipe well, mostly with concrete sumps, or reinforced concrete were constructed and eight cableways were installed. Many of the gage structures exceeded an over-all height of 50 feet and 11 of the gage structures ranged from 60 feet to more than 90 feet in height.

The most notable construction by the Louisville District during the period was the installation of the concrete gage house on Ohio River at Cincinnati, jointly financed by the Survey, Army Engineers, and Weather Bureau. Completed in November 1946, this structure has an overall height of 99 feet, and rises 84 feet above the ground level on the river bank. The standard, 6-foot reinforced concrete structure was the highest station of that type in the country. The location on the downstream side of a pier of the beautiful old suspension bridge connecting Cincinnati with Covington, Kentucky, designed by John Roebling nearly a hundred years ago, provided an excellent opportunity for desirable publicity as thousands of people cross the bridge daily. The structure was extended to the walkway of the bridge, giving direct access to the recorder. To acquaint the public with the use of the structure, as well as to satisfy the curious, the metal-covered door with its brass knob and inset lock, has four panes of polished plate glass, thus providing a view of the recording instruments and the carefully finished interior. In addition to the Stevens A-35 recorder, which furnished the base record, an Au long-distance telerecorder with receiver in the Weather Bureau office in Cincinnati, was installed. Other features include: telephone fixtures and connections, electric lights and wall plugs installed in the house and under the floor, and the flush tank and electric pump under floor. The power and telephone wires were laid under the bridge floor. An outside staff gage, with conspicuous foot-mark numerals, was installed on the well and the bridge pier for the convenience of the public and the boatmen on the river. Two intakes 30 feet long at elevations 9.0 and 11.3, gage datum, were provided. Pool stage on the Ohio River is at elevation 441.1 feet, above mean sea level, and the lower intake is at elevation 438.6 feet, above mean sea level. The structure was completed in about four months at a cost of $10,500.[119]

119/ Water Resources Bulletin, Feb. 10, 1947, pp. 22-25.

The flat slopes and severe floods made it necessary to operate nearly a third of the stations as slope stations, many of them for a major portion of the year; at some stations, in addition to the two slope gages, a third gage was used for the low-water rating. Operations to obtain the final record of daily discharge for these slope stations involved an extensive amount of field work, office analyses, and office computations.[120]

120/ Water Resources Bulletin, Nov. 1946, p. 217.

In 1941, sub-offices were established at Paducah and Williamsburg mainly for the purpose of more rapid and efficient coverage of floods and improvement in the operation of important gaging stations. With one engineer for about a year and two engineers thereafter, the Paducah office handled the field work on important gaging stations in the lower reaches of the Ohio, Wabash, Cumberland, Tennessee, and Green River Basins, and office work mainly on assignment from Louisville. With two engineers and a part-time clerk, the Williamsburg office handled both field and office work except for brief final review of records in Louisville for stations in the Cumberland, upper Kentucky, and Sandy River Basins.

As the two principal cooperating agencies, Kentucky Department and Army Engineers, were interested mainly in flood records, every effort was made by the Survey to obtain flood measurements. General high floods in 1939, 1943, 1945, and 1946 provided favorable opportunity to obtain needed measurements. The flash flood of July 5, 1939, in Eastern Kentucky was notable for the extremely high rates of rainfall and runoff and the severity of the damage and loss of life over a comparatively small area.[121] The flood of March 1945 on the main stem Ohio River was the highest since the 1937 flood and at Louisville, Ky., it was exceeded in magnitude only by the 1937 flood in the 100 years of Ohio River flood records at that point.

121/ Water-Supply Paper 967-B, 1945, by Floyd F. Schrader.

The adverse conditions encountered in making flood measurements is illustrated by a measurement of the Cumberland River made at Cumberland Falls during the flood of January 1946, the highest discharge measurement made at that point since the establishment of station in 1907. In a width of 500 feet with maximum depths of 15 feet, the discharge was about 50,000 second-feet and the velocities ranged from 12 to 15 feet per second in the main part of stream. Standing waves with a magnitude of 5 feet between crests and troughs and a distance varying from 10 to 20 feet between crests; these waves remained stationary for several minutes. Determination of the mean water surface required as long as 10 minutes. However, as the river bed was smooth ledge rock actual soundings were attempted only at a few points. After one long velocity count, it was found that submerged drift had completely flattened the upper half of meter cups although there had been no interruption in the counts.

For use primarily of the Department of Highways, J. V. B. Wells, in 1942, prepared a report on "Flood Discharges in Kentucky," in which he presented a summary of flood discharges, enveloping curves of maximum discharge and curves of flood frequency. The enveloping and flood frequency curves were indicated for each principal sub-basin. This report was extensively used by State highway engineers in their bridge studies.

In 1945, the Louisville District assisted State agencies and educators in the compilation of a volume on Kentucky's Resources for use as an educational unit in the school systems and for general distribution to acquaint the people of the state with their resources. The section on Kentucky's water resources, assembled and prepared by F. F. Schrader, was extensively illustrated and combined condensed facts with descriptive material to provide information on the water resources of the state, water problems in general, and the general methods of conducting water-resources investigations. Through cooperation of the State geologist, a separate bulletin containing the section on water resources was later published by the State. This project was considered most helpful in advancing the water resources work in the state.

In addition to the regular operations, the Louisville District annually performed work on two projects involving the Ohio River Basin as a whole. At the end of each water year, the district prepared an Index of Discharge Records in the Ohio River Basin for distribution to all Survey offices, Army Engineer offices in Ohio River Basin, and other interested parties. Also, after the end of each water year, the district conducted an extensive study to correlate all main-stem Ohio River discharge records from Pittsburgh to Metropolis, together with principal tributary records and prepared a report on these comparisons. This report was the final field action on discharge records for the main-stem Ohio River for the water year involved.

F. M. Veatch was district engineer until February 29, 1940, when he was transferred to the Tacoma District; J. V. B. Wells succeeded him and continued in charge until he was transferred to the Washington Office January 23, 1946, later becoming chief of the division. F. F. Schrader succeeded him as district engineer September 16, 1946.

Other Civil Service engineering personnel were:

Name	Period	Military Furlough
F. N. Hansen	July 1, 1939 to Oct. 14, 1941	
A. L. Reed	July 1, 1939 to June 4, 1946	July 7,1942 to May 22,1946
R. E. Fish	July 1, 1939 to Nov. 16, 1941	
J. E. McCall	July 1, 1939 to June 30,1947	Feb. 26, 1942 to May 1,1946
R. W. Pride	July 1, 1939 to June 30,1947	
J. A. Hanlon	July 1, 1939 to Dec. 14, 1939	
L. V. Page	July 1, 1939 to Mar. 13,1940	
	Dec. 8, 1941 to June 30,1947	
M. I. Rorabaugh	July 1, 1939 to Aug. 29,1944	
R. B. Vice	Nov. 25, 1939 to Dec. 3,1941	
C. F. Hains	Mar. 18, 1940 to Nov. 11,1946	
W. J. Moore	Sep. 30,1940 to Apr. 22,1942 1/	
H. C. Hickerson	Feb. 1, 1941 to Sep. 29,1946	July 16,1945 to Aug. 18,1946
P. W. Hensley	Apr. 1, 1942 to Aug. 30,1943 1/	
G. E. Rule	June 1, 1942 to Dec. 17, 1945	
D. R. Moulton	June 11, 1942 to Jan. 5, 1943	
H. F. Hall	June 16, 1942 to June 30,1947	June 5, 1943 to Feb. 14,1946
C. E. Lewald	July 18, 1942 to May 12, 1944 1/	
W. H. Jackson	July 16, 1943 to June 30,1947	
Miss L. R. Cummings	Aug. 18,1943 to Dec. 1, 1943	
D. D. Dickstein, Jr.	Oct. 27,1943 to June 30,1947	Apr. 19,1944 to July 28,1946
A. S. Curtis	Feb. 5, 1944 to June 30, 1947	
J. H. Kelley	Apr. 26,1944 to May 23,1944	
D. M. Phelps	Oct. 21,1944 to Apr. 29,1946	
R. L. Bailey	Apr. 2, 1945 to June 30, 1947	
E. M. West	June 20, 1946 to June 30,1947	
Miss R. Shaw	Nov. 4, 1946 to June 30,1947	
E. J. Kennedy	Dec. 12,1946 to June 30,1947	
E. G. Barron	Apr. 10, 1947 to June 30, 1947	

1/ Military furlough; did not return to district.

Miss Claire E. Putz was district clerk until November 2, 1942, when she was succeeded by Mrs. Irene E. Fraser.

Chattanooga, Tenn. - The number of stations was increased from 118 in 1939 to 128 in 1947, all but one equipped with recorders. Of the 128 stations, 12 were in Tennessee River Basin in Alabama, 3 in Georgia, and 1 in Kentucky.

With TVA, the principal cooperating agency, the district operations were dependent to a large extent on the requirements of that agency. Like the operations during the previous period, stress was placed on flood measurements. However, with the operation of new dams and power plants which had previously been in the construction stage, the emphasis was placed on those stations directly concerned with such operation. The TVA had built up a system of daily forecasting of river discharge at key stations and by that means, the Survey was notified of floods and was able to have men at the stations when needed. In connection with that system, the TVA installed numerous long-distance recorders, telemark gages, and radio stage transmitters in Survey stations.

During major floods at those stations required for operation, engineers obtained measurements on rising and falling stages to develop the loop stage-discharge curves. Measurements of the large rivers were made by battery-operated cranes and reels using 150- and 200-pound weights, thereby cutting in half both personnel and time. It may be mentioned that as a battery charge was usually sufficient for one long measurement. The field men carried two batteries, in order that one might be recharged while the other was in use.

With the completion of power plants and the installation of hydro-electric equipment at four plants, the Survey was called upon to check the manufacturer's rating of generators by means of current meter. As power plants were in the dams, that was the only method of making the checks. As the quantities measured ranged from 10,000 to 60,000 second-feet, it was necessary to make the measurements from boats and those measurements were usually made at night when it was possible to keep the power load steady, and when weather conditions were favorable. At least two pairs of measurements were made for each generator, using different meters in the same cross-section; the agreement in results was within 1 or 2 percent.

During the war, TVA power was a vital factor in the war activities of the region and that agency was able to obtain high priorities for construction materials. TVA also had a well-equipped construction organization so during those years, all new gage shelter and cableway construction was done by that agency, using plans and specifications prepared by the Survey. This arrangement resulted in a number of excellent stations at strategic locations which, because of manpower shortages, the Survey could not have built. Among the more important stations were those essential to the operation of the Cherokee, Douglas, Kentucky, and Watauga projects.

The gaging station on Clinch River at Scarboro was within the Oak Ridge area fenced in by the Atomic Energy Commission, and as that was a closely-guarded area, the Survey at first had difficulty in convincing the military police that it was necessary to visit the gaging station; the first contact required 2 days to obtain clearance, and then one of the police accompanied the engineer to the station, remained during the measurement, and escorted him back to the gate. Later, when Oak Ridge reached the production stage, the Clinch River records became very important. Certain minimum flows were required to dilute the wastes dumped into the river, and Norris Dam farther upstream released water as needed, the amounts to be released depending on the flow at the Scarboro station. The Oak Ridge management installed a long distance recorder in the shelter with the receiving recorder at the plant. Thereafter, the only formality in gaining entrance to the station was the presentation of a pass, which was renewed monthly.

C. E. McCashin was district engineer until September 1, 1941 when, on account of physical disability, he was relieved of administrative duties, and was succeeded by F. M. Bell. Civil Service engineering assistants were:

Name	Period	Military Furlough
W. R. Eaton	July 1, 1939 to Oct. 18, 1943	
W. J. Perry	July 1, 1939 to June 30, 1947	July 23, 1941 to Mar. 1, 1946
G. H. Wood	July 1, 1939 to June 30, 1947	
A. O. Patterson	July 1, 1939 to June 30, 1947	
Chas. Wells	July 1, 1939 to June 30, 1947	
D. D. Lewis	July 1, 1939 to Feb. 21, 1942	
R. H. Otness	July 1, 1939 to Apr. 2, 1940 Deceased	
Max Noecker	July 1, 1939 to Dec. 27, 1941	
M. F. Cook	July 1, 1939 to June 30, 1947	
F. C. Ames	July 1, 1939 to Sep. 28, 1939	
D. M. Corbett	July 1, 1939 to Sep. 12, 1941	
W. M. Branch	July 1, 1939 to Aug. 31, 1939	
E. M. McClure	July 1, 1939 to June 30, 1947	
G. W. Martin	Nov. 1, 1939 to Apr. 1, 1942	
O. H. Jeffers	Oct. 31, 1940 to Oct. 9, 1945	
Milburn Hassler	July 15, 1940 to June 30, 1947	July 17, 1942 to Dec. 17, 1945
E. P. Mathews	Dec. 2, 1940 to June 30, 1947	Jan. 8, 1943 to Mar. 4, 1946
R. E. Steacy	Mar. 25, 1940 to Jan. 7, 1943 1/	
L. D. Barker, Jr.	Dec. 30, 1940 to Sep. 4, 1942	
R. B. Sullivan	Dec. 21, 1940 to June 7, 1941	
M. J. Slaughter	Mar. 1, 1941 to June 30, 1947	
R. D. Donnell	Oct. 21, 1942 to Jan. 12, 1943	June 22, 1944 to Jan. 2, 1946
C. B. Palmer	Aug. 1, 1942 to June 30, 1947	
Miss T. L. Hinton	Oct. 20, 1942 to Aug. 31, 1945	
J. M. Terry	Oct. 8, 1943 to June 30, 1947	
H. L. Abercrombie	Oct. 28, 1946 to Apr. 30, 1947	
Daniel Carlton	Dec. 1, 1944 to Feb. 10, 1946	
L. C. Gray	May 17, 1943 to July 26, 1943	
J. O. Joerns	Nov. 22, 1944 to June 30, 1947	
Miss V. E. McGuire	July 6, 1944 to June 16, 1946	
(Mrs. V. M. Abercrombie)	Aug. 20, 1946 to Sep. 20, 1946	
D. W. Sykes	Apr. 26, 1943 to June 30, 1947	
H. C. Cook	Mar. 31, 1947 to June 30, 1947	

1/ Military furlough; did not return to district.

Miss Martha S. Herlevi was district clerk until April 20, 1946 when she was succeeded by T. J. Quarles.

Columbus, Ohio. - The activities of the Columbus District increased greatly during the period; the number of stations was increased from 91 to 187 and special investigations expanded the activities more than was indicated by the increase in stations. Much of the increase in the gaging stations was due to the additional Army Engineer cooperation. Early in the period, the Army Engineers took over the Muskingum Watershed Conservancy District, and the 38 stations being maintained in cooperation with that district. Additional stations required for that and other flood-control programs, increased the number of Army Engineer stations from 35 to 122. Included in the 187 stations were 16 on Army Engineer reservoirs in the Muskingum River Basin.

The heavy demand for water for cooling purposes, by the steel plants in the Youngstown area of the Mahoning Valley, made it necessary to keep current records of the inflow to and outflow from the city-owned Milton Reservoir of 9.5 billion gallons capacity, located 40 miles above Youngstown, in order that a minimum amount should be released from the reservoir to maintain the required flow in the river. The special investigation by the Survey began in June 1941 when E. J. Tripp and an assistant, were stationed in Youngstown and the two existing gaging stations were increased to 8 by additional installations. During the first year, the Survey engineer or his assistant started out at 5 a.m. on his daily task of reading the 8 gages, and was back in the office and a report of the discharge prepared by 8 a.m., the discharges being determined from rating curves checked by frequent measurements. The steel companies, power companies, and Army Engineers were notified by telephone of the daily discharges, and used that information in regulating the reservoir releases by special arrangement with the city. After the first year, local observers were employed to read the gages and telephone the Survey Office, thus eliminating the 5 a.m. schedule. During the critical year of 1942, the Survey's services were credited with conserving a billion gallons of water, a very considerable amount considering the water shortage. In 1942, the Army Engineers constructed the Berlin Reservoir of 29.7 billion gallons capacity, and became more directly interested in the regulation of the river, and three additional gaging stations were established. In 1946, with the construction of Mosquito Creek Reservoir of 32.5 billion gallons capacity, the Army Engineers began to call the local observers each morning and relay the gage heights to the Survey, which determined the discharges and notified the major steel companies. The reservoir operation occupied only a part of the time of the Survey engineers, and they maintained about 20 additional stations.

A series of seepage measurements in the Licking River and Mad River Basins were made in the fall of 1943 and the summer of 1944, for the purpose of defining a relation between geology and low-water flow; Dr. George White, who in 1945 became State Geologist, was employed by the Survey to interpret the geology of the area.

Another special investigation was that made for the city of Columbus during the winter of 1944-45. At the beginning of the winter, the water supply in the two city reservoirs was very low and the unusually cold weather prevented the usual winter runoff. To increase the flow of the Scioto River which supplied Columbus, the city pumped water into it from abandoned quarries. At the city's request, the Survey made 35 miscellaneous measurements at 3 points on the Scioto and tributaries, and furnished daily records from a regular gaging station during January and February. It may be added that the city supply was almost exhausted before the winter break-up in February.

As a result of cooperation with the State Highway Department, 14 gaging stations on streams having drainage areas ranging from 1 to 12 square miles, well distributed throughout the state, were established during the last two years. This program has as its purpose the collection of data upon which can be based improved and more economical methods of culvert design.

Information regarding floods from small areas is very meager and to obtain additional data, an investigation of the flood of June 1946 in Wayne and Holmes counties was made soon afterward. The flood was caused by rainfall of cloudburst intensity and to supplement the few Weather Bureau records, 12 local observations made by improvised rain gages were obtained. Peak discharges were obtained at the one gaging station, and at 12 other points by means of contracted openings or by slope-area measurements. The report was prepared by W. P. Cross and was published by the Ohio Water Resources Board.122/ That was the first of a series of special investigation, the object of which was to make basic stream-flow data of greater use to the public.

122/ The Flood of June 1946 in Wayne and Holmes Counties; Bull. 9, Mar. 1947.

Another publication was a compilation of past floods at existing gaging stations with a study of their frequencies, also prepared by W. P. Cross.123/

123/ Floods in Ohio, Magnitude and Frequency, Bull. 7, Oct. 1946.

C. V. Youngquist continued as district engineer until September 12, 1945, when he was given a WAE appointment which enabled him to accept temporarily the position of chief engineer of the Ohio Water Resources Board. Tate Dalrymple, who had been in the district since October 11, 1939, was acting district engineer until September 9, 1946, when he was transferred to the Washington Office and was succeeded by O. H. Jeffers, who had been in the district since October 10, 1945. Other Civil Service engineering personnel were:

Name	Period	Military Furlough
H. E. Cox	July 1, 1939 to June 30, 1947	
E. J. Tripp	July 1, 1939 to June 30, 1947	
H. F. Dowdy	July 1, 1939 to June 30, 1947	
C. J. Rossow	July 1, 1939 to May 12, 1940	
L. L. Sphar	July 1, 1939 to May 1, 1941	
E. H. Curtis	July 1, 1939 to June 30, 1947	
L. H. Skillman	July 1, 1939 to Apr. 1, 1940	
C. L. Muntz	July 1, 1939 to Aug. 11, 1945	
Nye Grant	Oct. 2, 1939 to Nov. 15, 1945	
J. L. Sheaff	Nov. 18, 1939 to Oct. 21, 1946	Jan. 1, 1942 to Mar. 24, 1946
R. M. Bush	Dec. 28, 1939 to June 27, 1940	
S. E. Rantz	Feb. 11, 1940 to Dec. 14, 1941	
H. H. Ellis	Apr. 2, 1940 to June 30, 1947	Feb. 20, 1943 to Mar. 15, 1946
L. R. Peterson	Sep. 23, 1940 to July 10, 1946	Aug. 12, 1942 to Feb. 7, 1946
F. W. Kennon	July 15, 1941 to Mar. 31, 1942	
E. E. Webber	Feb. 1, 1942 to June 30, 1947	
Robert Davies	Aug. 24, 1942 to June 30, 1947	
F. W. Workmaster	Sep. 16, 1942 to June 30, 1947	Mar. 24, 1944 to Apr. 1, 1946
M. D. Brands	Sep. 21, 1942 to July 31, 1944	
W. T. Augur	Oct. 16, 1942 to July 19, 1946	Apr. 30, 1943 to Feb. 4, 1946
J. B. Shjeflo	May 7, 1943 to June 30, 1947	
O. F. Clemmer	June 1, 1943 to June 30, 1947	
T. S. Graff	May 16, 1944 to Oct. 25, 1946	
R. K. Middleton	Aug. 23, 1944 to June 14, 1946	
W. P. Cross	Dec. 26, 1945 to June 30, 1947	
H. F. Wilson	Feb. 4, 1946 to June 30, 1947	
Kenneth Birath	Feb. 4, 1946 to Aug. 27, 1946	
J. A. Duffy	Feb. 4, 1946 to July 26, 1946	
G. A. Francis	July 29, 1946 to June 30, 1947	

Cont'd

Name	Period	Military Furlough
L. A. Rausch	Oct. 2, 1946 to June 30, 1947	
W. F. Smith	Oct. 7, 1946 to June 30, 1947	
L. E. Bidwell	Nov. 21, 1946 to June 30, 1947	
D. K. Koegler	Oct. 14, 1946 to June 30, 1947	
G. D. Francis	Jan. 20, 1947 to June 30, 1947	
B. A. Williams	Jan. 20, 1947 to June 30, 1947	
W. P. Rothwell	Jan. 20, 1947 to June 30, 1947	
M. R. Fisher	Feb. 24, 1947 to June 30, 1947	
Walter Hofmann	June 26, 1947 to June 30, 1947	

A. J. Lawler was district clerk.

Indianapolis, Ind. - The States of Indiana and Michigan continued to comprise the Indianapolis district. H. E. Grosbach was succeeded by D. M. Corbett as district engineer, September 14, 1941, and thereafter, under the unique State cooperative set-up[12/] in both States, the district engineer represented both the Surface Water and the Ground Water divisions.

12/ p. 48 and p. 51.

To carry out the administrative duties of both divisions in each State, Mr. Corbett set up an administrative office in the Indianapolis headquarters which handled matters of cooperation, personnel, finances, and equipment inventories. The engineer in charge of each technical project was held responsible for the work of that project and, what was equally important, for keeping within the budget for his project. In addition to ground-water investigations in each state assigned to ground-water personnel, and the surface water investigations in each state assigned to surface-water personnel, the lake level work in Indiana was assigned to J. I. Perrey and the responsibility for the stream-gaging records in Indiana assigned to M. A. Benson, who succeeded L. R. Sawyer August 15, 1946. Also, toward the end of the period, the position of district hydrologist was created for the purpose of making special interpretative reports of the stream flow data for the State Highway Department, including flood frequencies, and base flow of streams needed in the ground-water investigations. Toward the end of the period, the Highway Departments of both States, perhaps as a result of Tate Dalrymple's work on flood discharges through bridge openings from 1943 to 1947, began to furnish the Survey preliminary bridge plans at proposed sites, and the Survey made reports on the hydraulic factors involved. These reports contained flood data including frequencies, area, velocity, stage, discharge, and curves, and where a gaging station was near at hand, a cross section at the proposed site showing the .8 depth velocities as having a bearing on possible erosion. L. W. Furness was acting in this position following Mr. Dalrymple's detail to the district.

For the Michigan surface water investigations, the principal office was in Lansing, one sub-office was at Houghton in the upper peninsula, and another sub-office was at Grayling in the northern part of the lower peninsula. Each Michigan office computed its own records and sent them direct to Washington, and if necessary, battled with the Washington reviewers over the results. A. D. Ash in charge of the Lansing office was the district engineer's representative in the state and also coordinated the technical work of the Surface Water Division in the state.

The increasing need for stream-flow records in both states as shown by the great expansion of State cooperation, resulted in an increase in gaging stations from 68 to 180, and to the establishment of staff gages on 190 lakes. The problem of the lake level control in both states required new studies by the Survey.

The increasing importance of water, particularly in the middle west, was reflected by the publication in the Saturday Evening Post[125] of an article entitled "Will There Be Enough Water?"

125/ May 27, 1944 pp. 28-29.

The author of that article refers to the Survey as "a steady old-fashioned agency which all these years has plugged along without the aid of a public relations division." Mr. Corbett was quoted in the article, and a picture of a bridge measurement by means of a reel and crane was included: The writer of the article, after describing the Survey's work, added:

> So the chap you may see dangling from a cable over some river, intent on the movement of a queer device immersed below him, or the lad on a bridge, earphones in place and manipulating an out-landish gadget in the current, may be getting an answer. What those delicate instruments tell about the quantity of moving water added to what is known about the detail of local geological structures, can mean either the green light or the warning signal for specific factories whose very life blood today is water.

Indiana. - At the beginning of the period, there were 38 stations, 35 equipped with recorders. During the first half of the period, additional Army Engineer cooperation increased the number of stations by 13, of which half were installed the first year. With the increased State cooperation beginning in the 1943 fiscal year, 11 stations were established that year. At the end of the period, as a result of increased State and Army Engineer cooperation, the latter covering 27 stations, there were 87 stations in operation, 43 being equipped with recorders. In addition, there were 105 lake stations equipped with staff gages. At the lake stations, several measurements of the outflow were made at different seasons each year.

Many of Indiana's lakes had become recreational centers and conflicts had arisen between the lake shore residents who desired high lake levels, and the agricultural interests who objected to high levels which interfered with the drainage of the lands bordering the lakes. Legislation enacted in 1935 had provided means whereby 20 percent of the land owners could petition the State courts and have a lake level raised and maintained by means of a dam, the level not exceeding the natural high water.

In 1945, the Department of Conservation was authorized to establish the water levels of all lakes, and construct or supervise construction of all spillways and control works necessary to maintain such levels. The new authorization for the cooperating State agency made it necessary for the Survey to establish staff gages on 80 additional lakes, in order that with 25 gages established previously, records of the more important lakes could be obtained. It was also necessary to determine the normal level, and the highwater marks and, if possible, the highest point to which the lake had risen during the past 10 years. The latter was difficult to obtain accurately, being based on statements of local residents. Not only the maximum elevations were required but the flood flows into the lake and their effect on the lake levels were studied. The problem in designing the dams, which was that of the State agency, was to keep the average level of the lake at the elevation established by the Department of Conservation, and not allow the maximum level to be more than 1.5 feet higher. An additional investigation to give a more complete picture of the lake control problem was the observation of temperatures to determine the seasonal variations from the surface to the bottom of about 25 lakes. This information was of value to the State and Federal Fish and Wildlife Services.

Indiana streams are subject to severe floods and for emergency flood measurements, four power-operated cranes were obtained from the Columbus Office for use with 150-pound weights. The floods of March and May 1943 afforded an opportunity for extensive flood measurements. Rising-, crest-, and falling-stage measurements were made at more than 50 stations. Those measurements were made by 20 Survey field parties brought in from Michigan, Illinois, Kentucky, and Ohio, and 3 parties furnished by the Army Engineers. Many miscellaneous measurements had been made through contracted bridge openings and Tate Dalrymple was detailed to Indianapolis for three months primarily for those computations. Later in the summer, M. A. Benson of the Boston District and L. W. Furness of the Hartford District were detailed to assist Mr. Dalrymple and Mr. Sawyer.

At flood stages, there are frequently wide overflow areas, that on the Wabash River at Riverton reach a total width of about 4 1/2 miles. At that station, the highest stages are measured in the five openings of the railroad bridge. Realizing the risk of making flood measurements from railroad bridges, two engineers after measuring the Riverton station in May 1943, tied themselves together while walking on the ties over a washed-out section of railroad fill. One fell through and nearly dragged his companion with him; fortunately, the latter recovered himself and then dragged out his companion. The only casualty was the loss of the notes for the flood measurement made previously.

At some stations, it was necessary to make flood measurements from boats, and during one measurement of the Vernon Fork of Muscatatuck River at Butlerville made in March 1943, the Survey motor boat containing L. R. Sawyer and I. A. Heckmiller was forced against a tree by the swift current, and was so badly damaged that it sank. The engineers fortunately were equipped with life jackets and managed to reach the bank, 150 feet distant; the equipment was lost but later recovered.

Indiana claims the credit for being the first state in which a measurement was made by a woman employee; Elizabeth Hurst, an engineering aid, made a supervised wading measurement on November 19, 1942; in 1944, Loraine Pomp, also an engineering aid, made several wading measurements unsupervised and unassisted.

Toward the end of the period, the State Department of Health became more interested in stream flow records in connection with its pollution investigations, and frequently when that agency took river samples at points remote from a gaging station, the Survey would make a miscellaneous measurement at that point at the same time. Because of contamination of water supplies during floods, the Department of Health was anxious to obtain flood warnings, and the Survey was equipped to help with such warnings. The field men would telephone flood data to the district office, frequently at night, and the information would be relayed to the Department of Health the next morning. Because of this up-to-the minute flood information, the Weather Bureau would check with the Survey before issuing its flood warnings. That was particularly important on the Wabash River, where the conditions of the levees along that stream determined to a considerable extent the flood crests to be expected; such information was frequently furnished by the field men.

Michigan. - During the period, the number of gaging stations was increased from 30 with 17 recorders, to 93 with 52 recorders. That number included 16 stations in the Seney Refuge in northern Michigan, transferred to the Indianapolis district in the fall of 1941, but promptly reduced to 6 through the action of the Fish and Wildlife Service. In addition, there were 85 stations on lakes, at the outlets of which several discharge measurements were made at different seasons each year. The first substantial increase came in the 1942 fiscal year with the establishment of 21 stations as a result of the greatly enlarged State cooperation at that time and each of the last four years saw substantial increases in the number of stations. At the very end of the period, 7 stations were established for the U.S. Public Health Service near the mouth of streams flowing into Lake Superior. That agency was making a pollution study of the boundary waters for the International Joint Commission.

Michigan with its 11,000 lakes of all sizes, many of which are recreation centers, has a similar problem of lake level control to that in Indiana, and is attacking it along the same lines. In that connection, 95 lake stations equipped with staff gages were installed. Whenever the control of a lake level was being considered, the State called on the Survey, not only for the existing records of stage, but for an estimate of the maximum flood to be expected at the outlet. That required a study of flood frequencies ranging from 5 to 50 years, and perhaps a map of the lake to determine its capacity. The State officials would first hold a meeting with the lake association to discuss the problem, and Mr. Ash at the request of the State would occasionally be present as an advisor to furnish available information. There were frequent conflicts between resort owners on the lakes, and power companies operating on the streams, and the Survey's records aided the State in maintaining friendly relations with both.

Severe floods in the southern part of the State occurred during the last 3 years of the period, the 1947 floods being the worst. During that year, there were 12 parties, including 7 sent up from Indiana, making flood measurements. As a result of that intensive field work, the rating curves were well defined up to the crest stages. The floods were perhaps most severe on the Saginaw River, and after the 1947 flood, a report covering major floods in that basin from 1873 to 1947, with special reference to the latter flood was prepared. It contained a study of flood frequencies. As a result of the frequent floods, flood hydrographs giving flood stages and discharges, from which the base flow was deducted, were prepared for each of the 40 or more stations in the southern part of the state.

In connection with the Ground Water Division's investigation in the Iron River area,[126] 7 sets of 11 measurements each along Iron River were made to determine the seepage loss to the glacial drift through which the river flows.

126/ p. 289.

In addition to the district engineer, the Indianapolis District had the following Civil Service engineering personnel:

Name	Period	Military Furlough
J. I. Perrey	July 1, 1939 to June 30, 1947	Aug. 28,1940 to Dec. 23,1
L. E. Widman	July 1, 1939 to June 30, 1947	
I. A. Heckmiller	July 1, 1939 to Sept. 3, 1944	
J. C. Merrell, Jr.	July 1, 1939 to Jan. 19, 1944	
V. M. Mann	Sept. 6, 1939 to Mar. 22, 1946	Sep. 11,1942 to Jan. 25,1946
S. W. Wiitala	Oct. 1, 1940 to Aug. 12, 1946	May 21,1945 to Mar. 1,1946
A. D. Ash	Oct. 1, 1941 to June 30, 1947	
Max Noecker	Jan. 5, 1942 to June 30, 1947	
L. R. Sawyer	Feb. 20,1942 to Dec. 20, 1946	
A. Homyk, Jr.	Mar. 14,1942 to June 30, 1947	Jan. 29,1943 to Oct. 2,1945
W. L. Isherwood, Jr.	Apr. 1, 1942 to May, 1944	
J. D. McCoy	Aug. 7, 1942 to Nov. 19, 1943	
Mrs. E. H. Widman	Oct. 12, 1942 to Feb. 28, 1946	Deceased
R. L. Gibson	Dec. 21, 1942 to Aug. 4, 1944	
M. A. Benson	Oct. 7, 1942 to June 30, 1947	
G. E. Stanton	Apr. 16, 1944 to June 30, 1947	
L. W. Furness	May 4, 1944 to June 30, 1947	
L. W. Carrico	Aug. 1, 1944 to June 30, 1947	
L. Pomp	Aug. 7, 1944 to June 30,1947	
S. B. Koks	Sep. 19, 1944 to June 30,1947	
W. B. Reid	Dec. 1, 1944 to June 30,1947	
D. Pettingill	Apr. 1, 1945 to June 30, 1947	
T. E. Robertson	Apr. 30, 1945 to June 30, 1947	
J. D. Goshorn	Jan. 14, 1946 to June 30, 1947	
C. L. Alderson	Feb. 28, 1946 to June 30,1947	
D. J. King	Aug. 26, 1946 to June 30,1947	
B. F. Cooper	Sept. 9, 1946 to June 30, 1947	
C. W. Paris	Sept. 16, 1946 to Feb. 12, 1947	
J. E. King	Sept. 23, 1946 to June 30, 1947	
M. S. Skamser	Sept. 23, 1946 to June 30, 1947	
M. P. Mahey	Nov. 4, 1946 to June 30, 1947	
H. L. Hoffman	Nov. 12, 1946 to June 30, 1947	
E. R. Buxton, Jr.	Mar. 3, 1947 to June 30, 1947	
N. R. Rasmussen	Apr. 28, 1947 to June 30, 1947	

Urbana, Ill.-The period was a busy one for the Urbana District, and the number of stations was increased from 41 with 23 recorders in 1939, to 111 with 63 recorders, in 1947. Most of the increase occurred during the first 15 months when 41 stations were established. Two expanding programs were responsible; one the State-cooperative program with additional funds available, and the other, the Army Engineer program of flood-control, speeded up by the disastrous floods in the Mississippi and Ohio Rivers during the previous period. Seven construction parties were in the field for four months, and from one to four crews during the remainder of the year. The structures were about evenly divided between reinforced concrete, and 42-inch galvanized corrugated iron pipe. Subsequent construction was chiefly of the latter type, as those wells can be salvaged if the site is abandoned and the diameter was increased to 48-inches in order, as J. H. Morgan writes,[127] that

127/ Letter to author.

broad men canget through the trap door easily. Further expansion was seriously curtailed by the war, and after the war, shortages in materials and labor kept down the program.

For more efficient operation of the gaging stations, a sub-office was established September 4, 1942, at Davenport, Iowa, for stations in the northwestern part of Illinois, and another was established May 1, 1946, at St. Louis for stations in southern Illinois.

Wide-spread floods in May 1943 made it necessary to devote considerable time to their investigation. The floods were most severe in the central part of the state; all records were broken on the lower Illinois River and its eastern tributaries and also the Kaskaskia River. They were caused by a series of showers between May 6 and 21, which finally saturated the ground until the floods resulted. With the many gaging stations in operation, it was possible to obtain more data than for any previous flood in Illinois. That was in large part due to the arrangement with the Weather Bureau whereby the latter notified the Survey not only when rain occurred but also furnished forecasts of probable flood periods. In addition to the district's 3 field parties, 3 parties were furnished by the Louisville District, and several Army Engineer offices furnished parties, which worked under Survery supervision. As a result, 244 meter measurements were made at gaging stations, of which 47 were made by the Army Engineers. With the subsidence of the floods and less work at the gaging stations; computations of the peak flows were made at 29 points having no stations; 8 by slope-area, 15 at contracted openings, and 6 over dams. The Urbana personnel was in the field almost continuously for three weeks, working at night when critical stages required it. The resulting report containing the rainfall analysis by the Weather Bureau, records of stage at Army Engineer stage stations on the Mississippi, Illinois and Wabash Rivers, and elevations of flood crests for determining flood profiles, furnished by that agency, and a description of the effect on ground-water elevations and the description of sand boils by the Illinois State Water Survey which conducts the State's ground-water investigations, was published by the Department of Public Works and Buildings.[128]

128/ The floods of May 1943, in Illinois.

In recent years, studies of flood runoff have been increasingly concerned with the direct runoff caused by the excess precipitation, and expressed by means of the unit hydrograph. With State funds increased for that purpose,[129] a statewide study of unit hydrographs was

129/ p. 49.

startedon July 1, 1945, under the technical supervision of W. D. Mitchell. As 5,000 square miles were considered the upper limit of a drainage area suitable for such study, stations having greater areas were eliminated from the more than 100 gaging stations, as were those on streams having controlled flow. As a result, their remained 58 stations for which unit hydrographs were computed. Exhaustive studies of available precipitation records were made by various methods, also of infiltration used in its broadest sense, to separate the precipitation excess from the total precipitation. In addition, search was made to determine flows other than those caused by the base storm. For each of the 31 basins in which the 58 stations were grouped, there were presented the maximum recorded discharge for each gaging station, precipitation data, unit hydrographs, distribution graphs, ground-water depletion curves, and a comparison between observed and computed hydrographs. The project continued beyond the present period and was completed in May 1948, with the publication by the State of "Unit hydrographs in Illinois."

Although funds were available during the 1947 fiscal year for the small-streams program, difficulty in obtaining both materials and labor prevented any of the stations being installed that year. The construction funds did not lapse; however, as advance payment had been made by the State Division of Waterways.

With funds available for research in the 1947 fiscal year, a study of the backwater profile for steady flow in prismatic channels which had been started by W. D. Mitchell and E. G. Barron as a thesis for a masters' degree, was continued as an official project.130/

130/ p. 97.

During the last year of the period, an office study was started under the title of "draft-storage project." The scope of the project as first conceived was the bringing down to date of the flow-duration curves which had been published in the Transactions of the American Geophysical Union for 1936. But as frequently happens, the scope was broadened as the so-called "pilot studies" were made and procedures developed. By the end of the period, certain draft-storage data and curves, somewhat similar to that in "Flood data and draft-storage curves for major streams, 1929-1937," Publication 28, of the Maryland State planning Commission were added, as were the procedures outlined in the Survey's "Instructions for unit-storage curves, July 1946." Only the pilot studies had been completed by the end of the period.

To make the special studies during the last two years, a special studies unit was set up under the general supervision of the district engineer and the technical supervision of Mr. Mitchell. Referring to those studies which were actually in the field of the Water Utilization Division, Mr. Morgan writes: 131/

131/ Letter to author.

> Our special studies unit has remained under the Surface Water Division, although the Water Utilization Division reviewed its work and took part in its deliberations with our State cooperating parties. The arrangement has been very harmonious and helpful.

J. H. Morgan continued as district engineer and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
W. D. Mitchell	7/ 1/39 to 6/30/47	
J. H. Montgomery	7/ 1/39 to 6/30/47	
Myer Kramsky	7/ 1/39 to 6/ 6/46,	2/ 1/41 to 3/ 6/46
E. G. Barron	7/24/39 to 4/ 9/47	
Alfonso Wilson	9/ 9/39 to 6/30/47	7/27/42 to 1/22/46
J. R. Stipp	9/18/39 to 6/30/47	2/19/42 to 3/25/46

R. A. Stirni	10/ 2/39 to 1/ 1/40		
K. I. Darmer	12/11/39 to 4/ 5/40		
L. E. Bidwell	12/13/39 to 10/20/41		
C. E. Dahlstrom	1/22/40 to 7/ 5/40		
H. A. Weggel	8/ 2/40 to 3/12/41		
E. W. Beckman	4/ 1/41 to 6/30/47		
G. R. Beare	4/16/41 to 5/ 7/42		
W. E. Gustafson	5/19/41 to 2/16/42		
H. F. Kroenig	7/21/41 to 6/30/47		4/22/43 to 4/15/46
Irving Joseph	8/ 4/41 to 2/11/43	1/	
O. E. Barteldes	11/ 3/41 to 8/31/43	1/	
R. A. Croninger	5/25/42 to 5/18/43	1/	Killed in action.
K. M. Ogata	10/15/42 to 6/30/47		
R. A. Kroenig	12/ 7/42 to 7/23/43		
Stella Tatlock	12/28/42 to 6/19/45		
J. M. Busalacchi	10/13/43 to 6/30/47		
L. H. Hansen	5/30/44 to 6/30/47		
T. E. Anderson	5/ 1/45 to 6/30/47		
Marjory Bean	6/12/45 to 3/31/47		
W. J. Pusso	10/22/45 to 6/30/47		
J. G. Roberts	10/22/45 to 6/30/47		
Sarah Witherspoon	10/29/45 to 6/30/47		
R. M. Stauffer	2/12/46 to 8/ 2/46		
F. R. Walsh	5/14/46 to 6/30/47		
W. V. Bates	7/15/46 to 6/30/47		
C. C. Huffer	7/23/46 to 6/30/47		
C. D. Moore	10/21/46 to 6/30/47		

1/ Military furlough; did not return to district.

Miss Rosemary Woodworth was district clerk until March 15, 1943 when she was succeeded by Mrs. Dora Clifford.

Madison, Wisc.- At the beginning of the period, there were 89 river stations, of which 73 were in Wisconsin and 16 in northern Michigan in the Seney Refuge of the Biological Survey. The Michigan stations were transferred to the Indianapolis District in the fall of 1941. Added interest in Wisconsin streams by the Army Engineers resulted in an increase in Army Engineer stations from 9 to 31, chiefly in the fiscal years 1943 and 1944. At the end of the period, there were 94 river stations, of which 48 were equipped with recorders. In addition, there were 28 lake stations, 27 equipped with staff gages, and 1 with a recorder, at which records of stage were maintained. Power regulation was so wide-spread that records for 23 stations were computed by means of the integrator. The development of dams on a number of streams had reached the point by the end of the period that it was difficult to find gaging-station sites with sufficient fall to afford free control.

Working closely with the Public Service Commission and largely for its use, the procedure of keeping up duration curves and tables for each station, which was started in the previous period, was continued; revisions were madeevery two years. The Public Service Commission in connection with its responsibility for approving plans for dams, would request unit hydrographs on which to base the proper gate- and spillway-capacity. About 1942, with the increased interest of the Army Engineers in Wisconsin Floods, the procedure of preparing station lists showing the maximum flood recorded at each station, the runoff per square mile, and the percentage on the Myers scale of flood values, was started. The lists were brought down to date each year and sent, together with the duration tables, to the Public Service Commission, Army Engineers, consulting engineers, and power companies in the state. When the author asked if it was necessary to revise the flood list each year, he was informed that it was, as each year showed a larger flood recorded at some station. The State Highway Commission plotted the Myers scale percentages on maps and sent the maps to its division engineers for use in designing waterway openings.

The many power plants on the streams were of very considerable help in computing gaging station records during ice periods. Comparisons during the open season between flow and kilowatt-hour records of nearby streams showed close agreement and as a result, the kilowatt-hour records were used as a basis to determing the discharge during the ice periods.

There was a widely held view in the state that the low flows of the streams was decreasing and the high flows increasing, due to changes in land uses. To show the falsity of that view, Mr. Christopherson in 1947 made a statistical study of three streams, nearly free from regulation and having no storage. By means of mass diagrams, it was shown that there had been no significant change in the runoff distribution during the 31 years of record. That study was circulated among water users, and others throughout the state.

F. C. Christopherson continued as district engineer and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
C. C. Yonker	7/ 1/39 to 10/ 3/40	
R. H. Brigham	7/ 1/39 to 6/30/47	
M. S. Sachs	7/ 1/39 to 2/17/42	
D. C. Hurtgen	7/ 1/39 to 6/30/47	2/ 4/42 to 1/21/46
J. H. O'Keefe	7/ 1/39 to 9/10/42	
L. L. Bidwell	10/21/41 to 11/ 20/46	
D. L. Miller	8/22/42 to 6/30/47	
K. S. Brigham	2/13/42 to 6/30/47	
W. M. Shimasaki	6/17/44 to 7/28/45 1/	
LaVergne Becker	8/ 7/44 to 6/30/47	

1/ Military furlough; did not return to district.

Miss Helen E. Cunningham was district clerk until December 20, 1946, and was succeeded by Mrs. Marion L. Mather.

St. Paul, Minn. -At the beginning of the period, the St. Paul District comprised the state of Minnesota, the Hudson Bay Drainage in North Dakota, 2 stations in Iowa, a station in South Dakota, and 2 Mississippi River stations in Wisconsin; a total of 85 river stations and 239 lake stations, at which stage only was recorded. The Iowa stations were transferred to the Iowa City District soon afterward, and when the Bismarck District was created in October 1944, the 23 stations in North Dakota were transferred to it. That left the Minnesota stations and 2 each in South Dakota and Wisconsin. In 1940, the Thief River Falls sub-office was moved to Grand Forks but was discontinued in October 1944.

During the period, the State's program on controlling the lake levels was so far advanced that records of stage were no longer needed, and all but 33 lake stations were dropped. The number of river stations was increased to 114. The greater part of that increase was due to the expansion of the Army Engineers' program from 11 to 51, reaching a maximum of 60 in 1945. Of the increase, 10 were stations at which the Army Engineers furnished the records and the Survey made check measurements. The drought years of the previous period had been succeeded by a series of wet years, during which major floods occurred on almost every stream, especially in the Red River Valley. Cooperation with the Iron Range Rehabilitation Commission resulted in 5 additional stations in 1942 and war work for the

Army Engineers accounted for 3 stations; State and miscellaneous cooperation accounted for the remainder. The Gopher Ordnance Works near Rosemont was a smokeless powder plant; the acid wastes from which were dumped into the Vermilion River, and the Survey operated 3 stations along the river to determine the degree of stream pollution. To' exclude all animals and persons, and to avoid possible illness from the wastes, the right-of-way along the river was purchased by the Ordnance Works and surrounded by a high fence for a distance of several miles downstream.

Owing to their isolation, 2 international stations were visited regularly by airplane. The Basswood station near Winton was visited by a plane which landed on a nearby lake surface in summer, and the lake ice in winter. The plane was obtained at Ely 20 miles distant, and by its use, the station was visited in half a day, instead of the two days required for a boat trip. On one or two occasions during the winter when a plane was not available, it was possible to reach the station by driving to it on the ice. Once a snowmobile was used after a blizzard and before the snow froze, and that required nearly as much pushing as driving. The return however was easily made in the evening after a solid crust had formed. The other station was the Namikan River at the outlet of Lac La Croix, an international station operated by Canada, at which the Survey made check measurements. Under regulations governing commercial flights, an American plane could not cross the International boundry, and it was necessary to land on the American side and take a boat to the station about 3 miles downstream. By the use of the plane, the visit tothe station was made in half a day. Without a plane, it was necessary to hire a boat, which was equipped by the Survey with an outboard motor, field men carrying such motors as a part of their field equipment. There were two ways to reach the station by boat, the short way involving the 4 1/2 miles Dawson portage over the old Dawson trail, and now mechanized by means of trucks, with boat trailers which can be let down into the water surface; the longer way involved two shorter portages, Loon Lake and Beatty portages, where on a little track, a car for the boats was pulled to the top by means of a winch, operated by an old Model T Engine, and then coasted down the other side. Either route required about 1 1/2 days for the roundtrip. The Namikan station is a key station in the regulation of the Namikan chain of lakes and the Rainy Lake levels by the International Joint Commission. It is equipped with a 2-way radio by means of which the International Engineering Board is notified of the discharge. It may be added that loggers in that area are authorized to use the radio, and by that means, information regarding the spring break-up becomes available.

During the period, most of the stations established had corrugated iron pipe wells with small recorder shelters. Where severe ice conditions might destroy the pipe wells or floods that might overtop the economical height for the shelters, a few concrete structures were used. Water-stage recorders subject to overtopping were equipped with submersion covers.[132]

132/ p. 208, (1928-1939).

As a corollary to the many lake records, it may be added that because certain lake names were duplicated or triplicated, there was frequently an uncertainty as to which lake was meant when requests were received for the records of stage.

A farmer's cupidity for a guy wire on an A-frame had disagreeable results for one engineer. The engineer was just starting down the incline from the A-frame on the Minnesota River near Carver when the A-frame fell and threw him into the flooded river. Fortunately, he was able to reach shore some 2 miles downstream but had to walk back to the nearest house in a 10-above temperature. When the house was reached, an ubiquitous dog started to chase him away until the farmer came to the rescue.

P. R. Speer was district engineer during the period and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
K. B. Nelson	7/ 1/39 to 10/31/44	
B. R. Colby	7/ 1/39 to 5/15/40	
O. H. Jeffers	7/ 1/39 to 10/26/40	
C. H. Prior	7/ 1/39 to 6/30/47	
A. V. Leppanen	7/ 1/39 to 9/30/40	
J. C. Merrell, Jr.	7/ 1/39 to 1/31/41	
R. E. Oltman	7/ 1/39 to 4/ 3/46	4/13/43 to 1/15/46
M. O. Schmidt	11/22/39 to 9/30/40	
J. C. Berkenbosch	8/29/40 to 8/21/42	
J. B. Shjeflo	11/30/40 to 9/18/43	
E. B. Stevenson	10/ 1/40 to 11/ 2/45	
F. W. Thorstenson	11/19/40 to 9/ 4/45	
E. J. Carlson	5/12/41 to 12/29/41 1/	
C. E. Dalstrom	6/12/41 to 5/ 8/42	
R. E. Myers	2/ 3/41 to 12/ 6/43	
E. H. Bekkedahl	6/18/42 to 6/30/47	
N. E. Henning	5/27/42 to 1/28/43	
D. S. Spielmann	4/13/42 to 2/ 1/43	
D. A. Barton	10/27/42 to 4/11/44	
G. A. Haven	9/23/42 to 2/ 6/43	
J. E. Johnson	12/22/42 to 6/30/47	
C. H. D. Pihlstrom	1/ 1/43 to 10/21/45	
J. O. Rostvedt	7/ 1/43 to 6/30/47	
L. C. Guetzkow	1/25/45 to 6/30/47	
H. A. Sandven	2/16/45 to 9/28/45	
G. C. Froney	9/27/45 to 6/30/47	
J. H. Hess	11/18/45 to 6/30/47	
D. B. Anderson	1/10/46 to 6/30/47	
R. E. Leskela	4/ 1/46 to 6/30/47	

1/Military furlough; did not return to district.

M. P. Hullsiek was the district clerk.

Iowa City, Iowa. -At the beginning of the period, 69 stations were in operation, of which 10 were in bordering states along the Mississippi River. The studies of the Army Engineers for flood control projects started inthe previous period and expanded in the present period, required additional streamflow data, and 16 stations were established in 1940. These gaging stations on the rivers and streams of Iowa were so essential to the flood studies and related problems that the Army Engineers participated in some degree in the maintenance of 50 to 56 stations, the financial support being of the order of about one third of the total funds available in the period. In 1942, L. C. Crawford decided that the Survey districts in which the out-of-state stations were actually located should operate them and the operation of those stations was transferred to the respective adjacent districts.

Stations were established fromtime to time during the remainder of the period, increasing the total number to 82, of which about 50 were equipped and operated most of the time with water-stage recorders. Included in the 82 stations were 10 regular lake stations which were maintained in cooperation with the State Conservation Commission. In order to obtain more satisfactory records, water-stage recorders were placed on two of the important large natural lakes and one on the first artificial lake constructed by the

Conservation Commission. During the period, 10 reinforced concrete wells and houses and 6 miscellaneous types of pipe wells were installed.

As a part of the State program, the district office prepared 2 special bulletins which were published by the Iowa Geological Survey.133/

133/ Water Supply Bulletin No. 1: Summaries of Yearly and Flood Flow Relating to Iowa Streams, 1873-1940.
Water Supply Bulletin No. 2: Surface Water Resources of Iowa for the Period October 1, 1940 to September 30, 1942, 1944.

The network of gaging stations operated and maintained by the Survey in cooperation with other agencies was utilized by the Weather Bureau for flood warning and forecasting throughout the State, thus eliminating duplication of effort and river records.

During the period, the district inaugurated a unique feature in the cooperative program, which was the collection and computation of concurrent records of water and suspended sediment discharge at 4 stations where water temperature and quality of water data were also obtained. That work, so far as practicable, was integrated with the needs of investigations of the several Army Engineer districts and other Federal and State Agencies.

The computation of sediment discharge was a corollary to the joint sediment investigation which was carried on under the auspices of the Army Engineers and the Survey in cooperation with the Iowa Institute of Hydraulic Research and 5 other Federal agencies.134/

134/ p. 367 - 371.

Floods in 1944 and 1947, particularly the latter, were of a record-breaking character at a large number of the gaging stations, the records for some of which extended back to the 1903 floods. The widespread flood conditions afforded the first real opportunity to make actual current-meter measurements of high water and check the ratings developed at some stations in the early formative years of measurement work by the Survey. The author was curious to learn how the older ratings stood the test of modern equipment and methods, and was informed that some comparisons were not so good and others good, with the work of Albion Davis and C. Herlofson in the period of 1915-18 deserving special commendation for the preservation of important data under great handicap. These men worked with R. H. Bolster, a one-time member of the Survey, who held a per-diem appointment at that time and operated certain stations in conjunction with the activities of the Mississippi River Power Company in Keokik.

As a result of Mr. Crawford's cooperative activities with State agencies he was appointed by the Governor as the representative of the Engineers on the Iowa Post-War Rehabilitation Committee; later, as one of three delegates to represent the State on the Upper Mississippi Water Use Council; still later, a member of three special committees to report to the Governor on the Little Sioux, Coralville, and Chariton River projects of the War Department in Iowa.

R. G. Kasel continued as district engineer until transferred to Washington as Chief of the Surface Water Division, April 24, 1940, when he was succeeded by L. C. Crawford. Civil Service engineering assistants were:

Name	Period	Military Furlough
W. I. Travis	7/ 1/39 to 6/26/43	
R. W. Revell	7/ 1/39 to 9/20/41	
V. A. Koelzer	7/ 1/39 to 11/12/40	
G. L. Whitaker	7/ 1/39 to 1/28/44	
B. H. Randolph, Jr	10/23/39 to 8/28/40 1/	
J. B. Cox	11/ 1/39 to 5/24/47	9/17/42 to 7/31/45

Name	Period	Military Furlough
W. A. Shaw	7/18/40 to 1/17/41	
L. J. Snell	9/16/40 to 2/ 5/43 1/	
H. H. Biendarra	10/ 1/40 to 1/26/46	
C. F. Lindholm	6/ 1/41 to 6/30/47	12/ 3/42 to 12/17/45
P. C. Benedict	6/17/41 to 3/ 4/46	
H. D. Brice	7/ 1/41 to 11/21/41	
Samuel Mummy, Jr.	12/ 1/41 to 6/30/47	
R. E. Whiteman	4/ 1/43 to 6/30/47	
R. E. Myers	12/ 6/43 to 6/30/47	
R. O. R. Martin	2/17/44 to 4/ 2/46	
B. R. Colby	2/ 6/45 to 3/21/46	
H. H. Schwob	1/28/46 to 6/30/47	2/11/42 to 4/ 3/46
R. D. Schmickle	3/18/46 to 1/30/47	
B. C. Colby	8/12/46 to 6/30/47	

1/ Military furlough; did not return to district.

Miss Claire E. Putz was district clerk from November 2, 1942 to June 30, 1947.

Rolla, Mo.-At the beginning of the period, the Rolla District consisted of the states of Missouri and South Dakota, and gaging stations on the Missouri River and tributary streams in North Dakota below Bismarck, and Missouri River stations in Nebraska and, through the St. Louis Office, stations on the Mississippi River at Alton, Ill., St. Louis and Cape Girardeau, Mo., and on the Kaskaskia River at Carlyle, Ill. Resident engineers were stationed at Bismarck, N. Dak., Mobridge, S. Dak., Pierre, S. Dak., and Sioux City, Iowa. Beginning in July 1943, measurements were made of the Missouri River at 5 day intervals and on the tributaries at less frequent intervals.

The St. Louis Office ceased to be a part of the Rolla District February 6, 1946, and with the creation of the Bismarck District in October 1944, the stations in North Dakota and South Dakota were transferred to it. These transfers and the deletion of the stations operated by the St. Louis Office reduced the number of stations from 132 in 1939 to 96 stations with 43 recorders in 1947. Although Kansas became, at lease nominally, a part of the Rolla District about November 1941, the Kansas stations are not included in the district total.

Missouri streams are subject at times to severe floods and the Army Engineers increased their cooperative stream-gaging program from 14 stations at the beginning of the period to 58 in 1947; some of the increased cooperation being concerned with existing stations in order to permit the collection of adequate records.

The Tarkio project in cooperation with the Soil Conservation Service started in March 1934,[135] was discontinued June 30, 1940, when cooperative funds were no longer available.

135/ p. 81 (1928-1939).

During 1944 and 1945, three stations on very small drainage areas were established and operated for the Missouri Conservation Commission. That agency was making a study of the possibility of substituting a large number of small reservoirs for a few of the large flood control reservoirs proposed by the Army Engineers. The study was completed in 1945 and as the Commission was no longer interested in cooperating in the maintenance of these stations, they were discontinued.[136]

136/ Letter from H. C. Beckman to author.

Resident engineers were stationed at Boonville and Rushville and in connection with the Tarkio project, an engineer was stationed at Fredericktown until October 1939.

H. C. Beckman continued in charge of the Rolla district until February 7, 1946, when he relinquished the district to devote his entire time to his duties as regional engineer for the Mississippi River Basin. H. C. Bolon became district engineer at that time. Other Civil Service engineering personnel were:

Name	Period	Military Furlough
C. J. Eyberg	7/ 1/39 to 2/10/45	
C. H. Jennings	7/ 1/39 to 6/30/43	
W. M. Littlefield	7/ 1/39 to 10/15/44	
J. W. Odell	7/ 1/39 to 10/31/39	
W. L. Doll	7/ 1/39 to 6/30/47	10/15/40 to 11/30/45
E. R. Leeson	7/ 1/39 to 9/ 7/42	
G. N. Mesnier	7/ 1/39 to 11/30/41	
J. A. Short	7/ 1/39 to 11/30/44	
J. H. Meyer	7/ 1/39 to 10/ 4/40	
K. J. Craig	7/ 1/39 to 6/14/40	
A. G. Hely	7/ 1/39 to 6/30/47	
D. S. Wilder	7/ 1/39 to 11/23/40	
J. C. Berkenbosch	7/ 1/39 to 8/29/40	
L. P. Silverman	7/26/39 to 3/10/42 1/	
W. M. Pierce	11/20/39 to 3/ 3/42	
A. L. Post	12/ 8/39 to 2/17/41 1/	Killed in Action
E. A. Roemer	8/23/40 to 6/30/47	
G. W. Edelen, Jr.	11/16/40 to 6/30/47	
G. N. Hackmann	4/ 1/41 to 9/25/46	6/ 3/41 to 12/28/45
K. L. Hardine, Jr.	6/ 5/41 to 3/17/43 1/	
B. H. Janda	7/15/41 to 9/ 7/46	
H. L. Schwob	1/ 3/41 to 2/11/42 1/	
W. G. Stephan	3/ 3/41 to 11/ 2/45	
H. R. Stockton	10/ 1/41 to 8/20/42 1/	
D. L. Trisch	10/20/41 to 2/24/43 1/	
F. E. Singleton	2/21/41 to 11/ 9/44	
K. F. Livingston	11/ 6/41 to 1/27/43	
C. R. Trotter	4/27/42 to 4/16/43	
J. R. Snowden	6/ 8/42 to 9/ 5/44	
W. L. Andrews	3/ 1/43 to 6/30/47	
E. H. Sandhaus	8/ 9/43 to 6/30/47	
G. B. Riddle	9/15/43 to 6/30/47	
H. E. Moore	3/ 2/45 to 6/30/47	
J. P. Hale, Jr	5/16/45 to 6/30/47	
G. A. Delashmit	1/15/46 to 6/30/47	
M. A. Wilkinson	1/22/46 to 9/20/46	
A. L. Reed	6/ 5/46 to 6/30/47	
W. E. Willeford	3/25/46 to 6/30/47	

1/ Military furlough; did not return to district.

Mrs. M. T. Ramsey was district clerk until September 10, 1942, Mrs. T. L. Millar from Sept 11, 1942 to January 6, 1944, and Mrs. V. B. Curtis during the remainder of the period.

St. Louis, Mo. - The functions of the St. Louis Office continued virtually unchanged during the period. Of the 4 stations maintained at the beginning of the period, the stations in the Mississippi River at Alton, Ill. and St. Louis were continued; the station on the Kaskasia River was transferred to the Urbana District in 1943 as that district was operating other stations on that stream, and the station on the Mississippi River at Cape Grareau, Mo. was superceded in 1941 by a station at Thebes, Ill., which was nearer the mouth of the Ohio River and measured the entire flow of the Mississippi River at that point. In 1942, at the request of the Army Engineers, a station was established on the Mississippi River at Chester, Ill. The solution of a difficult problem at the Thebes station warrants a detailed account.

The Mississippi River Commission had long required the Army Engineers to obtain daily discharge measurements at Thebes whenever the Cairo gage at the mouth of the Ohio River showed stages above 40 feet, and those measurements had been made by the Army Engineers from a launch which required a party of 5 or more. To reduce that relatively heavy expense, the Survey was requested in 1941 to consider the feasibility of installing a cable at Thebes and using that point as a gaging station. R. D. Schmickle made a study of the situation and found that a cable installation would require a span of about 3,000 feet, and to keep it to the required clearance for navigation, one tower would be 165 feet high and the other, 30 feet high; the estimated cost was $32,000. As that was prohibitive, the use of the double track railroad bridge at Thebes was considered. There was insufficient clearance to work from the bridge. It was found, however, that the trusses were so supported on the piers as to leave space for a cable car above each pier, and that if an I-beam were installed on the under side of the bridge, a car supported by the I-beam would have a clear track of 3,400 feet. The installation of an I-beam was proposed to the Army Engineers, and was accepted by them as the best course to be followed. To get around certain red tape, the Army Engineers let the contract for the erection of the I-beam at a cost of about $10,000. The Survey equipped the special stand-up cable car with motor hoist and electric drive, and at one abutement, constructed a garage into which the car could be run. So completely equipped was the station that in Mr. Schmickle's phraseology, making measurements by one man "was stream gaging deluxe."137/

137/Water Res Bull Feb 1944 pp 14-16

As there was some backwater from the Ohio River at times, gage heights were continued at the Cape Girardeau station, which became the upper slope station for the Thebes station.

Each station except that at Alton was provided with power equipment for use with 300-pound weights; the equipment designed by the Columbus Office was somewhat different for each station to fit the particular bridge where it was used.

So important to the Army Engineers were the flood records that during floods, each station affected was measured daily, each measurement requiring about 6 hours, the Army Engineers furnishing one or more engineers when needed. At lower stages, measurements were made weekly. To train engineers in Survey methods, the Army Engineers about 1936 had started the procedure of detailing to the Survey for a six-month period, an engineer to work under the direct supervision of the engineer in charge of the office. When one detail was completed, another was started. By sodoing, trained Army Engineer personnel were available to assist when needed. Details for training were discontinued in 1946, chiefly on account of a personnel shortage.

The St. Louis Office was under the supervision of H. C. Beckman, the supervision relating chiefly to the general contact with the Army Engineers. The office was a part of the Rolla District until February 1946, after which date relations were severed, except through H. C. Beckman as regional engineer. All reports and records were transmitted directly to the Washington Office.

R. D. Schmickle was in charge of the St. Louis Office from July 1, 1939 to October 13, 1941; R. O. R. Martin from October 15, 1941 to February 15, 1944; and J. W. Odell from March 23, 1944 to June 30, 1947.

The complete list of Civil Service engineering personnel is as follows:

Name	Period
R. D. Schmickle	7/ 1/39 to 10/13/41
Milburn Hassler	7/ 1/39 to 7/15/40
J. W. Odell	11/ 1/39 to 11/28/41
R. O. R. Martin	10/15/41 to 2/15/44
	3/23/44 to 6/30/47
G. N. Mesnier	12/ 1/41 to 6/30/47
H. W. Ollar	1 / 8/45 to 6/30/47

Mrs Marie B. Perry was district clerk.

Fort Smith, Ark. - The number of stations operated by the Survey increased during the period from 59 to 85 as a result of expanded State cooperation and an increase in the number of cooperative Army Engineer stations. In addition to the Arkansas and Oklahoma stations, the Memphis station on the Mississippi River was operated by the Forth Smith District, as was one station each in Kansas and Missouri.

The activities of the district were largely concerned with establishing new stations or rehabilitating existing stations by installing recorders, chiefly in pipe wells attached to bridge piers, during the early years of the period and later, by making any flood measurements of the not infrequent floods to which the streams were subject. A large number of measurements were necessary because of the shifting channels of the streams; a large flood occurred on some streams almost every year.

Most of the stations were located near bridges from which measurements were made during high and maximum stages and fewer than a dozen cableways were utilized. At low stages, the bridge sections are generally poor, and as the streams are too deep to wade, boat measurements were made. The district had 3 boats equipped with outboard motors carried on Surveytrucks equipped with special boat carriers; with each boat was 1,500 feet of airplane strand, beaded to indicate distances, and the standard boat equipment for measurements.

For several years during the period, water temperatures were taken for industrial interests whenever discharge measurements were made. Finally, it was decided that as the seasonal variations did not change greatly from year to year, sufficient information on spot temperatures had been obtained and the practice was discontinued.

Arkansas: The increase from 21 to 35 stations was due chiefly to the increase in Army Engineer stations from 3 to 13; additional State cooperation accounted for the remainder. In addition to operating 11 Army Engineer stations, records collected by the Army Engineers at 12 other stations were reviewed and published.

During 1941, 1943 and 1945, floods on the Arkansas river were the greatest since the historic flood of 1833. The Army Engineers were particularly anxious to have the flood measurements made with the best possible equipment and in order to use 300-pound weights, the power equipment from the Memphis station was pressed into service at the Little Rock station during the October-November 1941 flood, and was brought in a truck by the Army Engineers who were cooperating in the operation of that station. Excellent measurements were made of the flood which lasted for several weeks.

During the 1943 flood, in addition to the Memphis power equipment, two engineers from the Jackson, Mississippi Office drove the Vicksburg self-propelled power equipment to the Van Buren station. As roads were flooded and bridges washed out, it was necessary to detour the last part of the journey via forest trails in the mountains.

The first flood crest occurred at Van Buren before the Vicksburg equipment arrived and in order to measure it, S. K. Jackson from the district office had to drive about 200 miles, the last 50 miles over forest trails, in order to reach the Van Buren station, 4 miles distant. He made frequent measurements for a week or so, using weights up to 200-pounds on a type-A crane; the resulting exercise was an excellent sleep inducer. A special investigation of that flood was made under the supervision of Hollister Johnson, and the results were to be published by the Survey. Again in 1945, the Army Engineers brought the Memphis equipment to Little Rock for daily measurements during the flood period. Local interest, which had been created by the 1941 flood, was raised to a higher pitch by the 1943 flood, and as the Survey had taken many flood pictures, the district personnel were called upon to talk about floods before the various Fort Smith civic clubs.

The station on the Arkansas River at Van Buren was considered the key station in the district and in addition to the discharge records, based on weekly measurements, daily sediment samples were obtained by means of a sampler kept at the bridge and daily samples for quality determination were obtained by the bottle method, the former being sent to the Army Engineers and the latter to the Quality of Water Office at Fayetteville for analysis.

A sub-office was maintained at Harrison for stations in the northern part of the state. Until March 1941, a resident engineer was maintained at Memphis for the Mississippi River station at that point, and also for stations in eastern Arkansas. The reduction in Federal funds for the Memphis station made it necessary to discontinue the residency and thereafter monthly measurements at Memphis were made by engineers from the district office. The Army Engineers made weekly measurements at Memphis by means of a boat and the records at the end of the year were computed jointly bythe Army Engineers and the Survey, beginning with the 1942 water year.

Oklahoma: During the period, the number of stations was increased from 30 to 47 with 46 recorders. The largest increase came during the first year when the State cooperative funds were increased about $5,000. In addition to the 16 stations maintained for the Army Engineers, records for 38 stations maintained by that agency itself were reviewed for publication. The Oklahoma stations, except 7 in the southeastern part of the state maintained by the Fort Smith Office, were operated by an office in Oklahoma City. That was more than a sub-office of the district, as it had complete office personnel and not only maintained the stations but also computed the records, and prepared its vouchers for transmittal to the district office.

Perhaps the outstanding characteristic of the Oklahoma streams, which are wide and shallow, is their wild behavior during the frequent floods to which they are subject. In a mean depth of 5 feet, differences of 3 feet between the peak and trough of the accompanying waves, 200 to 300 feet long, have been measured; and the velocities have been as high as 20 feet per second. A measure of the shifting beds is shown on one stream by measurements at bank full stage of 7 feet, the discharge during different floods ranging from 28,000 to 110,000 second-feet. At the Mocane station on the Cimarron River, the mainchannel is 600 feet wide between cut banks and has a flat sand bed; at low stages, a rise of 1 foot will increase the width from 50 to 500 feet. During the flood of May 4, 1944, on the Canadian River, an attempt was made to measure at the Newcastle station during the night; the channel was 1,500 feet wide, the stage 9.2 feet, the velocity about 22 feet per second, and the meter was equipped with 100-pound weight. As the surface was covered with debris, including bridge timbers, brush, and roots throughout the depth, the measurement was not an unqualified success, and the discharge was more or less estimated as 200,000 second-feet. The stage of zero flow is about 2 feet.

The flood of October 1946 on the North Canadian River had a peak discharge of some 70,000 second-feet at Beaver; about 40,000 second-feet at Woodward, 90 miles downstream; and 5,800 second-feet at El Reno, 138 miles farther downstream. Preliminary hydrographs indicated that the percentage of losses to the total volume were similar due apparently to the bank storage which did not return; it may be added that the discharge at El Reno is always less than at Woodward. The North Canadian River flows on a narrow ridge, higher than the streams on either side, and may lose water to the adjacent streams. Another characteristic of Oklahoma streams tending to reduce the accuracy of the records is the face that on a third of the streams on which stations were located, a large part of the total year's discharge might occur during a single flood.

As frequent as floods were, there were times when the streams were practically dry for long periods, a marked example of that being the drought from the fall of 1939 to the spring of 1940, during the latter part of which the stored water in Oklahoma City was reduced at one time to a month's supply and the source of the stored water was dry; timely rains then relieved that critical situation. That condition emphasized the need for continuing stream flood records. In connection with its water supply, Oklahoma City cooperated in the maintenance of two stations, one on the North Canadian River near El Reno, some distance above the city intake to its reservoirs, and the other on the canal leading to the off-stream reservoir in another drainage basin. Whenever a flood approached the El Reno station, the observer phoned the stage to the city Water Department which in turn contacted the Survey office for data on discharges. The Water Department would obtain samples of the water for analysis for hardness, as the flood might come from a portion of the drainage area where the water was heavily charged with gypsum. In that event, the flood water was by-passed; if from the non-gypsum area, it would be stored. The canal station registered the amount diverted as it was necessary that the total amount diverted during the year should not exceed the city's allocated diversion.

In the spring of 1947, the Bureau of Reclamation requested the Survey to obtain daily sediment samples at 4 gaging stations in the Washita drainage basin. A local observer took the integrated samples with a D-43 sampler and these samples were collected by an Engineer when he made a stream measurement trip through the area. After the Quality of Water Division at Stillwater analyzed the samples for percentage of sediment, the Surface Water Division, in connection with the records of discharge, computed the load in tons.

Until October 1946, the Army Engineers had stationed an engineer at Mangum to measure the Army Engineer and Survey stations in that southwest area, but when that cooperation was discontinued, the Survey stationed one of its own engineers there. Beginning in the spring of 1947, a sub-office was established at Liberal, Kansas, near the State line to operate the stations in the Panhandle (northwest Oklahoma). Another engineer was stationed in northeast Oklahoma at Vinita near the Grand River Dam during the period. These sub-offices were made necessary by the frequent measurements required. About 20 Oklahoma stations were measured weekly and the remainder at two- or three-week intervals.

J. L. Saunders continued as district engineer and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
H. G. Thomasson, Jr	7/ 1/39 to 2/16/42	
Verne Alexander	7/ 1/39 to 10/ 1/39	
L. L. Laine	7/ 1/39 to 6/30/47	
S. K. Jackson	7/ 1/39 to 6/30/47	
F. T. Schaefer	7/ 1/39 to 2/11/43 1/	
C. J. Chappel	7/ 1/39 to 3/15/40	
J. L. Patterson	7/ 1/39 to 6/30/47	5/21/42 to 1/ 2/46
A. O. Gierow	7/ 1/39 to 4/ 4/41	
F. C. Ames	9/29/39 to 6/30/47	
W. B. Sparkman	11/13/39 to 6/30/47	
R. F. McCauley	11/27/39 to 3/23/41 1/	
Jack McGowan	12/ 4/39 to 7/29/42 1/	
J. D. Pipkin	1/ 8/40 to 7/29/46	
R. G Bottoms	4/16/40 to 6/ 2/41	
H. J. Tracy	10/16/40 to 6/ 2/41 1/	
G. L. Haynes, Jr.	4/25/41 to 6/30/47	10/14/42 to 1/20/46
W. F. Dunkle	11/24/41 to 6/22/44 1/	
K. B. Schroeder	1/26/42 to 4/ 13/47	
A. J. Hanson	2/ 4/42 to 6/30/47	4/ 5/42 to 2/ 5/46
M. W. Proctor	3/21/42 to 4/ 6/43 1/	
V. L. O'Neill	4/11/42 to 6/30/47	9/11/42 to 11/ 3/45
A. C. Collins	8/ 3/42 to 6/30/47	
L. D. Reid	10/ 1/42 to 6/30/47	
F. H. Millard	2/ 4/43 to 3/22/45	
K. W. Walker	9/ 6/43 to 6/30/47	11/15/45 to 4/20/47
W. J. Murphy, Jr.	9/ 6/43 to 6/30/47	3/27/44 to 2/13/46
C. C. Rose	6/16/44 to 6/30/47	
Cecil Delp	7/ 6/44 to 11/ 1/46	
D. L. Hart	7/ 16/45 to 6/30/47	
T. M. McClain	8/13/ 45 to 6/30/47	

1/ Military furlough; did not return to district.

Bismarck, N. Dak.-On October 16, 1944, the Bismarck District, consisting of the states of North Dakota and South Dakota, was created with R. E. Marsh as district engineer. As a characteristic of the area is its wide open spaces with relatively few stations at first, a sub-office was established at Pierre, S. Dak., with W. M. Littlefield, engineer in charge, to operate the South Dakota stations. Mr. Littlefield had been in charge of the South Dakota stations when they were operated by the Rolla District. The Pierre office was virtually independent, except for major questions of policy. The only two experienced men in the district at the beginning were Messrs. Marsh and Littlefield, and with no available transfers from other districts, it was necessary to recruit personnel locally. As the important positions of clerk in each office were also filled by inexperienced personnel, the men in charge labored, at least in the beginning, under a double handicap. As the states are situated chiefly in the Missouri River Basin, it was a time of rapid expansion and during the period of less than three years, the number of gaging stations was increased from 68 to 144, one-third having recorders.

North Dakota: The first year was devoted largely to training the new personnel and becoming acquainted with the district. The real expansion began in the fiscal year and continued to the end of the period. The outstanding construction was that of the station on the Missouri River below the huge Garrison Reservoir that was being constructed by the Army Engineers. To provide for scour after the completion of the reservoir, the 4-foot concrete pipe structure having an overall height of 51 feet had its bottom 10 feet below low water. The upper 21 feet of the structure were enclosed by a reinforced 6-foot pipe for protection against possible slides. Plans were made for a cable of 1,730 feet span on steel towers 84 and 43 feet high, to be erected after the end of the period. The cost of the station was shared equally by the Army Engineers and Missouri Basin Departmental funds. The station had not been completed at the end of the period.

In June 1946, a sub-office was established at Dickinson, which was unique in its set-up. The Quality of Water Division was maintaining 9 full-time sediment stations and several part-time stations in an area in North Dakota and South Dakota, of which Dickinson was the center, and the Surface Water Division was maintaining 19 gaging stations in the same area. B. C. Colby was transferred from the Surface Water Division to that of Quality of Water, and placed in charge of the office under R. E. Marsh's supervision of stream gaging and P. C. Benedict's supervision for the quality of water work. The office force consisted of two assistants who made the discharge measurements and collected the water samples, and a chemist who made the analyses.

During the period, the total number of gaging stations in North Dakota was increased from 41 to 64, of which 22 were equipped with recorders.

<u>South Dakota:</u> The expansion of the program in South Dakota began the first year. The Bureau of Reclamation was making an intensive investigation in the southwestern part of the state and to aid that investigation, 20 stations were established on streams, and 12 stations on ditches that diverted water from Rapid Creek above and below Rapid City. A sub-office with an engineering personnel of 3 was maintained at Rapid City.

The old station on the Missouri River at Chamberlain was re-established. A little later, cooperation with the State Department of Game, Fish and Parks became effective and 12 stations were established, one above and one below the limestone outcrop of each of six streams rising in the Black Hills. Additional stations on the Belle Fourche below Moorcraft, Wyo. and Beaver Creek near Newcastle, Wyo., established by the Pierre office primarily for South Dakota interests became a part of the Missouri River Basin Departmental Program and were transferred to the Denver District.

The outstanding construction job was that of the Missouri River station, 6 miles below Fort Randall Dam, established in May 1947. Funds for the construction were provided by the Army Engineers who desired the station for their studies for the operation of the dam outlet works. The site selected jointly by Survey and Army Engineer personnel was on the west bank, and could not be reached from that side without extensive improvement of trails across the rugged terrain and down the high bluff at the gage site. To avoid that expense, all materials and equipment, including a military carryall with four-wheel drive, were loaded on a large barge at a convenient landing place about 8 miles upstream and towed to the gage site. It was anchored and used as a base of operations during the construction period. As the gage site was reached from the opposite bank, the construction crew was transported twice a day across the river in a 14-foot boat, equipped with outboard motor.

The well was constructed with precast reinforced concrete and the excavation was made inside the pipe. Sixty-inch pipe was used as long as it would settle, and then 48-inch pipe was used until the bottom elevation was reached.

The shelter was of 54-inch pipe. The structure had intakes at elevations of 3.0 and 6.0 feet. The pipe sections weighing more than 1 1/2 tons were handled by the carryall on the barge. Plans were made for a cableway of 2,000- to 2,150-foot span which would be the longest yet constructed.

The Ground Water Division was studying the ground-water supply of Sioux Falls, and at the request of the city, the Pierre Office in January 1945 made two series of measurements of the Big Sioux River above and below the well field. In commenting on that work, Mr Littlefield writes:[138]

138/Letter to author.

Twenty-four inches of ice slowed us up a little.

R. E. Marsh continued as district engineer and W. M. Littlefield as engineer in charge of South Dakota. Other Civil Service engineering personnel in North Dakota were:

Name	Period
K. B. Nelson	11/ 1/44 to 6/30/47
J. R. Eastman	11/13/44 to 6/30/47
H. C. McCreery	3/ 7/45 to 6/30/47
J. E. Powell	1/16/46 to 6/30/47
D. D. Gabe	2/11/46 to 6/30/47
R. P. Vice	6/19/46 to 6/30/47
P. F. Fischer	7/ 1/46 to 6/30/47
F. B. Sessums	9/ 1/46 to 6/30/47
O. J. Narum	3/30/47 to 6/30/47

Miss Eleanor C. Feigum was district clerk.

Civil Service engineering assistants in South Dakota were:

Name	Period
A. O. Himrich	11/16/42 to 5/31/46
R. A. Rath	9/ 1/43 to 3/29/46
D. F. Thoreson	10/ 2/44 to 6/30/47
F. B. Sessums	10/ 2/45 to 8/31/46
R. L. Holmes	10/19/45 to 6/30/47
F. E. Singleton	7/ 5/46 to 6/30/47
L. J. Snell	8/12/46 to 6/30/47
D. E. Quinney	8/19/46 to 1/17/47
K. L. Bearry	8/26/46 to 6/30/47
K. I. Darmer	10/30/46 to 6/30/47
O. H. Swanson	4/21/47 to 6/26/47

Lincoln, Nebr. - With the separation of Nebraska from the Denver District in August 1941 and the transfer of 69 Nebraska stations, district headquarters were established in Lincoln with H. C. Bolon, district engineer. No Missouri River stations in Nebraska were included as those were being operated by the Rolla District. With increased funds for the operation of the Nebraska stations, it was possible to make weekly discharge measurements at those having shifting sandy beds, which meant a majority of the stations. At the remaining stations, 2 measurements per month were made.

When the Republican River Compact became effective in 1943,[139] officials of the three states, together with Survey representatives, G. L. Parker and R. G. Kasel, met to select the stations needed to carry out the terms of the compact. They defined them as all stations on the main stem at State lines, on all principal tributaries at State lines, and on all principal tributaries at junction with the Republican River. Eighteen stations were thus finally selected --12 existing stations and 6 new ones. When compact funds became available in the fiscal year 1945, office space for headquarters for

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the operation, not only of the Compact stations but of others in the Republican River Valley, was sought in McCook, the principal city in the area. However, war-time activities made it impossible to obtain suitable quarters there and Cambridge was selected, and a sub-office was established there with 3 Survey engineers and a clerk and a State employee. For economy of operation, 4 compact stations were operated by the Topeka Office. During the period, no special reports were required by the Compact commission.

So flood conscious was the Republican River Basin that the Topeka Office of the Weather Bureau requested crest stages on practically every rise in the basin, and for the larger floods, reports on stage every few hours to enable flood hydrographs to be plotted.

The requirement of the Missouri Basin-Departmental Program during 1946 and 1947 added 22 stations during those years. In 1946, 2 stations on small tributaries of the Missouri River, Omaha Creek at Homer, and New York Creek at Herman, were established at the request of the Army Engineers who were investigating the run-off from areas of 30 to 50 square miles.

In many of the earlier installations, corrugated metal shelters had been attached to bridge piers to avoid long intakes and possibility of low water flow shifting away from bank installations. However, considerable trouble from silt had been experienced and during the present period, bank installations as being the lesser of the two evils, were made wherever possible. The standard type of construction was 48-inch galvanized corrugated iron pipe; an unusual feature was the flat metal door attached to a frame which fitted the circular shelter.

In addition to the Cambridge sub-office, others were maintained at Grand Island for stations in Central Nebraska, and at Bridgeport for stations in western Nebraska, where the State maintained its main office.

A special office investigation was a study of flood frequencies on the Platte River for the use of the State Highway Department in designing bridges at North Platte and Fremont. That consisted in plotting on special graph paper all floods on the Platte River, and from that determining the probable 25-year flood.

During the annual convention of the National Reclamation Association at the Fontenelle Hotel in Omaha, October 9-11, 1946, the Water Resources Branch joined with the Topographic and Geologic Branches in an exhibit. The Surface Water Division showed various equipment including a type-A crane with B-reel, current meter, and 100-c weight, and pictures of gaging stations.

H. C. Bolon continued as district engineer until May 8, 1942, when he joined the armed forces and was succeeded by D. D. Lewis, who came to the district February 14, 1942. Other Civil Service engineering personnel were:

Name	Period	Military Furlough
L. F. Hanks	8/ 1/41 to 6/30/47	4/26/43 to 7/22/46
C. V. Burns	11/29/41 to 6/30/47	
C. H. Carstens	5/ 1/42 to 6/30/47	6/15/42 to 1/ 3/46
E. R. Leeson	9/ 8/42 to 6/30/47	
Truex Upchurch	10/ 1/42 to 11/24/42 1/	
T. N. Griswold	11/12/42 to 4/17/43	
C. A. Shannon	11/18/42 to 1/21/43	
W. M. Shimasaki	5/27/43 to 10/15/43	
C. B. Albert	6/ 1/43 to 11/ 6/43	
D. T. Hartley	11/ 1/43 to 6/30/47	
G. L. Whitaker	1/ 6/44 to 6/30/47	

Name	Period
J. D. Hungate	9/ 1/44 to 6/30/47
R. G. Meininger	9/ 7/44 to 5/31/47
J. E. Lind	10/10/44 to 6/30/47
A. E. Hulme	11/17/44 to 6/30/47
T. E. Goolsby	10/18/45 to 8/31/46
M. G. Zellars	1/27/46 to 6/30/47
F. T. Schaefer	3/19/46 to 6/30/47
G. E. Philipsen	10/ 2/46 to 6/30/47

1/Military furlough; did not return to district.

Miss Lillian A. Jolliff was district clerk.

Topeka, Kan. -The period was one of very considerable expansion, the number of gaging stations increasing from 49 to 80, of which 59 were equipped with recorders. The expansion was due chiefly to the flood-control investigations of the Army Engineers, during the course of which the Army Engineer stations were increased from 14 to 33; some being stations previously maintained by the State cooperative program, and to 13 stations for the Missouri River Basin-Departmental Program. The former stations were chiefly in the eastern part of the state, and the latter, in the western part.

Four stations in the Republican River Basin designated as compact stations,[140] and which were financed from compact funds, were turned over to the Topeka Office July 1, 1946 by the Lincoln Office. Two state cooperative stations in the western part of the state were near the Nebraska line and with no other Kansas stations nearby, they were operated by the Lincoln Office. With the establishment of the Missouri Basin stations in the fiscal year 1947, sub-offices were established at Norton and Hayes, July 1, 1946, to maintain some 30 stations in these areas. The two Nebraska-operated stations were returned to the Topeka Office. The schedule for those offices called for discharge measurements every two weeks.

The State Highway Department had need for records from stations on streams having only a few square miles drainage area but, unfortunately, experienced personnel was lacking to operate such stations.

J. B. Spiegel continued in charge of the Kansas stations. However, because of inadequate financial support, the Topeka District about November 1, 1941, became a sub-office of the Rolla District under H. C. Beckman's supervision, with J. B. Spiegel, engineer in charge.

Other Civil Service engineering personnel were:

Name	Period	Military Furlough
H. P. Brooks	7/ 1/39 to 6/30/47	
A. J. Ferrin	7/ 1/39 to 6/30/47	8/12/42 to 3/20/46
G. W. Edelen, Jr.	11/16/40 to 12/17/44	
A. T. Klamm	7/ 1/39 to 6/30/47	
C. W. Sullivan	2/16/45 to 6/30/47	
L. R. Lennington	5/ 1/46 to 6/30/47	
I. R. Egbert	7/ 1/39 to 6/30/47	

The office clerk was J. D. Rose.

Austin, Tex. - The number of stations was increased from 140 in 1939 to 218 in 1947. Twenty-eight stations were established during the first two years, 11 being for the Army Engineers, 4 established in the Pecos River for the Pecos River Joint investigation and subsequently made a part of the regular program, and 2 for the use of the State Health Department in connection with salt-water pollution from oil fields in east Texas; 6 permanent stations were established

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for the Board of Water Engineers, and 4 stations for the seasonal study of return flow from rice irrigation fields in 1944; and during the last three years, 18 additional stations chiefly for the Board of Water Engineers' needs were established. An important need for new stations was in connection with additional water supplies, where in some areas ground-water supplies were inadequate and surface supplies were required. About 20 stations were maintained chiefly in that connection. A few stations were established in other years, and some stations were discontinued when the specific need for those records had been met.

The number of stations equipped with recorders was increased from 97 in 1939 to 168 in 1947. In general, the nonrecording gages were at stations in the eastern half of the state where the fluctuation of the streams is not very rapid; a few were on reservoirs.

At the beginning of the period, the Pecos River Joint Investigation was started and 37 additional stations, a majority equipped with recorders, chiefly on diversions both ditches and pumps, drains and wasteways, were established. All but 4 were discontinued when the investigation was completed. To maintain those stations as well as the existing stations in the Pecos River Basin, a sub-office with 2 engineers was established at Pecos, Texas. It was an intensive investigation designed to account for the inflow, outflow, and consumption of the surface waters in the large area studied. The field work was completed in December 1940, and the computed records transmitted to H. M. Stafford who was in charge of the Joint Investigation.

A gaging station worthy of note is that on Barker Reservoir, established in 1946. The dam and reservoir are unique as they are formed by earth section about 14 miles long, and having a "fish-hook" outline, the sides forming the reservoir. One recording gage is placed close to the dam and another near the upper end of the reservoir 9 miles upstream. The two recorders are necessary to obtain an accurate record of the reservoir contents, as they indicate the slope in the reservoir, which at times may be rather high due to a high stage at the upper gage caused by high flow in Buffalo Bayou, which enters the reservoir, and not to any effect from the dam itself.

The Lower Colorado River Authority, a State agency, operates 2 flood control and storage reservoirs, and 4 hydroelectric plants. It is a $50,000,000 project which has become a financial success because it was designed on adequate stream flow records.[141] One example was the rehabilitation of the plant at Austin, which had been designed in 1900 for a flow far in excess of that available; when redesigned by the Authority in 1938, its capacity was reduced to that shown by the 40 years of available records. The Survey maintained 13 gaging stations at which the local observers reported to the Authority when the river reached particular flood stages, and with the rating curves, the Authority determined the flow at each station and operated the system accordingly.

Current records of stage were used to a very considerable extent; many private interests arranged with observers to notify them of flood stages, and in the east Texas oil field, the Salt Water Disposal Committee, the controlling agency, had some observers report daily stage in order that salt water pumped from the wells and stored in tanks, could be discharged into the river when the flow was sufficient for dilution.

141/ Statement of C. E. Ellsworth to author.

Floods in June, July and November 1940 in south central Texas exceeded known stages on many small streams and at a few points, on larger streams. An investigation was made, the special field work for which consisted in searching for rainfall records to supplement those at regular Weather Bureau stations, and resulting in more than 50 acceptable records being obtained. Many flood measurements were made at regular gaging stations, where, as C. E. Ellsworth expresses it: 142/

142/ Letter to author.

***the methods used or the quantity of water measured might be considered unusual. A measurement was made of the Navidad River near Ganado, Texas, July 2, 1940, where the discharge was 56,600 second-feet, of which 23,000 second-feet was measured by wading. This is a record for a wading measurement in this district and may be a record for the United States.

The resulting report of the investigation was prepared by S. D. Breeding and was published as Water-Supply Paper 1046.

Serious floods, the greatest since that of September 1921, occurred in September and October 1946 on the streams in the vicinity of San Antonio and on Calaveras Creek was the greatest in at least 60 years, the peak discharge being 2,360 second-feet per square mile from 24.6 square miles. Supplemental rainfall records at 66 points were obtained. In addition to flood measurements at the one regular gaging station, 7 slope-area measurements were made at other points. A study comparing this flood with that of September 1921 was made by S. D. Breeding and the resulting report was published as Circular 32. In comparing the rainfall causing the two floods, Mr. Breeding noted that in 1921, the Weather Bureau had rejected a rainfall record of 21 inches as being improbable, but that "in light of evidence gathered since 1921, a rainfall of 21 inches in 24 hours is not uncommon in central Texas."

Flood measurements required a power-driven type-E reel and crane, but the Columbus District was unable to make delivery. The need was met by removing a type-A crane from its base and mounting it on the front of a Chevrolet Sedan delivery truck, equipped with red blinker-warning lights; a power-driven reel using a power take-off from the front of the automobile engine was constructed. The equipment was successful in handling a 150-pound weight. 143/

143/ Water Resources Bull., Nov. 1946, p. 221.

The Soil Conservation Service maintains gaging stations on the High Plains, at which the Survey makes some measurements and computes the records for two stations. During the period, seepage measurements which had been a part of the stream gaging procedure since the establishment of the Austin District in 1915 were made chiefly at the request of the Ground Water Division, and at points specified, as the needs of that division were predominant. In addition, 4 gaging stations were maintained, chiefly for ground-water studies.

There were many requests from war agencies for stream-flow records, one resulting in the establishment of 2 stations on Cypress River and a third on a reservoir, paid for the Lone State Steel Company which was financed by the War Production Board to erect a mill and produce pig iron. To answer many of the requests for stream-flow data, the Austin District compiled back records and analyzed them for the purpose of predicting the flow of streams having no records.

During the later years, a start of decentralization in the operations was made; the Galveston-Houston area was becoming highly industrialized, and water supply was an increasingly important factor. An office was established in Houston in 1941 with a personnel of 3 engineers and a clerk, which not only maintained the gaging stations but computed some of the records. Other permanent field offices were maintained at San Angelo and Forth Worth, and two seasonal offices were maintained at Amarillo and Vernon.

An account of the activities in Texas would be incomplete without a bit of "local color": On one occasion, an engineer at a reservoir station went down to read the staff gage inside the well, but when he saw several snakes coiled around the ladder, and others in the well itself, he changed his mind.

C. E. Ellsworth continued as district engineer and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
Twigg Twichell	7/ 1/39 to 6/30/47	
S. D. Breeding	7/ 1/39 to 6/30/47	
H. C. Pritchett	7/ 1/39 to 6/30/47	
V. L. Austin	7/ 1/39 to 6/30/47	
W. H. Goines	7/ 1/39 to 6/30/47	
C. E. Earhart	7/ 1/39 to 6/30/47	12/ /40 to 5/ /46 11/ /46 to 1/ /47
M. V. Brooks	7/ 1/39 to 4/24/46	
C. A. Young	7/ 1/39 to 7/5 /44	
E. L. Willis	7/ 1/39 to 2/26/41	
O. L. Pratt	7/ 1/39 to 10/ 5/40	
F. T. Lander	7/ 1/39 to 8/ 5/44	5/ /42 to 8/ 5/44 2/
Morris Fry	7/ 1/39 to 9/19/46	2/ /42 to 11/ /45
L. N. Jorgensen	11/27/39 to 6/30/47	12/ /42 to 3/ /46
Oscar Kelfer	12/11/39 to 7/31/42	
H. J. McDowell	12/14/39 to 6/30/47	
P. H. Holland	6/ 1/40 to 6/30/47	4/ /43 to 3/ /45
E. R. Watson	3/21/41 to 5/16/45	
G. D. Prock	3/21/41 to 5/31/42	
T. W. Weinheimer	8/16/41 to 6/30/47	7/ /44 to 12/ /46
Lynn Brown	8/16/41 to 4/ /46 1/	
M. D. Hale	9/15/41 to 6/30/47	3/ /43 to 8/ /46
J. L. Crawford, Jr.	4/16/42 to 6/30/47	
Mrs. Shirley Hunter	11/ 1/43 to 6/30/47	
L. L. McDaniels	8/ 1/44 to 6/30/47	
H. W. Albert	8/ 1/44 to 6/30/47	
W. C. Dodd	8/ 1/44 to 6/30/47	
C. R. Gilbert	6/22/45 to 1/ 6/47	
C. R. Conley	7/16/45 to 1/31/47	
F. D. Franki	8/30/45 to 1/ 2/46	
Miss C. Swanson	11/18/46 to 6/30/47	
R. L. Allen	12/ 2/46 to 6/30/47	
P. B. Earhart	12/ 2/46 to 6/30/47	
J. O. Joerns	4/21/47 to 6/30/47	

1/ Military furlough; did not return to district.

2/ On leave without pay beginning Aug 6, 1944.

Mrs. T. C. Schmitt was the district clerk.

Helena, Mont. - At the beginning of the period, the Helena District comprised the states of Montana and North Dakota, but with the creation of the Bixmarck District October 16, 1944, 4 North Dakota stations were transferred to it. During the period, the interest in protection from floods and in the development of the Missouri Basin in which most of Montana is situated, resulted in greatly increased appropriations to the Bureau of Reclamation and Army Engineers.

Under the Missouri Basin Department Program, funds were provided for the construction and operation of 36 stations, a larger number of stations than for any other state in the Missouri Basin. By 1947, 33 of those stations were in operation. In connection with the plan for flood control, the Army Engineers provided funds to increase their stations from 10 to 20. These increases occurred chiefly during the last two years.

The snow surveys and the operation of the international gaging stations for the International Joint Commission were continued. The station on Sherburne Reservoir had been added to the original 25 and in the fall of 1946, 18 stations in the Battle Creek and Frenchman River Basins were also designated as international stations making a total of 44 international stations. Many of them are situated from 25 to 50 miles from good roads and, at certain time, are very difficult to reach. As C. S. Heidel stated in 1941:[144]

144/ Water Resources Bull., May 1941, p. 74.

> Because of varying conditions of snow, mud, pools and running water, it has been necessary at times to travel by wagon, sled, skis, saddle horse and on foot with equipment for making discharge measurements. Some of the residents along the boundry do not send or receive mail for periods of three months because of transportation difficulties.

It was important that field plans be made to visit these stations as soon after the break of the ice as possible, and in 1941 a reconnaissance of six stations in one group was made by airplane. The area covered in a 2-hour flight required 2 or 3 days travel for inspection by the usual means of travel. The information obtained made it possible to arrange field work so as to obtain measurements at the right times.[145] That procedure was followed

145/ op. cit.

every spring subsequently.

While aerial travel was used chiefly for reconnaissance, planes were used advantageously in a few instances in making routine measurements. During the spring of 1947, a number of flights were made for the purpose of taking aerial photographs for inclusion in a report to the International Joint Commission on the water supply and its use in a special creek basin. A K-20 camera was borrowed from the army and some very satisfactory photographs were obtained. They showed conditions which it was impossible to observe from the ground at times when the ordinary trails were impassable.

The operation by the Army Engineers of the Fort Peck Reservoir in the interest of navigation required as high a degree of accuracy as possible in the records at downstream stations. Results of consecutive discharge measurements at some of those stations together with others on the Yellowstone showed such widely varying conditions of shift that it was thought possible those results might be partly due to errors in the measurements themselves. To investigate that possibility, a series of check measurements was started in August 1940; a second measurement was made immediately following the first, using alternate measuring points except near piers. The results showed that the average variation was less than 2 percent, indicating the accuracy of the measurement and showing that the variation in shift corrections were actually due to the changes in bed and control.[146] The check

146/ Water Resources Bull., Aug. 1941, pp. 126-127.

measurements were repeated each year. Another special investigation connected with the Fort Peck Reservoir was the rating of the spillway gates during periods of release by means of meter measurements made from the cable station a short distance downstream.

Several stations were located on intermittent coulees, ordinarily having no flow during the summer and winter months, the chief flow occurring during the spring break-up when highwater in all the streams, and the scarcity of bridges makes the stations inaccessible. To obtain records under these circumstances, R. D. Schuller devised an automatic starter which was placed on the recorders at 4 stations. A notched shaft was so placed that it engaged a notch in the periphery of the float pulley; when flow started, the float was raised, thereby allowing the notched shaft to release the clock weight and to start its fall, started the recorder.[147] By the use of the starter, a month's longer record was obtained each year.

[147] Water Resources Bull., Feb. 1943, pp. 22-23.

A clock-testing rack for testing different types of clocks was devised by W. A. Blenkarn. The rack consisted of 5 drums, with suitable attachments, and had clock wire attached to weights, wrapped around them. By means of this rack, clocks were tested after their return from the jeweler's, before being sent to the field.

A. H. Tuttle continued as district engineer and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
C. S. Heidel	7/ 1/39 to 6/30/47	
Frank Stermitz	7/ 1/39 to 6/30/47	
W. A. Blenkarn	7/ 1/39 to 6/30/47	
E. H. Bekkedahl	7/ 1/39 to 8/31/39	
H. C. Eagle	7/ 1/39 to 1/ 5/43	
R. D. Schuller	7/ 1/39 to 6/30/47	1/ /43 to 1/ 2/46
G. E. Harbeck, Jr.	7/ 1/39 to 3/23/40	
C. D. Bue	8/ 7/39 to 6/30/47	
H. D. McCreery	9/ 2/39 to 3/ 5/45	
W. C. Vaudrey	9/18/39 to 9/ /46	
J. M. Spearman	6/ 5/40 to 8/25/45	
J. D. Goshorn	8/ 2/40 to 9/ 5/42 1/	
R. H. Schaeffer	3/20/41 to 2/28/42 1/	
N. M. Voldseth	5/19/41 to 2/ 2/42 1/	
A. H. Williams	9/23/41 to 1/17/46	3/ /42 to 12/ /45
L. A. Gennell	4/14/42 to 9/13/43	
Ross Henry	10/ 1/43 to 7/6/ 45	
O. E. Moberg	11/23/43 to 6/30/47	
O. J. Folsom	7/ 5/44 to 6/30/47	1/29/45 to 1/7 /46
Q. L. Yuhas	8/ 3/45 to 6/30/47	
G. W. Buswell	12/21/45 to 6/30/47	
B. A. Anderson	2/25/46 to 6/30/47	8/ 7/46 to 10/ 1/46
J. C. Anderson, Jr	2/25/46 to 10/ 1/46	
F. C. Aagaard	6/ 3/46 to 6/30/47	
R. E. Young	6/17/46 to 6/30/47	
J. N. Jovick	8/ 5/46 to 6/30/47	
T. J. Fisher	10/ 1/46 to 6/30/47	
R. T. Plunkett	12/ 4/46 to 6/30/47	

1/ Military furlough; did not return to district.

V. J. Stermitz was district clerk during most of the period.

Denver, Colo. - The Denver District underwent both a major and a minor amputation of territory during the period but, due to the intensive investigation by the Bureau of Reclamation, operated a very considerably greater number of stations in 1947 than in 1940. Nebraska became a separate district with69 stations in August 1941.

and in July 1943, the 4 stations in the Bear River Basin in southwestern Wyoming were transferred to the Logan, Utah Office as a part of the Bear River Investigation.[148] The number of stations increased from 357 at the beginning of the period to 442 at the end, 427 being equipped with recorders.

[148] p. 89.

Colorado: The Bureau of Reclamation was pushing its investigations in all parts of the state and as the Survey's State-cooperative funds were inadequate, the Bureau was maintaining a very considerable number of gaging stations itself, and as its investigations proceeded, required more. Cooperation with the Colorado Water Conservation Board beginning in the fiscal year 1942, enabled the Survey to take over the stations which were being operated by the Bureau and the additional stations which were installed by the Bureau of Reclamation. These installations, unlike those made in the previous period, gradually approached Survey standards, and the stations were operated with a smaller loss of records. Many of the stations were in the Colorado River Basin in the western part of the state, and for economy of operation, a sub-office was established in Montrose in July 1941, in charge of C. B. Ham. By the end of the period, three engineers were being assigned to Montrose; one was an experienced hydrographer, detailed in 1945 by the Bureau of Reclamation to the Montrose Office.

A three-way cooperative arrangement in the Arkansas Valley was perfected in 1941 at the suggestion of the Army Engineers. The State Engineer was maintaining certain stations in that area; the Bureau, under Survey supervision, was maintaining other stations, and the Army Engineers, still others in connection with flood studies. Under the arrangement, the Army Engineers made measurements at all stations in the eastern part of the valley, the Bureau measurements at all stations farther west, and the Survey had general supervision and computed the records. By the arrangement, the amount of travel was greatly reduced.

Some Colorado stations having relatively low drainage basins have the bulk of their runoff during the melting of the snow early in the spring. A number cannot be reached during the winter due to their isolated locations, and it was important to learn the snow conditions before melting started in order that plans could be made to reach the stations later. In the spring of 1946, C. B. Ham made an aerial reconnaissance flying 150 miles in an hour or so, and found that as far as the end of the road, horses could be used instead of the skis or snowshoes that had been thought necessary. The previous year, he had obtained a "weasel" and had reached an especially isolated station over the deep snow.

Very little construction work was performed until Missouri River Basin funds became available in 1946 for the establishment of 10 stations. Those were chiefly on small streams and the construction work was of a routine nature. As local labor was practically nonexistent, it was necessary to make up the construction parties of a Survey engineer and several returned veterans employed as hydrographic field assistants. That arrangement proved very successful as the same men were used on succeeding jobs and gained skill in the work.

At the end of the period, there were 283 stations in Colorado, 279 having recorders.

Nebraska: During the two years of the period that Nebraska was a part of the district, the Survey had an engineer assigned to the Bridgeport Office until October 10, 1940, when decreasing cooperative funds made it necessary to discontinue that detail. In January 1940, an engineer was assigned to Lincoln for the more economical operation of the stations in the eastern part of the state. At the time Nebraska became a separate district, there were 69 gaging stations, 52 having recorders.

Wyoming: The pattern of the Wyoming work was not unlike that in Colorado. The Bureau of Reclamation was pushing its investigations in the Green River Basin, and as usual, had established additional stations which it was operating. The engineer in charge of that work had previously been employed by the Survey and being experienced in stream gaging, offered to make the measurements at theSurvey stations in that area if the Survey would compute the records for the Bureau stations. That arrangement continued until the summer of 1941, when the Bureau was no longer able, for lack of personnel, to have one of its engineers make the Green River measurements, and allotted the Survey a small amount which was sufficient to enable the Survey to take over the operation of the gaging stations; a few of the Bureau stations had been discontinued. To handle that work, a sub-office was established at Kemmerer. That office was soon afterward moved to Rock Springs and maintained until July 1, 1945, when it was closed for lack of personnel.

The previous fall, 1940, the State Planning and Water Conservation Board had cooperated directly for the first time and funds became available forthe installation of eight stations. A few of the new statuons were desired by the Board itself in connection with its own studies, but most of the stations were those desired by the Bureau of Reclamation, which was then making an investigation in the Missouri River Basin. With funds not available until October, and the desire to install recorder stations before winter stopped construction, two parties were placed in the field immediately, and with the aid of local labor which was still available, the stations were placed in operation as scheduled.

No additional stations for the Reclamation Bureau were installed until the spring of 1945, when the special appropriation to the State Planning and Water Conservation Board enabled that agency to cooperate with the Survey for the purpose of establishing during the next 18 months, 25 stations desired by the Bureau of Reclamation. Reconnaissance was started as soon as possible, and as galvanized metal shelters were to be used, it was necessary to get bids for building the structures. That delayed actual construction until the latter part of May. No labor was available but several teachers in Wyoming high schools were willing to take summer jobs as hydrographic field assistants, and two parties were placed in the field, each consisting of a Survey engineer and two teacher assistants. These parties, going from one job to the next with little loss of time, had constructed about half the stations that season. After the teacher-laborers left, a party consisting of Survey engineers continued the construction until winter. That fall Missouri River Basin funds became available for the establishment of 14 additional stations, including three on the Water Conservation Board list, which could not be established with the State funds available. Therefore, the spring and summer of 1946 was an extremely busy construction period. Although many veterans had recently returned home, few desired jobs as laborers on construction, and it was again necessary to make up parties with field assistants, this time however with returned veterans who would take field assistant jobs.

The increase in the number of stations in northern Wyoming made it desirable to concentrate the supervision of field operations in that area, and H. P. Eisenhuth, with headquarters in Sheridan, was placed in charge. Two additional assistants, in addition to the engineer in Riverton, were stationed at Buffalo and in Worland because of lack of living quarters in Sheridan.

Work desired by the Bureau of Reclamation, and the continuation of the long-time State Engineer's cooperative program, did not constitute the entire activities in Wyoming. The dry years in the late thirties had shown the need for a closer regulation of the water rights in the Bighorn River Basin by the State Engineer, and he employed a water commissioner during 1940. The next year the State Engineer proposed an arrangement whereby the Survey would assign an engineer to the Bighorn Basin, whose primary duty would be the maintenance of the gaging stations in that area, and also be appointed State water commissioner to care for the relatively little work in administering the water rights; when so engaged, he would be employed wholly by the State. That proposal was accepted by the Washington Office and as the measurements of the principal diversions were required, it was decided to investigate the increased flow in the Bighorn River from the Bureau of Reclamation's Wind River diversion dam to Manderson, below the principal diversions, a distance of 151 miles. That investigation required stations at several points on the river, at the mouth of each principal tributary, at all diversions, and measurements of return seepage and other wastes. That work was started in the spring of 1941 with J. G. Gyllenskog in a sub-office at Riverton, and continued through 1945. By that time, the number of gaging stations had increased to such an extent that the Survey engineer was no longer able to obtain the necessary measurements, and the investigation was discontinued. The results of each season's investigation were published in mimeograph form by the State Engineer.

Another special investigation was started in the spring of 1946--an investigation to determine the loss in transit of storage water released from the Reclamation Bureau's Seminoe-Pathfinder-Alcova reservoir system and transported to Guernsey Reservoir and thence to the Tri-State Dam in Nebraska, a total distance of 232 miles. At the suggestion of the State Engineer of Wyoming, an agreement was arranged whereby the states of Wyoming and Nebraska together, the Bureau of Reclamation, and the Survey were each to pay a third of the cost of the investigation which was conducted by the Survey with the assistance of engineers of the other parties to the agreement. Like the Bighorn River investigation, stations were needed at several points along the river at the mouths of the principal tributaries, and on all' principal diversions. Many diversions were by pumps and those were rated and records of the daily hours operated were kept. Field headquarters were established in Douglas, in charge of R. W. Moor, assisted by H. E. Hodges. It was anticipated that several years would be required to complete the investigation and it was continued beyond the present period of the history.

The number of Wyoming gaging stations increased from 108 to 152, with 141 recorders.

During the latter part of the period, all Branches of the Survey joined in presenting a Survey exhibit. The American Mining Contress held a meeting in Denver from September 9 to 13, 1946, at the City Auditorium, and at the suggestion of Director Wrather, space was obtained for a joint exhibit. The

Surface Water Division had a meter and heavy weight suspended from a crane, from the base of which the wheels had been removed, to allow fastening to the floor; a headphone was attached to the meter for the use of those interested. Water-stage recorders and charts were shown as well as rating curves and pictures of typical stations. A large wall map of the western states showed by means of pins locating the district offices and containing on their heads the number of gaging stations in each state. The moving parts of the meter attracted the chief attention of the surface-water exhibit.

The author continued as district engineer and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
J. H. Baily	7/ 1/39 to 6/30/47	
H. P. Eisenhuth	7/ 1/39 to 6/30/47	
L. F. Hanks	7/ 1/39 to 8/ 1/41	
H. H. Odell	7/ 1/39 to 6/30/47	3/23/42 to 12/ 3/46
L. R. Sawyer	7/ 1/39 to 2/16/42	
C. B. Ham	7/ 1/39 to 6/30/47	
R. F. Kaser	7/ 1/39 to 3/31/41	
C. J. Osborne	7/ 1/39 to 4/ 4/42	
F. D. Reed	7/ 1/39 to 7/26/39	
R. A. Wahl	7/ 1/39 to 8/15/39	
L. J. Glasier	11/ 4/39 to 11/24/42 1/	
J. D. Goshorn	1/ 3/40 to 8/ 2/40	
J. G. Gyllenskog	4/ 1/41 to 3/29/46	
H. C. Beaber	8/25/41 to 6/30/47	9/ 1/42 to 2/ 1/46
A. S. Sollid	9/20/41 to 7/24/45	
J. M. Ingles	3/10/42 to 3/16/44 1/	
F. W. Paddock	7/ 7/42 to 9/10/45	
A. N. DePaulo	8/11/42 to 6/30/47	
R. W. Moor	11/10/42 to 6/30/47	
Miss H. H. Hunton	12/ 1/42 to 1/18/44	
Miss E. E. Keen	12/28/42 to 2/ 8/43	
K. S. Essex	6/ 5/44 to 6/30/47	
A. B. Kaplan	7/16/45 to 8/ 5/46	
J. M. Spearman	8/27/45 to 6/30/47	
G. J. Miklas	10/15/45 to 6/30/47	
H. E. Hodges	1/28/46 to 6/30/47	
W. P. Fulton	2/25/46 to 6/30/47	
C. R. Sieber	2/25/46 to 6/30/47	
H. W. Wortmann	3/ 6/46 to 6/30/47	
E. A. Hopper	10/ 1/46 to 6/30/47	

1/ Military furlough; did not return to district.

Miss Nellie L. Esterly was district clerk.

Santa Fe, N. Mex.-Although the number of stations at the beginning of the period was 159, and at the end, 162, discontinuance of old stations and establishment of new ones caused more changes than indicated by the slight net increase. The chief reduction was in the stations being maintained for the Indian Service, when in 1942 that agency reduced its funds from $15,000 to $3,000, and the number of stations was reduced from 80 to 25; the records for the latter were not computed, but merely kept in the files. The greatest increase came at the beginning of the period when the Pecos River Joint Investigation 149/ required the operation of 67 additional stations, most of which were discontinued afterward. The greatest number of stations operated during the period was 240 in 1940.

149/ p. 88.

Field work for the Pecos River Joint Investigation began in July 1939, and to operate the 67 additional stations required, as well as the 15 regular stations, the basin was divided into three sections with a resident engineer in charge of each. Of the additional stations, 19 were at diversion points of canals or community ditches, all but one being equipped with recorders and 12 with Parshall flumes; 20 stations on drains and wasteways, 9 equipped with recorders; and 15 near the outlets of pumping plants where recorders were installed to show the periods of operation, the amounts pumped being measured by current meter and power consumption; in all, 54 additional recorders were installed. This was an intensive investigation designed to account for the inflow, outflow, and consumption of the surface waters in the large area studied. The field work was completed in December 1940, and the computed records transmitted to H. M. Stafford who was in charge of the Joint Investigation.

Beginning with the fiscal year 1942, cooperation started with the State Highway Engineer, resulted in the establishment and operation of 5 additional stations for the purpose of obtaining flood data needed by the Highway Department in its design of water-way structures. The station on the Rio Grande at Albuquerque was a tempting target for rifle shots and the 14-gage shelter was reinforced with so-called "armor" of 10 gage boiler plate to protect the recorder. At the same station, a clock was stolen and the recorder thrown into the well; the F. B. I. investigated and obtained from the guilty parties the cost of the damage done in the amount of about $500. As a precaution against "trigger-happy" citizens, 58 shelters in New Mexico had the armor reinforcing.

Cooperation with Colfax County[150]/ started in 1945, required the

150/P. 63.

establishment of 6 gaging stations, the installation costs of 2 being furnished by the Bureau of Reclamation. On July 1, 1946, as a result of the International Treaty with Mexico, the San Marcial station on the Rio Grande, showing the inflow to Elephant Butte Reservoir was taken over from the International Boundary and Water Commission. Whereas, in former days it had been possible to obtain a local observer not only to read the staff gage, but to make almost daily discharge measurements, the town of San Marcial no longer existed because of the flood of 1929, and it was necessary to employ a student at the School of Mines located at Socorro, 35 miles distant, to visit the station 3 times a week. A few months later, three stations of interest to the Bureau of Reclamation because of their studies for rehabilitation of the Carlsbad project, were installed and started in operation by the Survey. During the period, the Army Engineer stations was increased from 4 to 12.

Of the floods recorded, that of September 1941 reached the recorder at the Hondo station on the Ruidoso, and according to Berkeley Johnson, turned it up-side-down, truly an unusual occurrence; on the Rio Grande the flood of May 1941 made it necessary to raise the shelter 7 feet at the historic station on the Rio Grande at Embudo.[151]/ This was done by building a new shelter on top of the

151/ Follansbee, Robert, History of the Water Resources Branch of the U. S. Geol. Survey to June 30, 1919, p. 51.

old one which had been constructed of cobble stones by the observer in his spare time during 1914.[152]/ One effect of the floods on the San

152/ idem, p. 408

Juan at Shiprock was 17 feet increase in depth for 4 feet rise in stage. The only reason the depth was not greater was the fact that the sand was scoured out to the shale and had to stop. Another badly shifting station was the Rio Grande at San Acacia where shifts of 2 feet may occur in 24 hours, and shifts of 5 feet during the year.

One effect of floods was to undermine the wells which were, as a rule, built close to the shore to eliminate long intakes, and in some instances such undermining caused the well and shelter to capsize. To avoid that possibility, the bottom of the high concrete shelter on the Pecos River near Guadalupe was mushroomed out with reinforced concrete to a diameter of 16 feet at the foundation. A flash flood on the Conchos River just above Conchos dam eroded one bank to a depth of 39 feet, and within a foot of the A-frame.

In addition to maintaining the regular program, measurements of drains near Roswell had been made since 1939 for the Ground-Water Division's investigation of the artesian basin and was continued; also for that investigation, a series of seepage measurements on the Pecos River from Acme to Artesia was made to show the inflow to the river from the leakage from the artesian basin.

Resident engineers were obtained at Farmington, Albuquerque (2), Socorro, Tyrone, Roswell, Las Vegas, and Carlsbad. These engineers were rotated at irregular intervals. As it was almost axiomatic that the only way to obtain a house was to rent or buy, the result was that when changes occurred, the new man purchased or rented his predecessors house. Thus, the new man was sure of finding a house on his arrival.

Berkeley Johnson continued as district engineer and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
E. L. Barrows	7/ 1/39 to 6/30/47	
W. G. Bratschi	7/ 1/39 to 6/30/47	
J. N. Fitch	7/ 1/39 to 6/30/47	
C. A. McClelland	7/ 1/39 to 4/30/47	
R. E. Cook	7/ 1/39 to 6/30/47	
A. B. Goodwin	7/ 1/39 to 1/12/45	
F. F. LeFever	7/ 1/39 to 4/24/41	
R. C. Curtis	7/ 1/39 to 3/21/41	
V. R. Bennion	7/ 1/39 to 6/ 3/40	
Frank Robinson	8/ 1/39 to 9/ 4/41	
T. E. Yates	2/11/40 to 6/30/47	
J. O. Voerns	7/ 1/40 to 11/14/44	
L. J. Reiland	5/ 1/41 to 6/30/47	
W. F. Busch	10/10/41 to 6/30/47	10/14/41 to 2/ 4/46
J. B. Collins	10/12/42 to 11/11/43	
R. F. Petit, Jr.	1/16/42 to 2/28/43	
W. S. Griswold	2/16/42 to 12/ 2/42	
W. L. Garner	3/ 1/43 to 6/30/47	10/ 4/43 to 11/20/45
J. B. Franks	3/10/43 to 2/28/46	
G. L Oakland	3/30/45 to 6/30/47	
R. F. McC uley	1/28/46 to 6/30/47	
L. B. Baca	4/22/46 to 6/30/47	
L. E. Carroon	6/17/46 to 6/30/47	

The district clerk was Mrs Genevieve H Francis.

Boise, Ida.-The exterior boundary of the district was the same as during the previous period, but with the beginning of the Bear River Investigation July 1, 1943,[153] 8 of the 9 stations in the Bear River Basin

153/p. 90.

were transferred to that project. The special investigation of the Boise River Basin in cooperation with the Flood Coordinating Committee[154] was

154/p. 89 (1928-1939).

completed November 1941. The special investigation of the Corra Linn Reservoir and Kootenay Lake (Canadian spelling) in the Kootenay River

Basin made at the request of the International Joint Commission during the previous period[155] resulted in certain orders by the Commission rela-

155/ pp. 156-159 (1928-1939).

tive to the operation of that reservoir; and to insure compliance with those orders, the Commission in 1939 set up the Kootenay Lake Board of Control. That Board was composed of two members which was increased to four in 1943, half being Canadians. The American members were an Army Engineer Officer, who was the district engineer of the Seattle District, and T. R. Newell of the Survey, the latter being appointed December 17, 1942. The excavation at Groham Narrows was made in 1939 and storage of water started the same year. To insure compliance with the Commission's orders, the water power company which operated the reservoir, furnished the Board of Control weekly reports, except during flood periods when telegraph reports were furnished, including reading from 3 gages, operating head and output in kilowatts and discharge for 3 power units, sluice gates, and other necessary data. From these reports, the Board determined whether changes in storage were within the specified limits.

Between 1940 and 1944, 22 temporary stations were installed for the Army Engineers and beginning in 1945, the Bureau of Reclamation in connection with the intensive studies of irrigation possibilities, transferred funds for the installation and operation of 16 stations; in addition, 1 station installed by the Portland District was transferred to the Boise District, as well as 5 stations which the Bureau had previously operated. As frequently happens, the request for new stations to be installed before high water in the spring was received during the winter months. One station was to be located at an inaccessible site at an altitude of 6,200 feet. Because of the depth of the snow, the only means by which material could be transported was by sled or airplane; the former would have been more expensive requiring three days with the two nights spent in a snow bank. Therefore, the airplane was chosen. The plane's pilot made a reconniassance and decided that he could land the plane with material reasonably close to the site. The party of three landed at 9 a. m. and installed the recorder in a timber well and shelter and had the recorder in operation by 3 p. m.[156] Speed can be achieved when the need exists.

156/ Water Resources Bulletin, May 1941, pp. 77-78

Airplanes were also used for reaching other stations. That on Big Creek could be reached by a horseback trip of 35 miles from the end of the auto road, or could be reached by air in a day's time; an airplane was used at all seasons, being equipped with skis when landing in the snow, the point of landing being 2 miles from the station. Two other stations were visited monthly by plane during early spring months. The station at the outlet of Yellowstone Lake, in a region of very heavy snow was visited during the winter by use of a snow-mobile from Morgan, a distance of 65 miles. The round trip required one long day.

Although Bonners Ferry is protected by dikes from flood stages inthe Kootenai River, breaks have occurred in the dikes, making the residents flood conscious. In accordance with popular demand, the existing staff gage was replaced by a water-stage recorder in a concrete shelter having a plate glass window 42" x 49". Just inside the window, a special device on the recorder allows two weeks' chart to be inspected and a 10-watt fluorescent light makes the chart visible at night. The use of the gage during the first flood season after its construction made it possible for those in charge of protecting the dikes to follow the trend of the river closely and better perform their necessary duties. Frequently, small groups viewing the chart discussed the river problems to the presumably better understanding of those problems.[157]

157/Water Resources Bull., Aug. 1942, p. 110.

At the end of the period, 215 gaging stations of which 166 were equipped with recorders were being maintained. Except for a resident engineer at Bonners Ferry who maintained the 17 stations in the Kootenai River Basin, all stations were operated from the district office.

T. R. Newell continued as district engineer and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
P. C. Benedict	7/ 1/39 to 6/11/41	
F. C. Craig	7/ 1/39 to 3/ 2/44	
E. G. Bailey	7/ 1/39 to 6/28/42	
P. H. Andros	7/ 1/39 to 3/19/40	
H. W. Johns	7/ 1/39 to 2/ 1/41	
T. O. Miller	7/ 1/39 to 6/30/47	
E. J. Rusho	7/ 1/39 to 9/17/40	
L. J. Snell	7/ 1/39 to 9/12/40	
C. A. Thomas	7/ 1/39 to 6/30/47	
E. Hazel Haugse	7/ 1/39 to 6/30/47 2/	
P. G. Morken	12/ 4/39 to 9/15/41	
H. L. Walpole	3/ 5/40 to 12/ 8/40	
J. R. Throckmorton	10/28/40 to 3/29/41	
C. C. Fiske	1/24/41 to 6/30/47	1/17/43 to 1/11/46
W. H. Krabler	8/ 1/41 to 6/30/47	
D. R. Woodward	10/21/41 to 5/18/42 1/	
H. S. Hill	2/11/42 to 4/30/42 1/	
F. A. Johnson	6/30/42 to 1/ 4/44	
T. N. Lethlean	8/ 7/42 to 6/30/47	
W. I. Travis	6/30/43 to 6/30/47	
J. R Spofford	6/22/44 to 6/30/47	7/17/44 to 4/ 2/46
A. E. Comer	3/ 1/44 to 6/30/47	
M. G. Lewis	8/ 9/44 to 8/25/45	
R. W. Ferebauer	9/25/44 to 6/30/45	
R. W. Revell	2/13/46 to 6/30/47	
Leonard Koski	3/12/46 to 6/30/47	
C. R. Adelmann	4/ 1/46 to 11/13/46	

1/ Military furlough; did not return to district.

2/ Absent Feb 4, 1943 to Mar 31, 1944 due to illness.

In addition to her engineering duties, Miss Haugse acted as district clerk.

Idaho Falls, Ida. -The dual Federal and State role played by the Idaho Falls Office in collecting stream-flow records and in administering the water decrees for the use of storage and natural flow in the upper Snake River, which started with the creation of the Idaho Falls Office in 1919, continued practically unchanged, as shown by the following statement of Lynn Crandall:[158]

158/Letter to Author.

The activities of the district have become more or less standardized through many years of routine regulation of the waters of Snake River. That the system of cooperation between the U.S. Geological Survey, State of Idaho, and the Snake River waterusers has proved fairly satisfactory in practice is evidenced by the fact that for 30 years the waterusers have each year elected the District Engineer as watermaster on Snake River to administer natural flow rights and at the same time, he has been appointed as Special Deputy of the State Reclamation Engineer in charge of distribution of stored water from the various reservoirs

The district operated 38 regular gaging stations and 100 stations on canals during the irrigation season.

In addition to the regular activities of the district, Mr. Crandall in 1944 made with R. W. Davenport, a report entitled "Plans for Supplementing the Flow of Missouri River by Additional Storage Facilities." That was made in response to the request by the Secretary that the Survey review the proposed plans of the Bureau of Reclamation for storage in the Missouri River Basin. During the period, he also prepared numerous statements, tabulation of records, and assisted Bureau of Reclamation engineers in studies of water supply and water rights in connection with the proposed Palisade reservoir on Snake River. In 1939 and 1940, he was a member of the Idaho State Planning Board.

Mr. Crandall continued as district engineer and had the following Civil Service assistants:

Name	Period
W. V. Iorns	7/ 1/39 to 1/15/43
H. C. Eagle	1/ 5/43 to 6/30/47

School teachers were employed as temporary hydrographers during the irrigation season.

Salt Lake City, Utah. -With the exception of stations required under Federal Power license, the gaging stations in the Bear River Basin, both in Utah and Idaho, which had been operated by the Salt Lake City District were transferred on July 1,1943, to the special Bear River Investigation with headquarters at Logan, Utah.[159] By means of additional

159/ p. 90.

funds, both in Utah and Nevada, the number of gaging stations exclusive of those transferred to the Logan Office was more than doubled, increasing from 90 in 1939 to 197 in 1947, 176 being equipped with recorders. Because of physical disability, A. B. Purton, district engineer at his own request, was relieved of administrative responsibilities September 16, 1942, and was succeeded by M. T. Wilson.

Utah: During the fiscal years 1942 and 1943, when cooperative State funds were increased for that purpose, the Survey included in the cooperative program 30 stations on small streams which had been maintained by the State Engineer's Office, either independently or in cooperation with the Bureau of Reclamation in a study of small reservoir projects. The next large increase in stations came during the last two years of the period. In the 1946 fiscal year, the Bureau of Reclamation was making an investigation of the Central Utah project, and the upper basin states were attempting to divide the Colorado River water allotted to the upper basin; before the latter could be accomplished, the State of Utah wished to know its contribution to the Colorado River Water supply. Both investigations required additional gaging stations and the latter, special field work. To meet both needs, the State funds were greatly increased and 41 additional stations were established during the last two years. With the additional stations, the number of resident engineers was increased to 6, with field headquarters at Green River, Mexican Hat, Hite, Hanksville, Roosevelt, and Vernal, Utah. At the first two locations, field laboratories for determining daily silt loads were maintained and discharge measurements daily and weekly, respectively, because of the erratic shifting of the stage-discharge relationship.

Among the special field investigations were 3 boat trips on the Colorado and Green Rivers at various points. La Phrene, while resident engineer at Mexican Hat on the San Juan River developed a fondness for Colorado River boat trips as a result of the acquaintance with Norman Nevills, who specialized in taking passengers down the San Juan and Colorado Rivers in boats designed by himself. Mr Harris and associates had built two of the Nevills type of boats; thus, the means formaking the boat trips were at hand. The first investigation was that of the Green River from the mouth of the Yampa to

Green River, Utah, a distance of 220 miles. The nearest point at which the two boats could be trucked was Lily Park, Colorado. On June 11, 1946, a party of four, under Mr. Harris' leadership, started their trip and reached Green River, Utah, on June 20, having measured all tributary inflow except the larger one where regular gaging stations were in operation. As that was the high water season, it was only possible tomeasure the Green itself at the gaging station at Green River. A few months later, during low water, a more ambitious trip was undertaken from Linwood, Utah, to Lees Ferry, a distance of 785 miles. The party of three Survey engineers and a boatman with provisions for two weeks, left Linwood near the Wyoming-Utah State Line on September 20. At Green River, Utah, the party divided, one section taking its boat overland by means of a boat trailer to the Colorado River at the Colorado-Utah State line, and going down the Colorado River to the mouth of the Green where it met the second party, which continued the Green River trip. The reunited party continued down the Colorado River through the deep canyons. As the mouths of the tributaries were inaccessible except by boat, gaging stations had been located some distance upstream, and measurements were made at the mouths for comparison with the flow at the gaging stations. The river itself was measured at various points and water samples were taken from several tributary streams for the Quality of Water Division. In describing the trips[160] Mr Harris stated that the flow of Green River at that time was about a quarter of what it should have been for good boating, and on three different occasions, patches had to be applied to the boats after passing through rapids; another occasion "one of the boats was pinned against two rocks with the river pouring into the cockpit and holding it fast, at which time the writer and Mr. Brennan (the boatman) were contemplating a long hike and several swims back to civilization." Fortunately, that was not necessary as the boat was extricated and the party proceeded. The two extra oars became broken and before attempting to run Cataract Canyon which contained the largest rapids, one oar was repaired, the repairs lasting until the next rapids were encountered, when it was again repaired. As each repair shortened the oar about 4 inches and as there were 44 remaining rapids, the party began to worry about the spare oar when it became a minus quantity. This was one of those worries which did not materialize. The party reached Lees Ferry on October 17th.

[160] Water Resources Bull., Feb. 1947, pp. 59-61.

In June 1947, the latter trip was duplicated except that both boats were taken overland from Green River, Utah, to the Colorado River at the Colorado-Utah State line; the one tributary to Green River between Green River, Utah, and the mouth was measured by the resident engineer at Green River. During this high-water trip, one of the boats was capsized in running Ashley Falls rapid on the Green River, but was recaptured several hours later, 19 miles downstream. Three boat oars were the principal loss inthis accident, in addition to one day's time while extra oars were being rushed from Salt Lake City via Rock Springs, Wyoming, to the Browns Park area.

To determine the tributary inflow to the San Juan River in Utah, Mr. Wilson and Mr. Nevills made an airplane flight from the Goosenecks below Medicine Hat to the Utah-Colorado State line on April 27, 1947. The three tributary streams noted were measured a few days later.

In 1942, close contact with the engineering students of the Utah State Agricultural College at Logan began, and was later extended to the University of Utah. In that year, Dean Clyde was planning the annual inspection to Salt Lake City for the engineering students and Mr. Wilson suggested that the students might be interested invisiting the Survey Office and obtain at least a passing glance at stream gaging; that proposal was accepted. The next few years, a member of the Salt Lake Office went annually to Logan and lectured to the hydraulics class and occasionally took them on a short field trip. Beginning in 1946, W. V. Iorns, in charge of the Bear River investigation with headquarters in Logan, started a more ambitious program. During a four-dayperiod, August 5-8, assisted by A. B. Harris, he conducted a class in hydrology, which included both field and office work, participated in by the students. The following year, a shorter course was presented, followed a little later by a lecture on requirements and how to obtain Civil Service appointments. Contact with the University of Utah began about 1944 when a professor at the Agricultural College familiar with the Survey's contacts came to the University. He wished such contacts to continue and each year a member of the Salt Lake Office lectured to the students, or the latter came to the Survey Office for instruction. A further contact was made in April 1947, when during Engineering Week at the University, students in the various engineering courses had exhibits; that of the Civil Engineers consisted largely of Survey equipment loaned for the purpose which was a big factor in winning the prize.

Nevada: The first increase in the number of gaging stations occurred in July 1943, when five stations previously maintained by the Nevada Agricultural College for the Humboldt River Water Users and the the State Engineer's Office needed for snow surveys and stream-flow forecasting, became a part of the cooperative program, increasing the total number to 23. This program was again expanded in 1944 and 1945 by the additions of 11 stations, two of which were requested and financed by the Army Engineers.

During the fiscal year 1946, a cooperative investigation of the Argenta Sqamp area in the Humboldt River Basin required the installation and operation of three gaging stations, funds for the installation of which were contributed $1,000 by the Ground Water Division and $2,000 by the Bureau of Reclamation.

In the summer of 1946, the Bureau of Reclamation was investigating upstream storage in the Truckee-Carson Basin and requiring additional stream-flow records, provided funds for the establishment and operation of 7 gaging stations, and the Army Engineers desired three additional station. Some of these stations were to be located at high elevations actually in California and it was necessary to start work as soon as possible. L. R. Sawyer who was transferred from the Indianapolis District arrived in Salt Lake City August 20. Messrs. Wilson and Sawyer made the necessary reconnaissance and the latter started construction August 28. Three sites could only be reached by pack trips of 16, 12 and 5 miles respectively, and small timber shelters were installed. Timber shelters were also used on two of the remaining seven stations, but at the other accessible sites, 42-inch metal installations were made. What may well be a record was the installation of one of the metal shelters and a cableway by Wilson McConkie, of necessity without assistance. The stations at the more inaccessible sites were constructed by a party of three engineers.

When Mr. Sawyer was transferred to Nevada, he was given charge of all the Nevada stations, under the general supervision of the Salt Lake

City office. His headquarters were at Carson City; a resident engineer with headquarters at Elko maintained the stations in the eastern and central part of the state. At the end of the period, 47 stations were being operated by the Carson City sub-office.

The Civil Service engineering personnel of the Salt Lake City District were:

Name	Period	Military Furlough
A. B. Purton	7/ 1/39 to 6/30/47	
M. T. Wilson	7/ 1/39 to 6/30/47	
LaPhene Harris	7/ 1/39 to 6/30/47	
J. M. Herndon	7/ 1/39 to 3/ 7/40	
J. R. Conrath	7/ 1/39 to 2/29/44	
A. B. Harris	7/ 1/39 to 5/31/46	
C. A. Fox	4/ 1/40 to 3/ 4/44	
E. H. Peirce	2/16/42 to 3/14/47	11/ /42 to 7/ /46
A. V. Maxwell	6/ 2/42 to 6/30/47	
W. A. Jordan	11/ 9/42 to 8/21/43	
Wilson McConkie	12/ 1/42 to 6/30/47	
W. V. Iorns	12/16/42 to 8/ 2/43	
N. D. Nevills	10/11/43 to 6/30/47	
R. C. Culler	11/20/43 to 6/30/47	
W. A. Thurgood	12/29/43 to 11/16/44	
Elmer Butler	1/ 1/44 to 6/30/47	
D. J. Webb	3/20/44 to 6/30/47	
H. W. Chase	5/16/44 to 6/30/47	
R. S. Lord	7/28/44 to 10/26/45	
E. S. Borgquist	5/22/45 to 8/31/45	
D. R. Woodward	1/14/46 to 6/30/47	
W. H. Dean	2/ 4/46 to 6/30/47	
R. L. Carter	4/ 2/46 to 6/30/47	
J. W. Pehrson	4/22/46 to 6/30/47	
L. J. Jensen	5/15/46 to 6/30/47	
L. R. Sawyer	8/20/46 to 6/30/47	
M. R. Cooley	11/18/46 to 6/30/47	

Tucson, Ariz.--At the beginning of the period, 58 gaging stations, including 8 on the Colorado River and on large canals near Yuma, were being maintained. The Picacho station on the Colorado was discontinued, a station was established on the Gila Gravity Main Canal at Imperial Dam, and the station on the All-American Canal below Pilot Knob wasteway was changed to the wasteway itself. Experience through the years had shown that it was not necessary to make as frequent measurements at the Colorado River stations, and although engineers were stationed at Lees Ferry, Grand Canyon, Boulder City, and Yuma, they each looked after more than the Colorado River stations, as stations on the tributaries were gradually being installed near those points. The engineer at Grand Canyon took daily sediment samples and analyzed them in a laboratory installed for that purpose. A monthly report containing not only the sediment analyses, but also the discharge for the Colorado River at Lees Ferry and Grand Canyon and the main tributaries between Lees Ferry and Hoover Dam, was sent to 100 or more interested agencies and individuals. The report was compiled by the Tucson Office beginning about 1939 to satisfy the heavy demand for current stream-flow information. Weekly reports containing the discharge and diversions for all important stations below Boulder Dam were sent to the same interested agencies, and the Yuma and Boulder City engineers furnished daily reports to the Bureau of Reclamation and to the Weather Bureau.

Near the very end of the period, two-way radio equipment was installed at Lees Ferry where the resident hydrographer had no means of communication nearer than a telephone 70 miles distant.[161]

161/ Water Resources Bull., May 10, 1947, p. 100.

There were two special investigations of the Gila River.[162] The

162/ p. 17.

first, which lasted from August 1939 to June 1942, had no novel features for the Surface Water Division, but required the establishment by the Ground Water Division of several additional temporary gaging stations on the Gila itself, and on canal diversions. The second investigation, however, which lasted from July 1943 to October 1944, was more extensive in character and required more than the maintenance of regular gaging stations. It was in charge of B. R. Colby, who had two assistants. Temporary gaging stations were placed on the river and canals on four lines dividing the valley, one one-half miles north of Thatcher, another 4,000 feet north of Safford Valley Narrows, a third at Fort Thomas, and a fourth at Black Point to determine the surface flow entering and leaving the valley sections bounded by those lines. Also, as part of the work of determining the river gains from ground water and the losses from evaporation, 15 sets of seepage measurements from Thatcher to Calva, a distance of 46 miles were made between June 1943 and October 1944, the river being measured about every three miles. To eliminate variations in river discharge during each run, Mr. Colby devised portable shelters for recorders, which were placed in the river during seepage runs.

Beginning with the fiscal year 1942, cooperation with the San Carlos District, made it necessary for the engineer stationed at Safford to publish at 10-day intervals, reports containing the records for a number of stations that was increased to 15, and distribute them to twenty water users in the Safford Valley. These reports were required by the Federal Water Commissioner in his administration of the water rights in that area.

Anticipating cooperation with the Gila Valley Irrigation District, which started with the fiscal year 1946,[163] 5 gaging stations on 55

163/ p. 66.

miles of Willow and Eagle Creeks were installed in the fall of 1944, to determine the loss in transit of water diverted by the Phelps Dodge Corporation by pumping from the Salt River Basin to the Gila. Because of the natural inflows and losses, it was necessary to determine as accurately as possible the amount of diverted water actually delivered to Phelps Dodge at the lower end of the 55-mile reach. Discharge measurements were made at 10- or 20-day intervals and provisional reports of pumpage, losses, and delivered flow issued to all interested parties; in June and December, final reports were issued.

The effect of changes in water density, due to changes in sediment load and temperature on well gage readings in a reservoir, were observed at Bartlett Reservoir where the 16-inch well had a length of 193 feet, with the only intake a pipe 190 feet long at the bottom of the reservoir. Maximum differences of 5-feet between the elevations in the well and in the reservoir itself had been observed, when the well was drained for flushing and refilled with muddy water about 9 degrees colder. Observed reservoir surface gage heights plotted on the weekly recorder charts showed the daily variation caused by density changes.[164]

164/ Water Res. Bull., Feb. 1943, p. 30.

The activities described required an increase in gaging stations to 76 at the end of the period, 74 stations being equipped with recorders. In addition to the residencies on the Colorado River, of which the Yuma Office force was increased to 3 engineers, there were sub-offices at Safford, Holbrook and Phoenix. With the increase of work in the upper Gila Basin, and the publishing of reports at 10-day intervals, the Safford Office grew from 1 engineer having quarters in the Gila Water Commissioner's Office to 3 engineers with offices in the Federal Building.

The Holbrook Office with one engineer had charge of the stations in the Little Colorado Basin and supervision over the Lees Ferry and Grand Canyon engineers. The Holbrook Office also had to furnish advance records at 2-or 3-week intervals to the principal water users on the Little Colorado River. During the war years, however, the advance records through necessity were discontinued.

The Phoenix Office with 2 engineers handled the very critical cooperative work in that area. This work consisted mostly of streamflow records required by the Salt River Valley Water Users Association in their work on the Salt and Verde Rivers, and operations of reservoirs on those streams. To supplement the Association's reports, the Survey engineers made frequent current discharge reports at several stations. To perform adequate work with fewer engineers during the war, two complete radio transmitting and receiving sets were installed, the transmitters being located at two gaging stations for which reports were desired, one on the Verde River and the other on Tonto Creek. The Stevens telemark at each station transmitted signals once every 12 hours below determined flood stages, and hourly above those stages. One receiver was in the Survey's Phoenix Office, and the other in the Water Users Association's Phoenix Office. The cost of installation was paid jointly by the Survey and the association.165/

165/Water Resources Bull., Feb 1947, p. 39

The effect of Lake Mead on the flow of the Colorado River was of lively interest to the users of water from the lower river and a number of office studies were made during the period. The first, made by J. S. Gatewood, was a determination of the inflow-outflow balance which included specific computations for effect of bank storage. That study was continued by J. A. Baumgartner. In 1944, J. H. Gardiner continued the earlier study by including the evaporation loss, a large factor not previously considered. By so doing, he divided the total loss between evaporation and bank storage.166/

166/Water Resources Bull., Aug 10, 1946, p.

Two special reports were prepared during the period. In 1940, at the request of the Colorado River Commission of Arizona, the Survey compiled a summary of Arizona stream flow records prior to 1938, including virgin flow estimates. This was published as a State Commission report. Also at this time, Water-Supply Paper 967-A, "Floods of September 1939 in Colorado River Basin below Boulder Dam" was prepared.

A morale booster for the personnel in the scattered and, in some instances, isolated locations, was started by Mr Gardiner soon after he came to Tucson in April 1938. It was a monthly publication known as "The Arizona Water Wheel News" which first appeared in May 1938. It contained items of both official and personnel nature, contributed by the district office and the varuous resident offices. Commenting on the value of the "Water Wheel", J. S. Gatewood told the author that through the contributions and exchange of information and news items, "the district was knit into a more efficient and cohesive unit."

J. H. Gardiner continued as district engineer and he had the following engineering assistants:

Name	Period	Military Furlough
J. A. Baumgartner	7/ 1/39 to 6/30/47	
J. S. Gatewood	7/ 1/39 to 6/30/47	
R. H. Monroe	7/ 1/39 to 6/30/47	
W. L. Heckler	7/ 1/39 to 6/30/47	
A. A. Fischback, Jr.	7/ 1/39 to 6/30/47	4/28/42 to 8/19/46
S. O. Decker	7/ 1/39 to 6/30/47	
H. S. Hunter	7/ 1/39 to 1/ 3/41 1/	
F. S. Anderson	7/ 1/39 to 6/30/47	
R. E. Cabell	7/ 1/39 to 6/30/47	
W. T. Stuart	7/ 1/39 to 5/16/40	
H. E. Dahman	7/ 1/39 to 11/19/42	
A. J. Hanson	7/ 1/39 to 2/ 2/42	
E. C. Metz	7/ 1/39 to 1/28/41 1/	
C. T. Jenkins	7/ 1/39 to 6/30/47 1/	6/28/42 to 1/ 2/46
R. L. Blake	7/ 1/39 to 4/ 1/43 1/	
G. L. Haynes, Jr	7/ 1/39 to 4/30/41	
M. D. Dykers	7/ 1/39 to 6/30/47	
Q. C. Cornelius, Jr.	11/27/39 to 7/ 8/42 1/	
G. B. Smith	5/17/40 to 6/30/47	4/12/42 to 1/15/46
J. H. Watkins	1/ 1/41 to 6/30/47	
R. H. Lynn	9/ 1/40 to 5/ 3/41	
R. B. Sanderson	10/ 1/41 to 6/30/47	12/ 2/42 to 3/ 1/46
C. A. Baker	2/ 2/42 to 6/30/47	
Angelo Dalcerro	7/17/43 to 6/30/47	
J. E. Klohr	7/ 3/46 to 6/30/47	
L. R. Peterson	7/10/46 to 6/30/47	

1/ Military furlough; did not return to district.

In addition to the usual duties of district clerk, those of administrative assistant were performed by C. T. Pynchon during the period, except when he was on military furlough from October 1943 to November 1945 when Mrs. Lucille Siberts was chief clerk.

Tacoma, Wash.-At the beginning of the period, the number of gaging stations was about equally divided between those east, and those west of the Cascade Mountains, but the many new stations, both permanent and temporary, constructed in the western part of the state changed the ratio from 1:1 to 3:1 by 1947. However, the regular large-stream program, operated with the main State cooperator, was in 1947, still about equally divided east and west of the Cascades. The total number of stations was increased from 106 to 262, all being operated from the district office as no sub-offices were maintained.

During the first few years, 18 additional stations were established for the Army Engineers. The large increase, however, began in the fiscal year 1943, due largely to the small streams continuous-type inventory of western Washington, started for the Department of Fisheries and later supported both by that agency and the Department of Game.[167]

167/ p. 66.

Each year a major basin was selected, and a comprehensive network of gaging stations and miscellaneous-measurement points were established. Temporary stations were installed on the smaller tributaries where no regular station was in operation, and a relatively large number of miscellaneous measurements were made at other points. The temporary stations were maintained only for a year or so but are expected to be reestablished and operated again in conjunction with a repetition of the miscellaneous measurements every five to ten years in the future. The records from them, together with the records from the regular stations which are maintained indefinitely as a base to which the records from intermediate points can be related, furnished the beginning of the desired inventory. By the end of the period, these inventory networks had been started in four major basins in western Washington. Upon the completion of the first year of eachbasin inventory, a book of records with hydrographs and maps, the latter showing the location of the measuring points, was prepared and furnished the Department of Fisheries for its use in granting the various actual water rights. These books were brought up to date periodically by the addition of new sheets of records and hydrographs.

Due both to the net increase of 156 stations and the establishment of many temporary stations, a total of 277 installations was made. Early in the period, the use of demountable timber shelters on either concrete or timber wells was started. The 4 1/2-foot square shelters were of the panel type, as were also the timber wells. Smaller shelters and wells were used for the temporary stations. To construct economically and quickly the large number of structures required, arrangements were made with the Navy Department for the use of a large storage and power-equipped work shop in a building of the Navy Supply Depot in South Tacoma. The shop was in charge of a Survey foreman, a skilled mechanic, who with one or more helpers, cut and finished the panels for the sides and roofs of the structures. The cutting was done by power tools, and upon completion, the panels were painted by spraying. The panels were then stored until transported to the field by truck. At the time the author visited the store house, he found a very considerable number of finished panels awaiting field use. After the well excavation was completed, thepanel structures could be assembled in a few hours' time. Timber wells at sites which were to become key stations were lined with concrete at a later date. The construction was performed by Survey personnel with high school students employed as laborers during the summer season.

At cableways having side hill anchorage, "garages" for the cable cars were provided. Incidentally, it may be added that all cable cars used in western Washington have roofs; that fact, together with the further fact that water-proofing of forms for measurement notes originated in the Tacoma District in a previous period, indicates the prevalence of rainy weather in that area.

F. M. Veatch's personal interest in the effect of changes of forest cover on stream flow, prompted a special study beginning in the fiscal year 1945. Several gaging stations located generally in pairs, one on an area to be logged and the other on an area to remain in the "status quo" were established; rain gages were installed, and descriptions of the forest cover made. After the stations had been in operation for a year or more, it was discovered that to obtain the necessary accuracy in the records, some artificial controls were required and three were installed by the end of the period.

Beginning in 1946, the Army Engineers were revising their "308" report on the Columbia River, and desired the installation of 50 special staff gages. As the range of stage at some points was from 40 to 50 feet, the gages were bolted to solid rock and were reached by boat and by hiking. no discharge measurements were made at those gages, but their stages were tied to two regular gaging stations and by that means, rating curves were prepared for the staff gages.

The district operated 16 snow courses in cooperation with the Army Engineers, the city of Seattle, and a power company, being started in December 1943. As some, if not all, of the courses were at isolated locations high in the mountains, about 20 shelter cabins, of which half were constructed by the Survey, were stodked with provisions, not only for the snow surveys but also for the regular field work at gaging stations in the vicinity. Two snow courses were reached regularly by

Army Engineer "weasels", specially devised snow vehicles having caterpillar treads. In the spring of 1947, as an experiment, a helicopter was used on a snow-survey trip but a storm prevented its completion and the feasibility of that method was not determined during the period.

Winter work involving the isolated stations is hazardous and it was performed by two-man parties. Two incidents illustrate some of the hazards: In February 1947, Stanley Dragnich, wearing snow shoes, slipped off a strip of icy trail and bounded down the precipitous mountain side for several hundred feet, ending on the brink of a cliff 200 feet above the stream. As he was badly wounded, his companion, Sterling Osborne, being unable to carry him, left him in the snow with all the available clothing and went for help, returning 9 hours later with assistants. On another snow survey in April 1947, William Carroll slipped down hill on skis and by steering himself between two trees by means of his hands, the skis were caught and stopped him. Both injured men were incapacitated for several months.

Early in the period, periodic surveys of Nisqually Glacier on Mt. Ranier were started. The object was to determine the long-range effect of the glacier's recession on the stream flow, and as the city of Tacoma obtained a part of its water supply from that source, the surveys were made in cooperation with the City Light Department. The surveys comprised a plane-table contour map of the glacier by the Conservation Branch every five years with annual cross-sections at critical points.

An administrative manual for the field men, which steered them through the labyrinth government "red tape" was prepared by Mrs. Lucille I. Peterson, who had been the district clerk since 1928. It proved so valuable that it was kept current. She also prepared a manual pertaining to local disbursing. Both manuals were used by several other districts.

G. L. Parker was district engineer until October 16, 1939, when he bacame Chief Hydraulic Engineer, and was succeeded by F. M. Veatch, who came to the district on March 13, 1940. In addition to his duties as district engineer, Mr. Veatch was appointed to several boards by the International Joint Commission.[169/]

168/ p. 391.

Other Civil Service engineering personnel were:

Name	Period	Military Furlough
D. J. F. Calkins	7/ 1/39 to 6/30/47	
G. W. Caughran	7/ 1/39 to 11/ 4/47	
R. B. Kilgore	7/ 1/39 to 9/30/42	
I. E. Anderson	7/ 1/39 to 9/13/41	
G. M. Sherwood	7/ 1/39 to 5/31/40	
G. M. Thayer	7/ 1/39 to 10/ 5/39	
E. Z. Gray	7/ 1/39 to 7/24/39	
G. I. Teufel	7/ 1/39 to 7/10/39	
F. V. Burkebile	11/13/39 to 8/20/42 1/	
G. L. Bodhaine	1/12/40 to 6/30/47	12/14/41 to 1/ 6/46
P. C. Bent	8/ 1/40 to 6/30/47	2/27/42 to 11/28/45
Walter Hofmann	10/22/40 to 6/30/47	
H. C. Riggs	10/24/40 to 6/30/47	
W. H. Robinson	10/29/40 to 6/30/47	11/ 5/42 to 1/25/46
S. W. Dragnich	12/ 3/40 to 6/30/47	12/14/41 to 2/28/46
J. G. Dillon	8/ 1/41 to 10/ 9/42 1/	
J. R. Throckmorton	10/10/41 to 6/30/47	
M. M. Miller	2/16/42 to 6/30/47	7/27/44 to 4/ 9/46

Name	Period
Edwin Nasburg	2/24/42 to 12/25/45
E. G. Bailey	6/30/42 to 6/30/47
F. W. Kennon	9/23/42 to 4/ 1/46
C. E. Chapman	11/ 9/42 to 4/29/47
H. A. Sandven	11/23/42 to 8/ 7/43
H. M. Kirby	3/24/43 to 11/18/43
H. C. Broom	6/ 7/43 to 6/30/47
D. T. Seitsinger	11/ 1/43 to 1/ 1/45
P. G. Sherman	5/ 4/44 to 6/30/47
J. H. Johnson	5/29/44 to 1/31/45
M. W. Hyatt	7/ 1/44 to 1/18/45
Q. P. Bradford	9/19/44 to 7/ 2/45
J. C. Iddings	9/23/44 to 6/30/47
W. M. Carroll	10/16/44 to 5/16/47
W. F. Henager	2/ 1/45 to 2/13/47
W. L. McKay	3/ 1/45 to 6/30/47
F. B. Hagan	7/23/45 to 3/ 5/47
W. M. Darden	9/ 1/45 to 6/30/47
R. J. Parker	9/13/45 to 5/20/46
R. G. Rowland	3/ 1/46 to 3/12/46
E. A. Moore	3/18/46 to 8/23/46
G. W. Heath	5/14/46 to 11/17/46
Agnes Ranlett	6/24/46 to 6/30/47
H. W. Richards	10/ 1/46 to 6/30/47
C. F. Troxell	11/ 1/46 to 12/13/46
A. C. Kloske	12/ 1/46 to 2/22/47
L. V. Jacobs	12/13/46 to 6/30/47
S. R. Osborne	1/ 7/47 to 6 /30/47
F. T. Hidaka	2/ 3/47 to 6/30/47

1/ Military furlough; did not return to district.

Mrs. Lucille I. Peterson was district clerk during most of the period.

Portland, Oreg.-The present period was one of very considerable increase in the number of gaging stations, that increase being from 215 with 161 recorders in 1939, to 278 with 221 recorders in 1947. There were two principal causes: (1) the Army Engineers early in the period provided additional funds, both for the establishment of additional stations and for support of some existing stations, the number of cooperative Army Engineer stations increasing from 9 to 38; and (2) beginning in 1946, the Bureau of Reclamation provided funds to enable the Survey to operate 32 stations in Oregon, including 21 established by the Bureau previously.

To operate some of the new stations, a sub-office with three engineers was established at Medford in the summer of 1946, and with Survey engineers in that area, that office also took over the operation of a number of State cooperative stations previously maintained by State water masters. A total number of 52 stations were operated by the Medford Office, which also computed the records. In October 1944, a sub-office or residency was established in the State Engineer's Office at Salem, and that action resulted in a closer State contact, particularly in the supervision of the stations being maintained by the State Engineer's Office.

Beginning in 1937, samples from 8 snow courses inthe vicinity of gaging stations were collected about 3 times each winter for the Soil Conservation Service. Some of the snow courses were at isolated locations. There were 3 snow courses with elevations ranging from 3,800 to 5,200 feet in the vicinity of Diamond Lake in

North Umpqua Basin, involving at times 120 miles of foot travel, nearly all on skis, and the use of 4 shelter cabins requiring usually 8 days. There were also three courses at elevations ranging from 4,400 to 5,750 feet near a gaging station at Waldo Lake in the Cascade Mountains. The 5-day trip from Bend was made by two men using skis for a distance of 60 miles. The Soil Conservation Service maintained two shelter cabins stocked with provisions, the cabins being located a ski-day distance apart, one being at the lake. On one trip, the party in charge of John Kovtinovich reached the lake after dark and being unable to locate the cabin, were forced to spend the night in an old lean-to without blankets or food. Fortunately, they suffered no ill effects, and the following morning located the cabin within a few hundred feet. On another occasion in 1948, A. L Kimball and a companion spent the night in an improvised brush shelter in the snow on North Umpqua River.

Near the end of the period, as a result of requests for such information, the Survey began to take with regular measurements, water temperatures which would show later the effect of storage on the water temperature, and its suitability forfish life, and for the water supplies for industrial and domestic purposes.

The only use of an airplane during the period was in searching for the bodyof Blake Welsh who was drowned April 15, 1947, while preparing to make a boat measurement of the McKenzie River near Coburg; not high water, but at a stage too high for safe use of the boat for measuring. The boat capsized and Mr. Welsh was swept away in the swift, wide stream. In addition to searching by two motor boats, an airplane was used to search both the river and banks. A large pile of drift was located some distance downstream, and when the river went down, this drift was loosened by means of a large tractor, borrowed from the County Road Department and floated downstream. On May 5, a deputy sheriff continuing the search by airplane discovered the body 600 feet farther downstream from the site of the drift, it having been hidden by the drift. It may be added that Mr. Welsh's drowning while making a discharge measurement was one of a very few, less than half a dozen, similar accidents since the days of the Irrigation Survey in 1889 and 1890.

G. H. Canfield continued as district engineer and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
K. N. Phillips	7/ 1/39 to 6/30/47	
G. A. Kirkpatrick	7/ 1/39 to 6/30/47	
W. T. Miller	7/ 1/39 to 6/30/47	7/20/42 to 6/10/46
E. S. Borgquist	7/ 1/39 to 9/ 8/39	(W A E)
M. D. Brands	7/ 1/39 to 5/14/40	
	7/31/44 to 6/30/47	(W A E)
I. A. Cooper	7/ 1/39 to 7/21/41	
John Kovtynovich	7/ 1/39 to 3/ 1/40	
A. R. Peracca	7/ 1/39 to 1/ 2/43 1/	
K. J. Smouse	7/ 1/39 to 6/30/47	
	10/ 8/43 to 6/30/47	(W A E)
M. L. Hilleger	3/ 2/40 to 9/13/40	
W. W. Dean	4/23/40 to 6/30/47	
G. A. Burkman	10/14/40 to 6/30/47	7/ 3/42 to 4/29/46
	4/30/46 to 6/30/47	(WAE)
G. J. Backe	3/ 3/41 to 6/30/47	7/14/41 to 1/14/46
L. J. Jensen	4/ 1/41 to 3/ 5/43 1/	
M. D. Calkins	3/18/42 to 6/30/47	7/ 7/44 to 4/22/46
O. T. Dauelsberg	12/ 1/42 to 7/15/46	

Name	Period
C. C. Scott	3/25/43 to 6/ 7/43
E. H. Stolte	8/ 3/43 to 6/30/47
R. W. Childreth	11/22/43 to 6/30/47
J. F. Cleaver	8/14/44 to 6/30/47
C. A. Young	9/ 3/44 to 6/30/47
Blake Welsh	10/ 1/45 to 4/15/47
G. E. Koberg	6/18/46 to 6/30/47
R. H. MacLauchlan	9/16/46 to 1/ 6/47

1/Military furlough; did not return to district.

Miss Belle Irwin was the district clerk.

San Francisco, Calif. - The number of stations was increasedfrom 279 with 263 recorders in 1939 to 371 with 320 recorders during the period. The nearly 100 additional stations were due chiefly to the increase in stations operated for the Army Engineers and Bureau of Reclamation. During the first year, the Army Engineers requested the establishment of 18 stations in connection with their flood-control studies, and during the ensuing year, additional stations were established, the total number at the end of the period was 44. The increase in the number of Bureau of Reclamation stations was from 2 in 1939 to 43 in 1947, most of the increase occurring in the 1944 fiscal year following a conference with Bureau officials which resulted in 28 Bureau stations in the Central Valley Project being transferred to the Survey for operation and rehabilitation. In addition to the 371 stations reported, records for 30 were furnished for publication by the Los Angeles County Flood Control District and 13 by power companies and other agencies. In addition to the 414 stations, for which records were published, there were 61 stations maintained for Federal Power Commission permittees and licensees, the records for which were not considered of sufficient general interest to warrant publication in Water-Supply Papers. In December 1941, at the suggestion of the Washington Office, an engineer was stationed at the State Engineer's Office in Sacramento. The Central Valley Project, involving the utilization of the streams in the Sacramento and San Joaquin Valleys, was in the construction stage and in that connection, close cooperation with the State Engineer of California and the Bureau of Reclamation in the operation of certain gaging stations was desirable.

Beginning with the appointment of H. M. Stafford, who succeeded F. C. Ebert, deceased, as engineer in charge in 1943, the Los Angeles Office became largely independent of the San Francisco Office. It had its own allotment of funds, its own fiscal accounts, compiled its own records and transmitted them to Washington, and maintained the necessary cooperation with the counties and cities of southern California. The district engineer, however, arranged the State cooperation and apportioned those cooperative funds to each office. The division of the district area operated by each office was represented by a line between San Luis Obispo and the crest of the Tehachapi Mountains and extended eastward to Nevada.

In the San Francisco area, in which 250 of the 371 stations were located, a resident engineer was detailed to Atascadero in 1942 when the Army Engineers requested the Survey to make detailed studies of the water resources in the upper Salinas River Basin where the former agency had constructed a reservoir to supply Camp San Luis Obispo, an old National Guard Camp. As the diversion was into another basin, it was necessary to keep accurate records of the diversion, and its effect on the Salinas River. In addition to the 6 gaging stations established, seepage measurements were made during the low water season at 3-week intervals from the reservoir to the mouth of the river, measurements being made at 13 points of which 9 were on the river itself. A sub-office at Merced with 2 engineers, and one at Porterville with one engineer, were established in 1944, when the Survey took over the operation and rehabilitation of the Bureau of Reclamation stations connected with the Central Valley Project. There was no resident engineer at Lodi subsequent to 1942, although office space was retained in the post office building.

One equipment casualty was charged up to the war: The Navy establishment at Tiberon was preparing to put a submarine net across the Golden Gate, and before designing the net, borrowed two meters to measure the tidal velocities. After the war, one meter was returned but the other was reported missing as it had become entangled in the propellor of a naval vessel.

The Los Angeles Office was in charge of F. C. Ebert until his death in the field February 23, 1943, and after an interim of a few months, H. M. Stafford, formerly with the National Resources Planning Board, and an early day Survey employee in California[169] was placed in charge September 1, 1943.

169/ Follansbee, Robert, History of the Water Resources Branch of the U S Geol. Survey to 1919, p. 423.

Of the 371 regular stations in the San Francisco District, the Los Angeles area had 121, which was an increase of 41 stations during the period. A part of the increase began in the summer of 1941 when the agreement with Santa Barbara County became effective; 6 stations were established that year and 17 during the remainder of the period. The records of the stations in Santa Barbara County were of particular value to the Ground Water Division's investigations,[170] and an engineer

170/ p. 346.

was stationed in Santa Barbara with the Ground Water Division. Beginning in the fiscal year, the resident engineer, H. G. Thomasson, devoted much of his time in analyzing the accumulated stream-flow records and related hydrologic data, and in preparing sections of the report on perennial water yields, which were incorporated in the Ground Water Division's three reports on the Santa Barbara County investigations.[171]

171/ p. 346.

The Santa Barbara County work was not the only cooperation with the Ground Water Division, as during the Los Angeles River investigation for the Army Engineers, the Surface Water Division analyzed the results of seepage measurements made by other agencies. The chief cooperation, however, was the measurement of about 200 observation wells at intervals ranging from monthly to yearly, which had been carried on for many years, the number of wells gradually increasing.

Water is so valuable in southern California and the stream beds to shifting that many attempts were made to design artificial controls to eliminate shifts, and 20 percent of the stations were so equipped at the end of the period. In spite of the controls, however, it was necessary to make either weekly or bi-weekly discharge measurements at some stations throughout the year.[172]

172/ Proceedings Carson City Conference, Sept 18-20, 1946, pp. 23-25.

An important part of the activities of the Los Angeles Office was the intensive hydrologic studies made by H. C. Troxell, the first and most comprehensive of which was the study of the San Bernardino and eastern San Gabriel Mountains, started in 1941.

The San Bernardino County Flood Control District was organized to facilitate the development of a county-wide program of flood control, as well as to be the contact agency between the County and any Federal agency planning flood-control structures. The County officials had no program and were looking for suggestions. Mr. Troxell explained that much valuable information could be obtained from an intensive study of existing hydrologic data and as a result, the Survey was requested to outline a cooperative program which was presented and accepted. It was a 5-year office study, based on precipitation and runoff, and an analysis of each drainage basin in the San Bernardino and eastern San Gabriel Mountains. The purpose was to show the recoverable water in each basin, the amount depending on physiography, absorptive ability of the soil, available ground-water storage, and the magnitude of the natural losses.

Headquarters were established in the Flood Control District Office in San Bernardino, where Mr. Troxell had two full-time assistants and three part-time assistants who maintained the regular gaging stations in that area. No additional stations were established for the study. San Bernardino had been a sub-office for stream gaging in that area since 1919.

It was expected that the Ground Water Division would cooperate by furnishing a ground-water geologist, and P. E. Dennis spent about 6 weeks studying the geology and preparing a report on the "Geology of San Antonio Canyon, California, in relation to ground-water storage." He also spent an additional month or so preparing a report on "Geology of the San Timotes Creek Basin, California," with K R. Melin. At the end of that time, it was necessary for the Ground W ter Division to place him in charge of the investigations in Utah, and the shortage of personnel during the war years made it impossible to make another detail to the investigation. H. V. Peterson, in charge of the Survey's Soil and Moisture Program, supervised the subsequent geologic studies. The study itself was completed in 1946. The report which will be published as a water-supply paper, contained chapters on physiographic features; analysis of drainage basins by altitude, average exposure and vegetative cover (furnished by the Forest Service); climate and temperature; precipitation, the study of the probability or frequency of precipitation on individual days; snowfall; solar radiation; tabulation of flood runoff by 5-day periods, as being more reliable than recorded peak discharges, and being as long a flood runoff generally occurs, due to the absorptive qualities of the drainage areas, were later peak discharges supplemental to the 5-day periods; and seasonal runoff. The ground-water storage was determined from studies of precipitation and runoff.

With the foregoing as an example, a similar study on a smaller scale in Riverside County was started in the fiscal year 1947, during which the study was made in the Los Angeles Office. It was in progress at the end of the period.

While the San Bernardino study was in progress, a study of the evapo - transpiration losses by heavy native vegetation in the lower Santa Ana River Canyon was being made[173] It was started in the spring of 1944

[173] p. 70.

for the purpose of determining the amount of the water losses in the canyon, and the economic feasibility of measures which might be taken to salvage some of those losses. The losses were determined by the basic equation involving inflow, outflow, and change in ground-water storage, and involved measurements or estimates of all qualities of water, surface and sub-surface, entering, stored in, and leaving the canyon section, in a given interval of time for each of the years 1944, 1945 and 1946. To determine permeability of the valley fill, a pumping test was made of one of the irrigation wells of the Santa Ana Valley Irrigation Company, in May 1945. The hydraulic gradient at that cross section was determined on the basis of water level elevations in 2 wells 2,500 feet apart. The width and depth of the water-bearing materials at the cross section were defined by observation of water levels in wells, and by a cross section of the valley fill, based on test borings made by other agencies. The study was completed in June 1947, and a report "Water Losses in the Lower Santa Ana River Canyon, by M. B. Scott and H. C. Troxell," prepared. The description of the study was taken from that report.

H. D. McGlashan continued as district engineer and had the following Civil Service Engineering assistants: San Francisco Office

Name	Period	Military Furlough
R. C. Briggs	7/ 1/39 to 6/30/47 2/	
Chas Leidl	7/ 1/39 to 4/30/45	
Jesse Arnold	7/ 1/49 to 6/30/47	
C. J. Emerson	7/ 1/39 to 11/30/39	
B. C. Colby	7/ 1/39 to 9/ 1/42 1/	
D. A. Dudley	7/ 1/39 to 6/30/47	
F. A. Johnson	7/ 1/39 to 7/14/42	
H. M. Orem	7/ 1/39 to 11/15/42	
K. F. Schumacher	7/ 1/39 to 6/30/47	
A. C. Swanson	7/ 1/39 to 6/30/47	
P. M. Alexander	7/ 1/39 to 6/22/42	
H. J. Sexton	7/ 1/39 to 6/30/47	10/ 5/42 to 1/13/46
H. C. Pritchett	7/ 1/39 to 8/ /39	
C. D. Bue	7/ 1/39 to 7/31/39	
Harry Hulsing	12/ 7/39 to 6/30/47	1/16/43 to 3/13/47
Winchell Smith	3/ 4/40 to 6/30/47	
R. I. Mayo	8/19/40 to 9/30/46	
M. L. Hilleger	9/ 4/40 to 7/22/41	
R. P. Gilbert	12/ 2/40 to 3/15/43	
J. H. Stollard	10/20/41 to 11/23/42	
J. W. Odell	12/ 4/41 to 3/12/44	
H. E. Dahman	11/23/42 to 6/30/47	
W. L. Wellman	12/18/42 to 1/ 5/45	
R. C. Wheeler	2/ 1/43 to 6/30/47	
T. A. Cooper	2/15/43 to 6/30/47	
F. C. Craig	3/ 4/44 to 6/30/47	
D. L. Milliken	6/15/44 to 6/30/47	
F. B. McGraw	9/26/44 to 6/30/47	
R. S. Lord	11/ 2/45 to 6/30/47	
V. C. Bengal	12/6-21/45; 3/27/46; 9/26/46; 3/31/47 to 6/30/47	
A. H. Peracca	4/16/46 to 7/ 1/46	
George Anthony	6/28/46 to 6/30/47	
H. F. Matthai	12/21/46 to 6/30/47	

2/ In Venzuela September 4, 1945 to September 7, 1946

1/ Military furlough; did not return to district.

Los Angeles Office

Name	Period	
F. C. Ebert	7/ 1/39 to 2/23/43	deceased
H. C. Troxell	7/ 1/39 to 6/30/47	
Jarrett Oliver	7/ 1/39 to 6/30/47	
O. J. Wittman	7/ 1/39 to 6/30/47	
K. R. Melin	7/ 1/39 to 1/31/44	
R. S. Lord	7/ 1/39 to 4/14/40	
K. F. Schumacher	7/ 1/39 to 6/30/47	
G. I. Lang	7/13/39 to 6/30/47	
S. S. Butler	1/24/41 to 6/30/47	
M. B. Scott	2/ 2/42 to 6/30/47	

Name	Period
L. E. Kizer	4/24/42 to 12/14/42[1]
W. E. Dickinson	10/ 1/42 to 6/30/47
R. P. Dalton	12/ 1/42 to 8/17/43;
	10/ 1/43 to 6/30/47
H. M. Stafford	9/ 1/43 to 6/30/47
H. G. Thomasson, Jr	2/21/42 to 8/25/46
W. D. Gerke	2/11/44 to 6/30/47
George Anthony	10/23/43 to 4/30/44
V. E. Wicks	7/ 5/44 to 6/30/47
P. A. Faranda	7/16/45 to 1/22/47;
	6/15/47 to 6/30/47
S. E. Rantz	3/19/46 to 10/12/46
C. E. Burgess	4/ 8/46 to 6/30/47
A. S. Sollid	8/26/46 to 6/30/47

1/Military furnough; did not return to district.

Miss Helen C. Smith was the district clerk.

Honolulu, T. H.-With available funds substantially the same except for increases to take care of increased costs, there was but little opportunity to increase the number of stations and consequently, that number was only increased from 115 to 126, all equipped with recorders, and 96 percent with artificial controls. The rating of gaging station models started in the previous period was stopped after Pearl Harbor. At the beginning of the period, a new technique worked out by H. W. Palm[174] speeded up the time required to prepare and rate a model, and as a result, 29 were rated.

174/Water Resources Bull., Feb 1941, pp. 43-56.

The most inaccessible group of stations were those on the windward or north side of the island of Molokai.[175] When those stations were reestablished in 1937, it was customary to hire a sampan to take the engineer to that coast by sea, except when the weather was too bad, as the only means of approach was over a 3,000-foot mountain ridge. At the beginning of the war, the sampans were not permitted to go out, and the shortage of labor made it impossible to maintain the mountain trail. An arrangement was made with the Board of Hospitals whereby the Survey purchased a 30-horsepower diesel engine for a boat used to convey supplies to the Leper Settlement, and that boat was made available for reaching the windward side of the island.

175/pp. 162-3 (1919-1928).

A side light on the impressions of field conditions on a newcomer to the district were those of an engineer who spent a few months there in 1943. When he first visited a gaging station shelter, he took hold of the padlock to unlock it and received a centipede sting, and upon opening the door, he was greeted by a shower of scorpions and more centipedes. Thereafter, he always knocked on the door with a long stick to shake loose the inhabitants.

The Honolulu District, as would be expected, felt the impact of the war much more than any mainland district. Perhaps the most radical effect on the district operations was the use of airplanes for inter-island transportation; all surface transportation was immediately discontinued December 7, 1941, and thereafter, only airplane service was available. Use of airplanes continued after the war as reduced fares made it economical to use the planes which made several trips daily while ships offered only weekly service.

An effect felt more severly than in other districts was that due to the engineer personnel of Japanese descent. With the loss of some of the most experienced engineers to the Navy, it was necessary to carry on with juniors and aides, four of whom were Japanese-Americans. The understandable prejudice of the Army and Navy' against Japanese at that time barred them from many areas, and the non-Japanese personnel had to assume a heavier burden of field work. Some gaging stations were in areas taken over for jungle training where it was necessary to obtain advance permission from the Commanding Officer and making that contact frequently required as much time as the actual visit tothe station itself. From those areas especially, Japanese were barred. They were also barred even as passengers from the boats used in visiting the gaging station on the north coast of the island of Molokai.

Another effect was that on the work of the artesian well engineer. There were many wells in the Pearl Harbor area which were acquired by the Navy and as much construction work was carried on, many of the wells were abandoned. However, under Territorial law, all wells had to be sealed before abandonment. And although before sealing, the well pipe was sticking out of the ground, such a pipe meant nothing to the contractors, or to the constantly changing Navy personnel, and consequently, the artesian well engineer was kept busy spotting new construction which might cover up a well before it could be sealed, or its location marked for future action. Since 1915, the investigation of the artesian wells has been a part of the surface-water cooperative program with the Territory. That includes records of well head, salinity, new drilling, repair and abandonment, and administration of the Territorial laws relating to the conservation of artesian waters.

A minor effect of the war on the regular activities was the shortage of food in the restaurants. The many service men stationed on the islands became bored with their regular mess and formed the habit of patronizing the restaurants whenever possible, with the result that the restaurants would be sold out and close up sometimes early in the afternoon. Consequently, it became the Survey practice for the engineers to carry a supply of canned food to avoid going to bed hungry.

War-time requests for information were of two types; one, available sources of water supply for military establishments, and the other, estimates of the probable size of the flood peaks where such proposed establishments were to be located along waterways. As Mr. Carson adds[176]

176/Letter to author.

One of the striking features of this was that almost invariably the same information would be requested by two or more different authorities and would be repeated from time to time as the personnel changed.

The attack on Pearl Harbor was witnessed at close range by H. S. Leak who while on annual leave, was working for a contractor at Pearl Harbor on the morning of December 7th. When the bombing occurred, being unarmed, although if armed it would have done no good, he was a helpless bystander without cover and had to take it; fortunately, he was not injured. That same day, Paul Goo, a territorial employee in the district, had the front of his house blown off while at breakfast with his family, but none were hurt except Goo himself who had a minor injury due to a flying splinter. Messrs. Carson, Beardin and Leak were members of a volunteer home guard unit, known as the Business Men's Training Corps, which was uniformed, armed and trained bythe Army and participated in some of the Army maneuvers; later, most of the work was guarding water works, radio stations, warehouses and other essential installations. They took over those duties from the Army at night. Until the battle of Midway, which marked the turning point of the danger to Hawaii, the inhabitants were, in Mr. Carson's words, "pretty jittery," but afterward they felt there was no real danger of a second attack.

M. H. Carson continued as district engineer and had the following Civil Service engineering assistants:

Name	Period	Military Furlough
W. E. Armstrong	7/ 1/39 to 6/30/47	
G. T. Hirashima	7/ 1/39 to 6/30/47	
H. W. Palm	7/ 1/39 to 6/ 8/42	
H. C. McCreery	7/ 1/39 to 4/10/41	
H. S. Leak	7/ 1/39 to 6/30/47	12/31/43 to 12/ 7/45
J. W. Montgomery	7/ 1/39 to 1/25/42	
M. N. Nahm	7/ 1/39 to 4/10/41	
E. H. Bekkedahl	9/14/39 to 11/14/41	
Kenzo Takumi	10/31/41 to 6/30/47	
Hisashi Kanno	6/ 1/42 to 6/26/44	
R. K. Chum	6/11/42 to 6/30/47	
H. W. Beardin	11/ 5/42 to 6/30/47	
George Anthony	4/25/43 to 9/25/43	
George Yamanaga	6/ 3/43 to 6/30/47	
D. W. Lee	11/16/44 to 6/16/46	
J. G. Chun	7/ 8/46 to 6/30/47	
C. A. Wyse	8/12/46 to 6/30/47	
M. Y. Lee	1/ 2/47 to 4/15/47	
Hajime Matsuura	5/19/47 to 6/30/47	

Alaska.-Although the Water Resources Branch had carried on a limited amount of water investigational work in Alaska in cooperation with the Alaskan Branch from 1906 to 1913, and again from 1915 to 1921,[177] no such work had been performed by the Survey subsequently.

177/Follansbee, Robert, History of Water Resources Branch to June 30, 1919, pp. 291-8, 425-8.

The growing scarcity of wood pulp in the United States, which had been a prime reason for the second investigation (1915-21), continued, and was made more critical during World War II when the supply normally obtained from Europe was cut off. As a wealth of pulp wood is available in southeastern Alaska and as ground wood pulp is cheap but requires large amounts of power for grinding, an investigation of the power possibilities of that region was needed because the availability of cheap power was the principal unknown factor. In addition to power for grinding pulp, a number of cities needed additional water supplies. Water investigations were therefore required.[178]

178/Statement of N. C. Grover to author.

To meet Alaska's needs, the Survey included in its estimates for 1947 an item for work in Alaska, and Congress made available $14,000 for it. As this was insufficient to establish a full-fledged district in that region, where it costs about $1,000 per month for salary and expenses of each engineer, the first year's work was confined to a reconnaissance and rehabilitation of some stations which had been maintained during the previous investigation. A. O. Waananen was borrowed from the Albany Office and placed in charge of the Alaskan investigation, with W. W. Dean from the Portland Office as assistant, and they travelled by airplane to Juneau, arriving August 7, 1946.

The first step was a conference with B. F. Heintzleman, the U. S. Forest Service's regional forester, who had maintained subsequent to 1921 a few of the stations operated by Mr. Canfield. Mr. Heintzleman, who was also the regional representative of the Federal Power Commission, had long advocated Survey participation in a stream-gaging program and was able to furnish assistance by providing boat transportation and other services. Other Federal agencies, Alaska Native Service, National Park Service, Public Roads Administration, and municipal groups in Sitka, Petersburg, and Ketchikan also furnished valuable information.

In 1927, the Federal Power Commission had issued a preliminary permit to I. & J. D. Zellerbach of San Francisco covering power sites on eight streams, and another permit to George J. Cameron of San Francisco for a power development near Juneau. Gaging stations required by those permits were established and maintained by Wendall Dawson, formerly of the Survey. Later, he was employed by the Forest Service and continued the maintenance of some stations. A number of stations were operated until 1938, but subsequently only two were continued; the flow was measured chiefly through power plants, or at spillways from reservoirs. Such was the background of Alaskan stream gaging in 1946.

The first work was a series of trips to various sections of southeastern Alaska to inspect the old stations and make reconnaissances for new ones. After the first month, the reestablishment of old stations was begun. That on Sheep Creek near Juneau, having a weir control, started by Mr. Canfield in 1916, was in such good condition that no repairs were needed; at another station, where the channel was in a deep bed of gravel, the measurements checked the old rating curve closely. In all, four recorders were installed and one staff-gage station established, the latter at a station previously maintained by the City of Sitka, on Sawmill Creek.

If any work was to be done in the interior, it had to be started by the middle of September and accordingly, at that time, Messrs. Waananen and Dean headed for Fairbanks in the Yukon Basin, traveling by boat from Juneau to Skagway, thence by train to Whitehorse, and finally by bus over the Alaska highway to Fairbanks, the bus trip requiring 70 hours. Even so, the bus trip was obviously a great improvement over the trip down the Yukon from Whitehorse to Tanana, thence up the Tanana River to Fairbanks, a distance of nearly 1,400 miles, requiring about 10 days, that route being the only one available during the Survey's earlier work in Alaska. A reconnaissance of surface-water supplies was made in the interior where the water-supply situation is critical and during the winter season, the ground-water supplies from permanently frozen ground would have to be used. In passing, it may be stated that while Messrs. Waananen and Dean were in the interior, the habitat of the famous Alaskan mosquito, that "beastie" was not in evidence.

To complete the work planned for the 1947 fiscal year, the party travelled from Fairbanks to Chitina, Valdez, and Anchorage on the coast by truck loaned by the Survey's Alaskan Branch Office at Fairbanks, the distances ranging from 367 miles to Valdez, to about 460 miles to Anchorage. As the highways are generally gravelled, speeds of 40 to 50 miles per hour were made. Owing to the isolated region traversed, it was necessary to carry auxilliary gas tanks and emergency gas supplies.

In the Anchorage area, the work was chiefly a reconnaissance, but a staff gage was installed on Ship Creek near Anchorage, and later the Anchorage Public Utilities installed a staff gage on Eklutna River at Eklutna Lake. Seward was reached from Anchorage by means of a small plane making daily flights. In the coastal area, there is apparently sufficient water for all users but there are no records of actual quantities.

Before leaving Alaska early in November, three recording gages were installed in southeastern Alaska, and one near Juneau.

Late in April 1947, field work was resumed by R. I. Mayo, formerly in the San Francisco Office, with headquarters at Juneau. At the end of the period, 7 gaging stations were in operation.

Referring to the work, Mr. Waananen, in addition to furnishing the information on which the foregoing was based, stated that his personal experiences "were regular and normal with little or no excitement, the type usually expected in the land of the brown and grizzly bear."

GROUND WATER DIVISION

The recognition of the importance of ground-water supplies received great impetus during the war. The great increase in the use of water for industrial, agricultural, and municipal purposes increased the draft on ground-water supplies from 10 billion gallons to 20 billion gallons per day in less than 10 years. Throughout the nation, it became increasingly apparent that water supply was the basis of the economic development and as ground water was preferrable for many purposes, the States became increasingly aware that to participate in the growth of industry and agriculture, it was necessary to have reliable data on the extent and character of their ground-water resources. As a result, the States that had been cooperating during the previous period increased their cooperative offerings largely and additional States began cooperation with the result that the State cooperative funds were increased 200 percent during the period. In southern California and in southeastern Florida, the greatly increased drafts caused danger of salt-water encroachment.[179]

[179] Based on information furnished by A. G. Fiedler.

To meet the increasing demand for information on ground-water reports, the Survey revised Water-Supply Paper 427, published in 1918, which contained a bibliography of its ground-water papers. In the revised or second edition, not only were the Survey reports listed, but also those by State agencies, and articles by Survey personnel published in various scientific, technical, and trade journals, issued through January 1946. It was published in 1947 as Water-Supply Paper 992.

Organization

O. E. Meinzer continued as chief of the division until his retirement November 30, 1946, when he was succeeded by A. N. Sayre; A. G. Fielder was designated assistant chief on July 1, 1942. V. T. Stringfield had general supervision over field activities east of the Mississippi River; L. K. Wenzel, until his retirement in 1944 exercised a certain amount of supervision in the Middle West; A. M. Piper was in charge of investigations in the Pacific Coast states, until he was appointed Staff Scientist, Office of the Director, in October 1946; thereafter, the offices in those states were independent. Beginning in 1945, and continuing until he became chief, A. N. Sayre gave limited supervision to the ground-water work in states west of the Mississippi River. In general, the district offices were virtually independent, reporting directly to the Washington Office. With the beginning of the Missouri Basin-Departmental Program, the ground-water work required by that program was under the direction of G. H. Taylor with headquarters in Lincoln. That work was coordinated so far as possible with the regular State programs, and carried on by the regular offices except in North Dakota where the Grand Forks Office, having the cooperative

State work, was too remote from the Missouri Basin.

D. G. Thompson planned and organized programs for new field offices, and was responsible for organizing investigations for the war agencies and making the necessary contacts with other agencies. After his death February 19, 1943, C. L. McGuinness assumed responsibility for the investigations and answers to inquiries relating to war work. Miss Jane Daniel was secretary to the Chief of the Division throughout the period.

Decentralization, which had been started in the previous period, was greatly accelerated with the expansion of the investigations to new areas, due largely to additional State cooperation. The number of field offices was increased from 14 to 45. In general, there was an office in each cooperating State, directing the work in that state. In Florida, the work was divided between independent offices in Tallahassee and Miami, and toward the close of the period, there were offices in Grand Forks, and Bismarck, N. D., the latter in connection with the Missouri Basin Departmental Program. There were also two offices in Michigan, one being in northern Michigan, and those were virtually independent. In several states, there were sub-offices reporting to the principal office in the state. Of the 14 district offices in existence at the beginning of the period, or established during the first year, only the following had the same official in charge during the entire time:

H. C. Barksdale, Trenton, N. J.; D. J. Cederstrom, Charlottesville, Va.; H. H. Cooper, Tallahassee, Fla; W. N. White, Austin, Tex.;' C. V. Theis, Albuquerque, N. Mex; and S. F. Turner, Tucson Ariz.

STATE COOPERATION

The heavy draft on ground-water supplies by war industries in most sections of the country brought a realization that such supplies were not unlimited, and that information regarding their safe yield and the possible sources of additional supplies was needed. During the war years, many regular State activities were curtailed and surplus funds accumulated; it was therefore comparatively easy for the States to make new appropriations. As a result, State or municipal agencies, or both, in 18 states started cooperation during the period or resumed it after a lapse of several years. One State agency discontinued a small amount of cooperation when the Missouri Basin-Departmental Program became effective. At the end of the period, cooperation was effective in all but 7 states.

The increase in State cooperation during the latter part of the period when the effect on existing water supplies by the war effort became apparent, is strinkingly shown by the totals for each year:

1940	$208,450	1944	$262,675
1941	215,259	1945	325,265
1942	233,622	1946	492,518
1943	215,132	1947	616,306

The reasons for the increase in each state are presented in the following pages containing the details of cooperation. As cooperation was on a full 50-50 basis except during the 1947 fiscal year when 3 percent of Survey cooperative funds were held in abeyance, only the State cooperative amounts are shown.

Massachusetts. -Cooperation with the Department of Public Works continued on the same level through the first half of the period, but beginning with the fiscal year 1944, the funds were increased to enable the Survey to make a special study of the water supply in the vicinity of Cambridge. Under State law, communities in the Metropolitan area are required either to have supplies 10 percent in excess of the average consumption for the previous three years, or to connect with the Metropolitan water system. As the Department of Public Health claimed that Cambridge did not have the required excess, a claim disputed by that City, the State agency requested the Survey to make an investigation and the cooperation was increased for that purpose.

The results accomplished by the investigations already undertaken showed the desirability of a State-wide program. The Department of Public Works had $50,000 available for cooperation with all branches of the Survey, and as the topographic work was decreasing due to nearly complete coverage of the state, cooperation with ground-water was increased to $9,500 during 1947.

Annual cooperative State funds available:

1940	$1,000	1944	$2,500
1941	1,000	1945	2,500
1942	1,000	1946	2,500
1943	1,000	1947	9,500

Connecticut. - Cooperation with the State Water Commission which was started in the fiscal year 1938 was continued for the purposes of keeping current the observation-well program and making studies in the heavily pumped areas of the state.

Annual cooperative State funds available:

1940	$ 500	1944	$2,000
1941	1,000	1945	2,000
1942	1,000	1946	2,000
1943	1,000	1947	2,000

Referring to the cooperation, the State Water Commission in its Tenth Biennial Report for the years 1942-44, stated:[180]

180/p. 11, Tenth Biennial Report.

The State Water Commission is most appreciative of the aid given by the director and staff of the Ground Water Division of the Survey.***Their services have been of the highest order and the cheerful cooperation which has been extended to the State and its citizens in furnishing information is acknowledged with genuine pleasure.

Rhode Island. -The heavy draft on ground-water supplies by war industries and the many requests for information by industrial engineers for new sites showed the State Industrial Commission the need for a ground-water investigation, and cooperation became effective in the fiscal year 1945.

Annual cooperative State funds available:

1945	$1,200
1946	2,500
1947	2,500

New York. -Cooperation with the New York State Water Power and Control Commission, the Nassau County Department of Public Works, the Suffolk County Board of Supervisors, and the Suffolk County Water Authority, for the purpose of investigating the ground-water conditions on Long Island continued during the period. Until the fiscal year 1945, the State cooperative program had been confined to Long Island. The increased use of ground water by industry during the war years, and the inquiries regarding ground-water supplies, showed the need for a State-wide investigation and the State Commerce Department took the lead in urging that investigation by calling a meeting in Albany. A roundtable discussion participated in by Commerce Department, State Museum, State Geologist, State Health Department, and State Conservation Department, showed clearly the need for the proposed investigation, and the Commerce

Department put in its budget an item for it. However, as the State Water Power and Control Commission was directly concerned with both surface and ground water in the state, the Legislature made the appropriation for the State-wide investigation to that agency. Beginning in April 1945, an additional agreement was effected with the Commission for that purpose. The value of the new investigation was shown by the increased cooperation for it during the remainder of the period.

During the fiscal year 1942, cooperation with the City of Rochester was effected for the purpose of investigating an additional water supply but due to a change in city policy, a surface-water supply was selected and the cooperation was not continued.

Annual cooperative State, County and City funds available:

Year	State WP&Control Comm Regular	State WP&Control Comm Additional	Nassau Co.	SuffolkCo	Rochester	Total
1940	$2,850		$7,500	$2,000	$	$ 12,350
1941	2,850		6,500	2,000		11,350
1942	2,600		6,500	2,800	1,950	13,850
1943	2,630		5,500	1,200		9,330
1944	3,000		5,500	4,000		12,500
1945	3,000	$6,250	5,500	4,000		18,750
1946	4,500	18,750	5,500	5,000		33,750
1947	6,750	26,600	7,000	5,500		45,850

The variation in the Suffolk County cooperation during 1942 and 1943 was more apparent than real. In 1942, the Surface Water Division used $800 of that fund for the stream gaging stations connected with the ground-water investigations and paid certain ground-water expenses during 1943.

New Jersey.-Cooperation with the State Water Policy Commission continued during the period, the funds being gradually increased in the latter years on account of the increased cost.

Annual cooperative State Funds available:

1940	$ 8,100	1944	$ 8,000
1941	8,050	1945	9,050
1942	10,000	1946	9,250
1943	7,731	1947	11,000

Pennsylvania.-With the completion of the State-wide areal survey in 1936[181] cooperation with the Pennsylvania Topographic and Geologic Survey was limited to continuing the weekly readings of the observation wells.

181/p. 305 (1928-1939).

The increasing use of ground water for municipal and industrial supplies caused interest to be aroused in the advisability of enacting ground-water laws to supplement the comprehensive system of State laws for surface-water supplies. This interest was quickened by the Navy Department's apprehension regarding the demands on ground water due to the war-time activities. As a result, the State Geologist, G. H. Ashley, a one-time member of the Geologic Branch, whose office was attached to the Department of Internal Affairs, increased the cooperative funds in the fiscal year 1944 for the purpose of making a general ground-water inventory of the entire State, concentrating on the highly industrialized cities of Philadelphia and Pittsburgh at first.

During the war years, the State Geologist had been willing to have a large share of the cooperative funds used in the Philadelphia area on account of the war establishments in that area. With the end of the war, however, both the State and Survey officials felt that the State funds available should be used on the State-wide program and the Philadelphia Planning Commission was notified of that decision which would have virtually discontinued the ground-water investigations in that area. To prevent that action, the Planning Commission began cooperation in the fiscal year 1947.

Annual Cooperative State and Municipal funds available:

Year	State Geologist	Philadelphia Planning Comm	Total
1940	$ 400		$ 400
1941	400		400
1942	1,000		1,000
1943	500		500
1944	2,500		2,500
1945	2,994		2,994
1946	7,500		7,500
1947	12,500	$2,055	14,555

Delaware.-The municipalities of Lewes and Rehoboth Beach were concerned over salt water encroachment in the aquifer from which they derive their water supplies, and in the fiscal year 1944, cooperated for the purpose of obtaining records from two observation wells. The Lewes cooperation continued through 1946.

Annual cooperative funds available:

Year	Lewes	Rehoboth Beach
1944	$250	$250
1945	250	
1946	150	

Maryland.-The first State cooperation in Maryland ground-water investigations became effective when a special appropriation was made with the Maryland Department of Geology, Mines, and Water Resources in December 1942, for the specific purpose of studying the Baltimore industrial area. Due to excessive pumping a serious problem in that area had existed for many years, and rapidly increasing demands by the expanding war industries made that problem critical, especially as the likelihood of salt water encroachment was present. It was expected that field investigation would be completed by 1945 and to hasten it, the City of Baltimore cooperated during the 1944 and 1945 fiscal years.

The State had enacted the Water Resources Act of 1933 which created the Water Resources Commission for the purpose of conserving, protecting and utilizing the water resources of the State, and made it unlawful to appropriate or use any waters of the State without a permit from the Commission to be issued after a public hearing. Funds provided for the enforcement of that Act were totally inadequate, and little or no action had been taken. In 1941, the Commission was merged with the Department of Geology, Mines, and Water Resources, but no provision for the administration of the water law was provided in the Department's budget.

In 1945, with the results of the Baltimore investigation available as an example of the value of ground-water investigations and ground-water problems in other sections needing serious attention, the Department obtained a regular budget, appropriation for ground water amounting to $15,000 annually. As a result, the program was expanded to a State-wide basis.

Annual cooperative State funds available:

Year	State	Baltimore	Total
1943	$ 3,000		$ 3,000
1944	2,000	$ 950	2,950
1945	2,450	2,550	5,000
1946	15,000		15,000
1947	15,000		15,000

Virginia. - Cooperation with the State Geological Survey which had been resumed in the fiscal year 1938 continued during the period, being gradually increased on account of rising costs.

During the fiscal year 1942, the City of Newport News cooperated with the Survey for the purpose of investigating a possible ground-water supply, as the tremendous expansion of the population at that most important center of war activity required a larger water supply.

Annual cooperative State and municipal funds available:

Year	State Geol Survey	Newport News	Total
1940	$1,300		$1,300
1941	1,966		1,966
1942	2,000	$773	2,773
1943	2,000		2,000
1944	3,300		3,300
1945	3,600		3,600
1946	3,600		3,600
1947	4,200		4,200

North Carolina. - Until the present period, the only cooperation with the State had been indirect; beginning in 1931, the Surface Water Division, at the request of the Department of Conservation and Development, the cooperating State agency, had maintained periodic readings on a series of observation wells. Early in the present period, the increased use of ground water, particularly along the coast, had created the serious problem of salt-water encroachment. The newly appointed State Geologist, Dr J. L. Stuckey, who had become familiar with the Survey's ground-water work as a result of the Elizabeth City investigation,[182] was anxious to have a similar investigation extending over the entire coastal region and into the Piedmont region, and visited the Washington Office for that purpose. Cooperation became effective in July 1941 with the Department of Conservation and Development, of which the office of State Geologist was a part.

Annual cooperative State funds available

1942	$2,600	1945	$3,000
1943	3,000	1946	4,000
1944	3,000	1947	4,000

During the fiscal year 1941, the City of Wilmington cooperated to the extent of $200 for the purpose of having a brief investigation of its ground-water resources.

South Carolina. - The need for information on ground-water supplies caused the South Carolina Research Planning and Development Board, created in 1945 by the consolidation of several state boards, to seek cooperation and as that Board was cooperating in Surface Water investigations, it contacted A. E. Johnson in charge of the Survey's stream gaging in South Carolina. Messrs. Parker, Johnson and Mundorff met withthe state officials in Columbia in September 1945 and cooperation became effective in October. One cooperative agreement between the Survey and the State agency covering both surface and ground-water investigations was made, and the division of funds was made according to the relative needs of the two investigations.

Annual cooperative State funds available:

1946	$2,000	1947	$2,625

Georgia. - Cooperation with the Georgia Department of Natural Resources, started near the end of the previous period, continued. In the fiscal year 1944, the State agency became the

182/ p. 307 (1928-1939).

State Department of Mines, Minerals, and Geology. This change was mainly in name and in the chief personnel, as the functions remained virtually the same. In the fiscal year 1943, the State agency required additional ground-water investigations in the northern part of the State, and to make it possible to assign a ground-water man to that area, the State agency which was cooperating with three Branch divisions desired the reduction in funds allotted to the Quality of Water Division. The increase during the last two years of the period was due chiefly to the increased cost of operation.

Annual cooperative State funds available:

1940	$3,500	1944	$5,000
1941	2,300	1945	5,100
1942	2,875	1946	6,000
1943	5,000	1947	6,000

Florida.-The Florida Geological Survey in the State Board of Conservation continued its cooperation in increasing amounts. During 1940 and 1941, the increase was due to added cooperation with the City of Pensacola, and during the next 4 years, to some additional funds availalbe. In 1945, the Governor and his cabinet realized the great need for hydrologic data in the small basins containing lakes used for citrus irrigation, which had been found to be profitable, and agreed to match county and drainage district funds with State funds, the combined amounts to be used in cooperation with the Survey. As a result, the State Geological Survey was able to increase very greatly its cooperative funds.

In the fall of 1939, it was proposed to establish a pulp mill near Pensacola; as a large quantity of ground water would be required, both the City of Pensacola and the Pensacola Navy Yard feared the proposed increased use might have a harmful effect on existing uses, and the State Geological Survey was called upon for information. As a result, a three-way agreement between the State, City and Federal Survey was effected for the purpose of making a detailed study of the water supply of Pensacola and Escambia County.[183] That investigation was made during the fiscal years 1940 and 1941, and as it was shown that the available ground-water supply was sufficient for the city and the pulp mill, the cooperation was discontinued. After a change in the city administration, a small amount of cooperative funds became available beginning with the fiscal year 1945 for the purpose of continuing the observation-well program in that area.

[183] Florida Geol. Survey, 4th Bien. Rpt.

The cities of Miami, Miama Beach, and Coral Gables became much concerned over the encroachment of salt water due to the increasingly heavy pumping in the southeastern part of Florida, and desired an investigation of the water resources in that region, with the hope that additional supplies could be located. That required an intensive investigation extending over a number of years, and as State funds were not available to extend the State-cooperative program to that part of Florida, the cities with some help from Dade County raised the funds and entered into direct cooperation with the Survey. Many of the intensive phases were completed in 1943, and thereafter the cooperation was substantially reduced. Dade County, in which these cities are located, was not particularly interested in the project until later in the period; the southern part of the county contains considerable agricultural land, and by 1945, additional drainage work, together with military operations, had resulted in salt-water encroachment further than had been expected, and concern was felt for the adequacy of the ground-water supply for irrigation. There was also a better understanding of the purpose of the investigation and the county began cooperation in the fiscal year 1946.

During the later years of the period as the need for additional water supplies became more urgent, due to the continuing increase in population, the Cities of Fort Myers, Fort Pierce, Fort Lauderdale, Lake Worth, Delray Beach, and the County of Pinellas began cooperation. Owing to the Survey's lack of personnel, it was necessary to discontinue the Fort Myers and Fort Pierce investigations with the fiscal year 1946. St. Augustine, which had an inadequate water supply, cooperated during the fiscal year 1945, and was satisfied with the one year's results. The pulp mill established in Nassau County in 1939 was drawing so heavily on the ground water of that area that the company told the County to take whatever steps were necessary to start Survey cooperation, and the County began cooperation in the fiscal year 1944 for the purpose of continuing the observation-well program included in the intensive investigation of that area started at the end of the previous period.

Annual Cooperative State, County and municipal funds available:

	1940	1941	1942	1943
State Geological Survey	$ 4,000	$ 4,000	$ 6,000	$ 6,000
Pensacola	5,000	1,000		
Miami	14,000	21,800	14,358	10,450

	1944	1945	1946	1947
State Geological Survey	$ 6,550	$ 7,350	$16,000	$25,000
Pensacola		260	195	328
Miami	5,000	5,000	5,000	5,375
Fort Myers	3,000	4,250	2,000	
Fort Pierce	1,250	350	675	
Fort Lauderdale				8,500
Lake Worth	1,000	1,725	500	
Delray Beach				2,000
St. Augustine		2,000		
Dade County			4,000	4,219
Nassau County	250	250	250	250
County of Pinellas		375	1,250	1,500

Totals:	1940	1941	1942	1943	1944	1945	1946	1947
	$23,000	$26,800	$20,358	$16,450	$17,050	$21,560	$29,870	$47,172

Alabama. -Cooperation with the Alabama Geological Survey, which had been discontinued during the depression years, was resumed late in the fiscal year 1940. At that time the State Survey had funds for a project which it had expected to investigate itself, but being unable to obtain the necessary personnel, offered to cooperate with the Federal Survey if the latter could undertake it. The offer was accepted, and cooperation started then has continued during the period in gradually increasing amounts.

Beginning with the 1946 Fiscal year, the Alabama State Health Department became interested in the Survey's work on fluoride in ground water, and requested the cooperation which was accepted for fluoride studies in the Tertiary area of Alabama. Those studies were carried on in conjunction with the regular ground-water stuides in the Tertiary area.

Annual cooperative State funds available:

Year	State Geol Survey	State Health Dept	Total
1940	$ 700		$ 700
1941	2,500		2,500
1942	2,500		2,500
1943	3,125		3,125
1944	5,000		5,000
1945	5,000		5,000
1946	4,500	$2,500	7,000
1947	4,500	2,500	7,000

Mississippi.-The cooperative program with the Mississippi State Geological Survey, which was started in June 1938, continued on the same level during the period except for the fiscal year 1947, when the funds were increased 50 percent.

Annual cooperative State funds available:

1940	$5,000	1944	$5,000
1941	5,000	1945	5,000
1942	5,000	1946	5,000
1943	5,000	1947	7,500

Louisiana.-Cooperation with the Louisiana Department of Conservation, which was started in May 1938, continued at practically the same level, except during the fiscal year 1944 when additional funds were made available to meet the increasing demands from cities for Survey held in solving their ground-water difficulties. This increasing demand was largely the outcome of the Survey's success in advising the cities of Alexandria and Natchitoches regarding locations for additional wells. The newly-created Department of Public Works came into the cooperative picture in the fiscal year 1944, when other cities were calling on the State for help. Among those was Baton Rouge where the water supply was critical, and where the Chamber of Commerce and leading industries urged an investigation. The Department of Public Works was desirous of taking over that type of investigation and offered to finance the entire program. The Department of Conservation, very naturally did not wish to drop out of that popular field, especially as during that fiscal year, conservation funds were available to meet the State's share of the new investigations and declined the offer. However, cooperation was started by the Survey with the Department of Public Works, and the latter agency shared in the investigations during the remainder of the period. As conservation funds were less plentiful after 1944, cooperation declined to the previous level and Public Works cooperation was correspondingly increased.

A cooperative investigation with Caddo and Bossier Parishes was made in 1941 at the request of the Police Juries of the two parishes to determine whether a ground-water supply of about 10 million gallons per day was available for the industrial use of a prospective industry to be located in the Shreveport area. Another investigation in 1941 was that for the City of Natchitoches, where gradual depletion had reduced the ground-water supply.

Annual cooperative funds available:

Year	Dept of Cons	Dept of Pub Wks	Natchitoches	Caddo Parish	Bossier Parrish	Total
1940	$ 5,000					$ 5,000
1941	4,968		$500	$500	$480	6,448
1942	5,000					5,000
1943	5,000					5,000
1944	10,000	$3,500				13,500
1945	6,000	6,000				12,000
1946	5,000	6,000				11,000
1947	5,000	6,000				11,000

West Virginia. -Cooperation in West Virginia was brought about by the contamination of ground-water supplies by mining operations and oil well drilling. The West Virginia Geological and Economic Survey desired a State-wide inventory of all wells used for municipal and industrial supplies, to determine the extent of contamination in order that safe water supplies might be selected. Cooperation in the amount of $2,500 annually, was started July 1, 1941, and continued unchanged during the period.

Kentucky. -There had been no cooperative ground-water investigation in Kentucky prior to the summer of 1943, at which time a critical shortage in the Louisville area resulted from operation of newly-constructed chemical and rubber plants, and increased production schedules in other plants manufacturing war materials. To avoid reduction in plant output, the Governor allotted State war emergency funds to the Geological Division of the Department of Mines and Minerals for cooperation; the work was financed from this source until the close of the war. During 1944, the City of Louisville provided funds for deepening test wells. In 1946 and 1947, when war emergency funds were no longer available, the Louisville area studies were continued on a less-intensive scale through cooperation with the Cityof Louisville and the Louisville and Jefferson County Planning and Zoning Commission.

The Louisville Water Company obtains its water from the Ohio River. During the war, the concentration of industrial wastes from upriver manufacturing centers made it more and more difficult to obtain a satisfactory water with the existing filter plant. In the spring of 1945, the Water Company, as a precaution against the possibility that the river would have to be abandoned as a source, began cooperation for an investigation of the ground-water supplies of the area northeast of Louisville, with emphasis on the possibility of induced river infiltration. Cooperation was continued in 1946 and 1947.

The Bluegrass region in central Kentucky has always been faced with the problem of finding adequate water supplies for domestic and farm use. In 1946, four counties, Bourbon, Fayette, Jessamine and Scott, allotted funds to the Mines and Minerals Department to begin a three-year cooperative investigation of the supplies in these counties.

In 1946, the Mines and Minerals Department allotted funds to initiate a survey of the problems of the State with a view to the establishment of a comprehensive program in the near future.

Annual cooperative funds available:

Year	Dept M&M	L'ville Water Co	City of L'ville	L'ville & Jeff Co	Total
1944	$ 7,500	$	$2,096	$	$ 9,596
1945	10,000	3,000			13,000
1946	3,734	2,000	2,500	4,000	12,234
1947	7,339	5,200	3,000	3,000	18,539

Tennessee. -In August 1940, the construction of what was later known as the Chickasaw Ordnance Works, placed a greater demand on the Memphis ground-water supply, and the City Light, Gas and Water

Division began to drill 4 observation wells, and wished to have the Survey study the effect of the increased draft on the water levels. With the available funds and personnel, the investigation consisted in bringing up to date the well inventory made during the early years of the previous period,184/ and in reviving and expanding the obervation-

184/p. 313 (1928-1939).

well program. The investigation was completed in the fiscal year 1942, except for the maintenance of the observation-well readings which were continued by the city. The draft on the ground water was increasing and a year later, the city desired a more extensive and intensive investigation, and as that required full time personnel, the agreement effective in November 1943 was for $4,000, all that could be used at that time due to the personnel shortage. During the remainder of the period however, that shortage was relieved and the funds were increased to meet the expanding program.

Annual cooperative Memphis funds available:

1941	$1,700	1945	$ 2,500
1942	400	1946	15,000
1943		1947	17,500
1944	4,000		

Ohio.-Cooperation with Butler and Hamilton Counties, started in 1938, continued during the period for the purpose of conducting an observation well program which serves as a continuing inventory of ground-water supplies in the heavuly pumped areas north of Cincinnati. The Ohio Engineering Experiment Station favored a program of observation wells in other heavily pumped areas, the wells to be equipped with water-stage recorders, and started cooperation during the fiscal year 1942. During the fiscal years 1945 and 1946, the City of Canton cooperated for the purpose of having an investigation made to determine where a ground-water supply could be obtained.

The State Water Resources Board was created October 2, 1945, and in the field of ground water, had for its objective the ability to185/

185/Fourth Ann. Rpt., 1945, pp. 8-9

> ***foretell the safe perennial yield of a given area in order to avoid past experience of industry and agriculture in mining a stored source, only to discover in a short time that what was thought to be a perennial supply was being taken out of storage.

Cooperation was started almost immediately, the one objective being a Statewide program of observation wells, 100 equipped with water-stage recorders in heavily-pumped areas, and in areas less heavily pumped, a large number of wells read weekly. This program also includes systematic collection of well records and basic data throughout the state. Reports are published by the State whenever sufficient data are available.

Annual cooperative State and municipal funds available:

Year	Eng. Exp. Sta.	Butler Co	Hamilton Co	Canton	Water Res Bd	Total
1940		$3,000	$2,500			$ 5,500
1941		600	1,200			1,800
1942	$1,000	300	700			2,000
1943	750	200	1,000			2,950
1944	2,000	300	1,000			3,300
1945	2,000	300	1,000	$7,100		10,400
1946	2,000	500	1,300	2,400	$12,240	18,440
1947	2,000	500	1,300		25,260	29,060

Indiana. -Cooperation with the State Department of Conservation, Division of Geology, continued on a limited scale through the fiscal year 1943, for the purpose of maintaining the observation-well program started in 1935, and continuing the part-time study in the Indianapolis area. As a result of the direct appropriation for a water resources investigation made by the State Legislature beginning with the fiscal year 1944,[186] and the increased need for ground water, as shown by the

186/p. 48.

war-time activities, the cooperative amounts were greatly increased. They included contributions by local interests when the investigations to be undertaken were intensive as well as extensive.

Annual cooperative State funds available:

1940	$1,000	1944	$ 7,500
1941	1,000	1945	8,500
1942	2,360	1946	13,675
1943	820	1947	13,875

The increase during the fiscal year 1942 was due to special emergency funds allotted for the completion of the report on the Indianapolis area which extended into the 1943 fiscal year.

Michigan. -Cooperation with the Michigan Department of Conservation, through the State Geologist, which had been informal during the last 2 years of the previous period, was resumed on a formal basis at the beginning of the present period. Through the fiscal year 1944, it was for the purpose of continuing the observation well program started in 1932. The State Geologist had wished to increase the cooperation for the purpose of making intensive investigations, but was unable to do so until the fiscal year 1945. By that time, the war activities had caused excessive consumption of ground-water, and with indicated peace-time demands for ground water, resulting in requests for help from many cities desiring more intensive investigations, and contributing to the State agency for that purpose, the State agency was able to increase greatly its cooperation.

Annual cooperative State and municipal funds available:

1940	$500	1944	$ 500
1941	500	1945	4,500
1942	500	1946	15,500
1943	500	1947	29,575

In addition to cash contributions, the cities paid directly a part of the cost of test drilling, estimated at $17,000 for the period.[187]

187/Statement of State Geologist.

Referring to the cooperative ground-water investigations, Mr. G. E. Eddy, the State Geologist, told the author that his agency is thoroughly sold on the value of the work being performed by the Survey, and that if nothing more than the services already rendered the municipalities should develop, the expense of the investigation would be justified.

Wisconsin. -The use of ground water by war industries and municipalities so depleted the available supply in the southern part of Wisconsin, particularly in the vicinity of Milwaukee, that the water levels dropped alarmingly. Large areas in the eastern part of the state had been drained, and a law enacted that no more drainage would be permitted if the water levels would be lowered as a result. Another law was one requiring a permit from the State Board of Health before any new well to pump 100,000 gallons a day or more could be drilled, and if such pumpage would affect a public water supply, it was to be refused. Thus, there was need for a ground-water investigation, and the 1945 session of the Legislature made an appropriation of $10,000 for the first year and $15,000 annually thereafter for a study of the ground-water resources "to determine the present use and depletion thereof," each year's funds being good until expended or as the bill termed it, "nonlapsible." That was in reality a new research project and as the University of Wisconsin, among its other functions, is a highly-regarded research center for the State, the appropriation was made to the Regents of the University, who were empowered to cooperate with the appropriate agencies of the Federal Government in making the study.

To carry out the provisions of the law, the Regents appointed a committee of three, of which the State Geologist was chairman; that committee recommended cooperation with the Survey, and the agreement was signed by the Regents of the University. By the time the final arrangements with the Survey were perfected and personnel available, more than half the fiscal year 1946 had elapsed, and in view of the "nonlapsible' character of the appropriations, the cooperation for the first year was set by the Survey in the amount of $7,000 and for 1947, $17,000.

The Surface Water Division had been keeping up a small observation well program in connection with its regular field work, and in the fiscal year 1945, the Commission on Water Pollution which was cooperating with the Surface Water Division made available $500 for the observation-well programs; incidentally, an indirect aid to the Surface Water Division which continued that work.

Referring to the cooperative program, Mr. E. F. Bean, the State Geologist, writes as follows:

> Your visit to Madison must have convinced you that the cooperative arrangement between the University of Wisconsin and the United States Geological Survey for ground-water investigations is a very satisfactory one. The water superintendents and all others closely connected with the problem are enthusiastic about the research work being done.

Minnesota.-Cooperation with the Minnesota Department of Conservation, which started in the fiscal year 1946, was for the purpose of investigating the ground-water supply in the Red River Valley with special reference to the City of Moorhead and vicinity. The investigation was an outgrowth of a more limited study of Moorhead's sister City of Fargo, made by the Survey in cooperation with the State of North Dakota and completed in 1942. The results of that investigation warranted the larger study, including both the Minnesota and North Dakota portions of the Red River Valley in the general vicinity of the two cities. To finance the Minnesota study, the City of Moorhead, Clay County, and the Department of conservation contributed equal amounts, the Department of Conservation being the cooperating agency.

Annual cooperative funds available:

1946	$2,750
1947	4,750

Iowa.-Cooperation with the Iowa Geological Survey which was started in the fiscal year 1939, continued during the present period. Each biennium, the State funds were increased as the value of the work was recognized and the need for it became greater.

Annual cooperative State funds available:

1940	$ 7,000	1944	$13,000
1941	7,000	1945	12,000
1942	10,500	1946	15,000
1943	10,500	1947	16,000

Arkansas.-Cooperation with the State Agricultural Experiment Station in connection with the investigation of the Grand Prarie Region[188]

188/ p. 312 (1928-1939).

continued in gradually decreasing amounts as the project neared completion, and was discontinued with the fiscal year 1945. During the fiscal year 1947, it was resumed for the purpose of continuing the operation of the observation wells.

During the first year, the State Geologist made a small cooperative contibution but thereafter, his budget was too small to permit cooperation.

The Bureau of Research, University of Arkansas, created in 1944, for the purpose of helping industry solve some of ite problems, desired to expand its activities by participating in the ground-water investigations, which were of concern to industrial plants, and having funds for that purpose, began cooperation in the fiscal year 1946.

The City of El Dorado had a war industry plant as well as an increase in use of its water for oil refineries and, becoming doubtful of the adequacy of the water supply, cooperated for one year. Cooperation in the amount of $800 was offered in the fiscal year 1945, b but it was not until the following year that the Survey could undertake the investigation, at which time $1,700 additional was available. The results of the one year's study indicated that the water supply was adequate and the cooperation was discontinued.

The City of Crossett had a lumber mill and allied wood industries which were working overtime and, fearing for its water supply as well as anticipating an increase in the use of water, desired to cooperate with the Survey in the fiscal year 1945. The Survey was so short of personnel that it was not until the fiscal year 1947 that the personnel situation improved, and the cooperation could be accepted.

Annual cooperative State and municipal funds available:

Year	Agri Exp Sta.	State Geologist	Bur of Res	El Dorado	Crossett	Total
1940	$2,000	$100				$2,100
1941	2,000					2,000
1942	2,000					2,000
1943	1,500					1,500
1944	1,200					1,200
1945	1,200			$ 800		2,000
1946			$5,000	1,700		6,700
1947	500		3,864		$2,500	6,864

The 1947 reduction in Bureau of Research cooperation was due to the fact that the Bureau's funds were reduced that year.

The Agricultural Experiment Station cooperation had been based on evaluated services and that was discontinued in the fiscal year 1946; cooperation resumed in 1947 and was a cash contribution on actual cost.

North Dakota. -Cooperation with the State Geological Survey, which was started in the summer of 1937, continued through the fiscal year 1945. By that time, requests from some 30 municipalities for help in their ground-water problems were on file as they could not be met, and A. L. Greenlee, in charge of the Survey's investigation, had convinced the people of North Dakota that a State-wide investigation, of municipal water supplies was needed. The time was ripe for such expansion; 90 percent of municipal and practically all rural supplies came from ground water; agricultural returns had been large for the previous few years, and the State was in an excellent financial position. As a result, larger State funds were made available and the State Water Conservation Commission became the cooperating agency, with the State Geologist as technical advisor to the Commission. The State Water Conservation Commission had been created in

1937 for the purpose of having charge of studies of both surface and ground water in the state, but at that time devoted its attention to surface water, leaving to the State Geologist the study of ground water. However, when funds were appropriated for the State-wide investigation, they were appropriated by the Legislature to the Conservation Commission.

Beginning May 1, 1940, cooperation was effected with the City of Fargo for a study to determine if urgently needed additions to the municipal supply could be obtained from ground water. That investigation was completed June 30, 1942. During the latter part of the fiscal year 1944, the State Department of Health, which had certain responsibilities pertaining to public water supplies, realized the inadequacy of some of those supplies and offered $1,000 for cooperative investigations in the Dickinson and Fessender area and wished to have the work started as soon as possible. As Survey cooperative funds for that year were exhausted, the agreement was made for the fiscal year 1945, when such funds were available. The field work in the Dickinson and Fessenden areas was performed in the fiscal year 1944, the city of Minot cooperated in an investigation to determine if the aquifer which furnished the municipal water supply was capable of sustaining heavier drafts. Also, the Universityof North Dakota put up funds for test drilling in connection with the water-supply needs for the Bureau of Mines lignite gasification plant located on University property.

Annual cooperative funds available:

Year	State Geol Sur	Water Cons Comm	City of Fargo	City of Minot	Dept of Health	Univ of N Dak	Total
1940	$2,980		$ 100				$ 3,080
1941	3,000		2,400				5,400
1942	2,500		1,500				4,000
1943	2,500						2,500
1944	4,000						4,000
1945	4,100			$3,000	$1,000	$942	9,042
1946		$21,250					21,250
1947		21,250					21,250

In addition to the cooperative funds listed, the Water Conservation Commission in June 1945, made available $10,000 which was used with some cooperative funds in purchasing a hydraulic rotary well-drilling machine and accessory equipment from the War Department's surplus property.189/

189/Letter from P. E. Dennis to author.

In referring to the State cooperation, Dr. W. M. Laird, State Geologist, stated to the author that if the State had to do the work itself, great difficulty would be experienced in obtaining as highly trained personnel. He further stated that in his opinion, ground water is the most pressing geologic problem in North Dakota.

South Dakota. -The State Geologist had started a small observation-well program in 1936 and in the fall of 1939, he be gan cooperation with the Survey for the purpose of enlarging that program; $400 was allotted annually through the fiscal year 1945, when cooperation ceased. At that time, Missouri Basin funds for ground water investigations became available and the State Geologist felt that his small contribution was not needed.

During the fiscal year 1945, Sioux Falls cooperated to the extent of $1,750 for the purpose of determining whether there was sufficient ground-water storage in periods of low flow of the Big Sioux River to warrant additional wells.

Nebraska. -Cooperation with the Nebraska State Conservation and Survey Division, formerly the Nebraska Geological Survey, for a State-wide ground-water investigation, started in the 1931 fiscal year, continued on substantially the same financial level.

Annual cooperative State funds available:

1940	$8,000	1944	$7,050
1941	6,000	1945	7,520
1942	6,000	1946	7,500
1943	6,000	1947	7,500

Referring to the cooperative ground-water investigation, Dr. G. E. Condra, Director of the Conservation and Survey Division, stated 190/

190/ Nebraska Conservation Bull. No 29, Conservation & Survey Division, Feb. 1947.

> ***We believe that the results of this work have been beneficial and that the people of the state are now conscious of the fact that there is much ground water in the state, as evidenced by the progress made in pump irrigation, when the record shows that there were about 300 irrigation wells when the Survey was started and 6,000 wells now pump for 300,000 acres.

Kansas. -When cooperation with the State Geological Survey was started July 1, 1937, the Division of Sanitation of the State Board of Health wished to assist the ground-water investigations. Among its duties was that of being assured that the oil fields made such disposal of the salt brine from the wells that the public, domestic, and stock water supplies would not become contaminated. That agency had little cash for the investigation, but did have a well-equipped laboratory in charge of a good chemist, and offered to make the chemical analyses. W. D. Collins made an inspection of the laboratory and its methods, and after suggesting a few changes in the methods to make the results conform more closely with those of the Survey, the Board of Health's proposed cooperation was accepted. Later, the Board of Health contributed funds in addition to making the chemical analyses.

A year later, the Division of Water Resources of the State Board of Agriculture proposed cooperation. That agency, which had been cooperating with the Surface Water Division, had stationed at Garden City an employee who divided his time between field work for a number of gaging stations in western Kansas, and studying the efficiency of irrigation wells. As drawdown pumping tests were involved, equipment for making those tests was provided. G. S. Knapp, chief engineer of the State Division of Water Resources, suggested that as the ground-water program was concerned largely with an investigation of the irrigation in western Kansas, the Garden City employee would be able to make the needed pumping tests, and also maintain the observation-well program being established. With the acceptance of that offer, the State cooperation became a three-way arrangement, covered by one cooperative agreement with the State Geological Survey, the principal contributor. In addition, the city of Wichita contributed to the State Survey about $1,000 annually toward continuation of the investigation for a new water supply, and to observe the behavior of the well-field area after the new supply was developed.

The contributions by the State Board of Health averaged about $2,000 annually, and those by the State Board of Agriculture, about $2,500 annually.

Annual cooperative State funds available:

1940	$21,550	1944	$26,280
1941	20,545	1945	27,290
1942	31,200	1946	25,900
1943	26,455	1947	25,000

Oklahoma. -Cooperation with the Oklahoma Geological Survey, started in 1947, continued during the period. Beginning with the fiscal year 1942, the cooperative funds were doubled, due to increased need for the work and what was of greater importance, the State's resources had reached a point where increased appropriations were warranted.

Annual cooperative State funds available:

1940	$2,115	1944	$5,000
1941	2,300	1945	5,000
1942	5,000	1946	6,500
1943	5,000	1947	7,000

In addition, the Oklahoma Planning and Resources Board, in the fiscal year 1945, cooperated with all divisions of the Branch for the purpose of having the Survey prepare "Oklahoma Water, Quantity, Occurrence, and Quality of Surface and Ground Water," a report stressing the industrial uses of water and published by the State agency. The Ground Water Division's share in that cooperation amounted to $1,500.

Texas. -Cooperation with the Texas Board of Water Engineers for a systematic investigation of the ground-water supplies in Texas, started in 1929, continued. When the investigation was started and for some years afterward, one of the chief uses of additional ground-water supplies was for irrigation, particularly in the High Plains. In commenting on that use, the Board of Water Engineers stated[19] that from 1930 to 1946, the area irrigated from wells and springs had increased from some 120,000 acres to about 650,000 acres. The war years brought a great increase in the number and size of industrial plants with correspondingly greater demands on ground-water supplies. An excellent summary of the changed industrial picture was given by Time magazine in the issue of April 7, 1947:

> Texas long had almost everything it needed to take its place in the industrial sun--a great amount and variety of minerals, plus unlimited quantities of natural gas for cheap, clean fuel. But not until American Cyanamid Company came from the north in 1934 to build a $7,000,000 alkali plant in Corpus Christi did the industrial revolution begin. With a surfeit of raw materials (lime, sulphur, salt, seawater, gypsum) there, others were soon attracted to the Gulf Coast area. They poured in investments running into millions.
>
> On top of this came the synthetic rubber industry and war expansion. War's end brought no decline. (Last week the Government decided to keep the synthetic plants operating permanently.) DuPont spent $60 million on new plants, Dow over $35 million, Montsanto $11 million, Celanese Corp. $7 million.

For industrial use, water supplies must have acceptable chemical qualities, fairly uniform temperature, and be capable of rapid development. As only ground water meets those requirements, the greatly increased demand made necessary additional quantitative investigations in the industrial areas. Cities and counties cooperated in the investigations, contributing to the State Board of Engineers funds available for Survey cooperation. The City of El Paso, however, cooperated directly with the Survey. This was for the purpose of continuing the observations and preparing summaries of the results of the investigation made during the

19/Progress Rept., Sept. 1, 1944-Aug 31, 1946, Texas Board Water Engineers, Dec. 1946, p. 47.

previous period.[192] With the large increase in State funds during 1946 and 1947, further contributions by El Paso were not needed.

192/ p. 329 (1928-1939).

The Red Bluff District was vitally interested in the Pecos River Joint Investigation, and after its conclusion cooperated in the maintenance of the ground-water records. In the Pecos Valley nearly as much land is irrigated from ground water as from the Pecos River.

Annual cooperative State funds available:

Year	State Board of Water Engineers	El Paso	Red Bluff Dist	Total
1940	$29,800	$1,250	$4,500	$35,550
1941	35,700	1,250	4,500	41,450
1942	36,554	1,250		37,804
1943	35,772	1,250		37,022
1944	32,972	1,250		34,222
1945	29,300	1,250		30,550
1946	45,725			45,725
1947	51,000			51,000

Wyoming.-The drought years had so increased the use of ground water for irrigation that at the beginning of the period, there was a strong feeling that a ground-water law should be enacted. To obtain information on the State's ground-water supplies, the Wyoming State Planning and Water Conservation Board, the only State agency having funds available for that purpose, entered into cooperation with the Survey in the fiscal year 1941 to start the needed investigation. That cooperation continued until the fiscal year 1946, when the Legislature appropriated funds to the State Engineer for that purpose, and his office became the cooperating State agency. During the fiscal year 1943, the State Engineer who was ex-officio a member of the State Planning and Water Conservation Board, was able to supplement the State cooperative funds by $600.

In the spring of 1942, the City of Laramie was considering an additional source of water supply and contributed $3,000 to the Conservation Board for a cooperative investigation of the ground-water possibilities in the vicinity of Laramie. That cooperation continued through the next fiscal year, by which time it appeared that a surface-water supply would be more suitable and no further contributions were made.

The first investigation under the State cooperative program was in the southeastern corner of Wyoming and in the spring of 1941, the city of Cheyenne which was looking for an additional water supply, contributed $2,500 to the Water Conservation Board's cooperative funds for the purpose of extending toward Cheyenne that initial investigation. Subsequently, the City continued to contribute $500 annually. In 1946, the State Geologist contributed $100 toward the special investigations for the cities.

Annual cooperative State funds available:

Year	Water Cons Bd	State Engr	State Geolotist	Total
1941	$ 350			$ 350
1942	3,625			3,625
1943	4,925	$ 600		5,525
1944	2,150			2,150
1945	2,000			2,000
1946		2,000	$100	2,100
1947	500	2,350		2,850

Colorado.-During the dry years of the nineteen-thirties, the flow of the normally over-developed streams was so deficient that many wells were put down for the purpose of using ground water for irrigation. Most of the wells were in the valleys not far from the river channels and there was danger that extensive use of the ground water might reduce seriously the flow of the rivers. It became apparent that a ground-water law for the regulation of such development was needed, and in September 1940, A. W. McHendrie delivered an address before the Colorado Bar Association stressing the need for such a law. However, before the enactment of such a law, it was felt that a ground-water investigation should be made as a basis for such a law.

Mr. Clifford H. Stone, Director of the Colorado Water Conservation Board, was interested in having the necessary investigation made, and in August 1940, requested the Survey to make a reconnaissance of the State and estimate the cost of the needed investigation. W. N. White and C. V. Theis made the reconnaissance, accompanied by C. L. Patterson, chief engineer of the Water Conservation Board, and their conclusion was that the cost would be at least $150,000 and should be spread over a 6-year period. With full Survey participation, the State's share would be $25,000 for each biennium, and that amount was requested of the Legislature. It was not until the 1945 session that the ground-water item was granted. The $25,000 was for the biennium ending June 30, 1947. When the cooperative agreement was signed in July 1945, it was evident that difficulty in obtaining personnel and equipment would make it impossible to start the investigation promptly and the State funds were divided between the two years as follows:

1946	$10,000	1947	$15,000

The Survey funds were likewise divided.

New Mexico.-Cooperation with the State Engineer continued during the period. The increase in funds during 1940 was due to the fact that the State Engineer had $3,000 in his Water Reservoir fund which could be spared, and as C. R. Murray phrases it,[193] "considered that the best way to invest it."

193/Letter to author.

The Interstate Stream Commission was created in 1935, and among its duties was that of investigating, developing, and protecting the waters of interstate streams. Accordingly, when the Pecos River Joint Investigation was started in 1939, the commission contributed to the ground-water phase. That investigation was completed in 1942, and for the next three years the cooperative funds for investigation of other streams were reduced to $1,500 annually except for the last two years, when it was increased to $2,000. The reduction was due to the limited ground-water personnel which was unable to expand the program further.

In the fiscal year 1946, the all-branch Colfax County program was started[194] and continued through 1947. As a result of the 1946 drought, the Elephant Butte Irrigation District began to consider possible ground-water supplies to supplement the surface-water supply, and cooperated in an investigation during 1947.

194/p. 63.

Annual cooperative State funds available:

Year	State Engr	Interstate Stream Comm	Colfax County	Elephant Butte Irrig Dist	Total
1940	$ 9,500	$4,000			$13,500
1941	6,500	4,000			10,500
1942	6,500	4,000			10,500
1943	6,000	1,500			7,500
1944	5,500	1,500			7,000
1945	6,000	1,500			7,500
1946	8,000	2,000	$3,200		13,200
1947	13,000	2,000	2,000	$4,250	24,250

Idaho.-During the previous period, an investigation of the Snake River had been made and another in the Malad Valley[8] the

195/p. 334 (1928-1939).

latter a critical artesian area. About 1943, the State Reclamation Engineer, being concerned over the leaky wells in the artesian area, was making an attempt to plug those wells, and inventory all wells to determine what degree of control was being exercised. Beginning in June, 1943, he cooperated with the Survey for the purpose of determining the underground leakage and the depths of the leaks and in the fiscal year 1945 and 1946, he made available funds for a co-operative project whereby the Survey was to continue the artesian basin investigation and continue the readings of the observation wells selected.

During this period, there were occasional requests of investigations of various areas, but for lack of funds, such investigations could not be made. The requests showed a need for a State-wide investigation, and when Mark R. Kulp became State Reclamation Engineer, this situation was called to his attention by T. R. Newell, the Survey's District engineer. The former recognized the need for a State-wide inventory and increased the State's interest to the point where the Legislature appropriated funds for that purpose, during the fiscal year 1947.

Annual cooperative State funds available:

1943	$ 250
1944	1,050
1945	300
1946	300
1947	5,000

Utah.-Cooperation with the State Engineer, which had started in 1935, continued but during the last four years the economy-minded Legislature reduced the State appropriations, which necessitated a reduction in the work program. However, during 1946 and 1947, for the purpose of speeding up the investigations in those counties, Davis and Weber Counties contributed funds to the State Engineer, thus increasing the State cooperation.

For a special investigation of its water supply, the City of Ogden cooperated directly with the Survey during the fiscal years 1943 to 1946.

Annual cooperative funds available:

Year	State Engineer	Ogden	Total
1940	$10,000		$10,000
1941	8,000		8,000
1942	7,000		7,000
1943	7,000	$1,200[1]	8,200
1944	5,500		5,500
1945	5,500	1,200	6,700
1946	7,000		7,000
1947	8,000		8,000

1/For the biennium.

Nevada.-With the conclusion of the Las Vegas investigation in 1938[2], no ground-water work was performed in Nevada until the

196/p. 337 (1928-1939).

fiscal year 1945. An Army Air Base and the nearby Basic Magnesium plant at Henderson had so added to the population of Las Vegas that the draft on the city's ground-water supply was greatly increased. At the same time, there was increased development of ground water for irrigation in Pahrump Valley, lying to the west of Las Vegas Valley, and the State engineer feared that such increase would deplete dangerously the ground-water reservoir. He desired further study of the Las Vegas area and Pahrump Valley, and obtained the needed funds from the Las Vegas and Pahrump Artesian Basin Funds.

Until that time, the Legislature had made no appropriations for ground-water studies, although in 1939, a law regulating the appropriation and use of ground-water had been enacted. For several years, the State Engineer had attempted to obtain such funds as he realized that the scanty surface waters were nearly fully appropriated, leaving only the ground waters available for further appropriation. The successful conclusion of his efforts, reinforced by the example of the Las Vegas investigation, came in 1945 when the Legislature made an appropriation for a State-wide inventory of ground water.

In referring to the state cooperative program, which became effective July 1, 1945, the State Engineer stated:[197]

197/Bien Rept. State Engineer for the period July 1, 1944 to June 30, 1946, p. 55.

> It is evident that this program will extend over a long period of time as the State is large and has many ground-water basins. Then, too, when the major underground water basins have been studied and the many facts pertaining to them are known, the problem of safeguarding these waters intelligently, so that use can be made of them continually through the generations is one that requires continuous study and observation.
>
> The work of the U. S. Geological Survey in the cooperative program will incoude geological and hydrological studies of the ground-water basin, drilling of test holes to determine the character and water-yielding ability of the underlying formations; observations of water level in selected wells, permeability studies of the aquifers, pumping tests of wells, surface stream measurements, geophysical studies and other studies necessary for the proper solution of ground-water problems.
>
> Annual cooperative State funds available:

1945	$ 5,850
1946	21,000
1947	22,325

Arizona. -The drought years in the nineteen-thirties with the scanty surface-water supplies, had resulted in an extensive development of ground water for irrigation by private interests. With little or no information regarding the recharge supply of the natural ground-water reservoirs, the result was, as the State Water Commissioner stated,[198] that within a few years the supply became totally

198/Eleventh Bien. Rept., 1937-1938, p.

exhausted and the investment a total loss.

During the fall of 1938, there was some agitation by local engineers for a ground-water study and C. V. Theis, at J. H. Gardiner's suggestion, was called in to address a meeting on ground-water investigations. The agitation which continued resulted in an initial appropriation of $6,000 annually for a cooperative ground-water investigation. W. N. White came to Phoenix to arrange for the formal cooperation which began with the signing of the agreement August 1, 1939, and continued during the period.

Beginning with the fiscal year 1944, the State agency became the State Land Commissioner.[199] For the fiscal years 1946 and 1947,

199/p. 65.

the Legislature not only increased the annual appropriation to $15,000 but also made additional cooperative appropriations amounting to $18,000 and $22,000 respectively, to enable the Survey to obtain information in each important basin necessary for the basis of a ground-water law, and make a report to the next session of the Legislature.

The need for a ground-water law had been stressed by the Bureau of Reclamation during its cooperative investigation with the State. The Bureau stated[200] that the balance between surface irrigation and pumping must be maintained in order that the land would not become water logged by too much water, or the ground-water resources became entirely exhausted by excessive pumping.

200/33rd Ann. Rept., Ariz. State Land Comm., p. 5, 1944-45.

So critical did the ground-water situation become that during the latter years of the period, the Cities of Phoenix, Prescott, and Globe entered into cooperation in order that the Survey could study their particular ground-water problems.

Annual cooperative State and City funds available:

Year	State Water Commr	State Land Comm.	Phoenix	Prescott	Globe	Total
1940	$6,000					$ 6,000
1941	6,000					6,000
1942	6,000					6,000
1943	6,000					6,000
1944		$ 6,000	$2,500			8,500
1945		6,000	7,000		$1,000	14,000
1946		33,000	3,000	$4,000	500	40,500
1947		37,000	4,250	2,000	500	43,750

Washington.-Cooperation with the State Department of Conservation and Development, started July 1, 1937, continued. In the fiscal year 1942, two funds became available, one to continue the regular program, and the other a fund to investigate in collaboration with the Bureau of Reclamation, the ground-water features of the Columbia River Irrigation Project. The latter fund was made available for the four years required by the Columbia River Investiagion. The Legislature adopted a ground-water code effective in June 1945, and for the 1946 fiscal year, the general fund cooperation was increased to make up for the exhaustion of the special Columbia River fund, in order that the scope of the ground-water investigations would not be curtailed. Faced with administrative problems caused by the ground-water code, the cooperative funds were materially increased during the last year of the period when personnel became available.

Cooperation with the city of Tacoma continued but with the completion of the investigation, the funds were reduced to those necessary to keep up the periodic measurements of wells, springs, etc.

In the fiscal year 1940, the city of Bremerton requested an appraisal of available ground-water resources as a precautionary measure, if a national emergency demanded a large increase. That was shortly before Pearl Harbor after which, the demand was increased some 700 percent due to the presence of the Navy Yard.

The Public Utility District No. 1 was the Snohomish County agency, which was taking the lead in changing the County's economy from dependence on logging, then on the decline, to a more stable economy by sponsoring an inventory of all the County's resources. As ground water was an important resource, cooperation was started in the fiscal year 1945 and continued beyond the period.

In the fiscal year 1946, the city of Waterville desired information regarding the possibility of an additional ground-water supply and cooperated for the purpose of having a geologic reconnaissance. Cooperation with Walla Walla County was started near the end of the period and continued. At that time, there was marked local interest in the changing economic picture where a one-crop (wheat) economy was giving way to intensive cultivation of garden peas for canning and frozen pack. That required a water supply for supplemental irrigation, and the County was expected to provide funds for the purpose of augmenting the State program, but failed to do so during the 1947 fiscal year.

Annual cooperative funds available were:

Year	State Dept Gas & Dev	Tacoma	Bremerton	Snohomish Co PUD	Waterville	Total
1940	$2,000	$2,250	$1,500			$5,750
1941	2,300	2,100				4,400
1942	5,000	1,900				6,900
1943	4,763	900				5,663
1944	5,000	500				5,500
1945	4,212	500		1,250		5,962
1946	5,000	500		1,500	$100	7,100
1947	7,550	500		1,500		9,550

Oregon. -Cooperation with the Oregon Water Resources Department of which the State Engineer was the executive head, and also with the State Agricultural Experiment Station which had been resumed in 1938 for the purpose of maintaining an observation-well program in the Willamette Valley and in the semi-arid region east of the Cascade Mountains, continued with both agencies through the fiscal year 1941. At that time, the funds of the Experiment Station were reduced and its cooperation was discontinued, but the Water Resources Department continued its modest cooperation during the next two years. In the fiscal year 1944, the State Engineer felt the need for more data and as the Experiment Station had been the original sponsor for the ground-water investigations, that agency agreed with the State Engineer that his office, through the Water Resources Department, thereafter assume that sponsorship. During the next two years, the cooperative funds were materially increased and so important was the work becoming by that time, that for the fiscal years 1946 and 1947, the State Engineer had a separate item in his budget which allowed a further increase in the cooperative funds.

Annual available State cooperative funds:

Year	State Engineer	Agr Exp Sta	Total
1940	$ 355	$ 500	$ 855
1941	400	1,000	1,400
1942	475		475
1943	225		225
1944	1,725		1,725
1945	1,550		1,550
1946	2,725		2,725
1947	3,925		3,925

California. -Until the present period, there had been little cooperative ground-water investigation in California. Now, however, a number of investigations for counties and cities in southern California were made. In portions of Los Angeles and Orange Counties, a combination of a dry period lasting from 1918 to 1936 and increased pumping for irrigation, had so lowered the water levels that salt water was being drawn in and in addition, the ground water was being contaminated by oil refinery brines and other industrial wastes. The situation became so serious that in April 1939, a local committee investigating the coastal barrier in Los Angeles and Orange Counties, wrote F. C. Ebert, in charge of the Surface Water office in Los Angeles, asking for the Survey's help. That letter was forwarded to Washington, with the result that in October 1939, an agreement was signed by a group of four agencies, the Orange County Flood Control District, Orange County Water District, Los Angeles County Flood Control District, and Board of Water Commissioners, City of Long Beach. That cooperation continued until the fiscal year 1946, when the investigation was completed.

Increased use of ground-water in Santa Barbara County was lowering the water levels, and both the Army Engineers and Bureau of Reclamation were investigating possible projects in that area. Therefore, a knowledge of the perennial yield of the ground-water reservoirs was needed, and July 1, 1940, an agreement was signed with Santa Barbara County for an overall appraisal of the ground-water resources of the county. It was first proposed that the Survey investigate the effect of a proposal to divert water from the Santa Ynez River to the coastal plain near Santa Barbara. A. M. Piper made an investigation and decided that instead of investigating the controversial division project, the Survey should make a county-wide appraisal of the ground-water problems. A year later, an agreement with the Surface Water Division was made, largely for the purpose of rounding out the water resources appraisal and obtaining certain stream flow records needed for the ground-water appraisal. The Santa Barbara investigation continued during the period.

The demands of war industries in Los Angeles County, particularly oil refineries, had lowered the water level at such a rapid rate that by 1943, it was as much as 60 feet below sea level, and the encroachment of salt water was accelerated. July 1, 1943, an agreement was signed with the Los Angeles Flood Control District for an investigation, which was virtually an extension of the investigation started in 1939. The flood control district furnished half the cooperative funds and 9 municipalities in the western part of the county, furnished the remainder. The investigation was completed in 1947.

The overdraft on the ground water in San Bernardino County showed the need for a careful inventory of the inflow to, and outflow from, several ground water basins in the Upper Santa Ana Valley, and the County proposed a cooperative investigation which was started with the signing of the agreement July 1, 1946. It was continued beyond the period.

Annual cooperative funds available:

Year	Orange Co et al	Santa Barbara Co.	L A Co Fld Cont Dist	San Bernardino Co.	Total
1940	$ 5,000				$ 5,000
1941	13,500	$ 3,250			16,750
1942	10,500	8,800			19,300
1943	7,000	8,000			15,000
1944	6,000	8,500	$ 3,000		17,500
1945	1,500	11,000	8,000		20,500
1946	1,000	6,250	6,500		13,750
1947		7,500	2,000	$3,000	12,500

Hawaii.—Cooperation with the Territorial Division of Hydrography continued during the period.

The cooperative funds for the 1940 fiscal year were increased as a result of the Legislature's special act for a ground-water investigation of the Island of Hawaii, to relieve the more or less chronic drought condition on the island.

Beginning with the fiscal year 1941, and continuing for several years, the shortage of personnel made it necessary to curtail the ground-water program and the cooperative funds were reduced accordingly. During the fiscal year 1940, the county of Maui was anxious to speed up the investigation of that island and cooperated for that purpose.

Annual cooperative funds available:

Year	Division of Hydrography	Countyof Maui	Total
1940	$18,700	$1,000	$19,700
1941	10,750		10,750
1942	7,202		7,202
1943	9,486		9,486
1944	12,402		12,402
1945	11,947		11,947
1946	12,500		12,500
1947	13,111		13,111

Puerto Rico. -The Puerto Rico Aqueduct and Sewer Service was created by the Insular Legislature May 1, 1945. Its duties are to provide "an adequate service of sanitary sewage disposal, and an ample regular supply of pure water for said purpose and for all other domestic, industrial, and commercial purposes." In the exercise of those duties, it was to take over the operation of existing public water supply and sewerage facilities and establish new ones.

In some municipalities, the water supply was inadequate, and because of greatly increased demands, many additional or new supplies were needed, and ground water was looked to as that source. Soon after the creation of the new agency, Sergio Cuevas Bustamente, its administrator and chief engineer, took the initiative in arranging for a cooperative investigation of the Island's ground-water resources. As of May 1, 1945, cooperation was arranged for the investigation, which was expected to be completed June 30, 1946. However, as the project could not be completed in that period, the time was extended to June 30, 1947.

Annual cooperative funds available:

1946	$2,700
1947	1,700

Federal Cooperation

Federal cooperation during the period increased materially over that for the previous period. The increase was due largely tothe special investigations, not connected with the war activities, made for the Army Engineers, Bureau of Reclamation, and Indian Service, and war activities instigations for the Army Engineers, Navy Department, Federal Works Agency, and Defense Plant Corporation. During the last two years, the operation of the Missouri River Basin-Departmental Program, financed by funds appropriated to the Bureau of Reclamation, resulted in a large increase in Federal cooperation.

Annual amount of funds allotted:

1940	$32,700	1944	$ 55,801
1941	35,213	1945	33,233
1942	41,073	1946	147,992
1943	26,642	1947	144,600

Army Engineers. -The cooperation with the Army Engineers was chiefly in connection with three major projects. In the flood-control study of the Gila River, the possible effect of flood-water storage on ground water replenishment was desired, and funds were provided for that study during the early years of the period. During the war years, the War Department required investigation of ground-water supplies for its many new establishments, and provided funds for the more extensive investigations required. In a flood-control study of the Rio Hondo and lower Los Angeles River, started in December 1944, a concrete lining of the river channel was contemplated, and major problems included the possible effects of ground water on the concrete, and the extent of ground-water replenishment that occurs by natural seepage loss from the channel. The ground-water study continued to the end of the period.

Annual amount of funds allotted:

1940	$22,000	1944	$20,000
1941	20,000	1945	10,000
1942	26,000	1946	3,900
1943	14,000	1947	11,100

Bureau of Reclamation. -During the Pecos River Joint Investigation, funds were allotted to the Ground Water Division in 1941. There were no further allotments until the latter part of the period, when the Survey was requested to make three investigations. One was in connection with the Bureau's Valley gravity project in the lower Rio Grande Valley, another a compilation of existing data necessary to estimate the annual safe yield of ground water in the Salt River Valley, Arizona, and the third in connection with an investigation of the Pecos River Valley in New Mexico, additional information to that obtained during the joint investigation made early in the period.

The Missouri River Basin-Departmental Plan, which was financed by funds appropriated to the Bureau of Reclamation, increased the Federal cooperation greatly during the last two years.

Annual amount of funds allotted:

1941	$5,000	1946	$132,500
1945	2,000	1947	132,500

Indian Service. -The increase in settlement in the Gila River Valley upstream from the San Carlos Reservation, and the resulting need for additional irrigation was met by pumping from wells. At the beginning of the period, the Indian Service became concerned over the possible effect of that pumping on the flow of the Gila River entering the San Carlos Reservoir, and requested the Survey to make an investigation. The following allotments were made for that purpose.

1940	$10,000	1942	$6,000
1941	3,000	1943	3,500

Navy Department. -Most of the war-time establishments of the Navy Department as well as the enlargement of regular establishments required new or additional water supplies, and the Survey was called on for the necessary investigations.

Annual amount of funds allotted:

1941	$2,113	1944	$3,631
1942	2,308	1945	1,682
1943	2,158	1946	1,314

Flood Control Coordinating Committee. -Of the sediment projects started during the latter part of the previous period in cooperation with either the Soil Conservation Service or the Flood Coordinating Committee, all but two were discontinued within the first year. The Boise River Watershed investigation was continued until November 1941, and the Little Tallahatchie project until September 1942. The field work, including the readings of the observation wells, was performed by the Surface Water Division, but the Ground Water Division interpreted those records and for that work the following allotments of funds were made:

1940	$700	1941	$100

Public Works Administration. -A final allotment was made by the Public Works Administration to the Survey in the fiscal year 1942, and $6,700 was used for ground-water investigations in New Mexico and Texas.

Federal Works Agency. -Increased pumpage by an airplane factory at Lockland, Ohio required the drilling of 11 wells. As the new well field was near Hamilton in the Miami Valley, the city officials and many industries feared for the existing ground-water supplies, and opposed the project. The Federal Works Agency, as a war measure, requested the Survey to investigate the probable effect of the new field on existing supplies, and estimate the yield. Funds were provided annually beginning withthe 1942 fiscal year. In addition, 11 test wells were drilled at the expense of the Federal agency.

In the so-called Ypsilanti Triangle, the city of Ypsilanti, the Willow Run Bomber Plant operated by the Ford Motor Company, and the War Housing Project of the Federal Housing Authority required large quantities of water, and ground water appeared to be the only source. The Federal Works Agency was responsible for deciding the adequacy of the existing water supply and the Survey was requested to make an investigation. Funds were allotted for that investigation during the fiscal years 1944, 1945 and 1946. In addition, the Federal agencies drilled the required test holes at a cost of $8,000.

In the fiscal year 1944, a small sum was allotted for the investigation of a military water supply in Alabama, and in the fiscal year 1946, an allotment was made for the investigation of the ground-water resources of the Virgin Islands. That brief investigation was made by C. L. McGuinness on the completion of his Puerto Rico investigation.

Annual amount of funds allotted:

1942	$ 65	1945	$2,335
1943	6,984	1946	1,011
1944	7,170	1947	1,000

Rubber Reserve Corporation. -The Rubber Reserve Corporation, a war-time agency under the Reconstruction Finance Corporation, was concerned with the operation of plants producing synthetic rubber. An important area of such production is "Rubbertown" near Louisville, Ky. where the ground-water supply is being heavily drawn on by various industries. To determine the adequacy of the ground-water reservoir, the Rubber Reserve Corporation financed the Survey on its investigations in that area[201] for the purpose of drilling many test wells in a study of river infiltration. Drilling was planned and supervised by the Survey but was paid directly from Rubber Reserve funds by its agent, the DuPont Company. The amount of such funds was about $19,000.

201/ p. 277.

Funds transferred directly to the Survey were:

1945	$613	1946	$3,727

Defense Plant Corporation. -The second phase of the Gila River Investigation, started in June 1943,[202] was financed by the Phelps-Dodge Corporation through the Defense Plant Corporation, a war-time agency of the Reconstruction Finance Corporation. The funds allotted to the ground-water phase of the investigation were:

202/ p. 18.

1944	$25,000	1945	$12,500

National Resources Planning Board. -Of the funds provided by the National Resources Planning Board for the Pecos River Joint Investigation, it is estimated that $5,000 was allotted for ground water during the 1941 fiscal year.

Veterans Administration. -In the fiscal year 1947, the Veterans Administration requested the Survey to investigate the possibility of a ground-water supply for the Big Springs, Texas hospital, and transferred $290 to pay for the investigation.

Foreign Economic Administration. -To finance the work of G. F. Brown's geologic reconnaissance of Arabia from December 1944 to June 1946,[203] the Foreign Economic Administration transferred to the Survey the following amounts:

1945	$4,123	1946	$5,250

[203] p. 236.

Methods and Equipment

With the marked expansion of the ground-water investigations, wider use was made of the methods developed previously, and some new methods and devices were used.

Increase in test drilling. -Standing near the head of the list was test drilling. During the previous period, because of the expense involved, test drilling was limited largely to the states of Nebraska and Kansas where the cooperating State agencies owned drilling rigs; and perhaps a dozen investigations in other states where funds permitted test drilling by contract. In the many investigations for the war establishments made at the request of military, industrial, and municipalities in those areas, test drilling was a regular procedure in many areas. The two State-owned rigs were increased by three, another in Nebraska and one each in North Dakota and Nevada, the two latter having been purchased by the State agencies from surplus at the close of hostilities. The Survey owned no well-drilling rig, as the Director declared it to be the Survey policy to have all test drilling done by contract.

During the period, about 7,000 test holes or test wells were drilled under Survey supervision.

Development of pumping test techniques. -During the previous period, L. K. Wenzel had developed and experimented with the so-called Thiem equilibrium formula in making pumping tests to determine permeability or transmissibilityof the water-bearing material. In that formula, time was not a factor as the test was continued until a state of equilibrium in the ground-water level was reached.

In 1935, C. V. Theis, by analogy between hydrologic conditions in an aquifer and thermal conditions in a similar thermal system, developed a formula for determining the drawdown of the cone of depression at any distance from a discharging well. His work made possible the inclusion of time in the analyses, with the result that it was possible to determine the equation of the water level drawdown caused by pumping the well for a limited period of time, and by means of the equation to extend the curve over a much longer period of time. As equilibrium was not reached during the pumping tests, the formula became known as the non-equilibrium formula. By using various mathematical techniques, it became possible to take account of complicated geologic boundary conditions in predicting future drawdowns.

C. E. Jacob joined the Survey in 1936, and soon became interested in the mathematics of ground-water hydraulics with especial reference to the non-equilibrium formula which he developed mathematically, proving that Mr. Theis' assumption of the analogy was correct. Mr. Jacob was soon devoting most of his time to pumping tests in various parts of the country and developed new applications of the formula. One of his principal contributions was the training of new men assigned to quantitative problems. In 1944, Mr Jacob was transferred to the Washington Office, and during the remainder of the period, visited nearly every field office and lectured to the field men on the development and application of the science of ground-water hydraulics. Until retired for disability in 1944, Mr. Wenzel also devoted most of his time to pumping test procedures, and published Water-Supply Paper 887, "Methods of determining permeability of water-bearing materials," which was the standard handbook on pumping tests.[204]

[204] Based chiefly on statement of W. F. Guyton.

From the foregoing, it is seen that pumping tests were broadened and the results used to predict drawdown with various rates of pumping, even years in advance. They became standard procedure in quantitative analyses which became more numerous during the period.

Electrical-resistivity.-The only geophysical method applied to ground-water problems during the period was that of electrical resistivity. It was used in half dozen or more locations by R. A. Spicer of the Combined Geophysical Section of the Geologic Branch which was equipped to do either Gish-Rooney or D. C. measurements to depths of 3,000 feet. It was also used by the Albany Office near Binghampton, N. Y.[205]

[205] p. 244.

At an air base near Kingman, Arizona, the Army Engineers wished to develop a water supply. Thirty-one electrical depth profiles were completed, most of them extending to the 1,000-foot interval distance. It was possible, from the interpretation of the apparent resistivity curves, to determine the approximate distance to bedrock, predict the kinds of materials the drillers would encounter, and to select the best sites for future drilling. As a result, an ample supply of water was obtained.

An investigation of a totally different character was a study of salt-water encroachment from the gulf near Jennings, La. It was believed that the salt water was encroaching through the deeper formations and endangering the ground-water used for irrigation. In a preliminary study, 16 depth profiles were completed, extending to the 2,000-foot interval. They outlined the surface material and the underlying gravel deposits, and thus helped to determine the possibility of encroachment through the deeper formations. Another investigation to detect salt-water encroachment was made some distance from Miami, Fla. and was successful.

At Colfax, La., resistivity measurements were made to determine if that method would be helpful in locating sites for water wells. Well logs from the area indicated a very high clay content in subsurface material and the resistivity curves confirmed that situation.

One of the largest investigations was at Louisville, Ky., the object being to determine the approximate depth to bedrock in an area generally southwest of the city. In connection with numerous test holes, it would be possible to estimate the storage capacity of the ground-water reservoir. Eighty electrical depth profiles were compiled, making it possible to eliminate several test holes.

It was disconvered, both in Miami and in Binghamton, N Y., that in cities with proximity of water pipes, cables, etc. electrical resistivity methods were not successful.

In his problem of selecting well sites for the Grazing Service in western Utah, H. V. Peterson, in connection with the Soil and Moisture Program, used the electrical-resistivity method successfully.

These descriptions are taken from H. A. Spicer's paper delivered at the Lincoln Conference. In concluding his paper, Mr Spicer stated:

> As a result of my experience in geophysical investigations of ground water, I feel it is unsafe to predict whether or not a geophysical method will succeed in a particular area. The best way to do is try geophysical methods under the direction or guidance of a qualified person, giving the methods a thorough trial.

Electric Log. -A new tool which came into use to a limited extent, was the elctric log. The electric logging of wells, developed in Europe, was first used in this country about 1928 in exploratory drilling for oil and gas. It is a method in which electric currents under controlled conditions are passed down a well, and determine the difference in potential or earth currents, in the various formations penetrated by the well. The electric log is recorded to scale, photographically, and usually consists of two or more resistivity curves, and a potential curve. The resistivity curves give a graphical record of the apparent specific resistences of the formations penetrated; the potential curve is a record of the earth currents that occur spontaneously in the well hole.

In certain areas, the electric log has been found more useful than drillers' logs in correlating the principal water-bearing horizons over wide areas. In itself, the log is not an indicator of permeability, but studied in connection with other data, is of value.[206] Electric logging is a

206/ Abstracted from "Value of the electrical log for estimating ground-water supplies and the quality of the ground-water," by B.A. Barnes and Penn Livingston (unpublished).

recognized procedure in oil-well drilling and where test drilling was done by the Survey in oil regions, the contractors were equipped to make electric logs as a part of the contract, or if not, the oil companies generally permitted the Survey to use the electric logs of the oil wells in that general vicinity. Its first use by the Survey was in Texas during the exploratory well drilling in the Houston area in 1939.[207] In 1943, soon after the Maryland

207/ Water-Supply Paper 889-D.

investigations were being started, R. R. Bennett found considerable difficulty in correlating and integrating the drillers' logs in the Baltimore area, and electric logs were needed in the test drilling required. As no drilling contractors in that area were equipped to obtain electric logs, Mr Bennett constructed a simplified electric logger in 1944, and used it in his subsequent investigations.[208]

208/ Water Resources Bull., Nov. 1944, p. 206.

Aside from the Bennett equipment, the Survey owned no electric-logging equipment and therefore, the use of the electric log, in addition to Maryland and vicinity, was confined chiefly to Texas, Louisiana, and Mississippi. In other oil regions, the Survey was doing little ground-water work.

Magnetic-type well-casing explorer. -A device for measuring the length of pipe casing in drilled wells of small diameter was developed by S. E. Norris in the Columbus Office in 1947. A small horseshoe-type magnet made of the alloy "alnico" to keep a sharp point in contact with the casing, is attached to a 2-pound weight and lowered in the well, making the electric circuit, which is registered by an ohm meter. When the magnet slides off the casing into the open part of the well, the ohm meter indicates a marked resistence, indicating the end of the casing. The device was of particular use where the depths of old wells, usually drilled to bedrock, were not known and where the length gave the distance to bedrock.[209]

209/ Abstracted from "Magnetic type well-casing explorer" by R.H. Brown (unpublished)

Power equipment for lowering instruments in wells. -For use of the various methods used in determining leaks in artesian wells where it was necessary to lower the various instruments, depending upon the method used, several hundred feet or more, the cable suspending the instrument was first operated by means of a hand reel. This was a slow process and in 1925, Fiedler mounted a reel on the rear of a truck and operated it by means of power derived from the rear wheel.

By 1938, the need for determining salt-water leaks in wells had increased so greatly that it was decided to redesign and rebuild the power-driven equipment, and Penn Livingston was given that assignment. The work was started in February 1939 and finished about a year later. The equipment designed was an independent unit consisting of a chassis having a wheel base of 4-1/3 feet and a wheel gage of 33 1/4 inches, containing a twin-cylinder motorcycle engine attached to twin drums, each holding 1,500 feet of quarter-inch cable or about 5,000 feet of eight-inch cable. mounted tandem and accessories used in operating the instruments in the well. For short hauls, as the unit was not self-propelling, a trailer hitch was provided for towing, but for long moves, the unit was loaded on a one-ton panel body truck; one end of the cable was attached to an anchor in the truck and the motorcycle engine provided the power to pull the equipment up an incline made of two channel irons. Only one of the independent units was built during the period. When used by other districts, an engineer came from that district to direct the equipment where needed.

Ink-well mercury gage for measuring artesian head -An investigation of the Grand Junction artesian area by S. W. Lohman, started in Colorado in 1946, required the accurate measurement of shut-in artesian heads up to 121 feet above the ground surface. The mercury manometer devised by G. H. Taylor in 1931[210] was limited to a height of 50 feet, and that type of gage was not considered satisfactory for the heads being investigated. An ink-well mercury gage had been devised by the Utah State Engineer's Office, and that type was believed to be suitable. Using the Utah gage as a pattern, a gage was built in two sections, to extend its range, and embodied several improvements in design and construction.

210/p. 290 (1928-1939).

A wooden upright member containing glass tubing of 6-mm inside diameter is fastened to a wooden base fitted with a sliding drawer which holds the ink-well reservoir. This is a 2-oz. ink bottle having rubber stopper through which 2 1/4-inch aluminum or cooper tubes and the 1/4-inch glass tube pass. The aluminum tube at the left through which water enters from the well extends to a joint just above the normal level of the mercury; the tube at the right through which air and dirty water may be expelled, extends just to the bottom of the rubber stopper; the glass tubing extends just above the bottom of the mercury reservoir. The aluminum tubes are equipped with needle valves.

For measuring static pressure, a 1/2-inch globe valve was attached to the well and the latter shut in by closing that, and all other valves that might be attached to the well. After the artesian head had been allowed to recover, the gage was set on a level surface and attached to the globe valve; the right needle valve was closed and the left one opened to permit the mercury to rise in the tube. Not only was the mercury gage used successfully in measuring high artesian heads, but also in measuring the recovery for determination of coefficient of transmissibility and storage.[211]

211/Proc West-Central Branch Conf., Water Resources Branch, April 9-12, 1947, pp. 110-115.

Research Projects

There were five research projects during the fiscal year 1947. Of these, the largest was in connection with the hydrologic laboratory in Washington.

With the transfer of V. C. Fishel to the Kansas investigation in 1942, there had been no one in charge of the hydrologic laboratory which had been started with the New Jersey investigations in 1923.[212] With funds available, W. O. Smith was placed in charge of the laboratory, and ordered and installed additional equipment. He began studies of unsaturated

212/p. 180 (1919-1928).

flow and conductances of rocks, and also did some theoretical work on the computation of specific yield based on mechanical analyses.

Electric logs were being used to a considerable extent by the Survey, and it was felt that a study of the resistivity data obtained from the logs should be made. Accordingly, P. H. Jones in charge of the Louisiana investigations was detailed to that project. Astudy of available literature on electric-logging methods and principles, indicated that absolute values of resistivity of the rocks could be determined by the application of proper corrections for electrode spacing, bed thickness, temperature, etc. As a result, it was believed that the electric log could give information on the texture of granular aquifers, their porosity, and the character of the water filling the interstices, and so make possible the prediction of the quality of water in formations by use of electric logs and mechanical analyses, rather than by drill-stem testing. The formation factor was determined from mechanical analyses of drill cuttings from wells having different formation factors, and for which complete chemical analyses of the water samples had been made. The project which was showing promising results, was in progress at the end of the period.

An allotment was made to H. E. Thomas in charge of the Utah investigations, for a study of the ground-water geology of the Tertiary and Quarternary sequence in Cache Valley. This was particularly concerned with the possibility of developing the deeper aquifers, which had previously received little attention. Cache Valley was selected as that area contained the best surface exposures of the Tertiary strata in the entire Conneville Basin, and the correlation and evaluation of the aquifers with respect to ground water will aid in studies of aquifers inother valleys in the basin. The project, which was started by P. F. Fix in November 1946, was in progress at the end of the period.

In north Carolina, the flood plain deposits of streams in the Piedmont region are quite shallow and have yielded only small amounts of water. It was believed that a thorough study of the geology would yield information on the occurrence and quantity of ground water, that would be helpful in determining possibilities in other similar areas where water supplies are critical. An allotment was made to M. J. Mundorff in charge of the North Carolina investigations, and in determining the distribution, extent, and character of the flood plain deposits, 22 test holes averaging about 20 feet deep were bored in the flood plains of various streams. Although the project was completed, a report was not available at the end of the period.

The fifth project was a continuation of a study of the subsidence of the land surface in the Santa Clara Valley, California, caused by large withdrawals of ground water. An allotment was made to J. F. Poland in charge of the California investigations, who had studied that problem in connection with a Ph D thesis in the nineteen-thirties. However, the necessity for completing a cooperative report during 1947 made it impossible for Mr. Poland to make the investigation in the Santa Clara Valley, and the funds were used for other geologic research in the Los Angeles area, apparently not in connection with ground water.

Missouri River Basin-Departmental Program [213]

Although the ground-water program was designed primarily to meet the needs of the Bureau of Reclamation, it was broadened insofar as funds permitted to include the needs of the several Missouri River Basin states, other Federal agencies, and work considered basic by the Survey. All the states in the Missouri River Basin were included in the program except Iowa and Missouri, which, not being irrigation states, were not included in the Bureau of Reclamation's activities. G. A. Waring was in general charge of the Departmental Program from its inception during October 1945 until January 1946. G. H. Taylor, who had recently been released from the Army, was given charge of the ground-water program on January 13, 1946, with headquarters at the Branch office in Lincoln, Nebraska.

State-wide cooperative ground-water programs were in progress in Nebraska, Kansas, and Colorado, and the investigations required by the Departmental Program were incorporated with those programs, using the same personnel with such additions as were required. Although a state-wide cooperative program was also in operation in North Dakota and a small observation-well program in South Dakota during 1945 and 1946, both under the supervision of P. E. Dennis with headquarters at Grand Forks, North Dakota, a separate Missouri Basin ground-water office was established in Bismarck, North Dakota, in March 1946, to which G. A. LaRocque, Jr., on his return from military duty, was assigned to supervise the Missouri Basin program in both states. A small cooperative program was being carried on in southeastern Wyoming, but the Departmental program in both Wyoming and Montana was supervised from the Washington, D. C. and later from the Lincoln, Nebraska headquarters office. All the studies included the obtaining of both surface and ground water samples which were analyzed and studied by the Lincoln, Nebraska laboratory under the supervision of P. C. Benedict.

With "going concerns" in Nebraska and Kansas, additional personnel were obtained and the investigations were started in those states in October 1945. G. A. Waring made a reconnaissance of the remainder of the Basin in the fall of 1945, established observation wells in a number of areas, and spent several weeks on extended reconnaissance of the North Dakota Missouri-Souris area. Primarily because of inclement winter weather and lack of personnel, the main studies in areas other than Nebraska and Kansas were not begun until the spring of 1946. Requests for studies exceeded those permitted by available funds and priorities of areas to be studied were established as conditions dictated from time to time and were governed primarily by Bureau of Reclamation construction schedules and priorities.

Montana. - A few observation wells were established during the

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213/ Prepared chiefly by G. H. Taylor.

fall of 1946 on the Lower Marias Unit and active field studies were begun by F. A. Swenson during May 1946. These studies included aerial geologic mapping, an inventory of existing wells, selection and periodic measurement of the water level in 18 observation wells, and the obtaining of a correlation of other available hydrologic data. Eighteen test holes were completed under contract in May 1947 when 3,679 feet of 4-inch test hole were drilled on the project. The general study was completed during the 1946 summer field season, with the exception of the test hole drilling, and measurements of the water levels in the observation wells were continued by Bureau of Reclamation personnel.

Field work on the Upper Missouri-Souris Unit was limited during 1946 to the selection and measurement of 35 observation wells. Ten test holes were drilled under contract during June 1947, a total of 2,268 feet of hole being obtained. A general study of the Missouri River Pumping Unit areas between Fort Peck and the North Dakota State boundary, begun by F. A. Swenson during the spring of 1947, was completed that field season.

Beginning in June 1947, Mr. Swenson selected 32 observation wells, distributed over the state, which were measured periodically by personnel from the Surface Water District Engineer's Office at Helena.

Wyoming. - One regular project was studied prior to June 30, 1947. Field work in the Owl Creek area was started by R. T. Littleton in April 1946, and completed early in August. In addition to the geologic mapping, well inventory, establishment of 80 observation wells, and the spirit level determinations of the sea level elevation at each well, 6 sets of discharge measurements for a study of the losses in the South Fork of Owl Creek were made by the Surface Water District Engineer's Office at Denver. That office also made periodic readings of the water level in 19 observation wells after the field work was completed.

At the request of the Bureau of Reclamation, a special reconnaissance study of the Heart Mountain and Chapman Bench extensions of the Shoshone Project was made in August and September 1946 by F. A. Swenson. There were only 3 wells in the area, all highly mineralized and a domestic supply of good quality was being sought. This study showed that ground water of good quality and at shallow depths would become available to the settlers within a few years after the application of irrigation water was begun.

North Dakota. - Three areas were selected initially for early study. In the Lower Missouri-Souris Unit field work was started by G. A. Waring with a reconnaissance and location of some observation wells in September 1945. A general study including geologic mapping, inventory of wells, and selection of additional observation wells was started in April 1946 and continued through the period. To obtain additional geologic data, a test hole drilling contract was let in April

1947 which resulted in obtaining 17,976 feet of test hole. About 240 observation wells, 4 equipped with recorders, were maintained and periodic measurements continued.

Field work in the Heart River Unit was started in April 1946 by P. C. Tychsen and consisted of a detailed geologic examination of the valley, inventory of wells and selection of observation wells. The initial field work was completed in September 1946. Some additional field work was done during the summer of 1947, especially in the vicinity of Dickinson. Observations were continued on 18 wells, 1 being equipped with a recording gage.

In the Knife River Unit, the work was confined to a reconnaissance and selection of 12 observation wells in April and May 1946, detailed studies being deferred until geologic mapping by the Geologic Branch became available.

In addition to the above-named areas, 16 observation wells were selected for periodic observation in the Oakes area, 16 in the Jamestown area, and 13 in the New Rockford area where future investigations were to be made. A few observation wells were also selected in other areas for measurement at more infrequent intervals. In addition, assistance was given in the selection and periodic measurement of about 25 other observation wells distributed over the western half of the state and which were maintained in cooperation with the Surface Water District Engineer's Office at Bismarck and P. E. Dennis of the Ground Water Division at Grand Forks.

South Dakota. - Three areas were selected for initial study. In the Grand River unit, a general reconnaissance and selection of a skeleton network of observation wells was made in May and June 1946 by G. A. Waring and P. C. Tychsen. A general study including geologic mapping, a well inventory, and completion of the observation well network, was started by P. C. Tychsen in September and completed in October 1946. Thereafter, periodic observations of the water level in 27 wells, one equipped with a recorder, were continued.

A reconnaissance and selection of observation wells was made in the Oahe Unit in April 1946 by G. A. Waring and P. C. Tychsen. Thereafter, the periodic measurement of the water level in 138 wells was continued. G. A. Waring, assisted by J. S. Hornby, began a general study of the Oahe Unit in May 1947.

A reconnaissance of the Angostura Unit to locate observation wells was made in April 1946 by G. A. Waring and P. C. Tychsen. A general study of the area, including geologic mapping and inventory of wells and springs, was started in August 1946 by R. T. Littleton and initial field work was completed that field season. Through informal cooperation with the Soil Conservation Service, which was making studies in the area, a total of 54 test holes having a maximum depth of 32 feet were drilled under the general supervision of H. F. Haworth, Survey Geologist. Periodic observations of the water level in 37 wells were continued by the Soil Conservation Service after Mr. Littleton left the field.

About 25 wells located at strategic sites throughout the State were selected during the summer and fall of 1946 to be measured by personnel of the Surface Water Division Office at Pierre. Periodic measurements in a few wells in southeastern South Dakota were obtained from the South Dakota State Geologist, although no financial cooperation existed.

Nebraska. - One of the most important investigations in the Missouri Basin Program and the one on which the Nebraska activities were concentrated, was that of the Lower Platte River from North Platte to Fremont. There, the Bureau of Reclamation desired a capacity table of the ground-water reservoir east of North Platte. To obtain the needed information, it was necessary to make a quantitative investigation, supplementing and expanding studies made during previous years through cooperation with the Conservation and Survey Division of the University of Nebraska. Field work was started in October 1945 by H. A. Waite and assistants. About 70 shallow wells were hand-drilled at 1-mile intervals on 8 profiles across the valley. About 4 holes in each profile were cased and used as observation wells. To determine the transmissibility and storage coefficient of the water-bearing material in the valley, 5 Thiem pumping tests were made, one near Columbus, 2 near Grand Island, one near Wood River, and one near Elm Creek.

In each of the tests conducted, three pairs of observation wells were installed at distances of 100, 200, and 300 feet, respectively, on a line extending outward from the pumped well. One well of each pair was shallow and penetrated the aquifer only deep enough to extend below the sediments dewatered during the pumping test. The second well of each pair was deep and extended to the bottom of the aquifer. Periodic measurements of about 270 observation wells, 3 being equipped with recorders, were made, and sea level elevations were established at all observation wells. As the Lower Platte investigation was also a part of the cooperative ground-water program, a State-owned drilling rig was available for test hole drilling.

In the Republican River Valley, field work was limited chiefly to selecting a comprehensive network of observation wells and was started by H. A. Waite in January 1946. Of the 165 wells selected, about 70 were constructed by hand auger and cased with 1 1/4-inch pipe and sand points. Three of the wells were equipped with automatic water-stage recorders.

A resurvey and study of Box Butte County was begun by R. L. Nace during February 1946 to supplement an earlier report by R. C. Cady and O. J. Scherer published as Water Supply Paper 969. Field work included geologic studies, and inventory of irrigation wells, selection of observation wells, collection of ground-water samples for chemical analysis, and some test drilling. Elevations of the test wells were determined by the Topographic Branch working in the area. The flow and pressure head of several flowing wells were measured. Periodic measurements in 65 wells, 4 being equipped with recorders, were made. The Bureau of Reclamation requested that the investigation in Box Butte County be extended eastward to include a large part of the sand hills region in Nebraska. The purpose of that extended study was to make a general study of the geology and ground-water resources of the area. Field work included the measuring of the water levels in a great many existing wells to be used as control for the preparation of a water-table contour map. Such a map will be useful in determining the direction of ground-water movement beneath the sand hills region. The extended study was started by R. L. Nace who was succeeded by W. K. Bach later in the summer of 1946.

Kansas. - The investigations in Kansas were severely limited because work of greater priority in other parts of the Missouri Basin limited the use of funds for work on the Kansas Units.

The Kerwin Unit investigations, started by V. C. Fishel and assistants in October 1945, consisted of an inventory of wells, geologic studies, establishment of 24 observation wells, and running of sea level elevations to the wells. The field work was completed during the 1947 fiscal year.

The study of the St. Francis and Wells Unit was started in February 1946. The geologic studies, inventory of wells and establishment of 20 observation wells was completed in June 1946.

Work on the Kanopolis Unit consisted of supplementing by a more comprehensive observation well network, previous studies made under the cooperative program with Kansas State. It was started in February 1946 with the establishment of 20 observation wells, several of which were drilled for the purpose, by a State-owned drilling rig. The field work was completed in May 1946.

In connection with the Cedar Bluff Unit, studies were started in April 1946, to determine whether ground-water is available for municipal supplies for Hays, Victoria, Gorham and Russell, or whether such supplies will have to come from the proposed Cedar Bluff Reservoir. Field work on this special study was completed in May 1946. Because of a low priority, further work on this Unit was deferred.

Work on the Bostwick Unit was to supplement, with additional observation wells, an investigation made in 1942 under the cooperative State program. Field work started in February 1946. Although 24 sites for observation wells were selected, the inability to obtain materials prevented completing this work until late in the 1947 fiscal year.

Colorado. - Under the existing priorities of work, studies in Colorado could not be started in 1945 or 1946 with available funds. During October 1946, a change in priorities caused a decision to begin studies of the Lower South Platte River Valley from Kersey, Colorado to Paxton, Nebraska, as quickly as possible under the immediate direction of S. W. Lohman. Active field work was begun on April 1, 1947, by L. J. Bjorklund who was joined by R. T. Littleton on April 21, 1947. The latter resigned on June 13, 1947. N. M. MacNeill joined the project on June 9, 1947. The study of this area was only getting well under way by June 30, 1947, but considerable progress had been made towards the compilation of existing data and a test hole drilling contract had produced 1,400 feet of test hole by June 30, the contract of 5,000 feet being completed the next fiscal year.

In addition to the personnel of the Nebraska, Kansas, and Colorado offices, some of whom devoted a large part of their time to the Missouri Basin project, the following technical personnel devoted their entire time to the project, their activities being confined chiefly to Montana, North Dakota, South Dakota, and Wyoming:

G. A. Waring	Aug. 1, 1945 to June 30, 1947	
G. A. LaRoque, Jr.	Feb. 15, 1946 to June 30, 1947	
F. A. Swenson	Apr. 8, 1946 to June 30, 1947	
R. T. Littleton	Apr. 16, 1946 to Apr. 1, 1947	(see Wyo. list)
P. C. Tychsen	Mar. 18, 1946 to June 30, 1947	
H. F. Harworth	July 2, 1946 to June 30, 1947	(see Nebr. list)
J. S. Hornby	May 6, 1947 to June 30, 1947	

War Activities

In 1939, Mr. Meinzer, mindful of the importance of ground-water investigations during the first world war, assigned D. G. Thompson to take charge of the work of the Division related to water supplies for defense purposes. The latter developed contacts with the different war agencies which were largely responsible for the effective use of the Survey's services by those agencies. Owing to ill health, Mr. Thompson was forced to leave the office Nov. 5, 1942, and the work was carried on by G. C. Taylor, Jr. until the end of January 1943, when C. L. McGuinness was placed in charge.

Not only the War and Navy Departments with their many new military establishments, but also the many war-time agencies interested in the location of new industrial plants, were concerned with the water supplies for the new establishments, and wanted prompt reports dealing generally with specific quantities available. In many instances, it was necessary to make investigations involving both test drilling and pumping tests. In each instance, the requesting agency was willing to pay the cost of the test drilling and furnish the facilities for the pumping tests in order to obtain the results as soon as possible. Most of the investigations were made without charge but lengthy investigations were required, the agency requesting the investigation paid a part or all of the cost. A description of such payment is given under Federal cooperation.

From the preparedness days before the war until its close, a total of 3,711 requests were received from the following sources:

War	Navy	WPB and predecessors	Miscellaneous	Total
1,017	360	1,227	1,107	3,711

Miscellaneous includes Federal agencies other than those shown; State and municipal agencies, industrial officials, contractors, and consultants.

To give an idea of some of the investigations required, a few are described. One of the first investigations was that of the water supply for the Indiana Ordnance Works, a Dupont-operated plant at Charleston, Indiana. The supply was obtained from a Ranney water collector penetrating glacial outwash gravels. In August 1940, a Survey representative discussed the proposed water supply with the Dupont officials and some months later, another representative visited the plant and discussed the supply, the wells for which were under construction. In January 1941, two recorders were placed on test wells, and additional recorders were installed later. In July and August 1941, the Survey cooperated in acceptance tests of the collectors, and made a report to the War Department. Subsequent to that test, the Survey acted as a consultant on the ground-water supply of the ordnance works, and made recommendations concerning its operation when difficulties arise.

During the spring of 1943, a pumping test of wells at the Kankakee Ordnance Works near Joilet, Ill. was made at the request of the War Department. Its purpose was to determine whether the ground-water supply would be sufficient for the uninterrupted operation of the plant, as a test made by a State agency had been interpreted as showing that the supply was not sufficient. The Survey's test showed that the water supply was sufficient for continuous operation of the plant.

A third type of investigation was made from October to December 1943, in the vicinity of the Weldon Springs Ordnance Works, Weldon Springs, Mo., at the request of the War Department. It was necessary to store temporarily in pits, waste products, and the Survey was requested to determine the extent to which local water supplies, both surface and ground, would be contaminated. A report describing the extent of possible contamination and necessary measures to remedy it was made to the Army Engineers.

In July 1942, at the request of the Army Engineers, ground-water supplies at three airport sites in Baja, Calif. Mex. were investigated.

Additional investigations for various agencies are described under the activities of the various ground-water districts.

Special war-time services were performed by a number of the Survey personnel. G. H. Taylor, a reserve officer, was called to active duty in 1940 and assigned to Washington as a liaison officer between the Army Engineers and Survey. He rose to the rank of lieutenant-colonel, and was overseas during a part of 1943 and 1944. While in Washington, he prepared a part of a technical manual of the Army Engineers, entitled "Water supply and water purification."

C. V. Theis was assigned to the Army Engineers from November 1943 to March 1944 to investigate the ground-water supplies and the permafrost as related to the construction of buildings and gasoline storage tanks along the Alaska highway in Canada and Alaska. He prepared reports on water supplies at more than 50 air fields and camps and on permafrost conditions at 6 places.

H. T. Stearns spent a large part of the war years on special investigations, chiefly in the South Pacific. His work is described under the activities of the Hawaiian District.

At the specific request of the War Department, ten geologists of the Ground Water Division were commissioned in the Army and assigned to water-supply battalions or headquarters staffs overseas. The geologists so commissioned were:

Major R. C. Cady	Capt. R. C. Newcomb
Major R. M. Leggette	Lieut. R. C. Baker
Major H. E. Thomas	Lieut. Bernard Fisher
Capt. F. C. Foley	Lieut. W. C. Rasmussen
Capt. R. L. Nace	Lieut. S. L. Schoff

Military Geology. - In March 1942, the Army requested the Survey to make engineering studies of several countries in Africa, with respect to terrain, suitability of certain areas for dock sites, air fields, water supply, camp sites, soil and rock available. The Geologic Branch to which the request was referred had no one capable of making the water supply studies and A. N. Sayre was given that assignment. The available data consisted chiefly of descriptions given by various explorers, geologists, and engineers; the available maps were chiefly German maps obtained from World War I. The first reports were in the form of memoranda which included, in addition to the information requested, data on rivers as means of communications, frequency of floods, nature of banks and beds. The data were presented in tabular form, which as Mr. Sayre states, really sold that service to the Army.

July 1, 1942, the War Department asked the Survey to triple its staff engaged in that work, and the Survey set up the Military Geology unit. The Water Resources Branch was not directly connected with Military Geology but the following ground-water personnel were temporarily transferred to the Geologic Branch for detail to Military Geology:

A. N. Sayre	July 16,	1942 to Nov.	28, 1945	
G. A. Waring	Aug. 1,	1942 to Sep.	10, 1945	
F. A. Swenson	Aug. 1,	1942 to Apr.	8, 1946	
R. M. Jeffords	Aug. 16,	1942 to Sept.	15, 1942	
R. B. Morrison	Oct. 1,	1942 to Nov.	1, 1942	1/
L. C. Huff	Nov. 2,	1943 to Sep.	23, 1945	
S. S. Nye	Jan.	1944 to July	1945	2/

Mr. Grover did the river sheets for half a dozen countries. He was held on that work until other and more pressing duties demanded his attention. As the results were designed chiefly for General Staff strategy, the work of the unit was so secret that all the rooms used were kept locked.

Late in 1943, the Army became interested in the plan to send civilian specialists overseas to help with engineer intelligence of countries marked for invasion. In May 1944, Mr. Sayre and four others from Military Geology were sent to the southwest Pacific to "pin point the same sort of work," again quoting Mr. Sayre. A Few months later, another team, of which Mr. Swenson was a member, went to the Central Pacific with its destination Iwo Jima, and later Okinawa, for the prupose of helping with the problems of water supply and rock supplies (both important military items). Although not a part of the history of Military Geology, it may be stated that the Navy Department, independently of the Army, through H. T. Stearns who was doing a large amount of work for the Navy, arranged to send a ground-water geologist to Okinawa and D. J. Cederstrom was selected. Both Swenson and Cederstrom received bronze stars for their services.

Mr. Sayre applied for transfer from GHQ to duty with troops, and as a result, was present at the Leyte operations in the Philippines. There, the ground-water situation was ideal for development. The headwaters of the surface stream at Leyte were held by the Japanese, and the water was unsafe for use by the Americans. He received the Medal of Freedom, established to recognize civilian personnel.

Toward the end of the war, W. F. Guyton was assigned to Military Geology and sent to the Philippines to assist in engineering studies there, and later in Japan. Soon after the surrender of Japan, General MacArthur's headquarters requested Military Geology to detail a number of technical specialists to Japan for the purpose of making a

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1/ Permanent transfer to Geologic Branch.
2/ Former member of division, returned for detail to Military Geology.

quick inventory of the natural resources. To handle the inventory of water resources, F. M. Bell, M. R. Williams, and A. O. Waananen were transferred to Military Geology and flown to Tokyo in December 1945. They were assigned to serve as the Water Resources Branch of the Mining and Geology Division of the Natural Resources Section of General Headquarters, Supreme Commander of Allied Powers. As a result of the Water Resources investigations, two reports were prepared, which were published by the Natural Resources Section and distributed throughout General headquarters to all Military Government units and to the principal units of the Occupation forces. One report was on hydro-electric power by Bell and Williams, and the other on the hydrology of Japan, by Bell and Waananen, based chiefly on the records being compiled by the Japanese. The work was completed in June 1946 and the personnel returned.

Foreign Economic Administration 214/

By Executive Order of September 25, 1943, the Foreign Economic Administration was established within the Office for Emergency Management, to unify and consolidate governmental activities relating to foreign economic affairs.

As evidenced by the branches comprising the Bureau of Areas that was established as one of the operating bureaus of the administration, the territory covered was extensive and included the following branches: Liberated Areas, Special Areas, General Areas, German and Austrian, and Pan-American. The Bureau of Areas was responsible for the broad program, decisions regarding F.E.A. operations in all areas, and the coordination of such programs and with harmonizing them with State Department foreign policy and with military activities and requests.

Among the activities of F.E.A. was that of improving economic conditions in various countries of strategic economic importance through the assignment of Missions of experts which made surveys and plans for the utilization, improvement, and development of the local resources so that economic conditions within the countries would be advanced. One such mission of government experts went to Arabia and included G. F. Brown representing ground water. Mr. Brown was chosen for this assignment because of his experience in ground-water work, his familiarity in working with native peoples, and because of his interest in foreign work.

During the period December 1944 to June 1946, Mr. Brown made a geologic reconnaissance of the entire region, mapped 800 square miles in detail, determined the chemical quality of the waters in Central Arabia and located water in a new area that previously

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214/ Prepared by A. N. Sayre.

had no useful water supply. Though the report on these investigations was not especially encouraging with regard to the development of large supplies for irrigation, it was of great value in giving for the first time a realistic appraisal of the ground resources of the region covered.

Office of Inter-American Affairs[215]

By Executive Order dated July 30, 1941, the Office of Inter-American Affairs was created for the purpose of furthering the good-neighbor policy by formulating and executing programs through the use of governmental and private facilities which would advance national defense and strengthen the bonds between the nations of the Western Hemisphere. Two members of the Ground Water Branch, A. N. Sayre and G. C. Taylor, Jr., were assigned to conduct investigations in Central America for the improvement and development of water supplies from ground sources.

Mr. Sayre was in the field from June to August 1943, and Mr. Taylor was in the field from June 1943 to the end of January 1944. The investigations were chiefly for the improvement of village and city water supplies, and particularly for the communities along the Inter-American Highway. Work was done principally in El Salvador, but also in Nicaragua and Guatemala.

U. S. Commercial Company

At the request of the Navy Department, the U. S. Commercial Company, a subsidiary of the Reconstruction Finance Corporation, sponsored an appraisal of the potential economic resources and problems in the ex-mandated Japanese islands. Specialists from Federal agencies and educational institutions covered most fields of applied science, physical, biologic, and social. A. M. Piper was selected to appraise the water resources, both surface and underground. He was absent from the United States from the first of April to the end of December 1946.

Summary of operations in each state

A summary of the operations in each state is given in sufficient detail to present a fairly complete picture. Attention is called to the fact that the terminal dates of personnel in one state may not, in some instances, coincide with the initial date of duty in another state of transferred personnel as terminal leave may be included in the terminal date.

The section on State cooperation contains the reasons for such cooperation and the annual cooperative amounts.

215/ Prepared by A. N. Sayre.

Massachusetts. - Owing to the limited cooperative funds available, the investigation during the first half of the period was confined chiefly to the standard-type investigation of well inventories, available records of pumpage, and establishment of and maintenance of observation wells in the northeastern part of the state. A beginning had been made in Middlesex County when cooperation became effective in 1938. The well inventories were completed for that county and the number of observation wells increased to some 35, of which 2 were equipped with recorders. Five observation wells were established in other sections of the state, giving a fairly uniform coverage.

As a result of an increase in cooperation for that purpose,216/ a quantitative study in the vicinity of Fresh Pond in Cambridge was started in the spring of 1944 by H. N. Halberg, for the purpose of determining whether the drawing down of the Pond level by the City would induce ground-water inflow from a considerable surrounding area. The Department of Public Health had drilled 20 test wells and the Department of Public Works made seismic surveys to explore the geologic and ground-water conditions in the buried valley under the area. The Survey made the readings of the 20 observation wells, computed the well inventory and pumpage records. The investigation which was completed in 1946, except for continued readings of a few wells, showed the affect of the drawdown to extend as far distant as a mile. The report, "Recovery of ground-water supplies by pumping water-table pond," aided Cambridge in proving that its supply was sufficient.

During the last year, as a result of the very material increase in funds, a reconnaissance survey of the entire state was made and for the larger communities, well inventories and other data pertaining to the water resources were collected. In addition, for the Metropolitan area of Boston, an intensive well inventory was started, the observation-well program enlarged, and water samples collected chiefly for analysis by the State Board of Health to determine chloride and iron content. For a few samples, complete analyses were made by the Quality of Water Division.

The Massachusetts investigations were under the supervision of R. M. Leggette until he joined the military forces July 20, 1942, and was succeeded by M. L. Brashears, Jr., who had been in immediate charge of the Massachusetts investigations until July 29, 1944, when H. N. Halberg, having an office in Boston, was given immediate charge under Mr. Brashears' supervision.

Other Civil Service technical personnel were:

216/ p. 196.

Name	Period	Military Furlough
H. L. Pree, Jr.	Dec. 29, 1942 to June 30, 1947	Mar. 31, 1943 to Feb. 4, 1946
H. S. Taylor	Mar. 6, 1944 to Jan. 10, 1945	
W. E. Strong	Dec. 2, 1946 to June 30, 1947	
R. F. Johnson	Apr. 10, 1947 to May 2, 1947	

N. E. Lathrop was the clerk in charge.

Connecticut. - The investigation in the New Haven area was in progress at the beginning of the period. Although a state-wide WPA project started in 1934 had maintained records of water levels and analyses of water samples in the New Haven area until 1938, the real start of the intensive well-inventory investigation was started at the end of the previous period. A complete inventory of all wells and ground-water pumping plants was made, together with periodic measurements in a number of observation wells which was increased to 24 in 1942. Beginning in July 1941, samples from 24 wells were collected monthly for analysis for chloride content by the State Agricultural Experiment Station to study the salt-water encroachment. That investigation was completed in 1943, except for the continuation of the observation well readings and water analyses. The results of the New Haven study showed the value of the ground-water investigations, and to speed up the work in other areas, the cooperative State funds were increased. Another factor tending to increase the funds was the special investigations for the State agency for what Mr. Brashears termed "little jobs."

To obtain the greatest benefit, the subsequent investigations were made in the heavily pumped areas in order that information on critical ground-water conditions could be made available at an early date. Accordingly, the next investigation was in the Waterbury-Naugatuck area where heavy draft was made on the alluvial deposits in the narrow Naugatuck Valley, with danger of draining those deposits. It was started in 1943. As several vital war industries in that area were using the valley ground water, the War Production Board about the same time requested the Survey to make an investigation. In addition to the well inventory and pumpage records, 25 observation wells were established and samples from heavily pumped wells close to the Naugatuck River were analyzed for sulfates as the ground water was badly contaminated by the industrial wastes in the river water. That investigation continued during the remainder of the period. A report entitled "Ground-water conditions in the Waterbury area" was prepared by Lowry and Miles in May 1947. In addition to the two intensive investigations, reconnaissance surveys of other heavily pumped areas were made, and resulted in timely information regarding potentially critical situations in several of the larger communities.

The state-wide observation-well program was increased to 45 wells, none equipped with recorders, at the end of the period.

The Connecticut investigations were under the supervision of R. M. Leggette until July 20, 1942, when he joined the military forces and was succeeded by M. L. Brashears, Jr. who had been in the district since the previous period. The field work was performed from headquarters at Jamaica, N. Y. until December 31, 1946, when an office was established at Middletown in charge of J. J. Miles, Jr. Jean Lowry was detailed to Connecticut August 27, 1943.

Rhode Island. - When cooperation was started in September 1944, the city of Providence presented the most serious problem. Many industrial water users needed either larger supplies or supplies of better quality, and some plants using river water required ground water to supplement the river supply during periods of low flow. Consequently, the Rhode Island investigations were started in the Providence area by C. M. Roberts and H. N. Halberg. The well inventory included data on 300 wells, logs of 700 test holes bored for various special purposes, and pumpage records; five observation wells were established. In August 1945, seismic studies were made for the Rhode Island Industrial Commission under the direction of L. W. Currier of the Geologic Branch. As there was a possibility of some salt-water encroachment from Providence River, a few water samples were analyzed, chiefly by the State Department of Health. A progress report was issued in 1945 by the State agency. 217/

Owing to the small size of the state, the Survey's topographic maps were selected as the basis for the state-wide investigations. Following the Providence inventory, the Pawtucket and Georgiaville quadrangles were selected for the next investigation because of concentration of population and industry. The investigation in the Pawtucket area was finished during the period, but the report which is broadly similar to that for Providence had not yet been published. In addition to the state-wide investigation, a few special reports were made for State agencies.

An observation-well program was started in 1945, and by the end of the period, records were being obtained from about 25 wells, one being equipped with a recorder.

An office was established in Providence November 9, 1945, in charge of W. B. Allen under the immediate supervision of H. N. Halberg. The Rhode Island investigations were under the general supervision of M. L. Brashears, Jr.

New York. - During the period, the ground-water investigations were broadened from the very intensive Long Island studies, to include a state-wide investigation which was started in April 1945. At first, the state-wide program was administered from the Jamaica Office, but in July 1945, a separate office was established in Albany. R. M. Leggette was in charge of the New York State investigations, which were chiefly in Long

217/ Progress report on the ground-water resources of Providence, R. I., Geol. Bull. 1; and Well and test hole records for Providence, R. I., Geol. Bull. 2.

Island, until his military furlough July 20, 1942, when he was succeeded by M. L. Brashears, Jr. In addition, supervision was exercised over the investigations in Massachusetts, Connecticut, and Rhode Island.

Long Island investigations: The investigations made during the previous period had been largely concerned with areas in which the ground-water supplies were either actually or potentially critical. During the present period, however, the investigations became practically island-wide. The general program was one of expanding personnel for the purpose of increasing the number of observation wells and recorders; also for increasing the rate of geologic study of well cuttings and other records, to correlate more completely the various geologic beds which are practically island-wide. That study in turn resulted in additional studies correlating water levels with precipitation and pumpage, and with changes in the chloride content. The friendly attitude of the New York City Department of Water Supply, Gas, and Electricity made it possible to have analyzed for chloride content, about 1,500 samples annually in the Department's Mt. Prospect laboratory. In addition, assistance was given in installing an average of some 10 observation wells annually and in giving access to all records, as the City was vitally interested in the ground-water supplies.

In Nassau County, more than half the County cooperation was devoted to drilling about 20 test wells. The wells were about 70 feet deep, 17 being of small diameter, and 3 6-inch wells equipped with recorders. In Suffolk County during 1942, the Survey added to its well program about 40 observation wells drilled by the City of New York during the Survey's cooperative investigation in the early years of the century.218/ By so doing, the observation well area was extended about 25 miles eastward and considerable money was saved in drilling. The 40 wells were on the south side of the county and to round out the pattern and fill in blank areas on the north side, the County funds were increased, with the result that about 20 shallow 4-inch wells were drilled during the remainder of the period.

A new use of the ground water on Long Island was made during the period. Suffolk County is one of the three leading potato growing areas in the United States, and the growers discovered that supplemental irrigation was profitable. That resulted in a very large increase in summer-time pumpage, much of it concentrated in a relatively small area near the town of Riverhead, and nearby lowlying areas on the eastern end of Long Island. Being so close to the coastline, it was necessary to install observation wells in that area, and make a large number of chloride determinations for possible salt-water encroachment. By the end of the period, the installed pump capacity for irrigation was 35,000 gallons per minute. The problems presented by the rapid increase in irrigation pumpage were an important factor, causing the increased County cooperation during 1946 and 1947.

218/ Follansbee, Robert; History of the Water Resources Branch to June 30, 1919, p. 172.

Long Island has 5 well-recognized water-bearing zones, and it was not until the present period that the problems connected with the deep beds became apparent. The Lloyd sand has a southeast dip across Long Island, and at the western end, is tapped at a depth of 300 feet, while at the opposite end, it is 1,500 feet deep. In Nassau and Suffolk Counties, it is so deep that it is not used except along the north and south coasts where the water table, being near salt water, cannot be used for large supplies, and in Nassau County, the large communities are forced to the Lloyd sand. About 1944, the pumpage along the north shore became so heavy that salt water appeared, and the State agency requested the Survey to investigate the relationship between artesian head, spacing of wells, and the geologic horizon. The resulting information was used to regulate pumpage and locate sites for new community wells.

Long Island is a complete hydrologic province; the precipitation, except during storms, seeps into the ground and as stream flow represents overflow from ground water, the stream flow records are used in the computation of safe yield, which is considered to be precipitation minus evaporation and transpiration. For that study, the 6 gaging stations maintained by the Surface Water Division[219] were increased by two each year in Suffolk County, beginning in 1942. A study of the correlation of ground-water levels and precipitation on Long Island was published by C. E. Jacob in the Transactions of the American Geophysical Union in 1943 and 1944, and reprinted by the Water Power and Control Commission as Bulletin GW-14.

Recharge of water pumped for cooling purposes, was required by State regulation and as the effect on the ground-water temperature was affected by the warmer water returned, the Survey in 1936 began the practice of taking annually the temperatures in about 270 wells, and monthly in some 30 wells in the western part of Long Island.

The shortage of personnel during the years 1942-1945 prevented pumping tests being made, except one at the Grumman Aircraft plant, but during the last 2 years, 5 tests were made.

The observation-well program was increased to 300 wells, 25 equipped with recorders, on June 30, 1947. Most of the wells were shallow and the records representing water table fluctuations. In 1945, C. E. Jacob prepared a report[220] in which contour maps of the water table in the western and central parts of Long Island were presented.

In 1946, the State agency published as Bulletin GW-13, "The configuration of the rock floor in western Long Island," by Wallace de Laguna and M. L. Brashears, Jr., showing its depth below the surface at various points. The map was compiled during 1943 and brought up to date in 1946. Well log records for each of the four counties comprising Long Island were published in bulletins GW-8 to GW-11 inclusive.

219/ p. 185 (1928-1939).

220/ State Water Power and Control Comm.; Bull. GW-12.

During the war years, many services and short investigations were performed for military establishments and defense plants. The investigation in connection with the water supply for the Grumman Aircraft Engineering Corporation at Bethpage, Long Island, making planes for the Navy, had such unusual features that a detailed account is warranted. In the fall of 1943, the Survey, in cooperation with Nassau County and the Grumman Corporation, began an investigation of ground-water conditions at Bethpage where the water supply was obtained from 10 large-capacity wells. It was to determine chiefly the continuity and inter-connection of the various water-bearing deposits underlying the area to show whether ground water returned to the water table by means of the shallow recharge basins, could move down to the deep formations from which it is pumped, a requirement of the State Commission.

To obtain basic data concerning the effect of pumping at one well, on the water levels in the water-bearing beds overlying its screen and the effect of the ground-water recharge, 7 test wells were drilled by the Nassau County Department of Public Works near the recharge basins at Plant 2, the well casing being furnished by the Company. Recorders were placed on 2 wells and on the pond in the large recharge basin. The records from the 7 test wells indicated a rise in the water table from the recharge water. The well logs and geologic studies indicated inter-connection, allowing vertical movement downward of recharge water, and a slight rise in temperatures of water pumped from vicinity of warmer recharge water was observed. A pumping test made by C. E. Jacob also indicated an inter-connection of formations. During the early part of February and during May 1944, 3 tests were made to determine the effect of pumping at one well on the water level and in another located 2,000 feet distant. A detailed report by M. L. Brashears, Jr. was furnished to the U. S. Navy Department in order to satisfy State requirements.

In November 1946, a detailed investigation of the geology and water resources in the Camp Upton area in Suffolk County was made for the Atomic Energy Commission to determine if it were possible to obtain a billion gallons of water per day for cooling purposes at a proposed atomic pile. It was a complete inventory of wells and of surface and ground waters, without test well drilling or pumping tests. The investigation was completed in April 1947 and a report made, which indicated only about 200 million gallons a day was available.

State-wide investigation: The program contemplated a systematic areal survey or ground-water inventory on the county basis, followed later by intensive quantitative investigations. The state was divided into 7 investigational areas, and the field work was started in July 1945 in the group of 10 counties centered in Albany. Much of the geologic data was obtained from the State Museum records started many years previously.

As the investigation progressed, the observation-well program was gradually expanded until at the end of the period, readings from 30 observation wells, 6 equipped with recorders, were being obtained regularly, and the water samples collected were analyzed in general by the State Department of Health. By the end of the period, the field work and reports for most of the counties in the first group had been completed, and a start made on counties chiefly in the so-called "southern tier." The results of the reconnaissance investigations were published by the Geological Survey as mimeographed bulletins, the State having obtained funds to publish the County reports. Records for more than 10,000 wells were collected and more than 250 samples of water were analyzed.

In certain buried glacial valleys in upstate New York, very little is known regarding the depth of the fill material which often provides near-ideal facilities for underground storage of water. Electrical resistivity is a convenient tool for locating those valleys and determining their depth, and in 1946, the Albany Office purchased apparatus of the Gish-Rooney type for use in the county surveys. By taking advantage of the fact that well drillers case their wells only down through the unconsolidated or fill material, it was possible to explore old existing drilled wells in the buried valleys with a "magnetic well casing explorer,"221/ and determine the depth at which each well casing was seated on bedrock. Thus, considerable valuable information was obtained to aid in determining the dimensions of some of the underground reservoirs.

While the areal surveys were being made, increasingly heavy pumping in the vicinity of Binghamton, perhaps the largest concentration of ground-water pumpage in upstate New York, made it desirable to make an intensive investigation in that area. The first investigation in the area had been made by J. G. Ferris during November 1942, as the result of a request from the War Production Board. That agency desired information regarding water resources of all areas in which satisfactory municipal or industrial water supplies had been developed for new war plants and the expansion of existing plants. The present investigation was carried on in July 1945 by E. S. Simpson and by R. H. Brown in December 1945. In addition to the usual well inventory, one pumping test was made to estimate permeability, and the drawdown in a number of wells being pumped, measured to determine their specific capacities and the relative abilities of the various aquifers to deliver water. Because of the need for the data, a preliminary mimeographed report was issued as Bulletin GW-15.222/ Subsequently, 21 test wells were drilled by contract under Survey supervision from August to October 1946, and were later used as observation wells. By the use of electrical resistivity, 24 lines were run in the broad valley of the Susquehanna, both north and south of the river.

221/ p. 224.

222/ Progress Report on ground-water resources of Southwestern part of Broome County, N. Y., 1946.

Among the brief investigations made for special purposes were three involving pumping tests. The Veterans Administration requested an investigation of the ground-water supply for the Castle Point Veterans Hospital. A part of the investigation was a pumping test, April 22-23, 1946, on one well using two others of the 7 wells as observation wells. During an investigation at the Scotia Naval Depot, pumping test was made June 23-24, 1946, on the two supply wells, using a third well for observations. Two pumping tests were made at the Schenectady Municipal wells, one October 4-7, 1946 and the other January 9-12, 1947. It was impossible to interrupt the pumping for the water system, but the officials cooperated by alternately pumping and shutting down individual wells, as requested.

A brief "upstate" job, done several years before the state-wide investigation started, was that in cooperation with the city of Rochester during the 1942 fiscal year. The Geologic Branch had made a seismic survey to determine the shape of the buried valley of the old Genessee River, and the city was to drill several test wells about 500 feet deep. Cooperation was effected with the Ground Water Division to supervise the drilling of the wells. When 2 wells had been drilled, the city decided to seek a surface water source for an additional supply, and the job came to an end.

M. L. Brashears, Jr. was in charge of the New York and New England investigations during the remainder of the period. C. M. Roberts was in immediate charge of the Jamaica Office beginning October 14, 1943, and E. S. Asselstine, of the Albany Office beginning October 25, 1945. J. G. Ferris was assigned to the New York and New England investigations from July 1, 1939 to Sept. 10, 1943, and E. F. Schaefer from July 1, 1939 to Sept. 29, 1939. M. H. Wendels was the district clerk.

Other Civil Service technical personnel in New York State were:

Name	Period	Military Furlough
Long Island:		
J. G. Ferris	July 1, 1939 to Sept. 10, 1943	
E. E. Schaefer	July 1, 1939 to Sept. 29, 1939	
C. E. Jacob	July 1, 1939 to Sept. 27, 1944	
Wallace de Laguna	July 1943 to June 30, 1947	
D. W. Hickey	Jan. 10, 1944 to Aug. 21, 1946	
L. R. Wistoft	May 1, 1944 to June 30, 1947	
M. C. Jaster	June 9, 1945 to June 30, 1947	
G. W. Nelson	Sept. 27, 1945 to June 30, 1946	
N. M. Perlmutter	July 25, 1946 to June 30, 1947	
N. J. Luscsynzki	Aug. 14, 1946 to June 30, 1947	

Name	Period	Military Furlough
Upstate:		
E. S. Simpson	June 12, 1945 to June 30, 1947	
F. J. Engel	Sept. 11, 1945 to June 30, 1947	
E. J. Podorsky	Nov. 7, 1945 to Dec. 4, 1946	
R. H. Brown	Nov. 30, 1945 to June 30, 1947	June 29, 1945 to Nov. 30, 1945
C. R. Warren	Feb. 10, 1946 to June 30, 1947	
H. V. Rockefeller	Feb. 25, 1946 to June 30, 1947	
R. V. Cushman	July 1, 1946 to June 30, 1947	
Theodore Arnow	July 23, 1946 to June 30, 1947	
R. M. Jeffords	Aug. 7, 1946 to June 30, 1947	
H. A. Miller	Aug. 11, 1946 to June 30, 1947	
C. W. Carlston	Sept. 19, 1946 (W.A.E.)	
J. M. Berden	Oct. 15, 1946 (W.A.E.)	

Miss M. A. Mulhern was the clerk in charge.

New Jersey. - The investigation of a county area in New Jersey is a continuing process, so far as the collection of the basic facts of water levels and records of pumpage are concerned, and whenever sufficient information is obtained to be of general value, a report is issued.

During the present period, the investigations were extended to four additional counties, Salem, Mercer, Ocean, and Gloucester Counties, and the Newark area; and an additional study was made in Middlesex County, which had been originally investigated early in the cooperative program.

In 1939, an investigation was made in Salem County where heavy industrial draft from wells near the Delaware River threatened the permanency of the supply. It was begun primarily with the assistance of the Penns Grove Water Company and the E. I. duPont de Nemours Company. War demand was increasing very rapidly and war industries went inland and developed the shallow gravels by means of Ranney water collectors. As a result, heavy pumpage lowered the water table over a considerable area. About 40 observation wells were established and one pumping test was made. The investigation was continuing at the end of the period.

During 1941 and 1942, a detailed field study was made in the Coastal Plain area of Middlesex County, chiefly between Jamesburg and Perth Amboy, where most of the ground-water development in Middlesex County occurs. The study was concerned primarily with the factors affecting the safe yield of the more important aquifers. Records from the previously-established observation wells gave the water level fluctuations, and pumpage records maintained by the water users were compiled. Although the Survey did no test drilling itself, municipalities and industries drilled more than 20 test wells under Survey supervision; some were for observation purposes and others to trace the movement of salt water. To determine the permeability of the various aquifers, 6 pumping tests were made, and samples of unconsolidated materials were analyzed mechanically in the Washington laboratory. Sixteen water samples were analyzed by the Quality of Water Division. Artificial recharge of the ground-water supply by water spreading had been practiced for many years by the Perth Amboy Water Works, and as such recharge is necessary to maintain or increase the ground-water supply, further possibilities of that phase constituted a large part of the investigation. A progress report of the investigation was published by the State agency in 1943.[223] It may be added that the water supply for the Duhernal development, operated jointly by the duPont Company, the Hercules Powder Company, and the National Lead Company, was developed after the Survey made its investigation and furnished information, including that on recharge.

In 1942, the construction of additional industrial plants in the vicinity of Princeton, Mercer County, resulted in such an increase in pumpage that the water supply situation became critical. One of the additional plants was making penicillin as a war emergency operation, the site for which had apparently been selected without a study of a possible source of water, as test wells were not drilled until construction was well advanced. As the Princeton Water Company was unable to furnish the desired supply, the Chemical Company applied to the War Production Board for a permit to divert water from the Delaware and Raritan Canal. In support of its application, the Company requested the Survey to make an investigation, in August 1944, and that was made by H. C. Barksdale. As the process being employed was new and the amount of water required uncertain, the Company was unable, or at least reluctant to furnish a statement regarding the actual water supply needed. Consequently, the results of the investigation were inconclusive.

An investigation in both Middlesex and Mercer Counties was made in 1942, as a result of the revival of the New Jersey Ship Canal project which would cross both counties from Raritan Bay to the Delaware River. The Army Engineers were ordered to restudy the project, upon which they had last reported unfavorably in 1932. To determine the effect of the canal on the ground water, the Army Engineers requested the Survey, at the former's expense, to make a detailed hydrologic and geologic study of condition along the proposed route. That investigation indicated that the canal would lower materially the head of water in the Mogothy-Raritan formation throughout the state, and probably cause salt-water encroachment for a distance of perhaps 10 miles inland in a band about 100 miles long across the state. On the other side of the ledger, it would probably provide substantial recharge for some of these same aquifers, particularly in Middlesex County. This recharge would be beneficial if adequate fresh water were available to keep the water in the canal fresh.

223/ Special Report 8, The Ground-water Supplies of Middlesex County, New Jersey.

To assist the district personnel in that investigation, C. E. Jacob and E. G. Otton were detailed to the Trenton Office for several months.

Resort areas along the shore in Ocean County had been growing so rapidly in recent years and the draft on the ground water had increased to such an extent that in 1945, it was decided to study the factors relating to the safe yield of the aquifers there, particularly with respect to the possibility of salt water encroachment. This was chiefly a study of water levels and variations in salt content. A network of about 40 observation wells was established along the coastal part of the county, and water samples from those wells were taken twice a year for analysis by the Quality of Water Division. Twelve additional observation wells were established in the inland part of the county and water levels in those were measured at least monthly.

In 1946, an investigation was started in Gloucester County. It was the standard combination of observation wells for the study of water-level fluctuations, and sampling points in strategically local areas, combined with an effort to obtain an accurate record of the amount and distribution of the pumpage. One of the major problems was the threat of salt-water encroachment from the lower reaches of the Delaware River, if pumpage should become too heavy, or should be concentrated too close to the river.

The last investigation started during the period was in the Newark area. Although there were no public ground-water supplies in that area, private interests had made intensive use of the water supply. The Survey and the State Geologist had made a brief study in 1940, but had to discontinue it for other work. Early in 1947, that official having obtained an assistant whom he could assign to that area, desired to resume the study in cooperation with the Survey. Actual work was begun in January 1947, although formal cooperation did not begin until after the end of the period.

During the period, the number of observation wells was increased from 148 to 216, of which 51 were equipped with recorders. These wells did not cover the entire state but were confined to the areas in which investigations had been made.

H. C. Barksdale continued in charge of the New Jersey investigation and had the following Civil Service technical assistants:

Name	Period	Military Furlough
R. W. Sundstrom	July 1, 1931 to July 22, 1939	
R. C. Baker	July 1, 1939 to Mar. 2, 1946	Oct. 1942 to
E. J. Schaefer	Oct. 16, 1939 to Oct. 23, 1943	Dec. 3, 1945
G. D. DeBuchananne	Oct. 8, 1942 to June 30, 1947	
J. M. Birdsall	Aug. 22, 1944 to June 30, 1947	

Name	Period	Military Furlough
J. M. Ludlow 1/	Sept. 1, 1942 to June 30, 1947	

Pennsylvania. - During the first four years of the period, the activities had been confined to maintaining the observation-well program of about 30 wells, started in 1931, and in the absence of a ground-water office in Pennsylvania, the Trenton Office supervised that work. With the expansion of activities in the fiscal year 1944, an office was established in Philadelphia, and in April 1944, the Trenton Office relinquished its supervision of observation wells in Pennsylvania. It may be stated in passing that the Pennsylvania Water and Power Company, operating large hydroelectric plants on the Susquehanna River at Safe Harbor and Holtwood uses the records of wells in the Susquehanna River Valley in predicting the minimum flow. The weekly records are furnished the company as soon as received.

When the cooperative agreement between the Pennsylvania Topographic and Geologic Survey of the Department of Internal Affairs, and Ground Water, was increased for the purpose of making a state-wide inventory of ground-water resources, J. B. Graham was placed in charge of the Pennsylvania investigations in October 1943, with headquarters in Harrisburg. Philadelphia was the first area to be selected for study due to the war-time importance of industries and establishments in South Philadelphia. South Philadelphia is the most important area in Philadelphia with respect to ground water, as the occurrence of unconsolidated Coastal Plain formations is restricted to that area. The Navy Yard is the chief user of ground water and that is its principal supply, and as large industrial plants were also using ground water, water levels were declining, and the Navy became apprehensive of its future supply. As a result, that agency was greatly interested in the investigation. The Public Works Officer in charge of water supply at the Yard was from Texas where extensive ground-water investigations were being carried on, and not only knew their value but what cooperative services would be required. Preparatory to starting the South Philadelphia study, Mr. Graham went to Philadelphia to obtain all available data. His search led to the excellent scientific library of the Academy of Natural Sciences, supported chiefly by private subscription. As the study of ground water is within the field of the Academy, that agency was so much interested that office space was offered in its Department of Geology and the headquarters were moved to Philadelphia January 15, 1944.

Most of the water supply for the Navy Yard was furnished by 6 wells, and arrangements were made to have an employee take daily readings on them; also, accurate pumpage records were started. The quality of the water was an important factor as the ground-water supply had a fairly high iron content, and analyses of the water were made at 2-week

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1/ Part of the time employed in Surface Water Division in Trenton.

intervals by the Naval laboratory. To obtain a better quality of water, the Survey assisted the Navy Yard in selecting new sites, at two of which wells were drilled the first year. Within a few months, 8 interference pumping tests were made. During the remainder of the period, the work in the Navy Yard was increased; 3 additional deep observation wells and 6 shallow observation wells were drilled. Based on information suppplied by the Survey, pumps in some of the supply wells were lowered, and operating schedules were altered to utilize to better advantage the ground-water supply.

The quality of the ground water was becoming a big problem, as the recharge to the principal aquifer is supplied largely from the highly polluted Delaware and Schuylkill Rivers. The Navy laboratory's method of analysis was somewhat different from the Survey's, and to compare the two, the Quality of Water Division made a year's intensive study of samples collected by the Ground Water Division from all wells, and sent to the Washington laboratory. The observation-well program, by the end of the period, was increased to 15 wells in the Navy Yard, all equipped with recorders, those in static wells were float type, and those on pumping wells a bubbler type of pressure gage, a stock model designed for other uses but adapted to pumping wells by Graham and Huber. A report on the Navy Yard investigations to January 1945 was made a part of the general report of a private firm of engineers engaged to make a report on the water supply system. The investigation continued beyond the end of the period.

Although at first the South Philadelphia investigation was confined to the Navy Yard, it was gradually extended to nearby areas in which were large industrial users, with similar problems of supply. A measure of the need for the widened investigation is shown by the fact that almost as soon as the Navy Yard investigation was started, requests from the War Production Board, industrial users, and the Washington Office, were received for ground-water information.

While making the original study, the Navy Yard, during its drilling operations, put down one observation well outside the Yard, which with 7 selected existing wells, made a total of 8 observation wells outside the Navy Yard. Also, a well inventory in the South Philadelphia area and preliminary geologic studies were started. In April 1946, the geologic and hydrologic studies had reached a point where it was possible to make a preliminary report on "South Philadelphia Well Supply," which was presented as Appendix "B" of the report to the City by the Board of Consulting Engineers.

In January 1947, the Philadelphia Planning Commission entered into a cooperative agreement with the Survey for the period January-June, 1947. The City-Federal agreement supplemented the State-Federal program already in effect, making it possible to accelerate the inventory work in Philadelphia. The State fiscal biennum, beginning in June 1947, provided sufficient increase in ground water funds to permit the continuation of the Philadelphia work after termination of the City-Federal program in June of that year.

While the Philadelphia study was being made, numerous requests for ground-water data were being received, many from the Pittsburgh area where extensive use of ground water is being made. Consequently, when State cooperative funds were increased, beginning in June 1945, a ground-water investigation was started in Pittsburgh and the industrial area adjacent, the State Geologist believing that the available funds should be concentrated in areas of large industrial and municipal use. In the Pittsburgh area, the ground water used comes almost entirely from river valley gravels which to a large extent localized the problem. A sub-office was established in Pittsburgh in February 1946 in charge of J. H. Adamson, Jr. with one assistant.

The setting up of the observation-well program, one of the first steps, was aided very materially by previous work in that area. Following the disastrous flood of March 1936, which included the Pittsburgh area, a flood-study program was begun by the Pittsburgh City Engineer's Office, and as a part of that study, 18 shallow observation wells were established in downtown Pittsburgh. Thereafter, during each high-water period, those wells were measured. Of the 18 wells, 8 were found in good condition and with 5 additional wells selected, the systematic observation of water-level fluctuation in the area was begun. The well inventory, and pumpage records for Pittsburgh itself, together with chemical analyses of both surface and ground water were practically completed by the end of the period, and a start made on the adjacent area. The results will be published as the Allegheny County report, the first in the contemplated series of county reports.

The investigation in the Philadelphia area was extended to the adjacent counties of Bucks and Montgomery, both thickly populated and highly industrialized areas and formed the basis for county inventories which were in progress at the end of the period. In Bucks County, an electrical resistivity survey was run in the wide Delaware River Valley between Philadelphia and Trenton, the only promising area for extended expansion in that section of Pennsylvania.

The state-wide observation-well program was gradually increased to 66, including those in the Philadelphia and Pittsburgh areas, 17 being equipped with recorders.

The well inventories, which were the basis of the county investigations, were augmented by data on public water supplies from ground water, furnished by the State Department of Health.

By the end of the period, Mr. Graham's association with the Department of Geology, of the Academy of Natural Sciences, was so close that his services as a geologist were frequently called upon in the absence of its own geologist, and he was made a member of the Geology Staff.

Other Civil Service technical personnel were:

Name	Period
N. H. Klein	June 15, 1945 to June 30, 1947
R. R. Huber	July 30, 1945 to June 30, 1947
J. H. Adamson, Jr.	Feb. 2, 1946 to June 30, 1947
J. C. Kammerer	Jan. 25, 1947 to June 30, 1947

The district clerk was Miss Antoinette Turzanski.

Maryland. - Until December 1942, the only ground-water work in Maryland was the maintenance of 3 observation wells in the vicinity of Washington. With the beginning of State cooperation in December 1942, an office was established in Baltimore in charge of R. R. Bennett. The investigation was centered in the Baltimore industrial area where a detailed study of the long decline in artesian head and the contamination of wells and aquifers by salt water was made.

It was started in January 1943 with a well inventory and record of pumpage and drillers' logs. Surface geology was studied in detail by examining outcrops and measuring geologic sections. A detailed peg model was constructed consisting of 1/4-inch wood dowels inserted in a base map; the various lithologic units were represented in the wood dowels by means of different colored paint, giving a 3-dimensional picture of the sub-surface geology of the area. The correlation of the water-bearing formations was one of the most difficult parts of the investigation and it was not until the latter part of the field studies that those formations had been properly classified. Two test wells were drilled by the Bethlehem Steel Company and cuttings were collected at 5-foot depths, supplementing the drillers' logs of various wells; electrical logs were obtained by equipment devised by Mr. Bennett.[224]

An important feature of the investigation was the study of leaking wells by means of well-exploration equipment. Salt-water conductivity tests showed that salt water from the shallow aquifers was contaminating the deep aquifer, not only through wells with defective casing but also some salt water apparently leaked down the sides of some of the wells between the casing, as the latter did not always fit the rotary-drilled holes snugly. To determine the actual hole diameters, caliper logs were made, the special caliper used being devised by Mr. Bennett. About 10 pumping tests were made and some 150 water samples were analyzed in the Washington laboratory. The investigation was in progress at the end of the period.

In January 1944, at the request of the Navy, an investigation of the water supplies from wells of 3 Naval establishments in the Solomons area and the Naval Powder Factory at Indianhead was made. That was the chief war activity, but other general ground-water problems were investigated for the Navy, Army, and War Production Board.

224/ p. 224.

The larger cooperative funds available beginning with the fiscal year 1946, made it possible in July 1945 to expand the program and undertake several new projects. One was an inventory of all newly-drilled wells in the state, based on the well-drillers' completion forms submitted to the cooperating agency, in accordance with the State law, or by personal visits to the wells; detailed records of several hundred such wells were received from the drillers between July 1945 and June 30, 1947.

Another project was the systematic ground-water studies on a state-wide scale which started first in the 5 counties in the southern Maryland area. That area was selected because most of the water-bearing formations, generally at great depths in the eastern shore area, outcrop in those 5 counties, and are more easily examined. The investigation was in progress at the end of the period.

In connection with the other investigations being carried on, a study of the public water supplies obtained from ground water was started in July 1945 for the purpose of showing the sources of existing supplies and possible additional supplies from other formations. The observation-well program was expanded to cover the entire state, 120 wells with 11 recorders being in operation June 30, 1947.

Mr. Bennett continued in charge of the Maryland investigations and had the following Civil Service technical assistants:

Name	Period
R. R. Meyer	Feb. 8, 1943 to June 30, 1947
H. F. Johnston	Aug. 1, 1945 to Sept. 30, 1945
Charles Merrels	Nov. 14, 1945 to Aug. 2, 1946
C. A. Richardson	Feb. 8, 1946 to June 30, 1947
A. C. Pierce	Apr. 8, 1946 to June 30, 1947

The district clerk was June B. Specht to September 1946, when she was succeeded by Frances M. Bennett on January 2, 1947.

Virginia. - The investigation, comprising parts or all of 10 counties in the Coastal Plain of southeastern Virginia south of the James River, started in 1937, was the principal study by D. J. Cederstrom during the first two years of the period. By that time, most of the systematic field work which included the establishment of an observation-well program expanded from 5 to 15 wells, and the compilation of well inventories, well logs, and mechanical analyses of the water-bearing sands for permeability, had been completed in the fall of 1942. A preliminary report was published by the Virginia Geological Survey in 1941.[225]

225/ Ground-Water Resources of the Southeastern Virginia Coastal Plain; Cir. 1.

A special investigation for the City of Newport News in the winter of 1942 fitted into the general investigations and furnished some needed test drilling and pumping data. The city was in need of an additional water supply and wished to explore both surface- and ground-water possibilities, the latter being at Bacon's Castle, the long-ago headquarters for Bacon's rebellion against a Royal Governor. The City intended to drill 3 test holes 1,000 feet deep if necessary, and make a pumping test under Survey supervision. By the time 2 holes had been drilled and one converted into a producing well, the City had decided upon a surface-water supply, and the cooperative investigation was terminated. However, to obtain data from a pumping test, the drilling contractor drilled an observation well near the producing well, installed a pump on the latter and made a 3-day pumping test.

Another special investigation furnishing test drilling information was made at the request of the Navy Department in the summer of 1942. It was a hurry-up job to relieve a critical shortage in the city of Norfolk's surface-water supply, due to prolonged dry weather. The object was to drill a test well near Lake Prince, the City's reservoir, and from previous investigations, Mr. Cederstrom knew the general ground-water conditions and supervised the drilling. The test well was 970 feet deep and penetrated more than 300 feet of water-bearing sand. Soon after the test hole was completed, indicating an available flow of about 3,000,000 gallons per day, one of the heaviest storms known in that area, amounting to nearly 10 inches in 52 hours, occurred. The reservoir level rose 2 feet and as that relieved the critical shortage, the ground-water project was abandoned.

The special investigations described were only two of a very considerable number during the war years, as southeastern Virginia was an area of intensive Naval activity, and many calls were made on the Survey for reports on ground-water possibilities for the various establishments. Many of the reports required little or no field work beyond supervising considerable test drilling, but one request required a detailed investigation and report on the geology and ground-water conditions at Camp Peary, a training camp for SeaBees, near Williamsburg. It was made in 1942 and 1943, and as the ground-water was shown to have a rather high chloride content, plans were made for a permanent surface-water supply; in the meantime, a temporary ground-water supply of about 4,000,000 gallons per day was developed. These activities occupied so much of Mr. Cederstrom's time that the completion of the general investigation of southeastern Virginia was delayed. However, that delay had its compensation as much additional detailed and accurate geological information became available. During the special investigations, it was found that the mud samples from the test drilling did not give sufficient information regarding the formations, and Mr. Cederstrom began to study the microscopic fossils of sea shells. That study confirmed by eminent authorities, identified a formation of the upper Eocene Age, not previously known in Virginia and adjacent states.

With the end of the special investigations, it was possible to complete the general investigations in southeastern Virginia. The data used as a basis for the discussion of the ground-water possibilities were largely records of about 1,050 wells, many well logs, mechanical analyses of water-bearing sands, and chemical analyses of 137 water samples, both made by the Survey. The results were published in 1945 by the Virginia Geological Survey as Bulletin 63, "Geology and ground-water resources of the Coastal Plain of Southeastern Virginia."

Following the completion of the investigation south of the James River, that of the York-James Peninsula, extending as far inland as Richmond, was started. So many special war-time investigations had been made in that area that systematic field work was required only to fill in the gaps. The pattern was the same as that of the previous investigation and the field work was completed by the end of the period. The results are to be published in a State report.

An investigation of the public and industrial ground-water supplies of the Roanoke area in southwestern Virginia was started in the spring of 1945 by B. F. Latta, who was detailed to Virginia during Mr. Cederstrom's assignment for the Navy on Okinawa. The geologic studies were based chiefly on work done previously in that area. Through personal contacts with owners, an inventory of 70 wells and springs was made, and samples of water from 12 wells and 3 springs were collected for analysis by the Quality of Water's Raleigh laboratory. The results were released as a circular by the Virginia Geological Survey.

To make available at an early date the findings in the Coastal Plain investigation regarding chloride, the Virginia Geological Survey published Bulletin 58,[226/] in 1943. Started in 1943 was a report on the chemical character of Virginia Coastal Plain ground water, dealing with different aquifers of artesian water, with regard to hardness, fluoride content, chloride content, and the operation of softening by base exchange. It was completed by the end of the period, and published by the Virginia Geological Survey as Bulletin 68, "Chemical character of ground water in the Coastal Plain of Virginia."

The observation-well program was increased from 10 in 1939, about equally divided between the northern and southeastern parts of the state, to 14 in 1947, 5 being equipped with recorders.

In April 1946, an experiment in recharging a well under unusual conditions is worth recording. Artificial recharge with cold winter water for use in the following hot summer months is a proven economical practice in industry, as the cold water becomes only moderately warmer while in ground storage. In considering the desirability of encouraging that practice in the industrial Hampton Roads area, it was realized that those areas to be benefited by recharging were underlain

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226/ Chloride in Ground Water in the Coastal Plain of Virginia.

by strata saturated with brackish water, an undesirable feature even when diluted by fresh recharge water. Mr. Cederstrom believed that it might be possible to recharge a well without having the first water mix with the brackish water as the former is lighter and might float on top, and also that the weight of the column of fresh water in the well might push back the ground water. An opportunity to experiment was afforded by the wells which had been drilled at Camp Peary and later abandoned. In April 1946, one of the wells was recharged from the city water main, and later the water pumped from the well analyzed. The one test run indicated that about half the amount of water recharged was uncontaminated when pumped out, and that if a portion of the first run were kept in the ground, almost all the recharge water in later runs could be pumped back.227/

Mr. Cederstrom was in charge of the Virginia investigations during the period except from April 4 to August 15, 1945, when he was assigned to ground-water investigations for the Navy on Okinawa. B. F. Latta was detailed to Virginia during Mr. Cederstrom's absence. L. W. Youngquist, Jr. was in the district from August 5 to October 15, 1943.

North Carolina. - Before the beginning of cooperation for the state-wide investigation, D. G. Thompson in 1941 made a brief investigation of the ground-water resources of the Wilmington area in cooperation with that city. Cooperation with the State Geologist, whose office was in the State Department of Conservation and Development, became effective in July 1941, and M. J. Mundorff was assigned to the North Carolina investigations. The scope of the state-wide investigation was to determine the quantity of water available from ground water; to develop criteria for choosing favorable well-site locations; to determine the opportunities for increasing yield by deepening wells; to locate the areas capable of supplying large quantities for industrial development; and determine the quantity and quality of water available in each aquifer.228/ The usual well-inventory surveys were made on the county basis, several counties being covered in a single report. Due to the limited funds available, no test drilling was done nor pumping tests made during the State-cooperative investigations.

The Halifax area, comprising Northhampton, Halifax, Nash, Edgecombe, and Wilson Counties was the first one selected. It was a typical area along the "fall zone" where ground-water supplies were needed, but difficult to obtain because the Coastal Plain sediments are too thin to supply much water and the thin blanket of these materials makes it impossible to study the geology of the bedrock. Field work was performed by Mr. Mundorff chiefly during the winter of 1941-42, during which some 800 wells and municipal supplies were inventoried,

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227/ Artificial recharge of a brackish water well by D. J. Cederstrom (Mimeograph bulletin issued by Survey)

228/ Progress Report on Ground Water in North Carolina; Dept. Cons. & Develop.; Bull. 47, p. 9.

the geology mapped, and 49 water samples analyzed by the Quality of Water Division. Two observation wells were established in the area. The investigation was completed in 1943 and the results published by the State agency as Bulletin 51, "Ground-water in the Halifax area, North Carolina."

The second investigation was started in July 1942. It embraced the Greensboro area covering Alamance, Guilford, Forsyth, Caswell, Rockingham, and Stokes Counties, and was chosen as representative of a large part of the state. During the field work, about 1,300 wells were inventoried and samples from 45 wells and springs collected for analysis. The investigation was completed in 1944 and the report was published, "Geology and ground-water in the Greensboro area," by the State agency.

The third investigation, that of the Charlotte area, comprising Cabarrus, Mecklenburg, Gaston, Lincoln, Cleveland, Rutherford, and Polk Counties, was started in August 1944. It was typical of a third section of the state. The field work was about two-thirds completed by June 30, 1947.

A special non-county investigation for a possible new source of ground-water supply in the Elizabeth City area was made in April 1947. Much of the information available had been obtained during the regular investigation in the Coastal Plain and also during war-time investigations for Naval establishments in that vicinity. Only a limited amount of field work to fill in gaps was needed. The report 229/ giving the results of the investigation contains the inventory of 62 wells and analyses of 8 water samples and suggested possible sources for a new supply.

To make available at an early date, the geologic logs collected during the investigations for the various military establishments in the Coastal Plain, those logs were compiled by Mr. Mundorff and published by the State agency in 1944, as Information Circular No. 3, "Selected well logs in the Coastal Plain of North Carolina." A brief description of the various water-bearing formations in the area was also included.

In an endeavor to make more widely available, data on surface and ground waters and their quality, in order that their more complete utilization might be effected, the Department of Conservation and Development assembled all available data from the Surface Water Division, and climatology data from the Weather Bureau, covering the Neuse River and Cape Fear River Basins, and in 1947, published two reports. 230/

Northeastern North Carolina was an area of intense war activity,

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229/ Information Circular No. 6, "A possible new source of ground-water supply in the Elizabeth City area, N. C."
230/ Hydrologic data on the Neuse River Basin 1944-45, Hydrologic data on the Cape Fear River Basin 1820-1945.

with many naval bases and airfields, and during the war years, requests were received for investigation of many of those establishments. The investigations were usually well inventories in small areas, with water analysis, especially in areas threatened by salt-water encroachment. As assistance was rendered by the agency requesting the investigation, it was possible to do test drilling, make pumping tests, and determine permeability by laboratory analysis.

The most intensive investigation was that of the ground-water supply for Camp Mackall near Hoffman, made by Mr. Mundorff in the fall and winter of 1942-43. A large number of test holes were bored and 4 wells were drilled. The permeability of the water-bearing sands was determined both by pumping tests and laboratory analyses. For the 3 pumping tests, 11 observation wells were placed along 4 radial lines from the main well. During one of the tests, 5 wells were pumped together and observation wells were placed between them to determine the drawdown. It was decided that to obtain the required supply, it would be necessary to recharge the ground-water reservoir from the nearby Drowning Creek, and a canal was dug to the well field for that purpose. The investigation was finished in 1943 and a report furnished to the Army Engineers in May 1943.

The observation-well program was expanded from 9 wells in 1939 to 50 wells, 8 equipped with recorders, in 1947.

Mr. Mundorff continued in charge of the North Carolina investigations during the period, and had E. G. Otton as an assistant from September 1, 1943, to January 1, 1944. Mrs. A. P. Lynch was district clerk beginning January 11, 1943.

South Carolina. - When cooperation with the State Research, Planning and Development Board was arranged in October 1945, G. E. Siple was assigned to the South Carolina investigations under M. J. Mundorff's supervision.

Of the 166 cities and towns having public water supplies nearby, nearly three-quarters were supplied by ground water, and 98 percent of the rural population and a large part of industrial plants used the same source. As no previous systematic ground-water investigation in the State had been made, the purpose of the state-wide investigation was to obtain all possible information regarding the occurrence, quantity, and quality of water in the geologic formations, both for municipal and industrial supplies; determine methods of choosing favorable well sites and determine areas where supplies sufficient for industrial use existed. Finally, the general ground-water conditions, and related problems throughout the state, were to be studied.

The first and logical step in the investigation was a preliminary survey of the entire state. During that survey, all public ground-water wells and a large number of industrial wells, 720 in number, and 7 springs were inventoried, and samples from 65 wells collected for analysis. That preliminary investigation was completed in December 1946 and the results published by the State agency as "Progress report on ground-water investigations in South Carolina, by G. E. Siple; Bulletin 15."

Like that in North Carolina, the systematic investigation was on the county basis. The first group of counties selected comprised Harry, Dillon, Marion, Florence, Marlboro, Chesterfield, and Darlington Counties in the Coastal Plain, and the study was started in April 1947.

Georgia. - At the beginning of the period, the investigation of the Coastal Plain, started in 1938, was being continued by M. A. Warren. It was an intensive one, centered chiefly in the Savannah area where the drop in the artesian water levels due to the great increase in industrial pumpage from a remarkable limestone aquifer (Ocala) was causing concern; also, as the water levels were then below sea level, there was possibility of salt-water encroachment. To a lesser degree, the ground-water situation in the Brunswick area was studied. The investigation was continued until 1943. It included records from 1,536 wells in 12 counties, of which 1,380 were in the 6 counties in the Savannah-Brunswick area, and pumpage records. An elaborate pumping test on an industrial well in the Savannah area lasted from October 2 to 12, 1939, during which time the heavy pumping was reduced. Also, in connection with a war-time investigation of Camp Stewart in Liberty County, which was also a part of the general Coastal Plain investigation, a pumping test was made from November 26 to 28, 1940. Hydrographs from 73 observation wells were prepared and these showed the marked influence of the tides on the water level near the coast. Water samples from 37 wells in the 20 counties of the limestone aquifer area were analyzed by the Survey. The results of the investigation were published by the Geological Survey of Georgia in the State Department of Mines, Minerals, and Geology, as Bulletin 49 and 49-A,231/ the latter containing the records of 1,536 wells.

To meet the State's wishes for an investigation in North Georgia, S. M. Herrick was assigned to Georgia in December 1942 for work in that area under M. A. Warren's supervision. Two projects were started, one the geology and ground-water resources of the Atlanta area in the Piedmont area of Georgia, and the other a similar investigation in the Paleozoic area in the northwestern part of the state. Those investigations continued until March 23, 1944, when Mr. Warren entered the Navy. At that time, it was necessary to curtail the North Georgia projects, in order that the extensive observation-well program might be continued, and the many brief war-time investigations might be made.

C. W. Carlston, who was in charge of the Alabama investigations,

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231/ Artesian Water in Southeastern Georgia with Special Reference to the Coastal Area.

recorders to 118 wells with 6 recorders.

Mr. Herrick was given charge of the Georgia investigations January 1, 1946, H. E. LeGrand was his technical assistant from April 15, 1946 to June 30, 1947.

Florida. - The wide variation in field conditions, and the great distance between the principal centers of activities made it necessary to have two separate headquarters in Florida. The Tallahassee headquarters, in charge of H. H. Cooper, Jr., conducted the investigations in northern Florida. The investigations in southeastern Florida, gradually extending through the southern half of the state, had its headquarters in Miami.

Northern Florida: The intensive investigation of the Coastal Plain area of southeastern Georgia, which had been started during the previous period, made it desirable to extend the investigation into the northeastern corner of Florida where the ground-water conditions were similar. Mr. Cooper, in the fall of 1938, was devoting half his time to the work of the Ocala surface water office, and half to the ground-water work. For the latter, he started the investigation of Nassau and Duval Counties in the northeastern corner of Florida, under T. V. Stringfield's supervision.

That investigation, which continued intermittently during the period, was speeded up after a large pulp mill at Fernandina began pumping 26 million gallons per day in December 1939, thus causing a large cone of depression around Fernandina. Nine pumping tests were made, of which 2 were in Fernandina, 5 at Jacksonville, and 2 south of Jacksonville. During the investigation, 347 wells were inventoried, and altitudes determined on 219 used as observation wells. The Quality of Water Division analyzed 114 water samples.

In the Pensacola area, all municipal, industrial, and rural water supply comes from ground water. In December 1939, a new industry proposed to develop 8 million gallons per day, 14 miles north of Pensacola, and the City felt concerned that the new development might have an adverse effect on the available water supply. The City put up funds which were matched by the Federal and State Geological Survey, and an investigation was started in December 1939 by C. E. Jacob and H. H. Cooper, Jr. It was under the direct supervision of D. G. Thompson. In addition to the inventory of 48 wells, 8 of which were equipped with recorders, 2 test wells were put down by contract and 13 pumping tests made possible by the City authorities, the Naval Air Station, and two large industries. The pumping tests were made by C. E. Jacob. The chloride content of the water was an important factor and many samples were tested both in Washington and in the field. S. K. Love spent several days in the field, studying the relation between the fresh water in the Escambia River and other streams, and the salt water in Pensacola Bay. In April 1940, a progress report was prepared for the city, in which it was concluded that the proposed new development would have no appreciable effect in the vicinity of Pensacola. Later, four additional wells were drilled primarily as observation wells. The routine observations were maintained during the period.

One of the oddest war-time requests received by the entire Ground Water Division was that from the U. S. Maritime Commission early in 1942. The Commission, in connection with its construction of concrete vessels below sea level on Hookers Point, a peninsula on Tampa Bay, proposed to excavate three basins 100 feet apart, 75 feet wide, 1,200 feet long, and 17 feet below mean low water in Tampa Bay and cut the dikes when the ships were completed. To make the plan successful, it was necessary to keep the ground water pumped out of the basins and the Survey was requested to estimate the water required to be pumped from the formation under the basins. The investigation was made during the latter part of April and early part of May 1942 by Mr. Cooper. Twenty-seven test wells were drilled, primarily for the pumping tests which were made at 5 separate locations. It was estimated that a maximum of 3,000 gallons might be required. Some months later, after the basins were excavated, it was estimated that the pumpage was slightly less than 1,000 gallons per minute. A number of concrete vessels were constructed subsequently.

At the request of the Army Engineers in 1943, a special investigation was made by A. G. Unkelsbay of the effect of the drainage and sewage disposal wells in the vicinity of Orlando on the ground-water supply, including that of the Orlando Air Base. The principal aquifer consists of about 900 feet of permeable limestones which is overlain by relatively impervious formations which retard natural recharge to the limestones. Owing to the lack of adequate surface drainage, about 200 wells were drilled into the limestone in the Orlando area to drain the streets and dispose of sewage and other liquid wastes. As a rule, the piezometric surfaces are far enough below the land surface to allow gravity drainage. In order to obtain information regarding the depths at which water enters the limestone formations, eight of the drainage wells were explored by means of the deep-well current meter. A constant quantity of water was allowed to drain into each well, and the velocities measured at various depths. As a result of the investigation, it was concluded that although the aquifer receives large quantities of water through wells, it is so permeable that the effect on the piezometric surface is very small. 234/

The city of St. Augustine obtains its water supply from a field of 12 wells and the non-carbonate hardness of the water was increasing to such an extent that in the latter part of 1943, it was excessively high. At that time, the City made plans for a cooperative investigation with the Survey, which was made by H. H. Cooper, Jr. and A. G. Unkelsbay

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234/ Artificial recharge of artesian limestone at Orlando, Fla., by A. G. Unkelsbay and H. H. Cooper, Jr.; Econ. Geol. Vol. XLI, Number 4, pt. 1; June-July 1946.

from August to October 1944. Its object was to obtain the geologic and hydrologic information to determine the non-carbonate hardness in the chief aquifers, which are in the Plicene and Pleistocene formations. In addition to placing a recorder on one of the City wells, an inventory of 50 wells in the area was made. A typewritten report was made to the City in 1945.

In 1944, Pinellas County was much concerned over the salt-water encroachment in the artesian limestone aquifer due to the heavy pumping from wells supplying the citrus growers and public supplies. Accordingly, it began cooperation with the Survey to determine the rate of encroachment and the factors controlling it. The investigation continued beyond the period. Six hundred sixty-one wells were inventoried and 44 were selected as observation wells by having the altitudes of the measuring points established. Field determination of chloride content were made. A. G. Unkelsbay, F. C. Wiggins, and P. C. Smith were engaged in that investigation.

In September 1946, Brevard County began cooperation to determine the areas where the artesian water was too salty for general use. The investigation included an inventory of 796 wells; the elevations of the measuring points on 216 was established. Field determination of the chloride content of 385 water samples were made. The investigation was completed after the end of the period, and the results were to be published by the Florida Geological Survey.

During the period, the Tallahassee office drilled 7 test wells. At the end of the period, there were 108 regular observation wells, 26 equipped with recorders.

H. H. Cooper, Jr. continued in charge of the investigation and had the following Civil Service technical assistants:

C. C. Reker	July 25, 1942 to Oct. 6, 1942 1/
A. G. Unkelsbay	Feb. 1, 1943 to Nov. 7, 1945
T. C. Wiggins	July 25, 1946 to Sept. 4, 1946
C. F. Essig	Apr. 22, 1946 to June 30, 1947
R. M. Neill	July 8, 1946 to June 30, 1947
P. C. Smith	Jan. 15, 1947 to June 30, 1947

1/ Military furlough; did not return to district.

Southeastern Florida: The investigation of the water resources of southeastern Florida, 235/ especially in the Miami area of Dade County, was started in the fall of 1939 under the general supervision of V. T. Stringfield, whose principal assistant, W. P. Cross, established headquarters in Miami. In this comprehensive investigation, the activities of the Ground Water Division were concerned chiefly with the occurrence

235/ p. 19.

of water-bearing formations, their ability to transmit and yield water, the areas of recharge and discharge, and the direction of ground-water flow at different seasons of the year; also, the source and approximate rate of movement of salt water at different depths in the water-bearing rocks, and factors controlling salt-water encroachment.

In addition to the well inventory and pumpage data, the early work consisted in test drilling in order to obtain additional geologic data. That work was started early in 1940 and continued until more than 150 exploratory wells were drilled under Survey supervision, one being 812 feet deep, another 604 feet deep, and the remainder ranging from 20 to 350 feet deep, as it was found geologic samples from greater depths were not needed. The Soil Conservation Service was determining the capabilities of the land, and was designing and locating structures for the control of the water table, muck fires, and soil subsidence in the Everglades, and the Survey needed information in that area in connection with the study in the Miami area, but had been unable to reach that inaccessible area with the transportation at its disposal. In 1942, the former agency furnished transportation, hauling in the equipment, including a light portable drilling rig, by means of an air boat, which was flat-bottomed, drawing very little water and powered by a motor with a pusher-type airplane propellor.[236] It was guided by a rudder working in the propellor blast. Fifteen tests wells were drilled.

The establishment of a network of observation wells was simplified by the existence of about 10,000 wells, as ground water was the source of practically all water supplies and it was only necessary to install observation wells in the more remote regions. The total number of observation wells in the program was increased to a maximum of 259 in 1941, the number equipped with recorders varying from 37 to 21. The wells were connected with sea level datum by several hundred miles of level lines. In addition, about 200 shallow observation wells were installed.

Wherever possible, pumping tests were made, not only to determine the yield of the formations, but also to note any change in the quality of the water that might be caused by pumping, due to salt water encroachment. In conducting the tests, a Jaeger pump of 500 gallons per minute capacity was used wherever possible; it was set to pump the maximum that well would yield; and when equilibrium between drawdown and yield was reached, the test was ended. Six large supplementary pumping tests were made.

In studying salt water encroachment in the limestone, the area at Silver Bluff Miami was selected as that area had the largest number of wells ranging in depth from 45 to 100 feet, ready for use. All drainage and fire wells were inventoried to determine the areal and critical distribution points of access to the ground water, and to determine the altitude of the water table 14 2-inch observation wells were driven.

236/ Soil Science Soc. of Fla., Proc. Vol. V-A 1943, p. 47.

Four intensive studies were made between July 1941 and February 1942, each lasting 13 hours. During the tests, the fire wells were read hourly, and for these periods, the stage of Biscayne Bay, taken from the recorder station, was studied and water samples from the Bay collected for analysis. 237/

Geologic reconnaissance studies over most of southern Florida were made, for a better understanding of the underlying formations. For transportation, use was made of a "glades buggy" one type of which is a truck body supported by two sets of high wheels, each set having 3 wheels on each side, equipped with large tires to distribute the load; supporting the motor and steering gear with seat for the driver was a set of similar wheels with two wheels on each side. In a reconnaissance study of the outcrop areas in the Ten Thousand Island area off the west coast, the cabin cruiser, "Spoonbill," was made available by the National Audubon Society, which was interested in the water conditions in several rookeries, as the water level determines largely the type and abundance of food available to wild life. Thousands of samples of water from representative wells were collected for analysis by the Quality of Water Division. Many area studies of the altitude and movement of Biscayne Bay were made in various sections of Dade County.

The intensive stage of the investigation was completed by the fiscal year 1943, and subsequently the activities in the Dade County area were confined chiefly to continuing the various observations started earlier. Salt-water encroachment becoming a factor in the southern part of Dade County, in the 1946 fiscal year the County began direct cooperation with the Survey for the purpose of determining its extent. In that connection, a program of observation wells to note the salt-water movement not only in the aquifer itself, but also in the tidal canals was started, and a program of test well drilling to obtain the data necessary for an effective water-control program.

During the latter years of the period, several fast-growing cities in southern Florida cooperated for special investigations in their immediate areas, for the purpose of determining the quantity and quality, with reference to possible salt-water encroachment, of their existing supplies, and location of areas of additional supplies. The general pattern of each intensive investigation was the same; inventory of existing wells, establishment of program of observation wells and connecting them to sea level datum, collecting and analyzing water samples, drilling test holes for geologic data, and in some instances, making one or more pumping tests.

The first investigation was for Fort Myers and western Lee County in the southwestern part of Florida, beyond the range of the general investigation. It was started in November 1943, and was discontinued in June 1946. As a result, Fort Myers developed a new well field. A

237/ Econ. Geol., Vol. 40, No. 4, 1945.

report on Lee County will be published by the Florida Geological Survey. During 1944, an investigation was made for Fort Pierce and continued until June 30, 1946. It showed that, owing to the danger of salt-water encroachment, it was not advisable to drill additional wells in the existing field. While the Fort Pierce project was in progress, an investigation for Lake Worth was also started and completed early in 1945. As a result, the City drilled 5 additional supply wells. An investigation for Delray Beach was made in 1946 and as a result, the City installed 3 large-diameter wells.

In November 1946, an investigation was started at Fort Lauderdale, where previously some studies had been made as a part of the general investigation of southeastern Florida. This was a more intensive study of that area, during which 90 private wells were inventoried, 5 test wells about 200 feet deep were drilled, 52 shallow observation wells, and water samples from 15 existing observation wells, and water samples from 116 wells analyzed for chloride content. Later, samples from 36 wells were analyzed monthly. The first phase of the investigation was completed soon after the close of the period, and the results published by the Florida Geological Survey as "Report of Investigations No. 6, by R. C. Vorhis."

During the period, electrical-resistivity methods were used at several locations to determine whether they could trace the encroachment of salt water along the coast. One within the city of Miami was unsuccessful, due to influence from pipe lines, but another farther away from Miami, and a third near Cocoa indicated that the areas containing salt water could be easily traced.

What may be classed as a war-time activity was a brief investigation of ground-water conditions at Key West and nearby Big Pine Key in May 1941. The ground water is so limited and danger of salt-water encroachment so imminent, that the supply could not be increased appreciably. Key West was an important and fast-growing naval base and as additional water could not be obtained, the Navy requested the Survey, as a part of its operations in southeastern Florida, to determine the availability of ground-water supplies that could be developed and transported to Key West by pipe line. An investigation was made and a report made in August 1941. Subsequently, a well field was installed and the pipeline constructed.

W. P. Cross remained in charge of the work until May 27, 1942 when he entered the army, and was succeeded by Russell Brown who entered the army June 30, 1943, and was succeeded by G. G. Parker who came to the district February 16, 1940. Other Civil Service technical assistants were:

N. D. Hoy	Nov. 6, 1939 to June 30, 1947
E. W. Reed	Nov. 16, 1939 to Jan. 14, 1942
K. L. Jackson	Dec. 27, 1939 to July 31, 1941
	Nov. 16, 1943 to June 30, 1947
W. J. Drescher	May 12, 1941 to May 27, 1942

S. B. Radack	Nov. 26, 1943 to Nov. 27, 1944
J. W. Stewart	Nov. 22, 1946 to June 30, 1947
R. C. Vorhis	Nov. 25, 1946 to June 30, 1947
M. A. Warren	June 27, 1947 to June 30, 1947

Alabama. - When cooperation with the State Geological Survey was started late in the 1940 fiscal year, it was for the purpose of studying the ground-water resources of the outcrop area of the Cretaceous formations of Alabama, which includes the northern half of the Coastal Plain of the state, an area of abundant ground water. The investigation which was started in June 1940 by C. W. Carlston had for its purpose, the determination of the occurrence, quality, and availability of the ground water of 20 counties in a section some 50 miles wide, extending in a northwest-southeast direction across the central part of the state. Nearly every city and town in the area was visited and information obtained for every public ground-water supply, including records of 796 wells and springs. The Quality of Water Division in Washington made 162 preliminary and 19 complete analyses. The investigation was completed in 1942. A preliminary report, "Fluoride in the ground water of the Cretaceous area of Alabama," containing the chemical analyses and a description of the geology, based largely on published reports, was published by the Alabama Geological Survey in September 1943 as Bulletin 52. That report stated that most of the water containing harmful amounts of fluoride was from the Eutaw and Ripley formations, but that in areas of high fluoride, it was possible to obtain water of low fluoride content from other formations. A final and more comprehensive report on the Cretaceous area was published by the Alabama Geological Survey in September 1944 as Special Report 18, "Ground-water resources of the Cretaceous area of Alabama."

In 1942, an investigation of Mobile and Baldwin Counties was begun by Mr. Carlston but was interrupted by a special ground-water investigation for the Camp Rucker area in the southeast corner of Alabama, and by an investigation in the northern half of Choctaw County.

The Army Engineers requested the Survey to make pumping tests on the 5 wells supplying Camp Rucker, to determine the capacity of the water-bearing strata. Two pumping tests under the supervision of H. H. Cooper, Jr. were made on February 18 to 20, and March 8 to 10, 1943. Herman Gunter, Director of the Florida Geological Survey, participated in the second pumping test. For 24 hours prior to the first test, all pumping from wells 2, 3, and 4 was suspended and the pumping rates from wells 1 and 5 so adjusted so that they could remain constant during the test. At the end of the 24-hour period, when the water levels in the vicinity were in equilibrium, pumpage from well 2 was continued for 4 hours and the decline in wells 3 and 4, measured, periodically. At the end of that period, the recoveries in wells 2, 3, and 4 were measured for $1\frac{1}{2}$ hours. The second test was substantially the same, except that well 4 was pumped in place of well 2. The results were computed by the Thiem, Theis,[238/] and recovery methods. Samples from the 5 wells were analyzed by the Quality of Water Division. C. W. Carlston made the geologic study with assistance of members of the Alabama Geological Survey. A report was made to the Army Engineers August 1943.

At the present time, Choctaw County is Alabama's only oil-producing area, and it is regarded as a possible area of future industrial development, thus accounting for the high priority of the investigation of the northern half of Choctaw County. The field work was performed during February and March 1944, by P. E. LaMoreaux, and a report by Messrs. Carlston and LaMoreaux was prepared in April 1944 for the use of a proposed industry, and others interested.

In September 1944, the city of Mobile needed to supplement its water supply. An investigation was made by Mr. Carlston on the availability of ground water at the Mobile Water Works and Bienville Pumping Station at Mobile, Alabama. The study was undertaken to determine how much additional water could be obtained for the city of Mobile by the use of wells.

In March 1944, M. A. Warren, engineer in charge of ground-water investigations in Georgia, entered the Navy and Mr. LaMoreaux was assigned to temporary duty in Georgia, for the purpose of making an investigation of the geology and ground-water resources of six counties in east-central Georgia, and on completion of the Georgia investigation in March 1946, he returned to the Alabama investigations.

In May 1945, G. B. Peterson resumed the investigations in Mobile and Baldwin Counties, concentrating the work in the Mobile area, where salt-water encroachment was appearing in the wells used for air-conditioning equipment in the business district of the city. Measurements and chemical analyses of six observation wells near Mobile were made to determine the salt-water encroachment. A preliminary report, "Ground-water investigations in the Mobile area," was published as Alabama Geological Survey Bulletin 58, in 1947. Although field work was completed on the geology of the two counties to serve as a basis for the ground-water report on the area, the investigation continued beyond the period.

As a result of the cooperation with the State Health Department for a two-year period beginning July 1, 1945, an investigation of public supplies of the Tertiary area was undertaken for the determination of the fluoride content in ground water with reference to tooth decay and mottled enamel. The results of that investigation will be published by the Alabama Geological Survey as "Fluoride in the ground water of the Tertiary area of Alabama," by P. E. LaMoreaux.

238/ p. 222.

During the remainder of the period, investigations were continued in the Tertiary area and included detailed studies of the geology and ground-water resources in Choctaw, Mobile, and Baldwin Counties. The Mobile and Baldwin County investigation was pertinent because of the growing need for additional water supplies for municipal, industrial and private use in the Gulf Coast area of the state.

During this period, aid was given in reports or field consultations to many Federal, State, municipal, industrial and private parties. During the year 1947 alone, reports of this type were supplied to 4 Federal, 3 State, 43 municipal, 27 industrial, and 55 private parties, including information concerning the supplemental development of present supplies or in some instances, the development of new ground-water supplies.

The state-wide observation program started in 1940 with the selection of four wells was expanded to include 11 wells at the end of the 1947 fiscal year. Beginning in 1946, closer cooperation with the well drillers in the state was begun, which resulted in the state-wide collection of well logs, well samples, and current ground-water data.

C. W. Carlston was appointed June 6, 1940 in charge of the Alabama investigations until September 1945, when he was succeeded by P. E. LaMoreaux, who was appointed August 13, 1943. Other Civil Service technical assistants were:

Name	Period
W. M. Murphy, Jr.	Dec. 28, 1942 to Dec. 31, 1943 [1]
E. W. Jones	Nov. 18, 1944 to June 30, 1947
G. B. Peterson	May 15, 1945 to June 30, 1947

[1] Military furlough; did not return to district.

Mississippi. - The two chief investigations, both under the general supervision of V. T. Stringfield, had been started near the close of the previous period. The study of the Mississippi alluvial plain in the northwestern part of the state, known as the delta, was started by G. F. Brown, assisted by E. W. Reed, in the latter part of 1938. At that time, the artesian pressure had declined to the point where it was not sufficient to force the water satisfactorily through the homes of the residents of that region, as it had formerly done. Records from nearly 1,300 wells were obtained, water-well drillers furnished logs and samples of cuttings from 230 wells, and oil exploration companies gave electric logs and samples of additional borings. By means of the mechanical analysis of the water-bearing material in the laboratory in Oxford and permeameter tests, the permeability and size distribution of the material was estimated. Chemical analyses were made by the Survey and by the State Chemist. The field work was completed in 1946 and the results published by the State Geological Survey as Bulletin No. 65, "Geology and artesian water of the alluvial plain in northwestern

Mississippi."

The investigation of the Coastal area was started in March 1939 by G. F. Brown and E. W. Reed. At first, it was carried on by the same personnel who were making the delta investigation, and the time was divided between the two. Later, it was continued by V. M. Foster, and still later by R. W. Adams. Local interest had become aroused by the decline in the artesian pressure due to the great increase in draft caused by the rapidly expanding population. In the collection of records, very considerable assistance was rendered by the Army Engineers, who were supervising 4 military establishments and a shipbuilding industry in the area. Geologic studies were made; records from about 600 wells and 131 well drillers' logs were obtained and pumpage records compiled. By means of the mechanical and variable head permeameter, analysis of the water-bearing material, the coefficient of permeability was estimated. Chemical analyses were made chiefly by the Survey. The possibilities of salt water encroachment were estimated from repeated determinations of the chloride content in the several wells. Field work was completed in 1944 and the results published by the State Geological Survey as Bulletin No. 60, "Geology and ground-water resources of the coastal area in Mississippi."

Investigations for ground-water supplies at three army camps, made at the request of the Army Engineers, resulted in information of so much general value that the results were later published by the Mississippi Geological Survey. The first was that at Camp McCain, located in the delta region, made in 1943 by Messrs. Brown and Adams. Test holes at 38 locations were drilled by contract, and the cuttings from the logs were analyzed mechanically. In addition, the contractor made electric log tests in 10 of the 38 holes. Pumping tests followed well construction and consisted of measuring by steel tape the well water surface before, during and after pumping the well at a constant known rate, which was measured at the outlet. The water surfaces in adjacent wells were measured. The results were published in Bulletin 55, "Geology and ground-water supply at Camp McCain."

In 1943, a similar investigation was made at Camp Van Dorn in the southwest corner of the state by G. F. Brown and W. F. Guyton. A test well 1,699 feet deep was drilled by contract and an electric log surveyed by a commercial firm and the cost was borne by the Mississippi Geological Survey. Between January 26 and February 10, a series of 5 pumping tests were made by the Army Engineer personnel under Survey direction. The results were published as Bulletin 56, "Geology and ground-water supply at Camp Van Dorn."

A similar study was made at Camp Shelby by Mr. Brown during which the Army Engineers drilled an observation well and a test well in the center of Camp Shelby. The results were published as Bulletin 58, "Geology and ground-water resources of the Camp Shelby area."

The state-wide observation-well program was expanded during the period to 48 wells, of which 15 were equipped with recorders.

Mr. Brown was in charge of the Mississippi investigations during the greater part of the period; from February to October 1941, he was on detail to California, and from January 1945 to July 1946, he was detailed to the Foreign Economic Administration and State Department for work in Saudi Arabia. During most of the latter period, J. C. Kammerer was in charge of Mississippi work, including a well inventory, a few pumping tests, and the preparation of an open-file report on the Jackson area, in which Mr. Kammerer was assisted by P. L. Carroll.

Civil Service technical personnel, in addition to Mr. Brown, were:

Name	Period
E. W. Reed	July 1, 1939 to July 24, 1939
V. M. Foster	Jan. 2, 1940 to Sept. 2, 1941
R. W. Adams	Sept. 13, 1941 to May 31, 1945
J. C. Kammerer	July 9, 1945 to Oct. 30, 1946
W. F. Guyton	Mar. 6, 1946 to Mar. 9, 1947
P. L. Carroll	Aug. 28, 1945 to Sept. 19, 1946
T. J. Henderson	Dec. 26, 1945 to Sept. 19, 1946

Louisiana. - The first investigation during the present period in the state-wide study of ground-water, which was started near the end of the previous period, was that in the rice region Parishes of Jefferson Davis and Acadia. A preliminary study had been started in June 1938 by J. C. Maher, and in 1939, T. B. Stanley, Jr. was assigned to the investigation under Mr. Maher's direction. The information collected included logs of 20 wells; data on 441 wells, 128 being selected as observation wells for the purpose of determining the piezometric surface at varying seasons of the year; mechanical analysis of the material from 1 well; and 40 water samples which were analyzed in Washington. The field work was completed in August 1940 and the results published by the State Department of Public Works as "Ground-Water Resources of Jefferson Davis and Acadia Parishes, 1944."

The next investigation was that in Grant and LaSalle Parishes in the central part of the state which had been started in November 1938 by J. C. Maher, but discontinued during the winter, and resumed in the summer of 1939. The well inventory included data on 155 wells, periodic readings of 10 observation wells, a geologic study based largely on published reports, and analyses of water from 56 wells and three springs. The results were published by the Louisiana Geological Survey in 1941 as Bulletin 20, "Ground-Water Resources of Grant and LaSalle Parishes."

Investigations in Caddo and Bossier Parishes were made from January to June 1941 to determine whether a ground-water supply of 10 million gallons per day was available for industrial use, as an industry requiring that amount was considering a location near Shreveport. The investigation, made by L. O. Wiringa under the direction of Mr. Maher, indicated that amount was not available.

During the next 3 years, much of the time was devoted to investigations of water supplies for army camps. The establishment of army camps and airfields in the vicinity of Alexandria in Rapides Parish had shown the need for further investigation in that area since that made in 1938 and 1939, and the Federal Works Agency sponsored an explanatory program to develop a new well field as far from the existing wells as practicable. The investigation was made by Mr. Maher and P. H. Jones in the summer of 1942. Six test holes ranging in depth from 448 to 998 feet were drilled by contract, cutting samples were collected, and electric logs of the wells made. From the logs and formation sample analyses, the most promising water-bearing sands in each well were "drill-stem tested", formation water obtained, and the water level, temperature, and yield determined. As the results were satisfactory, the 6 test holes were reamed out to a diameter of 18 inches and supply wells developed.239/

An investigation was started in Natchitoches in March 1941 by T. B. Stanley and a typewritten report on the conditions was prepared. No additional ground-water supplies of good quality were found available within the city or its immediate envirous. By the late summer of 1943, the city was experiencing such a water shortage that the water was being turned off from 6 p.m. to 6 a.m. daily; the supply was obtained from shallow wells and the water level was being pumped to the bottom of the aquifer. The city had voted funds to drill a test-well 3,500 feet deep and the well drillers being familiar with the work being done in Alexandria, recommended that the Survey be requested to make an investigation. The investigation made in 1941 indicated the areas favorable to development, and from it, the areas where test drilling should be located were outlined. Then, under Survey supervision, the city drilled, electric logged, and "drill-stem" tested 9 test holes. The hydrologic conditions were outlined and supply wells were installed at favorable sites. An adequate water supply was obtained.240/

Early in 1944, the water supply of the Baton Rouge industrial district became critical, as static levels were down 220 feet in wells which originally had been artesian flow. The Chamber of Commerce and local industries urged the State to make an investigation under the cooperative program, and that was started in April by E. M. Cushing and P. H. Jones. The geology of the aquifers tapped was outlined and the hydraulic characteristics of the "cooling water" sands determined. Information from 200 outlying wells gave the record of decline of water level from pumping. About 400 wells were inventoried, and 53 of these, together with readings of additional wells in key locations, were used as observation wells. Pumpage records had been kept since 1940, but had not been computed or corrected, and these computations were made, water samples from 100 wells were chemically analyzed by the Survey, both in Washington and Austin. Electric logs of several oil wells in the field were obtained. The investigation was finished in April 1945, and the

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239/ Ground-Water Exploration at Alexandria, La., J. C. Maher and P. H. Jones; Econ. Geol. Vol. XL No. 3, May 1945.

240/ Ground-Water Geology at Natchitoches, La., by J. C. Maher and P. H. Jones, May 1, 1944 (mimeographed).

results published by the Louisiana Department of Public Works as "Progress Report on Ground-Water Resources in the vicinity of Baton Rouge, 1945."

In the late fall of 1945, the city officials of Monroe requested the Survey to make an investigation for an additional supply. To obtain an additional surface water supply would be expensive, and as West Monroe was using ground water, the possibility of a similar supply to augment the surface supply was considered. The investigation by P. H. Jones and C. N. Holmes was started in January 1946 and continued through the year. This was an intensive study during which 154 wells in the general area were inventoried, logs of 60 wells collected, the piezometric surface determined, and the geology studied. As a result, the City drilled 4 test wells, which were electrically logged to check the driller's logs. The samples were mechanically analyzed, and water samples analyzed chiefly by the Survey. A supplemental water supply for the city was proved to be available from wells. The results were published by the Louisiana Geological Survey as Bulletin 24, "Ground-Water Conditions in the Monroe Area, Louisiana."

During the entire period July 1939 to June 1947, a program of general state-wide investigations of ground-water conditions was in progress. Well inventories were made in several parishes, several thousand logs of water wells were collected, about 1,500 samples of water from wells were collected and analyzed, and information on ground-water conditions in many scattered localities was provided to industries, municipalities and individuals upon request.

Civil Service technical personnel were:

Name	Period
J. C. Maher	July 1, 1939 to Apr. 1944
T. B. Stanley	July 1, 1939 to Apr. 1942 1/
L. O. Wiringa	Jan. 1941 to June 1941
P. H. Jones	Jan. 10, 1942 to June 30, 1947
W. J. Drescher	June 1942 to May 1944 1/
W. L. Youngquist	Nov. 1943 to June 1944 1/
G. C. Taylor	Mar. 1944 to Feb. 8, 1945 1/
E. M. Cushing	Apr. 1944 to Jan. 11, 1947
A. B. Jones	Oct. 1, 1945 to June 30, 1947
C. N. Holmes	Nov. 27, 1945 to Sept. 6, 1946
H. B. Shepherd	Jan. 7, 1946 to Dec. 4, 1948
E. E. Richardson	Feb. 1, 1946 to Nov. 21, 1946
I. W. Thrasher	June 17, 1946 to June 30, 1947
A. N. Turcan, Jr.	July 1, 1946 to June 30, 1947

1/ Military furlough; did not return to district.

West Virginia. - Cooperation with the State Geologist started July 1, 1941, and R. L. Nace was placed in charge of the investigations, with headquarters at the State Geologist's Office at Morgantown. The cooperative program called for an investigation and detailed report of the ground-water resources in each county.

The first investigation was that of Harrison County, of which Clarksburg is the County seat. Shifts in population, caused by expanding industrial development due to the war preparedness activity in full swing, resulted in critical water-supply problems in some parts of the county. In addition, drainage water from coal mines was a possible source of ground-water contamination. An inventory of the public ground-water supplies for each city and town was compiled, and data on well logs obtained either from the State agency which had been compiling such data, or from industries and individuals. From those logs, a typical log for each water-bearing formation was constructed. Eight water samples were analyzed by the Quality of Water Division and 2 analyses of mine drains were obtained. A typewritten progress report "Ground-Water Resources of Harrison County, W. Va., Jan. 22, 1942" was released to the public.

The Harrison County investigation was the only county study completed during the period, as during the war years, the activities were devoted chiefly to investigations in various areas containing war industries. The most intensive investigation during those years was that of the West Virginia Ordnance Works at Point Pleasant, made between November 1942 and August 1943, at the request of the Chief of Army Engineers.

The water supply was obtained from 2 well fields by means of 6 Ranney water collectors, and the investigation was to determine the sources of the ground water supplying the collectors. R. G. Kazmann, assisted by R. M. Jeffords and E. J. Schaefer, made the investigation between November 1942 and April 1943. To obtain the necessary geological and water-well data, 86 wells were drilled or driven by the Army Engineers under Survey supervision. Those, with existing wells, gave about 100 observation wells which were read at least once during each working day, and 3 times daily during pumping tests. All wells were connected by instrumental leveling in order that piezometric surfaces might be prepared. Such maps were prepared for the different dates during pumping tests, and indicated the volume of material unwatered between those dates, and also how the water pumped was replaced by river water. The water pumped was from Ranney collectors, and was measured by Simplex venturi-tube meters equipped with continuous recording mechanism. Daily chemical analyses showing hardness and alkalinity were made of the water pumped in each collector, and daily water temperature was also obtained. Daily records of quality and temperature of Ohio River water were obtained. The stage of the river was determined hourly from a staff gage located 2,000 feet upstream from one of the collectors. Pumping tests in the south field were made between April 17 and June 10, and in the north field between May 17 and August 11. The investigation disclosed that the alkalinity of the water pumped decreased as a result of the pumping, indicating a mixture of river water with that in storage. A report was prepared for the Army Engineers.

Much of the information obtained at Point Pleasant was of value in the investigation along the Ohio River at Parkersburg about 75 miles upstream, made as a State-cooperative program in 1943 by R. M. Jeffords. The Parkersburg officials had since 1929 kept unusually good records of operations of the City's 18 wells bordering the Ohio River, quantities pumped measured by venturi meter and the quality of untreated water. Recorders were placed on several observation wells. The daily stage of the Ohio River was obtained from the Weather Bureau gage. A few analyses of river water and of a number of wells were made by the Quality of Water Division. The alluvial deposits in the well field were analyzed mechanically for permeability. Comparisons between stage of the Ohio River and the well field showed influence of the river on the ground water. The results were published by the West Virginia Geological Survey in 1945.[241]

While the foregoing investigations were being made, several weeks during 1941, 1942, and 1943 were spent in field reconnaissance in the highly industrialized area in the vicinity of Charleston. Increased pumpage during the last few years had seriously decreased the yield of some older wells. About 40 wells were inventoried for occurrence, quantity, and quality of the ground water; a few well logs were obtained, from which a geologic section was prepared; several water samples were analyzed either by the Federal or State Surveys. A reconnaissance report was published by the State Geological and Economic Survey in 1946.[242]

In addition to these investigations, reconnaissance studies were made during the period, and general ground-water information collected throughout the state. As a result of the general studies, two typewritten reports were prepared, one dealing with ground water supplies for mining communities, and the other with water for secondary recovery of petroleum.

To obtain relatively large amounts of water required, coal mining companies own and operate about 275 public water supply plants, more than half the total number in the state. Ninety percent of such water works obtain their supplies from ground water and much of it is poor in quality, and inadequate in quantity. Most systems must be continued for many years and it is less costly to consider development and maintenance of a satisfactory water supply than to improvise auxilliary sources at frequent intervals. The report summarized the available information on ground-water in the coal-producing section that had been

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241/ Bull. 10, Ground-Water Conditions along the Ohio Valley at Parkersburg, W. Va. by R. M. Jeffords.

242/ Rpt. of Investigation No. 2; Ground-Water Conditions at Charleston, W. Va., by R. M. Jeffords and R. L. Nace.

obtained during the cooperative investigation, showing in a general way where acceptable water supplies could be obtained. It also called attention to the value of the cooperative investigations.243/

As natural production from oil fields in the state declined, increasing attention was being given to the application of secondary recovery, and oil and gas injection had been practiced to some extent. Attention was directed to the method of artificial flooding, requiring ground water, and the report of that investigation contained a summary of information on the availability of such supplies. 244/

R. L. Nace continued in charge of the West Virginia work until September 19, 1942, when he entered the Army. He was succeeded by R. M. Jeffords who remained until September 13, 1945, and was succeeded by H. F. Johnson, who came to the West Virginia investigations August 1, 1945, and continued during the remainder of the period, under the general supervision of R. R. Bennett.

The district clerk was Doris E. Maier, May 1, 1942 to January 30, 1943; Earela L. Ogden, September 3, 1943 to March 31, 1945; Marguerite T. Robinson, January 26, 1947 to April 5, 1947.

Kentucky. - Although the municipal water supply for Louisville is obtained from the Ohio River, large quantities of ground water are pumped from glacial-outwash deposits underlying the river valley, as groundwater is much more satisfactory for many industrial users. The groundwater supply is limited and even before the war years, the increased pumping by air conditioning and other plants was beginning to lower the water levels. Early in the war years, new chemical and rubber plants were constructed, and the huge distilleries instead of operating from 10 to 12 hours, went on a 24-hour basis in the manufacture of industrial alcohol. The combined result was that, by 1943, the draft on the limited ground-water reservoir was so great as to draw it down nearly to bedrock in some areas. With State funds available, 245/ cooperation became effective September 1943.

An office was established in Louisville in charge of W. F. Guyton. The investigations were concerned primarily with the heavily pumped Rubbertown, distillery, and downtown areas. As complete an inventory as possible of 660 wells in Louisville and vicinity was made, and the geology studied and the extent of the water-bearing materials mapped. An observation-well program of 130 wells was started and pumpage records for the past 7 years (1937-44) collected; permeability was determined from mechanical analyses and several pumping tests. Also, as

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243/ Ground Water Supply for Mining Communities in West Virginia, by R. M. Jeffords.

244/ Water for Secondary Recovery of Petroleum in West Virginia, by R. M. Jeffords.

245/ p. 204.

a result of cooperation with the City of Louisville, 12 test wells drilled some years previously, were deepened an average of 45 feet. The results of the investigation during the first seven months were described in "Progress report of the ground-water resources of the Louisville area, March 1944," mimeographed by the Survey. The need for inducing infiltration and also recharging the ground-water reservoir by Ohio River water was stressed, in addition to investigating the possibility of additional ground water from the glacial outwash deposits of the river valley southwest of Louisville. Subsequent to 1944, the investigation in the heavily pumped areas consisted chiefly in maintaining records of water levels, pumpage, quality, and temperature.

The next phase of the investigation included recharging tests and test drilling southwest of the city. For the recharging tests, the distilleries offered to purchase water from the city, if the Survey would supervise the pumping into the wells; the only hitch was that the Survey had no pumping equipment. However, through the War Production Board, which was deeply interested, a city fire engine was borrowed and for nearly three weeks, pumping tests were made. Several lines of observation wells were established to determine the effect on the ground-water level. The tests proved successful and the Survey recommended that artificial recharge be made during the winter months when the river water is cold, and that industry use City water, instead of ground water during that period. That recommendation was followed. It might be added that during the pumping tests, the distillery officials were most cooperative, not to say hospitable.

By means of funds furnished by the Rubber Reserve Company 246/ in the spring of 1944, 45 6-inch test wells, ranging in depth from 60 to 139 feet, were drilled in the area southwest of Louisville. Of these, 17 wells all equipped with recorders, were located at the pumping-test site, three being in the bed of the river. The latter were drilled by means of a standard rig mounted on an Army Engineer dredge-boat, and the length of the casing was increased as the river rose, a well-known habit of the Ohio. A pumping test was made on the bank of the river where an 18-inch well was pumped at a rate of a million gallons per day for 35 days. From mechanical analyses of the geologic samples and the results of the pumping test, the permeability of the area was determined. To supplement the data on bedrock elevations obtained from the test drilling, H. C. Spicer of the Geologic Branch made electrical-resistivity studies, based on 80 depth profiles run on 5 sections across the area. Water samples were obtained on the completion of each observation well, and analyzed by the Quality of Water Division. The results of the investigation were issued by the Survey as "Ground-Water Resources of the Southwestern Part of the Louisville Area, Kentucky, by M. I. Rorabaugh, December 1946."

246/ p. 221.

As the result of cooperation with the Louisville Water Company,[247] an investigation of a strip of land 6 miles long and about half a mile wide, along the Ohio River northeast of Louisville, was made from February 1945 to March 1947. It is an area of glacial-outwash deposit in which the degree of connection between the river and the ground water, an important factor in the proposed use of the ground water, was to be determined. Thirty test wells, so located as to fit into the pattern of existing wells in the area, were drilled to bedrock, an average depth of 100 feet; fifteen of the wells were in the form of a cross, its center being at the location for the pumping test just downstream from the Louisville Water Company pumping station. Of these, 3 wells were in the river channel, being drilled by a standard rig mounted on an Army Engineer dredgeboat, the same one that was used in the earlier investigation. The test wells were used as observation wells, making with the existing wells, a total of 28 observation wells, of which 18 were equipped with recorders. The recorders on the wells were in portable metal shelters, fastened to the tops of the wells. A recorder was also installed to show the river fluctuations. A 12-inch well was pumped continuously for 14 days at a constant setting of the valve on the discharge line. Water samples taken during the pumping tests were made by the Quality of Water Division and by the Louisville Water Company, each analyzing half of the daily samples.

Quantitative studies to evaluate the hydrologic constants of the aquifer were made both by graphical and mathematical methods. To determine the degree of connection with the river, studies were made on the basis of chemical analyses, sections showing temperature distribution in the aquifer during the pumping test, shapes of water-level profiles in the test area, and shapes of time-drawdown curves for a number of observation wells. The results of the investigation, which was completed in July 1948, were published by the Louisville Water Company as "Ground-water resources of the northeastern part of the Louisville area, Kentucky, by M. I. Rorabaugh."

The ground-water investigations outside the Louisville area were started in September 1945 in the Bluegrass region of central Kentucky (Scott, Bourbon, Fayette, and Jessamine Counties). Although the three-year program under the direction of D. K. Hamilton with headquarters in Lexington, ended June 30, 1948, beyond the period of this history, it will be described in full. It consisted of a well inventory and detailed geologic study of ground-water conditions in each county, to show areas for potential ground-water development. Assisted by L. F. Boland and E. M. O'Connell, Mr. Hamilton studied the geology and made the well inventory. County maps based on the geologic work and checked by the well inventory and a structural map of Scott County, were prepared and printed by the State agency.

In January 1947, a beginning of a state-wide reconnaissance survey

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247/ p. 204.

was started. Its purpose was to determine the water-bearing characteristics of the various geologic formations in the state. Work was started by E. G. Otton in the Campbellsville and Elizabethtown areas before the end of the period. The results of those surveys were later published by the Department of Mines and Minerals.

W. F. Guyton continued in charge of the ground-water investigations in Kentucky until April 30, 1945, when he was succeeded by M. I. Rorabaugh. Other technical personnel were:

Name	Period	Military Furlough
W. T. Stuart	Aug. 19, 1943 to July 1, 1944	
Hazel Sublett	Sept. 25, 1943 to May 31, 1945	
G. B. Maxey	Oct. 17, 1943 to June 6, 1944	
E. M. Cushing	Oct. 21, 1943 to Jan. 15, 1944	
D. K. Hamilton	Mar. 6, 1944 to May 14, 1945	
N. S. Stephens	July 17, 1944 to Sept. 29, 1944	
B. H. Davis	Sept. 11, 1944 to June 9, 1945	
Gertrude Steele	Jan. 16, 1945 to Oct. 19, 1945	
R. W. Kellogg	June 5, 1945 to June 30, 1947	
W. W. Doyel	Aug. 4, 1945 to Aug. 30, 1945	
E. A. Bell	Jan. 28, 1946 to June 30, 1947	
D. M. Phelps, III	May 3, 1946 to Feb. 26, 1947	
E. M. O'Connell	July 9, 1946 to Dec. 26, 1947	
L. F. Boland	Sept. 9, 1946 to May 29, 1947	
E. G. Otton	Feb. 13, 1947 to June 30, 1947	

Nora M. Bush was district clerk until January 31, 1945; Barbara Tinsley until December 7, 1945; and Mary L. Grunder during the remainder of the period.

Tennessee. - The only investigation during the period was in cooperation with the City of Memphis, as reconnaissance surveys of about half of the state had been made in cooperation with the State Geological Survey in former years. 248/ During the reconnaissance survey of western Tennessee, considerable attention had been given to the Memphis area, and realizing that at some future time, an intensive survey of that area would be required, two observation wells equipped with recorders were selected for continuous observation by the city.

When the agreement with the Memphis Light, Gas, amd Water Division was signed in August 1940, F. H. Klaer, Jr. was placed in charge of the investigation, which consisted largely in bringing up to date the well inventory made in former years, and in expanding the observation-well program. In that connection, the 4 test wells which the City was drilling were equipped with recorders and used as observation wells. Recorders were also placed on 2 existing wells, making with the

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248/ p. 313 (1928-1939).

2 observation wells established during the previous period, a total of 8 recorder-equipped wells. To supplement the pumpage records kept by the City, industrial water users were contacted for the purpose of obtaining records from their wells. The investigation was completed during the fiscal year 1942 except for the continuation of the observation-well program by the City. Mr. Klaer was in charge of the investigation on a part-time basis until July 1941 when the Ohio investigations required his full time and R. G. Kazmann succeeded him.

The need for a more intensive investigation led to a new agreement with the City, effective in November 1943,[249] providing sufficient funds to place it on a full-time basis with headquarters on the project. When Mr. Kazmann arrived in Memphis in November 1943, he was unable to find office space, a chronic condition in those days, but through the Commanding Officer of the Memphis General Depot of the Army, was given temporary quarters which were still in use at the end of the period.

In the full-time project, many more pumpage records were obtained, thirty additional observation wells were established the first year, and water samples from 3 wells were collected for analysis in Washington. A geologic study was started by J. C. Kammerer in June 1944. A progress report "The water supply of the Memphis area, September 1944," was issued by the Survey.

Wells in the Memphis area obtain water from three sources, two of which are known locally as the "500-foot" and "1,400-foot" sand. The third source is from the sands and fine gravels in the alluvial terrace deposits. The investigation made previously was confined largely to the "500-foot" sand, with some data collected on the "1,400-foot" sand, including a number of pumping tests in which V. C. Fishel assisted. By the end of 1944, it was realized that the Memphis area had to be treated as part of an area known geologically as the "Upper Mississippi embayment" and plans for continuing the investigation were directed along these lines.[250] An investigation of the "1,400-foot" sand was started in July 1945 and was continued during the remainder of the period. The number of observation wells was increased to 45 of which 15 were equipped with recorders, and the City drilled 10 additional test holes in the southeastern part of Memphis, in order to locate sites for additional wells. Samples obtained from the drilling of City and private wells were studied, and 3 extensive pumping tests of the "1,400-foot" sand were made. Mr. Kazmann resigned December 31, 1945, and was succeeded by E. M. Cushing, who came to the district April 5, 1946. Other Civil Service technical personnel were:

249/ p. 205.

250/ Letter from R. G. Kazmann to author.

Name	Period
G. K. Mauney	Apr. 10, 1944 to Apr. 4, 1947
J. C. Kammerer	May 25, 1944 to July 8, 1945 & Oct. 31, 1946 to Jan. 24, 1947
G. F. Mack	June 21, 1944 to Feb. 2, 1945
Eunice Springer	Feb. 19, 1945 to Aug. 30, 1946
L. J. Kern	Mar. 5, 1945 to June 30, 1945
W. N. Laval	July 14, 1945 to Sept. 29, 1945
J. C. Matthai	Aug. 17, 1945 to Dec. 15, 1945
Robert Schneider	Dec. 19, 1945 to June 30, 1947
T. J. Henderson, Jr.	Sept. 20, 1946 to June 30, 1947
P. L. Carroll	Sept. 20, 1946 to June 30, 1947
W. C. Trammell	Mar. 24, 1947 to June 30, 1947

Ohio. - At the beginning of the period, the only investigation in progress was that in Butler and Hamilton Counties, started by D. G. Thompson and F. H. Klaer, Jr. in June 1938. As the buried valleys of pre-glacial streams are the chief source of ground water in those counties, the investigation was confined chiefly to those areas. To enlarge the well inventory, 84 test holes were put down by auger, and including them, the inventory covered 542 wells. Two deep-test wells drilled by contract were for the purpose of determining the depth to bedrock, and whether water from Miami Valley was entering Mill Creek Valley. An observation program of more than 150 wells, 15 in areas of heavy pumpage being equipped with recorders, was maintained. The records from those wells showed extreme fluctuation of a foot in water levels due to changes in atmospheric pressure. In the intake areas for artesian water, heavy precipitation had a marked effect on the levels in shallow wells; one case being noted where a 4-day rainfall of about 6 inches caused a 19-foot rise in water level; the passage of railroad trains caused a rise of several hundredths of a foot in nearby wells due to compression of the ground by the extra weight. Analyses of water samples from the 6 public water supply systems in the area were made in Washington. The investigation was completed in December 1940 and the results, together with a recommendation that additional sources of supply be sought, were published as Water Supply Paper 999.

A firm of consulting engineers was employed to investigate additional sources and proposed a rather elaborate plan. In the meantime, the rates of pumpage in the Mill Creek Valley were being increased greatly by the operations of an airplane factory at Lockland, and to insure an adequate supply for that war industry, the Federal Works Agency constructed a modification of the proposed plan consisting in part in drilling 11 wells. As the new well field was near Hamilton in the Miami Valley, the city officials and many industries feared for the existing ground-water supplies and opposed the project. The Federal Works Agency then requested the Survey to investigate the probable effect of the new well field on existing supplies, and also to estimate the yield. This required an intensive investigation and R. G. Kazmann was detailed to assist Mr. Klaer, and work was started in June 1942, from headquarters at Reading. To determine the effect on the Hamilton supply, 11 test wells for observation purposes were drilled north of the Hamilton field, and piezometric surfaces were mapped. Detailed pumping tests on 2 production wells were made, and measurements of the rate of recovery after the 24-hour acceptance tests on each of the 11 test wells. A report entitled "A quantitative study of the well fields of the Mill Creek Valley Water Supply Project, Butler County, Ohio" was made to the Federal Works Agency, in July 1943. Routine records were continued during the remainder of the period. At the completion of the report, Mr. Klaer was given charge of the investigations just started in Indiana, and Mr. Kazmann continued in charge of the Ohio work until November 1943, when he was transferred to the Memphis investigation. E. J. Schaefer succeeded him.

There were a number of smaller investigations made at the request of the War Production Board.

As a result of cooperation with the Ohio Engineering Experiment Station, started in the fiscal year 1942, a brief survey of heavily pumped areas in 11 cities was made, and 7 observation wells with recorders selected. The lack of personnel delayed the new program. As personnel became available, that program was continued and gradually expanded, together with observations from selected wells in the Butler-Hamilton County area.

The city of Canton, like many another city during the war period, was seeking an additional water supply and preferred ground water if available, as being less expensive, and cooperated with the Survey in the fiscal years 1945 and 1946 for an investigation. It was started by E. J. Schaefer in December 1944. Later, G. W. White, associate Professor of Geology at Ohio State University, made studies of the glacial geology and D. W. Van Tuyl was transferred to Columbus and assisted with the analysis of the data and preparation of the report. In the beginning of the investigation, it was believed by city officials that the best possibilities existed in the Sippo area west of Canton near Massillon. However, it was agreed that the investigation would include the entire area surrounding Canton with very detailed studies to be conducted in the Sippo area.

The profile of the buried valley was determined from the logs of 6 test holes drilled for the occasion. To determine the permeability, a 12-inch well 185 feet deep, was drilled for a pumping test with observation wells driven in north-south and east-west lines from the 12-inch well. The test wells were also used as observation wells. From studies of the pumping test data covering 223 days from September 19, 1945 to April 30, 1946, and recharge conditions in the area, it was found that a perennial supply of $3\frac{1}{2}$ to 4 million gallons a day could be obtained in the Sippo area. The city decided that as the development would have included a long main, its cost for that supply was not justified. However, studies in other parts of the Canton area, carried on concurrently with the Sippo work, led to the discovery of another buried valley north of the city along the West Branch of Nimishillen Creek, where recharge conditions were more favorable. This area was later found to be capable of supplying in excess of 10 million gallons a day and was therefore developed by the City for an additional supply. The results of the entire investigation were published by the Ohio Water Resources Board as Bulletin 3, June 1946.[251]

As soon as the Ohio Water Resources Board was created in 1945, cooperation was started with it to expand the observation-well program by the addition of 100 wells equipped with automatic water-stage recorders, to survey the ground-water resources of the state, county by county, and to perform intensive investigations in all the heavily pumped areas.

Studies of the continuing observation-well program in the Butler-Hamilton County area, a revised estimate of recharge in the Mill Creek Valley, and a discussion of general ground-water conditions in the area were made by E. J. Schaefer and R. J. Bernhagen and published by the Ohio Water Resources Board as Bulletin 8.[252] The results of another study of observation-well records in the state by D. W. Van Tuyl and R. J. Bernhagen were published by the Water Resources Board in March 1947, as Bulletin 5.[253] A report on the ground-water resources of Tuscarawas County, the first in a series of county reports, was published by the Board as Bulletin 6,[254] in May 1947, as a result of studies by J. W. Cummins, cooperative State employee. Work was also being carried on in Montgomery, Green, Lucas, Mahoning, Summit, and Ross Counties.

E. J. Schaefer continued in charge of the investigation and had the following Civil Service technical assistants:

Name	Period
D. W. Van Tuyl	Jan. 4, 1946 to June 30, 1947
S. E. Norris	Feb. 18, 1946 to June 30, 1947
R. C. Smith	Sept. 23, 1946 to June 30, 1947
R. E. Marzluf	Nov. 18, 1946 to June 30, 1947
W. H. Nicholson	Feb. 17, 1947 to June 30, 1947

R. J. Bernhagen, chief geologist of the Ohio Water Resources Board, assisted when time permitted, and J. W. Cummins, geologist of the Board, assisted on a full-time basis.

Indiana. - As a result of the greater use of ground water during the

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251/ The Ground Water Resources of the Glacial Deposits in the Vicinity of Canton, Ohio.

252/ Ground Water Conditions in Butler and Hamilton Counties, Ohio, 1946.

253/ Summary of ground-water conditions in Ohio.

254/ The Water Resources of Tuscarawas County, Ohio.

war years, the ground-water program was expanded greatly in the latter half of the period. Also, as there was but one State-cooperative agreement with D. M. Corbett, the Survey's representative, the investigations to be undertaken were decided upon in consultation with the Director, Water Resources Division of the State Department of Conservation, the Survey's district engineer, and the geologist in charge of the ground-water investigations. That was an arrangement effective in no other states except Michigan, Georgia, and South Carolina.

Through the fiscal year 1941, the cooperative funds would only permit the continuation of the observation-well program, and part-time continuation of the Indianapolis investigation, neither of which required resident Survey personnel.

Field work for the Indianapolis investigation was started in September 1938 by C. L. McGuinness and as funds were not available for a full-time study, it was a part-time study until the fiscal year 1942 when special funds were made available by the State for the completion of the investigation, and as a result Mr. McGuinness devoted his time to it from July 1, 1939 to December 1942. The field work consisted in the establishment and maintenance of 15 observation wells, which were read during the non-active periods by the State Division of Geology, collection of well data, including pumpage, which was largely estimated, running levels to the points of measurement on the 15 observation wells, for the purpose of preparing maps showing contours of the water table and piezometric surfaces, and measuring the observation wells at regular intervals. Water analyses were furnished by the Indianapolis Water Company. A geologic study based largely on existing data was made, and general recommendations for additional ground-water use were given in the report dated January 1, 1943, published by the State, entitled "Ground-Water Resources of the Indianapolis Area, Marion County, Indiana", by Charles L. McGuinness.

With the increase in funds beginning in the fiscal year 1944, a 10-year program was mapped out and a district office was established in Indianapolis July 19, 1943, with F. H. Klaer, Jr. in charge. Referring to the State-wide program, Mr. Klaer stated: 255/

> The main purpose of the present ground-water investigation in Indiana is to determine the availability, the quantity and quality of the ground-water resources of the state, in order that data may be available for the wise development and economic use of an important natural resource. It is planned to investigate the state on a county-by-county basis, preparing county reports on the availability of ground water, the quantity and quality of existing sources of supply and, in general, present as complete a picture as possible of the present inventory and future potentialities.

255/ Proc. East-Central Branch Conf. Nov. 7-9, 1946, Indianapolis, p. 26.

The first step was a reconnaissance of the state to determine the status of water supplies; each town was visited and municipal water superintendents, industrial users, well drillers and others interviewed. Many well records were obtained and a permanent file by counties was started. To that file was added the logs of oil and gas wells obtained by the State.

The many demands for special investigations and reports in the interest of the various war activities, delayed the State-wide program and it was not until September 1944 that the first county investigation was started. When a request for an investigation was received, a conference was held with the local interests to discuss the problem; a short reconnaissance was made to determine the extent and scope of the problem, and the amount of available data to serve as a basis for planning the investigation. If it was a large one, the local interests were requested to share the cost.

St. Joseph County was selected for the first county investigation, and as South Bend is one of the largest industrial areas in the state and a heavy user of ground water, the investigation was centered in that area. Field work was started in September 1944 by F. H. Klaer, Jr., J. G. Ferris, R. W. Stallman, B. W. Swartz, and H. L. Ballard. It was an intensive investigation, setting the pattern for the other county reports to follow. In addition to the inventory of some 200 wells and collection of pumpage records, and an observation well program of 15 wells, seven pumping tests were made between October 1944 and March 1947. To make the data on the South Bend area available before the entire county investigation was completed, the results of the investigation, including a geologic study and an estimate of the safe yield, was published in 1948 by the State agency as Bulletin No. 3, Part 1, "Ground-Water Resources of St. Joseph County, Indiana, Part 1, South Bend Area."

In December 1944, an investigation of Scott County was started, preliminary work being in the vicinity of Scottsburg, where increased use due to war industries and a dry summer, had caused a shortage in the water supply. A preliminary report by F. H. Klaer, Jr. dated April 1945 was issued by the State.

Other county investigations started during the period were those in Boone, Noble, and Adams Counties in February, March, and November, 1945. A partial inventory of wells in Tippecanoe County was made during 1945 and 1946, as a part of the special research project in cooperation with Purdue University. Much test drilling was done by the communities concerned, but none by the Survey. Where it was possible to do so with existing facilities, pumping tests were a part of the regular procedure. In the hydrologic studies, the base flow of the streams as determined by the Surface Water Division was used as a guide in studying recharge possibilities.

None of the county reports was completed during the period, owing to many special reports, usually for cities, and the shortage of personnel to carry on the county investigations. One special investigation worthy of a brief description was a pumping test made at Gas City in June 1944. To develop a more adequate supply, the City had contracted for the drilling of a test well, and the question of interference of a well developed at that point with other wells nearby, caused the State Board of Health to request the Survey to determine the possible interference. On June 19, 1944, the Survey installed a recorder in the test well, and then made a pumping test. The results of the test, together with a study of the results both by the Thiem and Theis methods,[256] was made and a report by Mr. Ferris giving in detail the computations of that study, and the conclusions reached, was issued by the State Agency in April, 1945, as Bulletin 1, "Memorandum concerning a pumping test at Gas City, Indiana, with a detailed discussion of the methods used in the quantitative analyses of water-well interference problems."

Toward the end of the period, a research project was started in cooperation with Purdue University by Messrs. Klaer, Ferris, and Stallman. Because of the increasing problems of ground-water supply through the state, the faculty of the School of Civil Engineering became interested in ground-water problems, particularly those pertaining to artificial recharge, as there was a University problem of recharge through gravel pits by means of runoff from a very small area. A two-year agreement, officially for the purpose of determining the hydraulic characteristics of various formations, was made through the cooperating State agency, and the investigation was started April 19, 1945, and continued during the remainder of the period.

In April 1946, a research project was started at the Jasper-Pulaski State Nursery by Messrs. Ferris and Stallman, to determine the effect of drainage ditches on the ground-water levels. To measure the flow of the two ditches, a weir was installed in each and 41 shallow observation wells were put down to note the change in the ground-water levels. The project continued through the period. A similar project was started in August 1946 for the purpose of determining the effect of drainage ditches on the level of Bruce Lake in Pulaski County. In that project, 45 shallow wells all less than 20 feet deep were put down.

By the end of the period, a generalized geologic map of the state, showing the ground water conditions, had been prepared, and a cooperative program with Indiana University, involving the preparation of maps showing the thickness of glacial drift and the bedrock topography, started.

Mr. Klaer continued in charge of the Indiana investigations and had the following Civil Service technical assistants:

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Name	Period
B. W. Swartz	July 17, 1944 to June 30, 1947
R. W. Stallman	Mar. 1, 1945 to June 30, 1947
E. A. Brown	Feb. 14, 1946 to June 30, 1947
H. L. Ballard	Mar. 25, 1946 to June 30, 1947
W. D. Thornbury	Aug. 19, 1946 to June 30, 1947 (W. A. E.)

Phyllis A. Clement was district clerk from February 23, 1944 to October 31, 1946, when she was succeeded by Mary M. Yoder.

Michigan. - During the first 5 years of the period, cooperation with the State Geologist was on such a small scale that it was impossible to do more than continue the observation-well program, which was under the direction of C. L. McGuinness, assisted by members of the State Geological Survey. During the last 3 years however, greatly expanded cooperation made it possible to lay out a state-wide program, consisting of an intensive coverage of the state by county units; the chief objective being to meet the immediate public need, chiefly that of the larger industrial areas due to the extensive development caused by the war effort. When the increased cooperation was being discussed, the State Geologist, R. A. Smith, declared that he wanted reports written in simple language easily understood, and did not want statistical reports that would be filed away on a shelf.

W. T. Stuart, transferred from the Louisville Office, was placed in charge of the state-wide investigations and established an office in Lansing July 11, 1944.

Antedating the expanded program was the investigation of the so-called Ypsilanti Triangle, started in August 1942. The city of Ypsilanti, Willow Run Bomber Plant operated by the Ford Motor Company, and the war housing project of the Federal Housing Authority required large quantities of water and ground water appeared to be the only source. The Federal Works Agency was responsible for deciding the adequacy of the existing supply and to decide that point, requested the Survey to appraise the ground-water resources. C. L. McGuinness was borrowed from the Indianapolis investigation, and with O. F. Poindexter of the State Survey, started the investigation in August 1942. The usual well inventory was made and observation-well sites selected to observe the effect of pumping from the bomber plant wells. In September 1943, sites for test wells were selected, and the wells were drilled by Federal agencies during the first half of 1944. Pumping tests were made on 4 of the test wells. The test drilling and pumping tests were supervised by E. G. Otton. Samples from 14 wells were analyzed chiefly by the interested industrial concerns. As a result of the investigation, an adequate water supply was assured and the operation of the bomber plant made possible.

The first investigation under the state-wide program was that of the Lansing area, started in August 1944 by W. T. Stuart and in January

1945, R. W. Stallman was assigned to the Lansing Office to assist in the investigation. Records and estimates of pumping tests were compiled; records from observation wells were used to define the piezometric surface; pumping tests were made; and a geologic study made as an aid in determining the recharge possibility. Mindful of the requirement to make the cooperative reports intelligible, the report on the Lansing area was almost a text book on ground-water methods. It was published by the State in June 1945 as "Ground-water resources of the Lansing area."

The next investigation was in the Benton Harbor area, where a recent influx of war workers had resulted in uncertainty as to the adequacy of the water supply. The field work was performed in February and March 1945 by Messrs. Stuart and Stallman. In addition to obtaining all available data, pumpage tests were made. From a geologic study and that of the hydrologic data collected, recommendations were made for future exploration. The results were published by the State in June 1945 as "Ground-water resources of the Benton Harbor area.

In July 1945, W. T. Stuart was assigned to the Iron River investigation and J. G. Ferris was placed in charge of the investigations in the Southern Peninsula.

As the result of an extended drought during the summer and fall of 1945, urgent requests for assistance were received by the Stage Geologist from the Cities of Battle Creek, Kalamazoo, Flint, Alma, and Holland. To meet those requests, it was necessary to set up the following new procedure for appraising the merit and urgency of each: A preliminary reconnaissance to determine approximately the time required and the type and amount of equipment needed; from that information, an estimate of the cost was given the State Geologist for the purpose of advising the cities and towns as to the extent the State and Survey was willing to cooperate as investigations of cities and towns require much more intensive work than rural areas. The next step in a metropolitan investigation was to obtain from all sources all available data concerning methods and difficulties encountered in developing ground-water in the area. An intensive canvass was made of all consulting engineers, architects, contractors, railroads, and highway departments to obtain data on surface and sub-surface geology. A search was also made of libraries, newspaper files, and historical collections to obtain copies of data regarding the geology and hydrology of the area as reported in the past.[257]

While the state-wide program was taking shape, the State Geologist, through the County School Commissioners, furnished school children with forms prepared by the Survey requesting information regarding

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257/ Proc. East Central Branch Conf., Nov. 7-9, 1946, Indianapolis, pp. 38-39.

their water wells. As a result, information on about 10,000 wells was obtained. That information augmented (1) the file of well logs obtained from the State Health Department, which has to approve applications for public water supplies, (2) logs from oil and gas wells which by law were filed with the State Geological Survey, and (3) borings of all footings for highway bridges, obtained from the State Highway Department.

The Kalamazoo investigation was started in December 1945. In addition to the well inventory, 21 observation wells, 6 equipped with recorders, were selected and pumping tests were made in 9 wells. Somewhat similar investigations were made at Holland, Battle Creek, Flint, and Alma, and pumping tests were made at nearly a score of other places, but space will not permit a description of those operations.

An investigation of Gun Lake was started in the fall of 1946 as a result of a dispute over the deepening of the drains entering the lake, as desired by the bordering agricultural interests, and the resort owners' fears that the lake level would be lowered. Sixty shallow wells ranging in depth from 8 to 12 feet were put down in connection with the installation of temporary control dams in drains bordering the lake.

An investigation, the purpose of which was unlike that of any other undertaken by the Ground Water Division, was the Iron River investigation. Some of the iron mines in the Iron River district are overlain by saturated glacial drift a hundred or more feet thick, which causes a serious problem of mine drainage where, in some cases, it was necessary to pump 30 tons of water for each ton of ore extracted. The investigation as originally proposed by C. V. Theis and C. F. Park, the latter a member of the Geologic Branch, included in addition to the mine drainage, types of ground-water circulation which could have caused the enrichment of the iron ore.

In 1944, Director Wrather, in company with State and local Survey officials on a trip through the state, visited the Iron River district and became so interested in the problem that he directed the beginning of the project. Although the cooperative agreement with the State covered only the mine drainage phase, the investigation enlisted the services of the Ground Water, Surface Water, and Quality of Water Division, special studies by the Geologic Branch, and special maps by the Topographic Branch.

The work program provided (1) for an inventory of the water pumped from the glacial overburden, also from the consolidated rocks, (2) an observation-well program including all existing wells in the surface of the glacial drift for the purpose of determining the piezometric surface, and (3) pumping tests to determine the capacity of the overburden as a reservoir and its capacity to transmit the water, and the possibility of unwatering those areas recharging the ore-bearing formations and transmitting the water downward into the mines. During the investigation, the Surface Water Division made numerous seepage measurements on streams throughout the area to determine the principal areas, and the magnitude of the gains and losses in the glacial overburden. The Quality of Water Division analyzed samples collected at various points to determine the progressive change in quality as the ground water moves from point to point, and from time to time, in each area. Field work was started in July 1945, in charge of Mr. Stuart who established his headquarters at Iron River. C. V. Theis devoted a part of his time as consultant and G. M. Stanley spent two summers in the study of glacial geology. The investigation continued during the remainder of the period. A "Progress Report on ground-water investigations of the Iron River District, Michigan" by C. V. Theis, W. T. Stuart, and G. M. Stanley was released in typewritten form in September 1946 to the State Geologist and to the mine operators of the district.

A state-wide observation-well program was steadily expanded and in June 1947, there were 167 wells. Employees of the State Geological Survey made the well observations until 1944 when the increased cooperation made it possible for the Survey to take over that program. Regular observation-well routes were established and in areas of comprehensive investigations, the readings were made weekly; at other areas at monthly intervals. One of the engineers attached to the Grayling Office of the Surface Water Division devoted a part of his time to the well readings in that area.

Civil Service technical assistants were:

Name	Period
G. M. Stanley	July 18, 1945 to June 30, 1947 (W.A.E.)
W. C. Waldbieser	Mar.11, 1946 to June 30, 1947
P. R. Giroux	Aug. 1, 1946 to June 30, 1947
C. C. Hoge, II	Nov. 7, 1946 to June 30, 1947
E. A. Moulder	Nov. 12, 1946 to June 30, 1947
Ted Thompson	Nov. 18, 1946 to June 30, 1947
R. A. Smith	Dec. 9, 1946 to June 30, 1947 (W.A.E.)
L. A. Wood	Jan. 27, 1947 to June 30, 1947
E. C. Rhodehamel	May 5, 1947 to June 30, 1947

Enid M. Smith was the district clerk.

Wisconsin. - With cooperation for an intensive investigation assured, 258/ the Survey contacted F. C. Foley while he was still in the Army, and arranged with him to start the investigation as soon as he was available. Mr. Foley arrived in Madison February 18, 1946, and obtained quarters in the University of Wisconsin's Science Hall near the State Geologist, who was the active representative of the University in the cooperation.

The plan of investigation was to study the Cambrian sandstone artesian aquifers of eastern and southern Wisconsin, and as the most

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serious problem was that caused by greatly increased pumpage in the Milwaukee-Waukesha area and its effect on the water levels, that area was selected first. It was started in April 1946 with an inventory of all available well data, and the selection of 20 observation wells in the area. To determine the water-bearing characteristic of the principal aquifer in that area, 54 pumping tests on 18 wells, chiefly under the supervision of W. J. Drescher, were made on existing wells between May 1946 and February 1947. The field work on that particular phase of the investigations in that area was completed by the end of the period and a mimeograph report, "Results of pumping tests on artesian wells in the Milwaukee-Waukesha area, Wisconsin," released by the Survey February 1948.

Although the Survey had made practically no ground-water investigations previously, the State Geological Survey for many years had been collecting well logs throughout the state and had about 61,000 well samples on file. As a result of the large number of logs and the great depth to bedrock making test drilling almost prohibitive, test wells were not drilled by the Survey in connection with the investigations during the period.

As the basis for the general investigations to be undertaken, the state-wide observation-well program was extended as rapidly as possible, and the wells were selected to include each type of ground-water occurrence. At the end of the period, there were about 100 observation wells, 17 equipped with recorders, located chiefly in the southern and eastern part of the state. At the beginning of the period, the Surface Water Division was maintaining 8 wells started in connection with the Soil Conservation Service's cooperative project in 1934.259/ In 1944, J. G. Ferris in charge of ground-water investigations in Michigan and F. C. Christoperson in charge of surface water investigations in Wisconsin, established additional wells in the upper Wisconsin River Basin, making a total of 17 wells when the ground-water investigations were started in 1946. The State Board of Health in connection with its responsibility connected with public water supplies, was interested in water levels, and pumpage as it affected the former, and in the summer of 1946, Mr. Foley prepared a form for recording daily pumpage and water levels, and another form requesting complete information on each well. The Bureau of Sanitary Engineering of the State Health Board had the two forms printed and as a start, sent them to about half the municipalities in Wisconsin, the pumpage and well readings to be reported monthly. By the end of the period, monthly reports were being received from most of the municipalities to which forms had been sent.

Mr. Foley continued in charge and had the following Civil Service assistants:

259/ p. 216 (1928-1939).

Name	Period
G. E. Hendrickson	Feb. 18, 1946 to June 30, 1947
W. J. Drescher	Apr. 30, 1946 to June 30, 1947
Mrs. E. A. Fox	May 5, 1946 to June 30, 1947

It may be added in passing that each member of the Survey staff was either a veteran or the wife of a veteran.

Iowa. - The investigations in Iowa had been started in 1938, chiefly for the purpose of obtaining data on pumpage of ground water and correlating that information with fluctuations of water levels, and the geologic source of supply. T. W. Robinson, who was in charge of the hydrologic features of the investigations, made a reconnaissance survey and obtained available well and pumpage records, and learned where the ground-water supplies were critical. In the fall of 1939, he extended the observation-well program to the northwestern part of the state where the Dakota sandstone occurs.

In 1937, before the cooperative program became effective, the State had started an investigation of Cerro Gordo County, which was designed to be the first of a series of county reports. That was one of the first investigations undertaken in the cooperative program and T.W. Robinson and A. P. Gerardi devoted considerable time to it. In addition to the inventory of wells, a special geological study of the deeper wells in the Mason City area was made by H. G. Hershey of the State Survey. Pumpage records from 1936 were collected and pumping tests were made on most of the deep wells. The investigation continued beyond the period.

In 1940, the Linn County investigation, a study of the area in the vicinity of Cedar Rapids, was started by A. P. Gerardi, continued in 1942 and periodically since by W. E. Hale. Well inventories were made and pumping tests made; the subsurface geology studied from which maps of the subsurface geology were prepared; and the quantity, quality, and water levels of all water-bearing rocks studied.

The Webster County investigation was begun by W. E. Hale in the fall of 1942 and was being continued at the end of the period. In addition to an inventory of the wells in the area, many sets of cuttings were obtained from wells drilled throughout the county. Particular attention was given to the occurrence of ground water in the City of Fort Dodge well field.

No more county investigations were started before the war years, as during those years most of the time was devoted to special investigations usually requiring only a short time for military establishments and war industries. Succeeding those war-time investigations, there were many requests from cities and industrial establishments for assistance in obtaining new wells or increasing the yield of existing wells.

The special investigations during and after the war numbered about 200 and a regular procedure was developed in consequence. All available data were assembled in the office and available well cuttings studied. The only field work consisted in collecting data that could be readily obtained. Reports for cities did not in general recommend specific locations for new wells. If the cities drilled wells, a request was made for drill cuttings at 5-foot intervals and at changes in formation. A Survey representative was usually present at pumping tests.

The Survey did no test drilling but through a representative kept up with current drilling and obtained cuttings from a large number of wells. Drillers' logs were procured from all of the drillers contacted.

As an aid to the various investigations in the state, two state-wide projects were started: (1) collection of production and permeability data started in 1943, and (2) preparation of piezometric maps of aquifers on a state-wide basis, started in January 1944.

So numerous were the requests for special investigations that it was not possible during the period to publish complete reports, the policy being to devote the time to meeting immediate needs, instead of curtailing that service for the purpose of preparing finished reports.

The dual control of the Iowa work whereby T. W. Robinson studied the hydraulic features and H. G. Hershey of the State Survey made the geologic studies, was discontinued. Mr. Robinson went to the Arizona investigation January 1, 1944, and Mr. Hershey became district geologist February 1, 1944. The C ivil Service technical assistants during the period were:

Name	Period
A. L. Detweiler	Feb. 7, 1940 to Feb. 28, 1941
A. P. Gerardi	Feb. 6, 1941 to Mar. 11, 1942 2/
K. E. Anderson	Sept. 8, 1941 to June 9, 1944 2/
W. E. Hale	May 5, 1942 to June 30, 1947
D. A. Barton	Apr. 11, 1944 to June 30, 1947
	(W.A.E. Sept. 22, 1945 to July 28, 1946)
A. F. Agnew 1/	Dec. 1, 1945 to Aug. 23, 1946
	June 23 to 30, 1947
J. B. Cooper	Sept. 3, 1946 to June 30, 1947
D. A. Morris	Oct. 1, 1946 to June 30, 1947

1/ On detail from Geologic Branch

2/ Military furlough; did not return to district.

Ethylmae Schultz was district clerk beginning June 19, 1944.

Arkansas. - During the fiscal years 1940 to 1945, the operations were confined to the observation-well program which was an outgrowth of the

Grand Prairie Region investigation started in 1928.[260/] To check the conclusions reached in that investigation, additional pumping tests were made in 1940 and 1941 by L. K. Wenzel and R. G. Kazmann. In making the 1941 tests, the well was pumped 32 hours and the discharge measured both by weir and by 6-inch orifice, and well levels corrected for barometric changes. Mr. Kazmann spent some time on the investigation during the spring of 1942. The report of the Grand Prairie Region investigation was published in 1945 by the Arkansas Agricultural Experiment Station as Bulletin 457, "Ground-water supplies for rice irrigation in the Grand Prairie Region, Arkansas." The spring water level readings of the 411 wells in the Grand Prairie Region were continued by Prof. Kyle Engler of the University, but the Survey helped make the measurements in 1947.

The cooperation with the Bureau of Research at the University of Arkansas and the city of El Dorado, both effective in the fiscal year 1945, created a full-time position in Arkansas and to start the investigations, N. A. Rose was detailed from the Texas District October 1, 1945. As the Bureau of Research desired to have the office near its own, headquarters were established adjacent to the Bureau's office on the campus of the University in Fayetteville. Mr. Rose had hardly made a start when he resigned in December. F. A. Hewitt was transferred from the Geologic Branch and came to El Dorado January 10, 1946, and R. G. Baker of the Ground Water Division assumed charge March 3, 1946, with headquarters at Fayetteville.

The first project was a reconnaissance of the State, started by Mr. Rose, to learn the ground-water problems. Collections of samples of public water supplies and information on wells, the latter by means of a questionnaire, were obtained and that work was continued by Mr. Hewitt until its completion in the fall of 1946. These samples of public water supplies were also desired by the Quality of Water Division, the analyses of which was a major part of its program.

In January 1945, the mayor of El Dorado had asked the Survey if a cooperative investigation of the ground-water supply for the City could be made, as the artesian head was declining. S. W. Lohman and G. C. Taylor made a brief reconnaissance and attended a meeting in El Dorado January 8, 1945. Mr. Lohman outlined the type of investigation needed, and the City and industrial users agreed to finance the City's share of the proposed investigation. Although cooperation became effective in that fiscal year, lack of Survey personnel made it impossible to start the investigation until September 1946, when Messrs. Baker and Hewitt could spare the time for it.

The problem was to determine how much water was being pumped and how much could be pumped safely. It was a quantitative investigation, chiefly, during which, in addition to the usual geologic study,

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260/ p. 312 (1928-1939).

well inventory, pumpage record, and 6 pumping tests were made from February to April 1947, from which 11 compilations of the transmissibility coefficient, and 6 of the storage coefficient were made. The theoretical drawdown for a constant rate of pumpage for various periods up to 20 years were computed. Samples from 7 wells were analysed by the Quality of Water Division. The investigation was completed about the end of the period and the results published by the Bureau of Research as Research Series No. 14, "Ground-water resources of the El Dorado area, Union County, Arkansas."

At the meeting in El Dorado January 8, 1945, the city of Crossett requested Mr. Lohman to make a reconnaissance of the Crossett area and recommend the type of investigation needed. That was done, and although cooperation was offered, it could not be accepted until a year later for lack of Survey personnel.

The investigation was started in the spring of 1946. In addition to the geologic studies, a well inventory with pumpage records, and one pumping test were made. An unpublished report was made to the City. On the completion of the special investigation around Crossett, the investigation in less detail was expanded to include the whole of Ashley County in which Crossett is located, as there are a few irrigation wells in the county. The field work was performed chiefly by Mr. Hewitt. The county investigation, including the Crossett area, included the inventory of 54 wells, a compilation of 10 well logs, and pumpage records through 1947. Chemical analyses of 21 well samples were made by the Quality of Water Division. A special study was made of the Sparta sands which are some 250 feet below the surface and are about 530 feet thick. It is an important aquifer in nearby counties but is not being utilized in Ashley County. The results of the Ashley County investigation were to be published by the University of Arkansas with the expectation that it would be the first of a series of county investigations to be made by the Survey.

As knowledge of the ground-water investigations in the state spread, inquiries from municipalities began to be received and by the end of the period, they numbered about 25. The burden of the questions was where was ground-water available, and where could better quality of water be obtained. As it was not possible to make field investigations for all inquiries, the best information in the files was furnished.

Mr. Baker continued in charge of the Arkansas investigations and had the following Civil Service assistants:

F. A. Hewitt	Jan. 10, 1946 to June 30, 1947
Vivian Canfield	Aug. 20, 1946 to June 30, 1947

North Dakota. - The state-wide observation-well program started in 1937, continued as a WPA project until 1940, when it became a part of the State-cooperative program. That year marked the beginning of detailed investigations in various parts of the state.

In the drift-covered areas which constitute a large part of North Dakota, test drilling is essential, and as the depth of the drift is extremely variable, many test holes are required, especially as few driller's logs are available. Therefore, test drilling was an important part of all investigations during the period.

During the low years of the nineteen thirties, many inquiries regarding ground-water supplies for irrigation had been received, and in the summer of 1940, a reconnaissance of 15 areas was made. As a result, the site of glacial Lake Dakota south of Oakes was chosen for the first investigation, which was to determine the capacity of the ground-water reservoir and its annual recharge.

That investigation was started in August 1940, by W. C. Rasmussen, under L. K. Wenzel's supervision. Bore holes from 5 to 25 feet deep were dug with hand augers at almost every section corner in the Oakes plain and 12 test holes, ranging in depth from 65 to 106 feet were drilled along and across the plain. In addition, records of the 50 existing wells were collected. Elevations of the measuring points in the bore holes and key wells were determined from USC&GS bench marks, and pumping tests on 4 separate well systems were made to determine the permeability and storage capacity. Mechanical analysis of the well cuttings, and permeability tests of the sediment samples covering the ancient lake bed were made by the Survey laboratory in Washington. The samples of ground water were analyzed by the Quality of Water Division. A mimeographed report of the investigations was published by the Survey as "North Dakota ground-water Studies No. 4, March 1947."

Just prior to the Oakes investigation, the City of Fargo proposed cooperation for the purpose of determining whether an additional ground-water supply was available in the immediate vicinity. The Fargo investigation was started in May 1940 by A. C. Byers and L. K. Wenzel, and was completed in June 1942. The 5 existing observation wells were augmented by 9 test wells drilled by the City of Fargo. Piezometric surfaces were developed, and pumping tests made to determine the permeability. Samples of sand and gravel were tested in the hydrologic laboratory in Washington, and 11 samples of water analyzed by the Quality of Water Division. A geophysical exploration by the electrical resistivity method was made at 31 locations and at depths of 400 to 500 feet, but the results were largely negative.

The investigation which failed to locate a satisfactory water supply in the limited area investigated, did indicate greater possibilities in a larger area surrounding that investigated and as a result, a 2-years' cooperative agreement with the cities of Fargo and Moorhead, and Cass and Clay counties was effected. The second investigation was started in July 1945; it included the entire Red River Valley in the Fargo-Moorhead area. A. M. Morgan was placed in charge of the investigation and headquarters established at Fargo November 18, 1945. As the existing well logs and the geophysical explorations were insufficient to determine a geologic cross section of the valley, 10 test holes having a footage of about 4,100 feet were put down on the North Dakota side by means of the State-owned hydraulic rotary machine; and later 21 additional test holes were drilled on the North Dakota side; the depth of the holes ranged from 154 to 608 feet and penetrated the granite under the drift. During the drilling, samples were collected at 5-foot intervals and at recognizable changes in formation. Also in 1946, 19 holes having a total footage of 1,942 feet were put down with a privately owned jetting machine on the Minnesota side of the river, and existing data for the Minnesota side was also compiled. In the Fargo area, water levels in 1 well close to the Northern Pacific tracks reacted sharply to the passing of trains, and levels in 2 wells were affected by the compression of the till and included aquifers, due to additional weight of water in the Red River channel when at flood stage. The coefficient of transmissibility was determined not only from the pumping tests in 1940 and 1941, but also from a pumping test at West Fargo July 7-9, 1945. The logs of 77 wells were compiled and about 560 wells inventoried and pumping records compiled. The result of both investigations will be published as "North Dakota Ground-water Studies No. 11, "Minnesota Ground-water Studies No. 1, " and "Minnesota Ground-water Studies No. 2."

Cooperation for the investigation at Dickinson[261/] was for the purpose of defining the area of influence in the single well field having an area of about $1\frac{1}{2}$ square miles, and the capacity of the aquifer to transmit additional quantities of water. The limited funds available did not permit extensive test drilling to locate well fields nor did they permit deep drilling to test additional aquifers at a greater depth. To make the investigation, T. G. McLaughlin was borrowed from the Kansas District, and A. L. Greenlee made the geologic studies. The field work lasted from March 27 to May 6, 1944. Two test holes, 142 and 191 feet deep respectively, were drilled by contract, and levels were run to the test holes and all existing wells. Pumping tests of the test holes were made, and data on existing wells furnished by the city. A mimeographed report was published by the State as "North Dakota Ground-water Studies No. 3, October 1946."

Following the Dickinson investigation, Mr. McLaughlin made a short investigation at Fessenden in May 1944, where the city had had a number of test wells drilled without success. The well inventory was made and a number of wells were tested by means of a small centrifugal pump attached to a gasoline engine, which showed that the water pumped came chiefly from storage in the wells thereunder.

As a result of cooperation with the City of Minot, an investigation was begun in August 1944 by A. M. Morgan who was borrowed from the Wyoming investigations until November, when P. D. Akin continued the study. Seven test holes, ranging in depth from 90 to 353 feet, were drilled, logs of 17 other wells, inventories of 58 wells and test holes, and pumpage records were obtained. Detailed pumping tests were made.

261/ p. 209.

Chemical analyses from 29 samples were made by the State Department of Health and other agencies. The field work was completed in December 1946. As the principal source of replenishment is the Souris River, the possibility of artificial recharge with surface water from that stream was pointed out as a source of additional supply or development of ground-water at other points along the Souris River. A mimeographed report was released by the Survey in 1947.

That same year, cooperation with the University of North Dakota was effected for the purpose of drilling a test well near the lignite gasification plant of the Bureau of Mines on University property. After an investigation, a test well was drilled by contract to a depth of 418 feet to a hard, white sandstone. That well, together with data on 6 other wells in the area, indicated little likelihood of obtaining an industrial supply at greater depth. Drilling, under P. D. Akin's supervision, was started October 12, 1944, and discontinued November 2, 1944.

During this time, correspondence from a great many towns was received by the North Dakota State Geologist requesting assistance in making ground-water studies for the purpose of determining possible sources of ground water for municipal use and on July 1, 1945, cooperation was begun with the North Dakota State Water Conservation Commission for the purpose of satisfying these needs of the municipalities. This cooperation was much more substantial than previous cooperation in the state. It was proposed that the studies would be used as the basis for county-wide ground-water investigation in the state, to be begun as soon as the immediate needs of the municipalities were satisfied. To the end of the period, however, the demands for investigation for the municipalities were so great that not a single county report was completed. In meeting the needs of the municipalities, the procedure adopted was to make an areal investigation including test drilling in the vicinity of the towns, to indicate areas where satisfactory water supplies could be obtained. The town then drilled supply wells by contract. After the wells were constructed, pumping tests were made on the wells either under supervision of the Survey or the consulting engineer for the municipality.

Under the expanded program, the first investigation was a continuation of that at Fessenden, because of the inconclusive results of the first study and the critical need for an additional supply. Test drilling was resumed in 1945, and the geologic study was made by Leonard Filaseta and P. D. Akin. That investigation, the results of which were published by the State as "North Dakota Ground-water Studies No. 1," was likewise inconclusive and indicated that the only probability of an adequate water supply appeared to be in the ancient Heimdal-Hamberg valley. A third investigation was started in the fall of 1945, suspended during the winter and resumed in May 1946 by Messrs. Dennis, Akin, and Brookhart. A total of 38 test holes were drilled to bedrock for a total footage of 5,300 feet. The field work was completed in October 1946. The geology was mapped and the well inventories brought down to date. As a result, Fessenden drilled wells at the points indicated and obtained an adequate water supply.

The next investigation was that of a small area in the immediate vicinity of Mountain, Pembina County, typical of a belt of beach and delta deposits that extend all along the shores of the glacial Lake Agassiz. Mr. Akin started the field work in the latter part of July and finished early in August, 1945. All available information from 19 existing wells was obtained and 25 additional test holes were put down by hand auger. Samples of cuttings from all the 25 wells were preserved for study and 10 samples were used in making permeability tests on the sands. All wells were connected by levels and a water table map drawn. From the permeability tests, the slope of the water table and the cross-sectional area, an estimate of the available ground water was made. A mimeographed report was published by the Survey as "North Dakota Ground-water Studies No. 2, June 1946."

During the remainder of the period, 7 similar investigations were made.

The Maddock investigation was made during June and July 1946, during which 14 test holes with total footage of 1,000, were drilled. The city constructed a well at the point indicated, and obtained a good supply of water. At Minnewaukan, 28 test holes aggregating 1,900 feet were drilled during the field work which lasted from July to September 1946. The investigation in this area was not completed at the end of the period. In the Buxton area, 7 test holes totaling 203 feet were drilled during the field investigation August to October 1946. Chemical analyses of 17 samples were made. A progress report was issued in January 1947 as "North Dakota Ground-water Studies No. 5." During the Aneta investigation, begun in the fall of 1946 and completed in April 1947, 7 test holes having a total footage of 300 feet were drilled. A progress report was issued October 1947 as "North Dakota Ground-water Studies No. 7."

The Sharon investigation was made in April 1947, during which 9 hand-bored auger holes were put down and 11 test holes totaling 800 feet drilled. A pumping test of the school well was made. A progress report was issued December 1947, as "North Dakota Ground-water Studies No. 8." Investigations in the vicinity of Hope were made during May and June, 1947. Ten test wells with a total footage of 1,021 were drilled and chemical analyses of 16 samples were made. A progress report was issued April 1948, as "North Dakota Ground-water Studies No. 9." In May and June, an investigation at Portland was made, during which 7 test holes totaling 1,400 feet were drilled. It extended beyond the present period.

L. K. Wenzel was in charge of the North Dakota investigations until June 1940, when W. C. Rasmussen was placed in charge under Mr. Wenzel's supervision. He remained until May 31, 1942, when he entered the Army, and was succeeded July 13, 1942, by A. L. Greenlee who resigned October 14, 1945. P. D. Akin was in charge until January 24, 1946, when P. E. Dennis was transferred from Utah.

Other Civil Service technical assistants were:

Name	Period
A. C. Byers	Summer seasons of 1940 and 1941 1/
A. M. Morgan	Aug. 20, 1944 to Apr. 25, 1947
P. D. Akin	Oct. 5, 1944 to June 30, 1947
Leonard Filaseta	Aug. 3, 1945 to Feb. 6, 1946
H. K. Wold	Mar. 26, 1946 to Apr. 25, 1947
D. P. Sheldon	Apr. 1, 1946 to June 30, 1947
J. W. Brookhart	Apr. 28, 1946 to June 30, 1947

1/ Headquarters Washington.

G. R. Bosard was the district clerk beginning July 19, 1944.

South Dakota. - From the beginning of the period to June 30, 1945, except for a special investigation near Sioux Falls, the ground-water work consisted in maintaining a State-cooperative observation-well program which averaged about 50 wells. The wells were located chiefly in the southeastern part of the state as the beginning of a state-wide program. At first, the program was operated by the Iowa Office for convenience, but in 1943, it was transferred to the North Dakota Office.

Sioux Falls obtains its supply from a well field and during the dry years, the pumpage from the wells reduced the flow of the Big Sioux River to such an extent that it was dry in the vicinity of the well field and that cast doubts upon the adequacy of the ground-water supply. The Army proposed to locate a camp near the city, and the need for an additional supply became urgent, and at the Army Engineers' suggestion, the City requested the Survey to make an investigation, offering to co-operate in its expense and to pay the cost of the test drilling. The investigation was to determine whether there was sufficient ground-water storage in the existing well field, to warrant additional wells or whether it would be necessary to extend the well field upstream.

The offer was accepted and a reconnaissance made by the Grand Forks Office. The investigation was started in November 1944 by G. E. Otton, with some assistance by members of the Grand Forks Office. Test holes in the existing field were located, and their drilling and the subsequent pumping tests supervised. To define the well field, test holes were also located across the valley to the north. As a part of the investigation, the Surface Water Division made two sets of measurements of Big Sioux River above and below the well field, and a measurement of Skunk Creek. The investigation was stopped early in 1945, as Mr. Otton entered the Army. As a result of the investigation, the city located the additional wells closer to the axis of the valley where the recharge from the river would be greater.

During the last two years of the period, the ground-water investigation was coordinated with that of the Missouri River Basin Departmental Program and is there described.

Nebraska. - The state-wide cooperative investigation covered a large part of the Republican River Valley in the first years of the period. It began in June 1939 and continued through 1942, and the field work consisted chiefly in drilling with two State-Federal Survey portable hydraulic rotary drilling rigs, 734 test holes, which with 31 drilled previously, made a total of 765 test holes, ranging in depth from 8 to 319 feet with an average depth of about 50 feet. Each drilling crew consisted of a geologist and two sub-professional employees, divided between Survey and State employees. From the logs of the wells, it was possible to construct geologic profiles in each county, and to determine the contour of the impervious bedrock, and the thickness of the water-saturated formations in the valley. A preliminary report in 4 parts was published by the Nebraska Conservation and Survey Division as Water Supply Paper 1, "Ground-water in the Republican River Basin in Nebraska." R. C. Cady was in charge of the geologic and hydrologic studies with some supervision by L. K. Wenzel, and continued until he joined the military forces in February 1942. Up to that time, there had been no permanent headquarters for the Survey personnel engaged on the ground-water investigations in Nebraska, but in August 1942 when H. A. Waite was transferred from Kansas to take charge of the Nebraska work for the Survey, he established permanent headquarters in Lincoln with the cooperating State agency.

During 1942, Mr. Waite had no Survey assistant and owing to the restrictions imposed by gasoline and tire rationing, he devoted a large part of his time to the cooperative test-drilling program, and in measuring the water levels in the state-wide observation wells. The observation wells gradually decreased in number from about 500 to 250, some becoming unfit for observations. The test-drilling program which was stressed during this period, gave a better understanding of the subsurface conditions with particular emphasis on the areas favorable for ground-water development. With the quickened tempo of the war effort, special field investigations and reports were made in response to requests for ground-water data for military establishments during the early war years.

At the request of land owners, a study of the pump-irrigation possibilities of an area of some 70 square miles lying north of O'Neill was made in the summer of 1944. It was a cooperative investigation between several agencies including the State Bureau of Irrigation, the U. S. Geological Survey, the Federal Bureau of Soils, in addition to the State Conservation and Survey Division. During the investigations, 13 test holes, ranging in depth from 39 to 84 feet were drilled and the geology studied together with that of the soils and their adaptability to irrigation. A report was published by the State as Water Supply Paper 2, "Ground-water survey of area north of O'Neill, Holt County, Nebraska Conservation & Survey Division."

With the start of the Missouri Basin Departmental Program in October 1945, much of the activity was integrated with that plan and expanded by it. It is described under the activities of the Missouri Basin Departmental Program.

During the annual convention of the National Reclamation Association, held at the Fontenelle Hotel in Omaha, October 9-11, 1946, the Ground Water Division joined with the other divisions in having an exhibit of its activities. The ground-water diorama was obtained from Washington, together with various diagrams.

Mr. Waite continued in charge of the Nebraska investigations and had the following Civil Service technical assistants:

Name	Period
R. L. Schreurs	May 16, 1944 to Aug. 27, 1944
R. L. Stribic	Oct. 1, 1945 to June 30, 1947
M. F. Sunyoke	Oct. 15, 1945 to Nov. 1, 1946
F. G. Schnittker	Nov. 5, 1945 to June 30, 1947
Ray Bentall	Nov. 9, 1945 to June 30, 1947
H. F. Haworth	Jan. 21, 1946 to July 1, 1946
R. L. Nace	Feb. 12, 1946 to Aug. 12, 1946
G. D. Jones	May 1, 1946 to June 30, 1947
W. K. Bach	July 21, 1946 to June 30, 1947
E. A. Duncan	Nov. 20, 1946 to June 30, 1947
J. W. Nelson	Nov. 20, 1946 to June 30, 1947
F. E. Busch	Jan. 20, 1947 to June 30, 1947
C. F. Keech	Feb. 17, 1947 to June 30, 1947

Phyllis J. Beckman was the district clerk from August 11, 1943 to June 6, 1947.

Kansas. - The inventory of Kansas ground-water resources required test drilling to augment the available geologic data, and at the beginning of the period, the State Geological Survey purchased a hydraulic rotary drilling rig, and the Survey purchased the necessary water truck and trailer for the drilling tools. Thus equipped, test drilling became an important part of the investigations.

So numerous were the separate investigations, usually on the county basis, and so uniform the general pattern, that it is unnecessary to describe in detail each one, even if space limitation would permit. The basis of the county investigations was the mapping of the geology; the inventory of wells, collection of driller's logs, augmented by test drilling for additional information; determination of permeability by mechanical analyses of water-bearing materials; collection of pumpage records, either actual or estimated; establishment of observation wells connected with sea level datum and maintained subsequently; and collection of water samples for analysis by the State Board of Health. In some studies, pumping tests by the non-equilibrium method were made mainly in cooperation with the State Board of Agriculture. The necessary geologic studies were based not only on the data collected but also on previous studies in the areas concerned. Water-table contour maps and depth-to-water maps were made for each county. Beginning with the Scott County investigation, early in the period, it became the practice to show by contours the thickness of the saturated material, which was the distance from the upper surface of the water table to bedrock. In some counties, the thickness was too small for that procedure. When completed, the results were published as bulletins by the State Geological Survey.

The magnitude of each investigation is summarized in the following table:

County investigations in Kansas

County	Fieldwork	Wells Inven- toried	Obser- vation Wells	Test Holes	Water Samples	State Bull- etin	Author
Ford	Oct. 1938 - Aug. 1939	531	37	21	65	43	H. A. Waite
Morton	July - Sept. 1939	158	19	11	36	40	T. G. McLaughlin
Meade	July - Sept. 1939; 1940	354	28	24	45	45	J. C. Frye
Stanton	July - Sept. 1939	147	17	11	36	37	B. F. Latta
Scott	Fall 1939; Summer & Fall 1940	282	29	23	30	66	H. A. Waite
Finney & Gray	Fall 1939; Summer & Fall 1940	543	53	28	55	55	B. F. Latta
Hamilton & Kearney	Sept.-Oct. 1939; Aug.-Dec. 1940	320	39	24	48	49	T. G. McLaughlin
Seward	July - Aug. 1940; also 1943	162	11	17	18	67	F. E. Byrne & T. G. McLaughlin
Grant & Haskell	May - Oct. 1941; Oct. 1942	227	30	30	51	61	T. G. McLaughlin
Kiowa	Summer 1941	101	7	18	30	65	B. F. Latta
Jewell	Aug. - Nov. 1941	250	52	11	36		V. C. Fishel & H. A. Waite
Stevens	July - Sept. 1942	129	9	9	26	61	T. G. McLaughlin
Thomas	6 wks. Summer 1942; 2 wks. in 1943; 1 wk. in 1944	115	10	29	24	59	J. C. Frye
Republic & N. Cloud	Summer 1942	291	9	113	51	73	V. C. Fishel & S. W. Lohman
Pawnee & Edwards	Summer 1944 & 1945	360	9	133	71	80	T. G. McLaughlin
Norton	July - Aug. 1945	285	15	64	45		J. C. Frye
Barton & Stafford	3 mos. 1942; 3½ mos. 1944	382	21	106	95		B. F. Latta

In addition to the counties listed in the preceding table, similar investigations were made in Barber, Kingman, and Rice Counties, but as the reports were not completed, the detailed information is not available.

The investigation of Republic and Northern Cloud Counties listed on the preceding table was made at the request of the Bureau of Reclamation which, in connection with its surveys in the Republican River Basin, was interested in the feasibility of irrigating some of the area from ground water. Preliminary surveys by the Bureau, including the drilling of 5 test holes, had indicated that possibility.

During the war years, the regular program was interrupted by the necessity for making numerous but brief investigations of small but extremely important areas. A few of the more important are described.

The first was a brief reconnaissance of ground-water resources in southeastern Kansas and adjacent areas in Missouri and Oklahoma, made at the request of the Kansas State Chamber of Commerce. Its purpose was to obtain a geologic report on ground-water resources of that area for presentation to the War Department, in connection with a proposed series of integrated defense plants requiring large ground-water supplies. The reconnaissance was made by G. E. Abernathy, a State employe, early in 1941, and was based chiefly on information obtained from various sources in that area. The report was published in Bulletin 38, "1941 reports of studies."

In January 1942, the architect-engineer team constructing the Kansas Ordnance Plant near Parsons, requested the Survey to cooperate in making test borings at proposed dam sites along the Neosho River, and also in making an investigation for a possible ground-water supply in the Neosho River Valley; subsistence for the drilling crews was to be furnished as well as the additional labor required. The investigation was made by C. C. Williams. During the field work, which lasted from January 15 to February 9, 1942, 8 test holes were drilled at the proposed dam sites, 4 observation wells established, and a pumping test on one well lasting 98 hours, made by the contractor under Survey supervision. For that test, 7 observation wells were drilled nearby. Both the equilibrium and non-equilibrium methods were used in computing the results, and those were found to be in substantial agreement. To obtain additional data for the water-table contour map, 18 holes in the alluvium of the river valley were bored by hand auger in October 1942. The results were published as Bulletin 52, part 2, "Ground-water conditions in the Neosho River Valley in the vicinity of Parsons, Kansas."

As an aid in solving ground-water problems during the war years, S. W. Lohman and his staff in 1942 prepared a report calling attention to the availability in Kansas of large ground-water supplies of satisfactory chemical quality for many national defense industries. The report also contained a chapter on surface water supplies by the Surface

Water Division. A companion report called attention to the large quantity of ground water of good quality in south-central Kansas. Both reports were published as Bulletin 41, "1942 reports of studies."

An investigation of a 7-mile area of the Kansas River Valley in the vicinity of Kansas City, Kansas, although not specifically requested by war agencies, may be considered a war-time activity. The steady increase in the demand on ground water in the area was sharply accelerated by the increased use by old industrial plants, and still more by many large new war plants. The investigation was started in July 1943 by V. C. Fishel, who spent 2 months making a well inventory of about 110 wells and gathering other available data. The outstanding feature of the investigation was the pumping tests made in January and February 1944 by the Army Engineers in which the Survey participated. Not only was a well drilled solely for the pumping test, being filled in later, but 38 nearby observation wells were also drilled. A series of 18 tests were made. The results of the investigation were published as Bulletin 71, "Ground-water resources of the Kansas City, Kansas area."

Similarly, an investigation in the Smokey Hill Valley, in which two important military establishments and several important cities were located, although not specifically requested, was a war-time activity as its purpose was to obtain the answers to questions which were certain to be asked. It was made chiefly during the summer of 1943 by B. F. Latta. The nature and thickness of the water-bearing material was determined, inventories made of 98 wells, and samples from 55 wells analyzed. During the following winter, 109 test holes were drilled and in the spring, the Bureau of Reclamation cooperated in putting down 11 small observation wells.

A similar investigation of the Arkansas Valley in Sumner and Cowley Counties was made during 1943, by C. C. Williams, which included drilling of 143 test holes and collection of 43 water samples for analysis. The information obtained was furnished the War Production Board and other agencies, in connection with the location of war industries.

Several investigations were not classifiable as County investigations. The first was a brief investigation made by J. C. Frye in Atchison County in June 1940, at the request of the agricultural agent. A prolonged drought during the winter and spring had caused serious deficiencies in rural water supplies, and additional areas for ground-water supplies were sought. The second investigation was that for a ground-water supply to replace the surface water supply for the city of Lawrence, made at the request of the City Water Department. It was made by S. W. Lohman. During the field work, which lasted from October 30 to December 23, 1940, 29 test wells were drilled, well inventories from 16 wells, mechanical analyses of water-bearing material, and water samples from 34 wells analyzed. Both reports were published as Bulletin 38, "1941 reports of studies." The third investigation was that of the oil-field areas in Russell and Ellis Counties, made by J. C. Frye and J. J. Brazil, a State employe, in the summer of 1941. Outcrops of the water-bearing formations were studied and their thickness measured; 7 test holes were drilled; 232 wells were inventoried, and samples from them analyzed for chloride content; and mechanical analyses made of water-bearing formations. The results were published as Bulletin 50, "Ground-water in the oil-field areas of Ellis and Russell Counties, Kansas." An investigation was made in 1944 by T. G. McLaughlin at the request of the officials of Russell for the purpose of determining whether a satisfactory ground-water supply was available. As the surface-water supply was contaminated by oil-well brines through underground percolation, the results were included in "Ground-water supplies at Hays, Victoria, Walker, Gorham, and Russell, Kansas." A small oil field, known as the Whelan pool in Barber County, was a potential source of contamination, and the State Board of Health requested an investigation of a small area in the lower part of Elm Creek Valley to determine the extent of oil-brine contamination in the ground-water. C. C. Williams and C. K. Bayne, a State employe, made the investigation from August 1 to September 12, 1945, during which 25 test holes were drilled, 48 wells including the test holes inventoried, and 51 samples collected for analysis. The results were published as Bulletin 64, pt. 3, "Ground-water conditions in Elm Creek Valley, Barber County, Kansas."

In the fall of 1945, an investigation of the Arkansas Valley in the vicinity of Hutchison was made by C. C. Williams at the request of that city. The City contracted for the drilling of 32 test holes under Survey supervision, and the Survey drilled 7 additional ones. Records from 96 test holes and wells, and pumpage records, were collected; mechanical analyses of water-bearing material was made for permeability; and geologic studies were made. Chemical analyses of 63 water samples were also made. The results were published as Bulletin 64, part 5, "Ground-water conditions in Arkansas River Valley in the vicinity of Hutchison, Kansas."

The Bureau of Reclamation was making a study of irrigation possibilities in Kansas, and in connection with the proposed Cedar Bluff Reservoir, wished to know whether the present and future needs of the towns of Hays, Victoria, Walker, Gorham, and Russell, could be supplied by ground water, or whether provision must be made to utilize reservoir water. The Survey was requested to make an investigation as a part of the Missouri Basin-Departmental Program. It was made in April 1946 by B. F. Latta, who supervised the drilling of 27 test holes, and made the usual well inventory. As a result of the investigation, it was concluded that large supplies of ground water do not exist in the area. The report was published as Bulletin 76, pt. 6, "Ground-water supplies at Hays, Victoria, Walker, Gorham, and Russell, Kansas."

Through the description of the various years' investigations are found references to the so-called "equus beds" which cover a broad area between the Smokey Hill and Arkansas River Valleys. That formation had long been considered as a possible new source of supply for Wichita, the largest city in the state, whose ground-water supply on account of its poor chemical quality was unsatisfactory. The investigation made during the previous period[262] had resulted in a new well field in that formation 20 miles northwest of the city, first used in September 1940.

The study for Wichita's new supply covered only a part of the important formation, and the investigation of the "equus beds" was continued during most of the period; not being confined to one or two counties, it was not classed as a county investigation. All of McPherson, nearly all of Harvey County, and smaller parts of Sedgwick, Reno, and Marion Counties were included in the investigation made by C. C. Williams and S. W. Lohman, which was concluded in 1946. Including the results of the Wichita investigation, detailed geologic studies of the various formations in the area were made, 720 wells inventoried, 161 test holes drilled, and the logs of those wells and test holes collected; in addition, 229 chemical analyses of ground waters were made. The report which also contained a geologic map, water-table contour maps, maps showing lines of equal change in water level on several dates from June 1940 to October 1944, cross-sections of the area test drilled, and a map showing distribution of chloride in ground waters was published as Bulletin 79, "Geology and ground-water resources of a part of south-central Kansas, with special reference to the Wichita municipal water supply."

During the period, the observation-well program was increased from 181 wells to about 500 wells, 12 being equipped with recorders.

S. W. Lohman was in charge of the Kansas investigation until August 14, 1945, when he was succeeded by V. C. Fishel, who came to the district August 10, 1941.

Other Federal Civil Service technical personnel:

Name	Period
H. A. Waite	July 1, 1939 to July 31, 1942
J. C. Frye	July 1, 1939 to Dec. 31, 1941 1/
W. W. Wilson	Apr. 17, 1941 to June 30, 1947
C. C. Williams	Oct. 25, 1941 to Apr. 1, 1947
B. F. Latta	July 7, 1942 to June 30, 1947
D. W. Berry	Jan. 21, 1946 to June 30, 1947
T. G. McLaughlin	Apr. 27, 1942 to Sept. 30, 1945
A. R. Leonard	Feb. 2, 1946 to June 30, 1947
M. H. Rush, Jr.	Apr. 12, 1946 to June 30, 1947

The district clerk was Mrs. Ruth Wilson until February 1942, Mrs. Fern Ashby until September 19, 1945, and Mrs. Wilma Howard for the remainder of the period.

262/ p. 321 (1928-1939).

1/ Accepted appointment with State Geological Survey.

Oklahoma.- Of the three counties comprising the Panhandle investigations, two had been completed during the previous period. The investigation of Beaver County was started in July 1939 and like those in the other two counties, it included a study of the outcrops of water-bearing formations and an inventory of 822 wells, the measuring points for which were connected with sea-level datum. Except for certain geologic features, the investigation was completed and the geologic studies interrupted by the war, were not completed during the period. Unlike the later investigations, those three were areal surveys, as funds were insufficient for quantitative studies.

Although a number of investigations destined to become county-wide were started, the necessity for making special studies and reports during the war years prevented the completion of any additional county investigations during the period.

In 1939, as a result of inquiries from City officials and others interested, an inventory of the wells and pumping records in Norman were made, a few pumping tests made, and a report made to the city. In the fall of 1942, two large navy bases were established, one north of the city and one south of it. Both were pumping from the same ground-water reservoir, with the result that the water levels in the Norman well field between the two navy base well fields dropped nearly 200 feet within a year. The City of Norman wished to drill additional wells and the WPB requested the Survey for a report. Early in 1944, the Survey made a dozen pumping tests on wells at both navy bases and in Norman, and about 50 water samples were analyzed. As a result, the City drilled additional wells and obtained a larger supply. The wells investigated were all in the Garber sandstone and Wellington formation. In the same area, an investigation of the possibilities of the alluvium in the Ten-Mile Flat area of the Canadian River Valley was made for the Navy. In addition to a well inventory, a pumping test was made and 6 water samples analyzed. That investigation was considered the beginning of the Cleveland County project.

In July 1941, an investigation of the underflow in the North Canadian Valley above Oklahoma City was started. The Oklahoma Planning and Resources Board was considering the adjudication of the water rights, and wished to know whether the underflow was sufficiently large to be considered. By hand auger, 52 wells were put down and the observation from those, together with observations from a few existing wells, made it possible to plot the ground-water contours; 35 test holes totaling 2,000 feet were drilled by contract. Several pumping tests on El Reno city wells were made and the permeability also determined in the laboratory, using variable-head apparatus. The investigation, completed in 1943, showed the underflow to be relatively small.

A critical situation was developing in Oklahoma City in 1943. A large airbase and an aircraft manufacturing plant outside the city had their own supplies, but the large influx of workers lived in the city and were dependent on the city supply. The city reservoir was nearly empty and as plans were made to drill additional wells, the WPB requested the Survey for an opinion as to the adequacy of those plans. A reconnaissance survey was made, including the installation of a recorder on one well to check the drawdown, and a report made that the plans were satisfactory. Perhaps it was fortunate for the Survey's reputation that soon afterward, heavy rains replenished the storage supply.

The Ottawa County investigation was started in 1944 as the result of a WPB request. The City of Miami was drilling wells for the Goodrich Company Tire Plant, and the Survey made an investigation to determine whether sufficient water for the plant could be obtained. The city had just completed drilling the wells, and 5 pumping tests on them were made. These tests showed that the full amount originally required could not be obtained from the wells. Accordingly, the requirements were reduced and methods of reuse of water were installed. A well inventory of the area was made and water samples collected, and the investigation was expanded to cover the entire county. It was in progress at the end of the period.

During 1944, the Ground Water Division was called upon to prepare a section on Oklahoma ground-water resources for the publication "Oklahoma Water," being sponsored by the State, and had a separate allotment for that purpose.263/ To obtain information on an important aquifer for which the data were inadequate, a pumping test to determine the transmissibility was made, and inventories of a number of public ground-water supplies were made to supplement the inventories furnished by the WPA, the more important of which were checked.

With an increase in personnel, it was possible to start the Grady County investigation in August 1945. It was a study of an important aquifer in a region where the surface water supply is scanty and of a very poor quality. While the investigation was in progress, the City of Chickasha in the spring of 1946 was looking for a better water supply than that from the Washita River. The Survey made pumping tests on the airport well, and on a well at Ninnekah, a few miles distant, on the same formation underlying Chickasha, but neither tests showed sufficient water. The county investigation was resumed and considerable geologic mapping was performed. The investigation was in progress at the end of the period.

Four investigations not resulting in county reports during the period were made. One on the special investigations being made for "Oklahoma Water" in 1944 was near Tipton where a pumping test of the irrigation well at the Southwestern Cotton Substation was made. From logs furnished by an oil company, a gravel-filled channel in the terrace deposits in the Tipton area was partially mapped. As that town was searching for an additional supply, the Survey advised test drilling an area to the westward where the channel should be. The test drilling confirmed this

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263/ p. 211.

and later, the City drilled two supply wells and obtained an abundance of water.

The City of Duncan that same year requested help in finding an additional supply. The Survey made pumping tests and found the coefficient of transmissibility so low that another source was advisable. The only other known ground-water source was test-drilled and an unsuspected shale formation was encountered which was also unsuitable. The city finally had to turn to a lake supply.

The construction of the Altus-Lugert Reservoir by the Bureau of Reclamation made it necessary to drain the reservoir supplying water to the City of Altus. The reservoir, because of the drought in 1943, failed to refill, creating a critical shortage of water in the city and at the Army Airbase. The Airbase, needing a water supply, requested the Survey to investigate the available supply and 5 wells were drilled. Pumping tests were made and the supply was found to be of very poor quality and limited in amount. Soon afterward, fortunately, the critical situation was relieved by rains which replenished the city's storage.

The final investigation was for the City of Durant, made in the fall of 1946. Desiring to change from a surface water supply to one from ground water, the city drilled 7 wells and then asked the Survey to investigate. Three pumping tests were made which indicated that the supply was sufficient.

In addition to the requests leading to the special investigations described, there were nearly 500 inquiries from municipalities, industries, and individuals. The others were answered by letter, giving such information as was available, or by brief reconnaissance where necessary.

S. L. Schoff was in charge of the Oklahoma investigation, except during his military furlough from July 17, 1942 to April 29, 1946, when E. W. Reed carried on.

Other Civil Service technical assistants were:

Name	Period
Thomas McCauley, Jr.	Sept. 30, 1941 to Dec. 20, 1941
E. W. Reed	Jan. 9, 1942 to June 30, 1947
D. W. Schacht	July 1, 1942 to Sept. 26, 1942
C. L. Jacobsen	Oct. 5, 1942 to May 20, 1945
P. K. Sutherland	Dec. 27, 1943 to May 23, 1945
G. L. Oakland	Sept. 11, 1944 to Dec. 15, 1942

Texas. - At the beginning of the period, there were five projects under investigation, the High Plains Investigation, the Pecos River Joint Investigation, the special investigations in the Houston-Galveston area, the state-wide investigation by counties, and the observation-well program. As Texas was an area of intense war activity, both by military and industrial establishments, practically all the time of the entire personnel during the first two years of the war was devoted to answering the many requests for information, involving in some instances special investigations and pumping tests. With the exception of the Pecos River Joint Investigation, which was discontinued early in the period, the projects that had been started in the previous period were continued. Two new projects were started, one to collect basic data for all public-water supplies in the state, and the other, an investigation of the Pecos River Valley to bring down to date the data that were collected during the Joint Investigation.

The Pecos River Joint Investigation 264/ in the Texas portion of the Pecos River Basin included ground-water investigations which were started in July 1939 by J. W. Lang and P. E. Dennis, under A. N. Sayre's general supervision, and the field work was completed in December 1940. An inventory of some 900 wells and springs was made and a study made of the drillers' logs of wells drilled for tests for oil and gas. In the irrigated districts, about 1,200 auger holes were put down and readings of the water surface in them were taken at regular intervals, and the relative elevation at the surface of many of them were obtained either by spirit leveling or barometrically. Maps of the irrigated districts were compiled, showing the areas of different depths to ground water and the slope of the water table, and a limited amount of geological work was performed. A report covering the investigation was prepared by C. V. Theis, A. N. Sayre, and others, was published by the National Resources Planning Board. 265/

Perhaps the most important, and certainly the most intensive, investigation during the period was the second phase of the Houston investigation, started in the fall of 1938. The first phase of the investigation in the Houston area, which was completed in 1933, had indicated that the ground-water supply was sufficient for immediate needs at that time. However, early in 1937, the pumpage was increased about 40 percent when new wells near Pasadena were placed in operation, and the decline in water levels was so rapid that fear was again felt for the adequacy of the ground-water reservoir. The City of Houston contributed $5,000 to the cooperating State agency for a second investigation and that was started in the fall of 1938 by C. R. Follett and N. A. Rose, with headquarters established in Houston. In the spring of 1939, W. F. Guyton was assigned to the investigation, and remained at Houston until the fall of 1941 when he was assigned to a special investigation in the Lufkin-Nacogduches district.

The field operations included the expansion of the observation-well net of 82 wells of the previous investigation to 185 wells; bringing the

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264/ p. 15.
265/ The Pecos River Joint Investigation: Reports of the Participating Agencies, June 1942.

previous well inventory up to date by including new wells, giving a total of 1,018 wells; compiling records of about 300 drillers' logs and about 200 electrical logs of wells that had been drilled by oil companies in the general area; and making pumping tests in 21 city-owned wells. An important part of the new work consisted of exploratory drilling in new territory, during which the City, between March 27, 1939 and August 6, 1939, under Survey supervision, drilled 13 deep test wells $5\frac{1}{2}$ inches in diameter, ranging in depth from 360 to 2,000 feet. The wells were electrically logged and the graphs thus obtained were compared with the drillers' logs, and the drill cores and drill-stem sand samples from the wells were mechanically analyzed. In the fall of 1939, pumping tests were made in 21 city-owned wells, under the direction of C. E. Jacob, to determine the coefficients of transmissibility and storage of the water-bearing beds. In addition, 46 shallow test wells in groups of 2 to 6 wells each, were put down in the outcrop area, and water levels in them were measured regularly in connection with studies of recharge. From available data, geologic profiles of the ground-water reservoir were prepared, as was also a map showing the approximate altitude of water levels in wells drawing from the most heavily pumped sands. A study of the location of areas or beds of sand containing salt water was made. Samples of water from some 60 selected wells were taken twice a year and analyzed by the Survey in the Austin laboratory. The second phase of the investigation was completed in 1940 and the results were published as Water-Supply Paper 889-C. A companion paper describing the exploratory drilling and studies made in connection therewith was published as Water-Supply Paper 889-D. The records of water levels in the observation wells and of pumpage were continued.

The Houston area was an important center of war activity, and the heavy draft on the ground-water was lowering the water level to the point where the War Production Board became alarmed over the effect of the decline in water levels on the operation of the existing wells, with reference to the depths below the land surface at which the pumps were set, and the capacity of the electric motors for the pumps. In most wells, the depths to pumping levels were unknown, and information regarding the character of the pumps and positions of the pump bowls was needed. The Survey was requested to make an investigation, which was done by N. A. Rose and W. T. Stuart during the period February to April 1943. That investigation was concerned with the pump settings and the pumping levels, and the data collected were more detailed in that respect than for any other city in the United States. 266/ A report covering the investigation was made to the War Production Board.

Investigations, chiefly of a routine nature, were continued in the Houston area, during which the observation wells were increased to 241, and samples from 30 selected wells were collected and analyzed annually. In November 1945, pumping tests were made on 6 wells drilled by the city in its new southwest well field. By using the average values of

266/ Unpublished report on war work of the Ground Water Division.

coefficients of transmissibility and storage obtained from the tests, computations of future water levels to be expected under various assumed rates of pumpage were made. From December 1944 to September 1945, the field operations were directed by N. A. Rose, assisted by W. H. Alexander, Jr. Mr. Rose was transferred to Arkansas and was succeeded by J. W. Lang.

Perhaps the second most important investigation that was made during the period was in the Galveston-Texas City-Baytown district which had been started in 1930 as a part of the Houston investigation and discontinued with that investigation when funds were no longer available. Like Houston, Galveston became concerned about its ground-water supply, owing to the increased draft by industry centering about Texas City and to its own increased pumping from the Alta Loma well field, all from a common ground-water reservoir; and in 1938, the City contributed funds to the State agency for a resumption of the cooperative investigation. The investigation included an inventory of 726 wells, an observation-well program of 15 wells, compilation of pumpage records, and a test-well drilling program which was done by the city. The City of Galveston, under Survey supervision, in 1941 drilled 4 test wells ranging in depth from 940 to 1,221 feet in the vicinity of the Alta Loma well field, and in 1941-42, drilled 12 test wells in an area north and northwest. Pumping tests were made. As a result of the latter exploration, the city drilled 6 wells from which most of its supply was later obtained. The new city wells were completed in 1942.

There were many smaller investigations which are described somewhat briefly. In August 1941, W. L. Broadhurst moved his headquarters from Plainview in the High Plains to Longview in northeastern Texas, and during the ensuing year, devoted most of his time to ground-water studies in the latter region. He made detailed investigations of the geology and the occurrence and development of ground water in Gregg, Harrison, and Marion Counties, and described the results in manuscript reports which later were mimeographed and are to be published as water-supply papers or contributions to geology. Each of the reports includes a section on surface water by Seth D. Breeding. Preliminary investigations, including water well inventories, were made in eight additional counties, of which five were covered by Mr. Broadhurst and three by Mr. Follett. It was planned to follow the preliminary work in these counties with more detailed studies but this had to be abandoned because of the urgent need for ground-water investigations, requiring the services of both Broadhurst and Follett, in other parts of the State--investigations which were largely connected with the War effort.

A second investigation was started in the Lufkin area by W. F. Guyton in 1941. The first investigation in 1936-37, described in Water-Supply Paper 849, had shown that the Carrizo sand offered opportunities for fairly large scale development. Following that investigation, the City of Lufkin drilled a well to the Carrizo sand for its public supply, six wells were drilled to the formation by the Southland Paper Mills, of which five were put into operation, and plans were made by the city of Nacogdoches to put down additional wells to the sand.

The earlier studies and subsequent drilling operations had shown that the Carrizo sand was of wide occurrence, that it was fairly uniform in thickness and character, and that it had known areas of outcrop. The aquifer, therefore, seemed well adapted for study by means of the Theis non-equilibrium formula. In August and September 1941, several pumping tests were made on their battery of wells by the Southland Paper Mills. The results of these tests were analyzed by Mr. Guyton and the coefficients of transmissibility and storage were determined. With these figures and application of the Theis formula estimates were made of the drawdowns to be expected in the wells themselves and at varying distances from them as a result of continuing pumping at the current rate, and for varying increases in the current rate. The results were summarized in a report by Mr. Guyton which was released in manuscript form in December 1941, and was published in the Transactions of the American Geophysical Union for 1942. 267/ Later, when the estimates of drawdowns were compared with the true drawdowns, shown by measurements in widely spaced observation wells, the average difference was found to be comparitively small.

During 1941-43, considerable attention was given to the Sparta sand in various parts of the territory between Lufkin and Nacogdoches. The outcrop of the sand was studied by Mr. Rose and a considerable number of test wells were put down and pumped under the partial direction of Guyton and Rose. The results of the investigation to the fall of 1943 were released in November 1943 in a manuscript report by Messrs. Guyton and Rose in November 1943.

Of the many war-time requests, descriptions of five resulting special investigations are presented.

Early in 1941, for Camp Swift, a site was selected about 3½ miles north of Bastrop. The site was excellent except for its water supply, where the nearest source of surface-water supply was the Colorado River, which was more than 2 miles away and about 200 feet lower in elevation. In the spring of 1941, the Survey made an investigation and reported that the facts seemed to justify test drilling and pumping at a selected location on the camp site. Accordingly, two test wells were put down and tested by pumping under the direction of R. W. Sundstrom in October and November 1941. The results were encouraging and a little later, five additional wells were put down. The wells ranged from 531 to 584 feet in depth and drew from sands in the middle portion of the Wilcox.

In June and July 1941, the seven wells were given systematic pumping tests under the direction of Mr. Guyton. At the time the tests were

267/ Pt. I, p. 40.

made, it was contemplated that the camp, which was originally designed to train 35,000 men, might be called upon to contain 50,000. The results of the tests were analyzed by means of the Thiem and Theis formulas and the tentative conclusion was reached that five of the best wells would stand continuous operation at the rate of 800 gallons a minute each. It was pointed out, however, that an elaborate set of assumptions had been made to reach the figures given in the report, some of which were unfulfilled, and that the results of the computations as given in rates of pumping and drawdowns might also be considerably in error. Therefore, it was recommended that water-level measurements be made in all the wells, and the pumpage from each well recorded once a day. This was done, and the figures were made available to the Survey. Later, two additional wells were drilled somewhat to the eastward of the first line of wells. It developed, however, that the five original wells were almost adequate for the needs of the camp, which ultimately contained about 45,000 men and the new wells were practically unused. Thus, an adequate supply of water of acceptable quality was obtained for one of the largest army camps in Texas.

As a result of a request by the Army Quartermaster Corps in September 1941 concerning the availability of 5 million gallons per day from wells in the vicinity of Killeen and Belton, for the water supply for a new camp (Camp Hood), an investigation was made by R. R. Bennett in October, during which an inventory of the wells and drillers' logs were collected, samples from 2 wells collected for analysis, and a brief geologic study made to supplement information on file. A report stated that it was not likely that the desired supply was available at the camp site. Wells for the camp supply were drilled several miles to the east of the camp site in the spring of 1942, and in September, the Survey was requested to make a pumping test of them. A series of 8 pumping tests between September 29 and November 4, 1942, was made under the supervision of W. F. Guyton and W. O. George.

In August 1942, at the request of the Army Engineers, who had succeeded the Quartermaster Corps in the construction of Army establishments, a reconnaissance survey for the availability of 4,500,100 gallons per day for the North Camp Hood Tank Destroyer Center was made by Mr. Sundstrom. He tentatively concluded that the required supply could probably be obtained from several properly spaced wells, to be confirmed by a test well several miles southeast of Gatesville; that an accurate drillers' log be kept, the well to be electrically logged on completion and a pumping test made. The test well was drilled in October and a pumping test was made under Survey supervision. Nine wells were subsequently drilled and a series of pumping tests made between January 16 and March 19, 1943, also under Survey supervision.

The investigation of the Big Spring area made in 1937 and 1938 268/

268/ p. 329 (1928-1939).

had shown little possibility of developing additional ground water of good quality and had suggested that a surface-water supply be sought. Accordingly, two reservoirs to store surface water were constructed a few miles from Big Springs. By 1943, both reservoirs were empty and as a State hospital and a large Army Air Base had been recently constructed, and the population increased by war activities, the demands on the water supply was so great that a critical situation arose. The City and the Army Engineers, in the fall of 1943, requested the Survey to make an investigation of the possibility of obtaining ground water in the valley of the North Fork of Concho River, 20 to 30 miles distant. J. W. Lang made the investigation which was completed in May 1944. Eight test wells were drilled by the city in the valley area recommended, and pumping tests made on 7 wells to determine the drawdown. An additional supply limited in quantity was obtained.

The Celanese Corporation was constructing a plant near Bishop, and its ground-water supply, increasing the draft on the fresh water sands near the coast, required approval by the War Production Board. The Survey was requested to make an investigation and Mr. Sundstrom made a reconnaissance in June 1944 and recommended that pumping tests in the existing wells be made. Tests on 4 wells were made a month or so later under his supervision.

An investigation, indirectly associated with war activities due to the war-time increase in population, was made for the City of Bryan in 1944. The City considered the drilling of additional wells and requested the Survey for further help, as 5 wells had been drilled as a result of an investigation made during the previous period. 269/ Pumping tests on those wells were made between June 15 and July 4, 1944, under the supervision of Mr. Sundstrom. The results of the pumping test showed that the city would be safe in drilling an additional well in the field without danger of unwatering the artesian sands from which the wells were drawing water.

With the rapid increase in ground-water use, the need for certain basic information relative to all public water supplies, became so urgent that in 1944, a project was started to collect for each public water supply, itemized data on its source, amount of water consumed, storage facilities, number of customers served, and the chemical character and treatment of the water. Where the source was ground water, records of drillers' logs were compiled; also the character of pumping equipment, well yield, record of water levels, and water temperature. During the period, the State agency published that information as "Public water supplies in central and south-central Texas," "Public water supplies of eastern Texas," and "Public water supplies of southern Texas." 270/

In the Pecos Valley, nearly as much land is irrigated from ground

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269/ p. 330 (1928-1939).
270/ The latter was also published as Water-Supply Paper 1047.

water as from the Pecos River, and when the Bureau of Reclamation was making its investigations in 1946, it contributed $6,000 to the Survey for further studies in Pecos and Reeves Counties. That investigation was started in the fall of 1946, by D. B. Knowles and J. W. Lang, for the purpose of bringing together available data on ground-water developments to date, with especial reference to irrigation from wells near Pecos; also to record the effects of past and present withdrawals on the ground-water supply and if possible, to determine the future limit of well irrigation. This was largely a well-inventory program, during which records of nearly 600 wells and springs, 191 drillers' logs, and records of pumpage from nearly all wells, 29 being measured by current meter, were collected. As much of the area had been geologized previously, the geologic study was largely of a supplemental nature. As the suitability of water for irrigation depends largely on its sodium content, chemical analyses of 522 wells and springs were made by the Austin laboratory. The investigation continued beyond the present period. The results to July 1947 were published by the State agency as "Preliminary report on geology and ground-water resources of Reeves County," and "Records of wells and springs in northern Pecos County."

In the fiscal year 1946, the Bureau of Reclamation was making a survey of irrigation possibilities in the lower Rio Grande Valley and in connection with a proposed large international reservoir between Laredo and Rio Grande City, desired a report on the ground water in the area to be covered by the highline canal in Hidalgo and Cameron Counties. G. H. Cromack and W. L. Broadhurst made an investigation in 1944-45 and the results were released to the Bureau of Reclamation in 1945.

An investigation of the geology and ground-water resources of Comal County was started in 1941 by R. R. Bennett, and taken over by W. O. George in September 1943. The study was interrupted repeatedly by work relating to defense and war projects and was not completed until 1946. The investigation comprised part of the study of the discharge, recharge, and movement of ground water in the Balcones fault zone. The discharge of springs from the Edwards limestone in this zone, which is about 250 miles in length, averages about 400 million gallons a day. Of all the springs, the Comal Springs are the largest; in fact, they have the largest average flow of any known springs in the southwestern part of the United States. The principal purpose of the investigation in the county was to determine the source of the water that issues from the Comal Springs.

The results of the investigation are described by Mr. George in a report which was released in mimeographed form in February 1947, and is to be published later as a water-supply paper. The report includes a section on chemical character of water by W. W. Hastings and a section on surface-water runoff by S. D. Breeding.

The occurrence and development of ground water in the San Antonio area, Texas down to 1934, is described in Water-Supply Paper 773-B. In the summer of 1946, Penn Livingston, assisted by Jack Barnes, made a second investigation in the area to bring the record down to date. It was found that although the total discharge of ground water in the area was about 155 million gallons a day in 1946, compared with 97 million gallons a day in 1934, the artesian pressures nevertheless showed no net decline; in fact, they averaged slightly higher in 1946 than they were in 1934.

A report entitled "Ground-water resources of Bexas County, Texas," summarizing the results of the current studies and long-time observation of water level fluctuations in wells was published in mimeographed form in May 1947.

W. C. Rasmussen employed most of his time during 1946 in a field investigation and preparation of a report relating to the geology and ground-water resources of Caldwell County in south-central Texas. The report was released in mimeographed form in May 1947, and later is to be published as a water-supply paper.

The High Plains occupies an area of about 35,000 square miles and covers parts or all of 45 counties in the western part of Texas. In a large portion of the area, irrigation from ground water, since the dry years of the nineteen-thirties, has increased at an unprecedented rate. The investigation of that area was started with a PWA grant in 1934 and became a part of the State cooperative program in 1937. The area was so vast and the need for basic data so great that the studies, usually by county units, were confined largely to well inventories, changes in water levels as shown by observation wells, records or estimates of water pumped, and water analyses. Later investigation included geologic studies with reference to thickness and character of water-bearing sands, source of ground water, and recharge and discharge of the underground reservoir.

A special investigation on the High Plains beyond the county unit was made in 1938 and 1939. It was a study of the ground-water discharge along a 75-mile stretch of escarpment extending southward from Quitague Creek to Double Mountain Fork of the Brazos River. The flow from all known springs and seeps were estimated, and the larger ones mapped; all losses of ground water by evaporation and transpiration not accounted for otherwise, were estimated. The total ground-water discharge in that stretch was estimated as about 19,000 acre-feet annually.271/

From the beginning of the state-wide investigations by counties to the end of the period, studies had covered in some degree 33 counties, and 7 progress reports were issued, 6 being mimeographed reports by the State agency, and 1, Water-Supply Paper 889-F, published by the

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271/ Water-Supply Paper 889-F, p. 390.

Survey. In addition, detailed investigations of local areas in the vicinities of Amarillo, Borger, Denver City, Etter, Lubbock, Midland, and Seagrams were made.

The program of systematic observations of water levels in wells which was started in the Winter Garden district in 1929 was gradually expanded to state-wide proportions in the 1930's. At the end of the period, a total of about 1,200 wells were under observation.

W. N. White continued in charge of the Texas investigations and had the following Civil Service technical assistants:

Name	Period
S. F. Turner	July 1, 1939 to Aug. 20, 1939
Penn Livingston	July 1, 1939 to June 30, 1947
N. A. Rose	July 1, 1939 to Dec. 31, 1945
W. F. Guyton	July 1, 1939 to Aug. 28, 1943
R. W. Sundstrom	Aug. 20, 1939 to June 30, 1947
R. R. Bennett	July 1, 1939 to Aug. 15, 1942
P. E. Dennis	Oct. 2, 1939 to July 1, 1941
W. O. George	Jan. 2, 1940 to June 30, 1947
W. H. Alexander	Oct. 15, 1941 to June 30, 1947
W. L. Broadhurst	Mar. 5, 1942 to June 30, 1947
J. W. Lang	June 1, 1943 to June 30, 1947
W. C. Rasmussen	Jan. 4, 1946 to Sept. 15, 1946

There were no military furloughs.

Mrs. Margaret Petmecky was district clerk until September 30, 1942, and Mrs. Alice Lee from September 1, 1943 to February 15, 1945.

Wyoming. - Ground-water investigations were started in November 1940 by T. W. Robinson who was in charge of similar investigations in Iowa and South Dakota. The Pine Bluff area in the southeastern part of the state was selected, as ground water was being increasingly used for irrigation. A well inventory was made with the usual geologic study, and 29 wells were selected as observation wells for monthly measurements except two, which were equipped with recorders. In the summer of 1941, the Survey in cooperation with the local office of REA, measured the discharge and power consumption of 23 electrically operated pumping plants in the area. By so doing, an approximate check on the quantity of ground water withdrawn by those pumps was maintained by computing well pumpage from the electrical energy used. In August 1942, the investigation was expanded to include all the southeastern part of Laramie County, with special reference to the well-irrigation area near Carpenter. In March and April 1943, a test-drilling program in the Pine Bluffs area which consisted of 34 wells in 4 north-south lines across Lodgehole Creek Valley, ranging in depth from 20 to 185 feet, a total of 2,400 feet being drilled, was undertaken. Thirty of those wells, later reduced to 20 wells, were kept open and were used as observation wells in addition to the 29 wells selected when the investigation was first started. The investigation was completed in 1946, and thereafter only the routine observations showing the effect of increased pumping were continued.

When the Wyoming investigations were started, C. V. Theis, R. C. Cady, and T. W. Robinson made a brief investigation for the City of Cheyenne and measured a few wells, but it was not until June 1941 that the city requested an investigation for an additional water supply which was needed both for the military establishment near the city and for the increased population of the city itself, due to the war activities. The city supply consisted of a surface-water supply which could not be increased without going far afield, and a rather small ground-water supply, which it was hoped could be enlarged. Forty-nine wells were selected for regular observations. During the following year, observations were continued on 43 wells and begun in 19 other wells, 10 of which were near Federal, 24 miles northwest of Cheyenne. Of those, the city had drilled 4 during the latter part of 1942 to test the ground-water possibilities of that area. Those wells, when tested, proved disappointing and were not used as a part of the city system, and their periodic observation was discontinued. In 1945 and 1946, the city drilled 10 additional wells near its wells field; five were considered to be failures and the other five, although considered to be a success, were not connected with the City system. The periodic measurements in the city-supply wells and in other selected observation wells were continued. Two progress reports were issued, one by F. C. Foley in 1943, and the other by A. M. Morgan in 1946, covering the results from 1943 through 1945.

In May 1942, the City of Laramie was seeking an additional water supply and requested the Survey to determine the available ground-water resources. Its water supply was obtained from two springs and three wells. Work was started at that time, and the well inventory included about 50 wells, a majority of which were used as observation wells. A study of the recharge to, and the discharge from, the Casper formation, the source of the ground water, was also made. The investigation was completed with the field season of 1943, as the city had decided in the meantime to seek a surface-water supply.

In March 1943, the ground-water investigations were extended to the southern part of Goshen County. The geology was mapped and the water-bearing beds identified and their distribution determined. The water levels in many existing wells were measured and the elevations of the ground level at the well determined. A shortage of funds made it necessary to discontinue the investigation before the basic field work was completed.

A preliminary field investigation at Rawlins was made during May and June 1946. The investigation was made at the request of the U. S. General Land Office and the State Engineer to determine whether the drilling of oil wells in the area adjacent to the springs supplying the City of Rawlins, would affect the flow of those springs. Other brief investigations were made for the towns of Ranchester, Glendo, and Kaycee in 1946. Analyses of water samples were made in the Albuquerque laboratory until the establishment of the Lincoln laboratory in 1946, when the subsequent samples were sent there for analysis, as the Wyoming investigations were in the Missouri River Basin.

Mr. Robinson remained in charge of the Wyoming investigations to which he could only devote a part of his time, until June 11, 1941, when F. C. Foley was assigned to the Wyoming investigations with headquarters at Cheyenne. He remained in charge until August 2, 1942, when he entered the Army. A. M. Morgan, who had been assigned to the Laramie investigation May 19, 1942, succeeded him and remained until January 26, 1946. Other technical personnel were:

Name	Period
J. B. Graham	July 27, 1942 to Sept. 16, 1943
D. A. Warner	Sept. 8, 1945 to June 30, 1947
R. J. Littleton	Feb. 25, 1946 to Apr. 15, 1946 and
	Apr. 2, 1947 to June 14, 1947

When the Denver Office was established by S. W. Lohman in August 1945, the Wyoming investigations came under his supervision. Previously, those investigations had long-range supervision from Washington.

Colorado. - When cooperation became effective for the ground-water investigation in July 1945, S. W. Lohman was given charge and he established headquarters in Denver in August 1945.

Two areas were selected for the first investigations, the Big Sandy Creek area near Limon in the eastern part of Colorado, and the sump-drain feature of the San Luis Valley project, which was of long standing.

The Big Sandy Creek project was started with a reconnaissance by Mr. Lohman in September 1945, and field work started by T. G. McLaughlin in October. The investigation included an inventory of 171 wells, the supervision of 39 test holes put down by the State agency, and the collection of many logs furnished by local drillers. Chemical analyses of water from 30 representative wells were made in the Albuquerque laboratory. The geologic mapping covered 1,440 square miles, with special reference to the development of irrigation by ground water in the Big Sandy Creek Valley above Limon. Field work was completed in September 1946 and the results were published in November 1946 by the Colorado Water Conservation Board as Bulletin 1 of its Ground-Water Series, "Geology and ground-water resources of parts of Lincoln, Elbert, and El Paso Counties, Colo."

The San Luis Valley sump-drain study was one that had been made by various agencies for many years in connection with the possibility of increasing the flow of the Rio Grande. An area of 2,300 square miles in the northern part of the San Luis Valley lies in a closed basin, and studies had been made to construct a subdrain from the low point of the closed basin to the Rio Grande, and to estimate the quantity and quality of the ground and surface water which could be made available in that manner.

In connection with an intensive investigation of the San Luis Valley, the Bureau of Reclamation was considering the sump-drain study. The Colorado Water Conservation Board was much interested in this project, and its director appointed a second Closed Basin Committee consisting of R. J. Tipton of the Water Conservation Board, D. M. Forester of the Bureau of Reclamation, and S. W. Lohman of the Survey. At a meeting held in Monte Vista in October 1945, the details of the cooperative agreement were worked out, whereby the Bureau assumed the major cost of the ground-water investigation, including the drilling and test-pumping of about 33 test wells, putting down some 200 shallow observation wells, running level lines to all the wells, making the observation-well measurements, and collecting the water samples. The Bureau also was to pay the Quality of Water Division for analyzing the water samples. The Survey was to supervise the test drilling and pumping tests, geologic logging of all wells, compute the quantity and quality of the water to be expected from the sump drain.

The test drilling was not started by the Bureau until April 1946 at which time, W. J. Powell and W. K. Bach were assigned to the project. Thirty-three test wells were drilled and pumping tests were made. The field work was completed in November 1946. During the investigation, both Mr. Lohman and Mr. McLaughlin made frequent inspection trips. The data obtained will be included in a later report with that obtained from a detailed study of the adjacent irrigated area.

As is usual during ground-water investigations, there were requests from a number of communities for help in obtaining additional water supplies. The City of Craig was considering an additional supply from deep artesian wells. Mr. Lohman's investigation indicated that a deep artesian supply would be insufficient and of poor quality, and an enlargement of the supply from the Yampa River was advised. The town of Dove Creek was contemplating deep drilling for a water supply but Mr. Lohman's investigation indicated that the needed supply could be obtained from properly developed shallow wells in the alluvium of a small intermittent stream near the town. Three wells were put down which yielded about twice the amount expected.

In connection with the Big Sandy Creek investigation, it was discovered that the wells supplying Limon were improperly located with the result that the water supply had been short for many years. Within a deeper channel south of the present wells, more productive sand and gravel were found, and two new wells were drilled in that channel.

The City of Eads was desperate for an adequate water supply and had drilled a 1,200-foot well to the Dakota sandstone where salt water was found. It was planned to drill an even deeper well at a cost of many thousand dollars when the Survey's advice was requested. A brief field investigation showed the futility of further deep drilling, and shallow test drilling in several nearby areas underlain by promising thicknesses of sand and gravel was recommended.

An investigation of the Grand Junction artesian basin, which is a valuable source of limited supplies of artesian water for domestic use, was begun in July 1946. A reconnaissance of the geology and recharge area was made, including an inventory of all flowing wells. Detailed head and flow tests were made on many wells, using an improved ink-well mercury gage specially designed for the project 272/, and levels run to all of them. The investigation was not completed by the end of the period as it was planned to map the geology in detail and continue the hydrologic studies.

As a part of the Missouri River Basin-Departmental Program, the Bureau of Reclamation desired an investigation of the South Platte River Valley between Kersey, Colo. and Paxtun, Nebr. Although plans had been made some months before, the impossibility of obtaining an engineer prevented the investigation being started until April 1947. Headquarters were established in Fort Morgan, Colo, with L. J. Bjorklund in charge, assisted by R. T. Littleton, who made the geologic studies. W. E. Code of the Colorado A & M College, Fort Collins, had for several years been collecting records on about 1,000 irrigation wells and to avoid duplication, copies of those records were obtained. Then an active field inventory of the wells in Morgan County was begun and observation wells were established. Many logs were obtained from local well drillers, and from a study of those logs, tentative locations for test holes to be drilled in June were made. A contract had been let for the drilling of 5,000 feet of test holes, to begin before the close of the fiscal year. R. T. Littleton resigned in June and to have a geologist supervise the test drilling, which began June 25, Howard Haworth was borrowed from the Lincoln Office.

At the end of the period, 60 observation wells were being maintained, of which 3 were in the country-wide net of key wells.

S. W. Lohman continued in charge of the Colorado investigations and also those in Wyoming.

The Civil Service technical assistants in Colorado were:

272/ p. 225.

Name	Period
T. G. McLaughlin	Oct. 1, 1945 to June 30, 1947
W. J. Powell	Dec. 3, 1945 to June 30, 1947
W. K. Bach	Feb. 4, 1946 to Aug. 10, 1947
L. J. Bjorklund	Apr. 2, 1947 to June 30, 1947
R. T. Littleton	Apr. 21, 1947 to June 14, 1947

Miss I. L. Schooler was district clerk.

New Mexico. - In March 1939, an investigation at Hot Springs, N. Mex. had been started, and continued until July 1940. The City of Hot Springs had been using the hot springs for their therapeutic value, and had drilled artesian wells for irrigation and had obtained the same water. That well field had been declared a ground-water district, and the State Engineer desired to know how long the existing use would continue without lowering the water level. When the latter occurred, water might be drawn in from the Rio Grande and thus change the mineral content. The discharge of some 35 wells and 15 springs were measured, the temperature recorded, and samples of water analyzed in Washington. The geologic relationship of the occurrence of the springs was studied. A report entitled "Thermo waters of the Hot Springs Artesian Basin, Sierra County, N. Mex., by C. V. Theis, G. C. Taylor, Jr., and C. R. Murray," was prepared for publication by the State Engineer.

At the beginning of the period, the Pecos River Joint Investigation [273] was started and the field work continued through December 1940. The ground-water report was completed in March 1941. This investigation was in part a continuation of the Pecos investigation near Carlsbad, started during the previous period,[274] but covered the geology of the entire Pecos, both in New Mexico and Texas, and the ground-water hydrology of the basin as affecting irrigation and the gains and losses of the Pecos River. Studies of leakage from Lake McMillan and Lake Avalon were made. The work in New Mexico was performed by C. V. Theis, A. M. Morgan, O. L. Loretz, and W. E. Hale. The results were published by the National Resources Planning Board.[275]

A report on the water supply near Carlsbad, largely an outgrowth of the Pecos River Joint Investigation, was prepared by Mr. Hale in 1940 for publication in a forthcoming biennial report of the State engineer. In 1941, Mr. Murray supervised the drilling of a test well near Deming, which showed the presence of additional deeper aquifers in the Mimbres Valley and the possibility of reducing the interference between wells in an over-developed section of the valley; a second test

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273/ p. 15.
274/ p. 333 (1928-1939).
275/ The Pecos River Joint Investigation: Reports of the Participating Agencies, June 1942.

east of the Florida mountain, drilled in 1944, had the same results.

Even before the beginning of World War II, a large amount of the energy of the New Mexico Office was spent in special investigations of water supplies for military establishments for the War Department, not only in New Mexico but in nearly all states in which the Survey had at the time no ground-water offices. This work for the war effort included later the study of water supplies for prospective carbon black and other industrial plants needed in preparing for war. Contrary to results elsewhere in the United States, where competent preliminary advice on water supply was not always sought, no military establishment in New Mexico that developed its own water supply, had a water shortage during the war.

Because of the necessity for war-time investigations and military furloughs, the non-military work in New Mexico during the war period consisted almost entirely in maintaining water-level records and inventories of pumpage in the irrigation areas. The latter were made by determining the duty of water in a number of typical farms and applying this duty to the irrigated acreage. This work was done by C. R. Murray and P. D. Akin.

Near the close of the war, it was possible to increase the personnel and start additional investigations. One of the first was the extension of the work to the Bluewater area in Valencia County which started in 1945. That same year, the all-branch cooperation with Colfax County was started.276/ The ground-water part of this work consisted of the preparation of a geological map of a large part of the county in which the Geologic Branch cooperated, and a study of the availability of water to wells throughout the plains part of the county. The report was prepared by R. L. Griggs.

In April 1945, an investigation of the non-thermal flowing artesian wells lying south of Hot Springs was started at the request of the State Engineer. As the City of Hot Springs obtains its supply from that source, the immediate purpose of the study was to determine whether the city supply would be endangered by additional development. The overall purpose was to study the geology and hydrology of the artesian basin. A preliminary report by Messrs. Murray and Theis was prepared near the close of the period, and a detailed report was to be made later.

In the 1947 fiscal year, cooperation with the Elephant Butte Irrigation District resulted in an investigation looking for a ground-water supply to augment the inadequate surface-water supply during dry years. In general, water was found to be available throughout most of its area, but that the first effects of pumping would probably be to decrease the surface supply of the area. This work was done by C. S. Conover. The work was continued beyond the end of the period.

276/ p. 63.

A critical shortage of Santa Fe's water supply due to a drought occurred in 1946, and a brief investigation was made during July and August 1946 by Mr. Murray.

The Bureau of Reclamation was making an investigation in the Pecos River Valley and desired additional information to that obtained during the joint investigation. During that investigation, the Survey had suggested that brine might be pumped into certain nearby sink holes and allowed to evaporate and thus diminish the quantity being discharge into the Pecos River. The Bureau was also interested in the problem of using the Hondo Reservoir, which was one of the first constructed by the Reclamation Service, but had proven so leaky that its use had been abandoned. Hondo River has practically no channel and during high water, spreads over the country flooding Roswell. Hondo Reservoir is an off-channel reservoir in an old sink and it is possible to use it for flood prevention; the water so impounded, percolating to the ground-water and raising the water-level in the artesian irrigation wells. Other problems on which information was needed were the effect of the pumping of shallow water in the Roswell Basin upon the flow of the Pecos River, and the possibility of ground-water irrigation on the upper Pecos Valley. The Bureau of Reclamation transferred to the Survey $11,000 to investigate those possibilities. The investigation which was started in January 1947 consisted of a geologic study of Hondo Basin, permeability studies of the sink holes near Malaga Bend, pumping tests near Roswell, and a geological study of the Pecos Valley in San Miguel County. In connection with the studies of the effects of pumping near Roswell, the Surface Water Division made a seepage run on the Pecos River in the Roswell Basin each winter to indicate any changes in the invisible inflow to the river.

Mr. Theis continued in charge of the New Mexico work during the period although for extended periods from 1943, it was "in absentia," while he was attached to the staff of the Northwest Division of the Corps of Engineers (Alaska Highway), 277/ and engaged in ground-water studies connected with iron mining in Michigan. 278/

Civil Service technical assistants were:

Name	Period	Military Furlough
A. M. Morgan	July 1, 1939 to July 10, 1942	
C. S. Conover	July 1, 1939 to June 30, 1947	Aug. 16, 1941 to Dec. 30, 1945
W. E. Hale	July 1, 1939 to June 17, 1942	
G. C. Taylor, Jr.	July 1, 1939 to Nov. 17, 1939	
O. J. Loeltz	Nov. 18, 1939 to Oct. 8, 1942 1/	
C. R. Murray	Sept. 1939 to June 30, 1947	

277/ p. 234.
278/ p. 289.

Name	Period	Military Furlough
P. D. Akin	Feb. 24, 1941 to Dec. 1944	
U. N. Benge	Nov. 5, 1943 to June 30, 1947	
R. L. Griggs	Dec. 1945 to June 30, 1947	
R. T. Bean	Dec. 13, 1946 to June 30, 1947	
R. S. Jones	Jan. 20, 1947 to June 30, 1947	

1/ Military furlough; did not return to district.

Idaho. - Until 1943, the only ground-water work in Idaho was the maintenance of three observation wells in the Rathdrum Prairie in Kootenai County in connection with an investigation of the contiguous Spokane Valley of Washington.[279]

As a result of cooperation with the State Reclamation Engineer, started in June 1943, Penn Livingston from the Texas District and H. R. MacDonald from the Utah District, investigated the artesian wells in the Malad Valley near Malad City, during June and July 1943. About 45 artesian wells were tested for leaks with the Au deep-well meter,[280] and recommendations made for repairing the leaky wells. About 140 wells were visited but many of them could not be tested with the meter owing to their small size or bad condition. Realizing that additional study of Malad Valley would be required to determine the safe withdrawals from the artesian basin, that recommendation was made. The State Reclamation Engineer, during the next two fiscal years, continued small scale cooperation which enabled personnel from the Utah District to establish and maintain 164 observation wells in the valley at first, but by 1946 the number of wells was gradually decreased to 60.

During the fiscal year 1947, the cooperative funds were sufficient to start a state-wide investigation, and July 30, 1946, R. L. Nace was transferred from the Nebraska District and given charge of the investigation, with headquarters in Boise. He made a reconnaissance of the state to determine the nature and location of the ground-water problems, and establish the beginning of a state-wide observation-well program with a goal of 300, of which 70 were in operation June 30, 1947. He made a re-inventory of wells in the Malad Valley in order that a final report might be prepared. A series of well-inventory surveys on a state-wide basis was also started, with a well inventory in the Boise River Valley.

In addition to Mr. Nace, R. W. Mower was an assistant from December 2, 1946 to June 30, 1947.

Utah. - At the beginning of the period, investigations in Cedar City

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279/ p. 341.
280/ Water-Supply Paper 596.

Valley and Parowan Valley started in 1938 at the request of the State Engineer, were in progress. This was an intensive study of the ground-water discharge and recharge in the two valleys. The State Engineer, under the ground-water code adopted in 1935, had in his files a large amount of data pertaining to the location and logs of wells and discharge records of water pumped from irrigation wells. Records of observation wells were also available giving the background of several year's records as the basis for the investigation; records of 749 wells and measurements of discharge of 123 wells were utilized. The geologic work augmenting previous studies comprised studies essential to the understanding and interpretation of the ground-water problems. The work was started July 1938 by H. E. Thomas, assisted by W. K. Bach and continued until July 1940. G. H. Taylor devoted several months to the investigation. These results were published as Water Supply Paper 993.

The next investigation was that of Tooele Valley started in October 1940 by H. E. Thomas. The field work was continued intermittently until June 1942. The geologic studies were made by F. C. Foley, and later by G. B. Maxey, W. K. Bach, and P. E. Dennis devoted several weeks to the work. In addition to much data pertaining to quantities of water drawn from wells during 1938-1940, inclusive, and many water level measurements furnished by the State Engineer, all available drillers' logs were collected; also private records of the discharge of two mine-drainage tunnels. Twenty-four wells were selected to indicate the changes of storage in the ground-water reservoir. Interference and permeability tests were made, and field determinations of chloride content were made on samples from 175 wells. The Quality of Water Division made analyses of samples from 99 wells, 3 springs, and 8 streams in the Washington laboratory. The results of the investigations were published as Technical Publication No. 4, "Ground-water in Tooele Valley, Tooele County, Utah, by H. E. Thomas," in the 25th Bien. Report of the State Engineer.

Between major investigations, Mr. Thomas, early in 1942, prepared a supplemental report to Water Supply Paper 796-D, bringing down to date the results of subsequent observations on the Ogden Valley Artesian Reservoir. More complete information on three wells was obtained, and the capacity of the reservoir was reestimated. The results were published by the State Engineer as Technical Publication No. 2, "The Ogden Valley Artesian Reservoir by H. E. Thomas."

The next investigation was that in Pavant Valley started November 1942, by Mr. Dennis. The field work included a study by Mr. Maxey of the geology in relation to ground-water occurrence, and periodic measurements of water levels and flows of practically all wells in the valley. Six recorders were maintained in wells and from April 13, to May 24, 1943, Penn Livingston was borrowed from the Texas District to measure, by means of the deep-well meter, the leakage in 48 of some 100 artesian wells in the Flowell area. The Surface Water Division established and maintained a station on Chalk Creek and made periodic measurements of other streams in the area. Piezometric profiles were constructed to determine the direction of the underground flow; in November 1943 and 1944, after the flowing wells had been closed, interference tests, using 5 different discharging wells were made. The investigation was completed in October 1945 and the results published by the State Engineer as Technical Publication No. 1, "Underground leakage from artesian wells in the Flowell area, near Fillmore, Utah," and Technical Publication No. 3, "Ground-water in Pavant Valley, Millard County, Utah."

The City of Ogden was faced with a critical shortage in its water supply due to the war-time increase in population, and cooperated with the Survey for the purpose of obtaining if possible, an addition to its supply which came from artesian wells in the Ogden Valley. Available data were periodic water-level or pressure measurements maintained by the City of Ogden since the investigation of the Ogden Valley about in 1934; also a recorder record on one well since 1938. In addition, the State Engineer in 1936 had made interference tests of wells. That was done at the request of well users who feared that recently drilled wells by the Utah Drought Relief Administration were interfering with their supplies. P. E. Dennis and H. R. MacDonald started the work in March 1943, and performed the greater part of the field work during that summer. As the Army Engineers were interested in obtaining a water supply for Army establishments in that area, W. B. Nelson was detailed by the Army Engineers to the investigation, and also furnished data on wells drilled by that agency. Water-stage recorders or pressure recorders were installed on four wells and piezometric profiles were compiled. Mr. Livingston made a test of leaks in one well being drilled by the Army Engineers. Chemical analyses from 27 wells were made in the Survey's Albuquerque laboratory and the Army Engineers made 150 analyses in their Salt Lake City laboratory. A typewritten report, "Ground-water in the vicinity of Ogden, Utah," was released in December 1944.

That investigation raised some additional questions, and to obtain the needed answers, the city on July 1, 1944 extended the cooperation. During the second investigation, which was made by Messrs. Dennis and Nelson, three different pumping tests were made in the vicinity of Ogden. One was made in January 1945 on the airport well, no other observation well being used. In March and April, a test of the Ogden Drought Relief Administration well in the mouth of Ogden Canyon, to determine its interference with wells about two miles distant was made; a water-stage recorder was placed on one well, and periodic measurements were made in 10 other wells. Samples of water were taken during those tests and analyzed by the City of Ogden. The city drilled two wells during 1945, and at the completion of the first well, a pumping test was made during August and September, using 17 other observation wells. In May and June 1946, both wells were tested, using 20 observation wells. During the 1947 pumping season of the city wells, four recorders were operated on observation wells. A typewritten supplemental report was furnished the City of Ogden.

After the war, additional personnel became available. Davis and Weber Counties contributed funds to supplement the investigation in those areas and an investigation of the East Shore area was started in July 1945. The City of Bountiful in Davis County had drilled a well 450 feet deep without finding water. Protests by water users against the city drilling additional wells led to the investigation, which was being carried on by Mr. Thomas at the end of the period.

In November 1946, P. F. Fix, a professor of Geology at the Utah Agricultural College who held a w.a.e. appointment in the Survey, started a study of the aquifers in Cache Valley as a research project.[281/]

The Geologic Branch during 1946 and 1947 was making a study of the northern part of the Utah Lake Valley, and Mr. Thomas made a field study to determine the piezometric surface in that area. There are some 3,000 wells reaching different aquifers, and three piezometric surfaces were determined. The field work was completed in June 1947.

The reports of the various investigations were used chiefly by the State Engineer in determining whether applications for additional wells should be approved, the State's duty under ground-water law.

G. H. Taylor was in charge of the Utah investigations from July 1, 1939 to November 1940; H. E. Thomas, December 1940 to June 30, 1942; P. E. Dennis, July 1, 1942 to December 21, 1945; and H. E. Thomas again after his return from military duty January 1946 to June 30, 1947. Other technical personnel were:

Name	Period
G. B. Maxey	Sept. 15, 1941 to Oct. 17, 1943
H. R. MacDonald	Sept. 13, 1942 to May 19, 1944
W. B. Nelson	July 3, 1944 to June 30, 1947
R. G. Butler	Aug. 1, 1945 to June 30, 1947
P. F. Fix	Feb. 3, 1947 to June 30, 1947

Nevada. - As a result of the survey of leaky wells in the Las Vegas artesian basin,[282/] most of these wells were repaired or plugged and a conservation program initiated that resulted in an estimated average saving of more than 2,000,000 gallons per day. Water levels, however, continued to decline particularly during the war years with the increased demand on the ground water and in July 1944, as a result of State cooperation, a further study of the area was made. G. B. Maxey was transferred from the Louisville Office to make the investigation under the supervision of P. E. Dennis, in charge of ground-water investigation in Utah and Nevada. H. C. Jameson, artesian well supervisor for

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281/ p. 226.
282/ p. 337 (1928-1939).

the Las Vegas Artesian Basin, assisted in the compilation of the hydrologic records. The State Engineer had kept up the inventory of the wells since 1939, and a supplementary inventory was made during the present investigation. During that inventory, a discharge record was obtained for most of the artesian wells and springs from 1924 to 1944. In 1924, the citizens had become alarmed over the ground-water supply and the Nevada Experiment Station had made measurements of head and discharge of the wells at that time. At irregular intervals, subsequently, measurements of the flow of a few wells and water level measurements in non-flowing wells had been made. A geologic study was also made during the present investigation. At the conclusion of the investigation in 1946, records of water levels by water-stage recorders and by monthly measurements were continued on about 80 wells. The results of the investigation, up to the summer of 1945, together with recommendations for curtailing drilling, improved well construction and continuation of the work, were published by the State Engineer in March 1945, as "Progress report on the ground-water resources of the Las Vegas Artesian Basin, Nevada, by George B. Maxey and C. H. Jameson." So important was the Las Vegas field that additional reports giving data on water levels and artesian pressures and a summary of the ground-water studies were published.283/ The last report indicated that the safe yield of the valley had nearly been reached.

About the time that the Las Vegas investigation was started, field work in Pahrump Valley, which had developed some of the largest artesian flows in the west, was also started.

When the state-wide program became effective July 1, 1945, T. W. Robinson was transferred from Safford, Arizona, to Carson City, Nevada, and placed in charge of the Nevada work. Before beginning the cooperative program, it was decided that it would be impossible in general to obtain quantitative results in all of the valleys in the state as the field was too large and the necessary data for such results too few.

However, it was deemed desirable to study quantitatively those areas in which there had been development of ground-water or in which development could be expected in the near future. As a result, during the present period, the investigations were largely quantitative and as

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283/ Water Resources Bull. No. 3: "Water levels and artesian pressures in wells in Nevada, 1924 to 1945" - (contains records for most of the Las Vegas wells), Apr. 1946; Water Resources Bull. No. 4: "Well data for Las Vegas Valley," June 1946; Water Resources Bull. No. 5: "Geology and Water Resources of Las Vegas, Pahrump and Indian Spring Valleys, Clark and Nye Counties," 1947; Water Resources Bull. No. 6: "Ground-water in Las Vegas, Pahrump, and Indian Spring Valleys" - (a summary), 1947.

detailed as the available hydrologic data and limited geologic studies permitted. In selecting the areas to be investigated, which were generally decided by the State Engineer, preference was given to municipal water problems, and then to irrigation problems as presented by the water users. To make it possible to do test drilling where necessary, a Failing No. 314 rotary well-drilling rig was purchased from surplus property by the State Engineer through the use of cooperative funds. During the present period, 5 wells ranging in depth from 70 to 1,008 feet were drilled. For that work, a driller and helper were hired, with a Survey employee as supervisor.

The first investigation undertaken was that of Lovelock Valley, where for a few dry years, the water supply for the City of Lovelock derived partly from ground-water was deficient particularly during the summer months. Finally in 1945, the situation became so critical that water was strictly rationed. There were many shallow wells in the city, but the quality of water was poor. The city desired an investigation to locate a ground-water supply of good quality. The investigation was started by Mr. Robinson in November, 1945, and continued until March 1946. The geologic study was made by J. C. Fredericks. Available well data were obtained and water levels measured during the investigation. The results were published by the state as Water Resources Bulletin No. 2, "Ground-water resources of Lovelock Valley, 1946."

In March 1946, an investigation of Meadow Valley Wash, was started by D. A. Phoenix. For the area in the vicinity of Panaca, an intensive and detailed study was made. About 1938, cheap power from Boulder Dam made it possible to pump ground water for irrigation in the vicinity of Panaca and the success of that venture stimulated similar use of ground-water elsewhere in Nevada. To determine as nearly as possible the safe limit of pumpage in the pioneer area, a water inventory was made. The surface inflow to the Panaca area was measured at the gaging station on Meadow Valley Wash, near Panaca; the underground inflow was based on the coefficient of transmissibility determined from a pumping test made June 11 and 12, 1946, on one well, and the water-table slope based on observations in two wells; the width of saturated material was based on the logs of existing wells; the flow of springs was measured by current meter. The outflow was the total of (1) water discharged by evaporation from soil and transpiration, (2) surface flow leaving the valley, (3) underflow, and (4) pumpage for irrigation. Evaporation and transpiration were based on the experiments made in the Esalante Valley, Utah[284]; the surface flow was measured by means of a four-foot weir; the underground flow was based on a pumping test in a well drilled by the Survey for that purpose, and the amount of water pumped by 8 irrigation wells and one public supply well. The field work was complete in November 1946 and the results of the investigations were published by the state as Water Resources Bulletin No.

284/ Water-Supply Paper 659a.

7, "Geology and ground-water in the Meadow Valley Drainage Area, Nevada, ***, 1948."

About the time the Meadow Valley investigation was started, a cooperative investigation of the Argenta Swamp area was started by Mr. Robinson. That area lies on the Humboldt River a few miles north of Battle Mountain. The Bureau of Reclamation had purchased several thousand acres of land in that area for a Bureau project, and had transferred downstream the water rights appurtenant to the Argenta Swamp. Citizens of Battle Mountain desired an investigation to determine whether that land could be irrigated from ground-water without interfering with the flow of the Humboldt River. A cooperative program between the Surface and Ground Water Divisions, the State Engineer, and the Bureau of Reclamation was arranged. The Surface Water Division installed 3 gaging stations, a part of the cost which was paid by $1,000 ground-water funds and $2,000 by Bureau funds. The field work was started in the spring of 1946 when several shallow observation wells were drilled. Observation of water levels in wells and the flow of Humboldt River above and below the Argenta swamp were continued in the present period.

Like Lovelock, the City of Elko had a water shortage especially during the summer months. The shortage was due to the expanding population, and in 1946, the city officials desired to increase the supply of ground water. The investigation by J. C. Fredericks and O. J. Loeltz was made in November and December. Pumpage records since 1937 were available by the City. Logs of 12 wells were utilized and pumping tests in 4 wells were made during November and December. A mimeographed report "Ground-water in the vicinity of Elko, Nevada," published in 1947, presented the results.

Reconnaissance studies were started in Grass Valley, Paradise Valley, Fish Lake Valley, Eagle Valley, and the Reno-Sparks area.

Analyses of the water samples taken during the various investigations were made largely by the University of Nevada, which was equipped to render that service without charge.

In addition to T. W. Robinson, district engineer, the Civil Service technical personnel were:

Name	Period
G. B. Maxey	July 1, 1944 to June 30, 1947
J. C. Fredericks	Oct. 1945 to Feb. 15, 1947
D. A. Phoenix	Jan. 2, 1946 to June 30, 1947
O. J. Loeltz	Mar. 16, 1946 to June 30, 1947

Arizona. - Until the beginning of the present period, there had been no State cooperation in Arizona, and no continuing investigational program. There had, however, been a few areal surveys covering areas of especial Federal interest and supported wholly by Federal funds. State cooperation began soon after the beginning of the present period. About the same time, the Army Engineers and the Indian Service each desired investigations and as a combined result, it was possible to establish an office in Tucson and begin what proved to be a gradually expanding program covering all parts of Arizona. S. F. Turner was placed in charge of the Arizona investigations.

The first investigation was that in the Queen Creek area started in August 1939. That was a small area, and the Army Engineers suggested that it be used as a "guinea pig" to try out the methods and train the relatively inexperienced personnel for the larger Gila River investigation to be made later. For much the same reason, the Santa Cruz River Basin investigation was started in September.

The general methods used were those described at length in connection with the Gila River investigation, except they were not so extensive. To determine the stream-bed losses in Queen Creek, funds were transferred to the Surface Water Division for the installation and operation of a gaging station on the creek near the upper end of the valley. The Ground Water Division installed and operated a number of temporary stations farther downstream to measure the losses in the various reaches during flood flows and thus determine the ground-water recharge. The losses from steady flows of clear water were determined by runs of seepage measurements. An inventory of pumpage was made; changes in ground-water levels measured in 60 observation wells; studies of evaporation losses from surfaces of flood flows, and from wetted stream-bed surfaces after such flows had passed; and amount of water that penetrated downward was studied in several hand-drilled test wells. The field investigation was completed and a confidential report was transmitted to the Army Engineers in January 1940. 285/ In addition, a paper was published in the American Geophysical Union Transaction for 1942. 286/

In the Santa Cruz Valley, the investigation was to determine the annual ground-water recharge, its quality, source and direction of flow; and to furnish the information desired by the Army Engineers, the probable effect on the ground-water supply of proposed flood control reservoirs. Owing to the scanty rainfall, which usually occurs as hard rains of short duration, the chief source of recharge is the infiltration losses from flood flows in stream beds that are dry most of the time. The recharge was studied by 5 methods (1) losses between gaging stations on the same stream (2) losses as determined by series of seepage measurements, which included all inflows and diversions

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285/ Ground-water recharge from flood waters of Queen Creek, Arizona, by S. F. Turner, L. C. Halpenny, H. M. Babcock, and R. B. Morrison.

286/ Recharge to ground water from floods in a typical desert wash, Pinal County, by H. M. Babcock and E. M. Cushing.

(3) determining recharge points by means of moisture penetration tests (4) computing recharge from canal and irrigation seepage, and (5) computing underflows from contributing sources.

In measuring surface flows, use was made of existing gaging stations augmented by a number of auxiliary stations installed and operated by the Ground Water Division during the investigation. To check results of the seepage runs which were made at the infrequent times when the flow in the streams was fairly steady, the drop in water level in the pools left in the river bed after flood flows was measured daily until the pools disappeared. The direction of flows was determined from water level contours constructed from readings in numerous wells in and near the area studied. Records of pumpage were collected as well as results of seepage losses from canal systems, usually furnished by the operators of those systems. The underflow at various key points was computed by means of measured cross-sections of the valley fill using permeabilities determined by pumping tests. Those investigations were made by H. M. Babcock, E. M. Cushing, H. R. McDonald, H. G. Fernandez, and D. H. Bratton, with the geologic studies by G. A. Waring. The field work was completed in late 1942 and the results transmitted to the Army Engineers and published by the Survey in mimeograph form.[287]

The most noteworthy work during the period was the intensive Gila River investigation. This investigation, which had two phases, one lasting from October, 1939 to June 1942, and the other from June 1943 to October 1944[288] was really one investigation and is so treated.

The first phase covered the Duncan-Virden Valley in the upper end of the general Gila River Valley, and the Safford Valley, from the lower end of the 25-mile canyon section separating the two valleys, to the San Carlos Reservoir. In determining the loss from stream beds, the existing gaging stations both for streams and canals were utilized and 20 auxiliary gaging stations on dry washes were installed and operated by the Ground Water Division, the stations being equipped with self-starting recorders devised for the purpose, which operated only during periods of flow. Seepage measurements were made monthly during the summer seasons of low flow. Changes in ground-water storage were determined from observation wells, in 11 lines across the river bottoms at intervals of about 5 miles, 7 to 13 wells about 500 feet apart being installed in each line, a few in each line being equipped with recorders. Staff gages were installed in the river at each well-line crossing and the readings recorded when the well observations were made. Pumping tests were made to determine permeability. The unusual feature of the investigation was the measurement of the large quantity of water consumed by salt cedars (tamarisk) and other water-

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287/ Ground-water resources of the Santa Cruz Basin, Arizona, by S. F. Turner and others, Tucson, Arizona, May 14, 1943.

288/ p. 17-18.

loving plants which lined a large portion of the river banks. To determine that amount, an experiment station was established in April 1940 in the river bottom near Safford. In May, 7 soil tanks were installed, two containing salt cedar, two baccharis, and three bare soil. The water level in the tanks was measured each morning as well as the amount of water as added to bring the water level back to the desired level. Water-stage recorders were maintained in wells in salt cedar, baccharis, and mesquite thickets and in groves of cottonwood trees at various points in the river bottoms. Transpiration was also measured by botanical methods.[289/] The investigation came to a close in June 1942 and preliminary results were transmitted to the Army Engineers and Indian Service and also published by the Geological Survey in a mimeographed report entitled "Water resources of Safford and Duncan-Virden Valleys, Arizona, Aug. 15, 1941." The field work on this project was carried out by L. C. Halpenny, W. T. Stuart, H. M. Babcock, H. R. McDonald, R. S. Morrison, and Thomas McCauley.

The second phase was confined to the Safford Valley, as the Indian Service had a controversy with the Phelps Dodge Corporation, and would not allow the investigation to include the Indian Reservation. Therefore, the area selected started at the reservation line, and extended sufficiently far upstream to include a large area of salt cedar which was to be cleared later and also a large area to remain uncleared. It was expected that the investigation would continue until the amount of water saved by clearance could be actually measured. The area selected was the 46-mile reach of the valley from Thatcher to Calva, within which the amount of water used by the river-bottom vegetation, 60 percent salt cedars, was to be determined, together with the chemical character of the surface and ground-water. The previous investigation had shown the loss of 70,000 acre-feet from the river-bottom vegetation in one year. The methods used were substantially those of the previous investigations, but greatly intensified. The large experiment station was especially noteworthy.

This station consisted of 29 soil tanks, and a very complete Class "A" weather station, with continuous recording instruments. The tanks were 10, 6, and 4 feet in diameter and 10, 8, 6, 5½, 4, 3½ feet in depth, being among the largest used for this type of work. Cottonwood trees were grown in two of the largest tanks, and salt cedars in two of the largest and all of the medium-sized tanks. Baccharis was grown in the smaller tanks and the evaporation from bare soil surfaces of various types was determined with the smaller tanks. Depths to water of 2, 4, 6, and 8 feet were used in the experiments. The field work was discontinued in December 1944. The results will be published as a water-supply paper.

While the Queen Creek, Santa Cruz and Gila River investigations were getting underway, a geologic reconnaissance of the Big Sandy Valley

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289/ American Geo. Union Tran. 1941, pp. 738-743.

in Mohave County was made to determine the possibilities of obtaining artesian water for irrigation. As it was found that such possibilities were not promising, a quantitative investigation was not made. The survey lasted from October 1939 to February 1940 and was made by R. B. Morrison. The report was released in mimeograph form.

Beginning in April 1943, at the request of the War Department, an intensive investigation was started for the purpose of locating additional ground-water supplies for the Army Air Corps Flexible Gunnery School near Kingman, Ariz. The school had been supplied with water from wells penetrating volcanic rocks north of Kingman, but the great expansion of the school required a large additional supply, and the investigation indicated that the existing source would be adequate for only a limited time for the enlarged school. Beginning in August 1943, a program of test drilling and pumping was started in the Hackberry Wash area about 18 miles distant. The Geophysics Section put down 31 electrical depth profiles, which helped materially in determining sites for drilling. As a result of the investigation, an ample supply of water was obtained.

In the fiscal year 1944, cooperation with Phoenix became effective for the purpose of determining the ground-water resources of the lower Verde River Valley and of Paradise Valley. The investigation was started in June 1944, by H. R. MacDonald, J. F. Hostetter, H. D. Padgett, and F. I. Bluhm. The source, rate, and direction of movement of the ground-water were determined in the Verde River Valley below Bartlett Dam. The quantity of underground storage in, and the rate of recharge to the present well fields in the valley was determined as well as the effect of silting upon recharge from the Verde River. The electrical-resistivity method of geophysics was used to locate sites for new well fields and these sites were test drilled and pumped. Three reports were issued as follows: "Geology and ground-water resources of the Verde River Valley near Fort McDowell, Arizona," November 1, 1945; "Further investigations of the ground-water resources of the Verde River Valley near Fort McDowell, Arizona," May 18, 1946; "Geophysical investigation of possible aquifers in the vicinity of Williams and Moore Ranches, Verde River Valley, Arizona," February 10, 1948.

The Paradise Valley investigation was chiefly a geologic study during which measurements of existing wells were made and data on 89 existing wells and drillers' logs on 13 wells were collected. A pumping test on an irrigation well drawing from the principal aquifer was made to determine the transmissibility. The investigation was completed late in 1946, and a mimeographed report entitled "Geology and ground-water resources of Paradise Valley, Maricopa County, Arizona" published by the Survey in January 1947.

The following year (1945), cooperation became effective with Globe. During previous years, the City had drilled a number of dry holes and the City's consulting engineers, being familiar with the

Phoenix investigation and the Survey's work for some of the Army camps during the war, advised the City to request the Survey's cooperation. The investigation, which was started February 20, 1945 by G. E. Hazen, was chiefly a geologic study. Records of existing wells and drillers' logs were also obtained. The best sites for additional wells were selected, based on the geological and hydrological work. Electrical-resistivity probes were run at these sites and the best selected for drilling. The investigation was completed in the summer of 1946 and a mimeographed report entitled "Geology and ground-water resources of the upper Pinal Creek area, Arizona," published in December 1946.

As a result of a talk by Mr. Turner on the work of the Geological Survey given before a mineral society at Prescott, cooperation was effected with that city in the fiscal year 1946. The existing surface water supply was deficient and a ground-water supply appeared to be the nearest source of additional water. Like that for Globe, the investigation was a detailed geological study, which showed by geology and the electrical-resistivity method, where water might be found. This was followed by test drilling. The work was started October 10, 1945 by H. M. Babcock and K. K. Kendall and the field work was completed in June 1947. The report is being prepared for publication.

During the last two years of the period, the critical water shortage showed the need for a ground-water law, and to bring that need before the citizens, the State Land Commissioner requested Mr. Turner to give a series of addresses throughout the state, under the Commissioner's sponsorship. A special session of the Legislature was called in September 1945 to consider legislation needed for the enactment of a ground-water code. The information on ground-water resources of the entire state was so scanty that enactment of a ground-water code was postponed, and a law was enacted requiring the registration with the State Land Commissioner of all irrigation and drainage wells having capacities of 100 gallons per minute or greater, and annual reports of the amount of water pumped. A special appropriation was made for cooperation with the Survey, directing it to correlate and study all available data on the ground-water resources and gather additional data where necessary, and compile reports and comprehensive statements covering such information; such reports to be available to the 1947 session of the Legislature.

Considering the size of the state, the small amount of data available and the deadline date a little more than 2 years distant, the problem was solved by making reconnaissance surveys of the various ground-water basins beginning with those most economically important. The investigations were designed chiefly to show the current conditions and the nature of the problems to be met in framing a ground-water code.

The requirement that wells be registered was of great assistance in preparing the reconnaissance reports. Unfortunately, the requirement for annual pumpage reports was not enforced. Some, at least of the most economically important, basins had been studied in detail in the earlier years of the period. Reports on the Safford, Duncan, Santa Cruz, and Cactus Flat-Artesia areas, the latter having been studied in detail during the investigation in the Safford Basin, were prepared by bringing down to date the lists of new wells, the depth to water measurements, and the records of pumpage, which had been kept up in the meantime. For the other areas studied, Salt River Valley, San Simon Basin, Holbrook Area, Wellton-Mohawk Area, Wilcox Basin, Gila Bend Area, Date Creek Area, and Peeples Valley, the reports were chiefly geologic, with records of wells and drillers' logs, together with records of pumpage. Where available, statements regarding the problems to be met were made and estimates of the safe yield were made when possible.

To make the reports intelligible to citizens and the legislators unfamiliar with the ground-water terminology, they were written with as few scientific terms as possible. However, as it was necessary to use technical terms where precise ideas were involved, and to make the reports more understandable by the public, the Tucson office published March 18, 1947, a mimeographed report entitled "Definitions of geologic, hydrologic, and chemical terms used in reports on the ground-water resources and problems of Arizona." This report proved to be a "best seller," and requests for it were received from other states and also foreign countries.

During the last two years of the period, the Bureau of Reclamation, in connection with its study of the Central Valley project, desired a compilation of existing data necessary to estimate the annual safe yield of ground water in the Salt River Valley between the Granite Reef and the Gillespie diversion dam. Available data comprised stream flow, pumpage records of irrigation districts, and water level fluctuations. Funds were transferred to the Survey for that purpose. The results were published by the Bureau as a part of its Central Valley project.

Mr. Turner remained in charge of the Arizona investigation and had the following Civil Service technical assistants:

Name	Period	Military Furlough
R. B. Morrison	Oct. 2, 1939 to Aug. 31, 1942	
H. R. McDonald	Nov. 27, 1939 to Sept. 5, 1942	
	May 1944 to June 30, 1947	
W. T. Stuart	May 15, 1940 to Aug. 13, 1943	
E. M. Cushing	Aug. 16, 1940 to Dec. 8, 1942	
Thomas McCauley	Mar. 16, 1941 to Sept. 1942	
L. C. Halpenny	Apr. 16, 1941 to June 30, 1947	
H. M. Babcock	Nov. 20, 1942 to June 30, 1947	Sept. 15, 1942 to
J. H. Brown	July 26, 1943 to Jan. 31, 1945	Dec. 4, 1945
D. H. Hall	Oct. 1, 1943 to Jan. 20, 1944	
G. E. Hazen	Dec. 17, 1943 to Dec. 14, 1945	(W.A.E.)
T. W. Robinson	Jan. 1, 1944 to May 16, 1945	

Name	Period	Military Furlough
J. F. Hostettler	Apr. 25, 1944 to Nov. 16, 1945	
T. P. Shelley	July 1, 1944 to Nov. 2, 1945	
H. D. Padgett	Sept. 22, 1944 to June 21, 1945	
M. B. Booker	Dec. 5, 1945 to June 30, 1947	
P. F. Fix	Dec. 14, 1945 to Aug. 3, 1946 (W.A.E.)	
R. S. Jones	Feb. 14, 1946 to Jan. 15, 1947	
S. C. Brown	Mar. 18, 1946 to June 30, 1947	
Mrs. I.I. Jones	Mar. 21, 1946 to Mar. 23, 1947	
K. K. Kendall	Apr. 1, 1946 to Jan. 31, 1947	
F. I. Bleilim	Oct. 1, 1946 to June 30, 1947	
R. L. Cushman	May 21, 1947 to June 30, 1947	

Mary J. Scott was the district clerk.

Washington. - There were two hold-over investigations, one with the City of Tacoma started in 1937, and the other an investigation of the underflow of the Spokane Valley as a part of the State-cooperative program started about the same time.

The field work for the Tacoma investigation was continued by J.W. Robinson who, with the assistance of J. E. Upson, Jr., completed the geologic mapping in 1942. The routine measurements of wells and springs were continued and other hydrologic data were collected on a reduced scale during the remainder of the period. The results of the investigation were contained in a report by Mr. Robinson and A. M. Piper, under the title, "Ground-water resources and pertinent geologic features of Tacoma, Washington." That report now is undergoing revision for release in duplicated form.

Beyond keeping up the routine measurements of hydrologic data, the Spokane Valley investigation was deferred until 1941. At that time, an aluminum rolling mill and a magnesium plant were considering a location on the Rathdrum Prairie section of the Spokane Valley and a large supply of water was needed by each plant. As the low flow of Spokane River is derived from ground water, the War Department requested an investigation, and to supplement the previous hydrologic investigation, a geologic study was needed. During 1941 and 1942, L. C. Huff studied the distribution and character of the water-bearing formations, and inventoried about 340 wells. The number of observation wells was increased to 31, of which 2 were equipped with recorders, and 10 with float gages. Spokane city wells were studied by a pumping test which showed the high permeability of the outwash gravel. The movement of ground water in the Spokane Valley is relatively rapid; wood chips scattered on the surface in many wells move slowly down the gradient of the water table, and by observing that phenomenon in many wells, local well drillers have gained considerable knowledge about ground-water movement. As a result of the 1941-42 investigation, it was possible to make more accurate estimates of the underflow that had been made previously. The results of the Spokane Valley investigation were included in a report deferred for more complete geological study after the war. The report now is planned for early revision and release in duplicated form.

The first new work was near Bremerton to determine the availability of ground-water supplies. Mr. Upson made a geologic study, and the information obtained enabled the city to expand its water supply with the increasing war-time population.

An investigation of the ground-water resources of the Bureau of Reclamation's Columbia River Irrigation Project was started in August 1940. It was concerned with the availability of supplies for farms and for communities; also with ultimate drainage problems and possible percolation of return flow to areas outside those irrigated. G. C. Taylor, Jr. made an inventory of 1,072 wells and 36 springs over three units of the area that are scheduled for early settlement, and 44 wells were selected for periodic observation. Although the inventory which continued to July 1942 covered three units, the data, in connection with the geologic studies based largely on the previous work, made it possible to estimate the necessary depths and probable yield of wells needed in the plans for settlement over the greater part of the area. In that connection, water requirements for domestic use and stock water were estimated on the basis of gallons per day per square mile. The base data from that inventory, with a descriptive text, were released to the public by the Survey and will be published by the Bureau of Reclamation. The report has been used as a basis for successful prediction of results on most of the preliminary development wells of the Bureau. Further work in the Columbia River Basin was started in 1945 and 1946, when T. E. Eakin made a semi-detailed study of the geology in a representative area. However, before the report was completed, he transferred to other work. The results of the later study will be incorporated in work planned for the project area.

As a result of cooperation with Snohomish County, an investigation of that county was started in 1944 by J. W. Owen and J. W. Robinson, the geological work was deferred until 1946 when R. C. Newcomb undertook completion of the project. An inventory of about 800 wells having an average depth of less than 200 feet was started in the fall of 1944 and completed in the spring of 1945. Nearly complete chemical analyses of representative water samples were made, and about 50 additional samples were analyzed by field methods for hardness, and 18 for hardness and chloride content. The reconnaissance geologic mapping and the resulting studies were completed in June 1947. They will be published as a Water Supply Paper and in the meantime have been approved for duplicated release to the open file.

During the fall of 1945, Mr. Eakin made a geologic reconnaissance on the Columbia plateau north of Badger Mountain for the purpose of determining the possibility of additional water supply. A report entitled "Ground-water resources of the Waterville area, Douglas County, Washington," was made and placed in the open file.

The last investigation started during the period was that in Walla Walla County. It was an extension of the investigation made in 1933,[290] as it involved an intensive geologic study in the foothills area surrounding the valley. Mr. Newcomb started the investigation in 1946 but owing to personnel shortage, was able only to complete the earliest phases of the work during the present period.

Under the state-wide cooperative program for systematic evaluation of the ground-water resources, it was planned to make a preliminary inventory in those areas where no public source of ground-water information was available. The first area selected was the central part of the Chehalis Valley and some adjacent areas, and was chiefly concerned with the ground water of the unconsolidated deposits filling the valleys. The inventory listed 125 wells; it was begun in January 1947 by R. A. Kelly, Jr. and finished by W. N. Schlax, Jr. in May 1947. A preliminary report on ground-water resources of the central Chehalis Valley was issued by the Survey

A somewhat similar investigation in Whatcom County was made during 1947 by Messrs. Newcomb and Schlax, and thereafter, Mr. Schlax made a geological study over the Wenas Creek Valley in the Yakima drainage.

During the period, the state-wide observation-well program was increased from 22 to 122 wells, three being equipped with recorders.

A. M. Piper was in charge of the Washington investigations until April 1, 1946, when he was assigned to the economic survey expedition to ex-Japanese mandated islands,[291] and was succeeded by Mr. Newcomb, who came to the district January 3, 1946. As both Washington and Oregon investigations were under Mr. Piper's direction with headquarters at Portland, Oregon, the following Civil Service technical assistants were available for both State investigations:

Name	Period
George LaRocque	July 1, 1939 to Jan. 21, 1940
J. E. Upson	Feb. 1, 1940 to Oct. 6, 1941
J. W. Robinson	Feb. 12, 1940 to Apr. 4, 1947
L. C. Huff	Sept. 20, 1941 to Nov. 2, 1943
G. C. Taylor, Jr.	Sept. 24, 1941 to Oct. 9, 1942
T. E. Eakin	Aug. 16, 1943 to Aug. 21, 1946
J. C. Manning	June 20, 1946 to Feb. 3, 1947
R. A. Kelly, Jr.	Oct. 31, 1946 to Feb. 24, 1947
F. A. Watkins, Jr.	Dec. 13, 1946 to June 30, 1947
W. N. Schlax, Jr.	Mar. 31, 1947 to June 30, 1947

290/ p. 341 (1928-1939).
291/ p. 237.

Oregon. - The ground-water activities were concerned chiefly with expanding the observation-well program started in 1938 and in making investigation of ground-water resources in restricted critical areas. At the beginning of the period, there were 65 wells which had been established in connection with various investigations during the previous period. Of these, 16 were in the Willamette Valley in the western part of the state, and 49 east of the Cascade Range in the semi-arid part of the state. In the latter area, nearly half were in the Walla Walla Basin and were observed by the State Watermaster for that basin. With the gradual reduction in cooperative funds, the number of wells was reduced to 55 in 1942, one being equipped with a recorder that year. The increase in cooperative funds effective July 1, 1943, made it possible to expand the program and the number of wells was increased to 78 with one recorder at the end of the period. Many of the observation wells were placed in new areas as their basic hydrology became known during local investigations.

In 1941, before the operation of the Oregon Agricultural Experiment Station was discontinued, J. E. Upson made a reconnaissance of ground-water possibilities in Lake County in cooperation with that agency. With Mr. Upson's transfer to Santa Barbara the study was deferred until after the war.

When additional funds became available in July 1943, a canvass of public water supplies, similar to that made in Washington in the previous period, except that it was made by personal contact instead of by correspondence, was started by Mr. Robinson and completed by June 1944. Data for the public water supplies of 73 cities and towns derived from ground water were compiled in typewritten form and made available to the public at the Survey's office in Portland. Also, in 1946 and 1947, Mr. Robinson made an investigation of Prineville Valley in the central part of Oregon, where the flow of a number of artesian wells had been reduced by the drilling of additional wells. As a result, the earlier well users had referred the matter to the State Engineer. A typewritten report on the ground water of the area was released to the open file. As both Oregon and Washington are handled by one office, one personnel list is presented with description of the Washington investigations.

California. - When the cooperation with Orange County and Los Angeles County agencies became effective in January 1940, A. M. Piper, in charge of investigations in California, established an office in Long Beach. G. A. LaRocque, Jr. was in charge of this office during 1940; subsequently, J. F. Poland was in charge.

The first investigation was that known as the Long Beach-Santa Ana project, the field work for which was started in January 1940. It was a study of the geology of the Quarternary deposits, the source of ground water in that area. Special attention was given to the effectiveness of the coastal barrier--the so-called "Newport-Inglewood" fault system, roughly paralleling the coast line--in restraining the movement of saline ocean waters into the ground-water basin. Within the area were 6,000 to 8,000 active or potentially active water wells of substantial capacity, ranging in depth from 6 to 1,950 feet. At the beginning of the investigation, there were available many thousand water-level measurements which had been made by various agencies beginning in 1904, including some by the Surface Water Division; also, several thousand complete chemical analyses of ground water. During the field work, which was completed in 1944, 3,600 water-level measurements were made; also 2,300 partial chemical analyses of water were made by A. A. Garrett at Long Beach, and some 40 complete chemical analyses were made by the Quality of Water Division in the Albuquerque laboratory.

The hydrologic features of the investigation were concerned with the historic fluctuations of water level in relation to the magnitude and change in draft, the degree of salt-water encroachment, and the effectiveness of the coastal barrier. The last element was appriased from geologic, geochemical, and hydrologic data but the most specific evidence was obtained from differences in fluctuation in wells on opposite sides of the barrier, three pairs of deep observation wells were constructed as part of the cooperative program.

In the coastal areas of Los Angeles and Orange Counties, the geologic and hydrologic features were studied by means of peg models containing all available logs of water wells; for each well, a peg colored to represent the log was placed on a map base. To determine whether the barrier faults cut the youngest deposits of recent age, 64 shallow observation wells were bored in the 5 low-level gaps containing recent deposits and profiles were prepared showing water levels for the shallow wells tapping the "semiperched" water and pressure levels in selected deep wells. Maps showing the water-level contours for September 1936 and for April 1941 were also prepared. About 20 pumping tests were made to determine plant efficiency, but none were made for permeability and transmissibility. The results of the investigation will be published as three water-supply papers devoted to the geology, chemical character of the water, and the hydrology.

Soon after cooperation with Santa Barbara County became effective, a sub-office was established in Santa Barbara in January 1941. This project was under the local charge of G. A. LaRocque, Jr., until he entered the Armed Forces in February 1943, and subsequently J. E. Upson took charge. As it was an overall appraisal of the ground-water resources of the county, the usual well inventory for each ground-water basin was made. An observation-well program of 177 wells, some of which had been observed previously, was established. Later, the number of wells was increased to 185, of which 6 had recorders and 6 had float gages. The principal purpose was to determine the perennial yield of each ground-water basin; those of the two principal stream systems, Santa Ynez and Santa Maria, and two small south-coast basins, the Carpenteria and Galeta Basins. Mr. Piper realized that to determine the perennial yield of the ground-water reservoirs, additional stream gaging stations were needed, and at his suggestion, the Surface Water Division began cooperation with Santa Barbara County on July 1, 1941, established 6 additional gaging stations, and cooperated in the hydrologic study. In that investigation, which continued during the remainder of the period, there was no salt-water encroachment although the ground-water level had been drawn down low enough locally to develop potential salt-water encroachment. About 50 pumping tests were made on selected wells to determine the permeability and transmissibility of the water-bearing formations in the several ground-water basins. The results of the investigation, covering the geologic investigations, records of pumpage, and hydrologic study, were presented in three reports to be published as water-supply papers, on the geology and ground-water resources for the three areas, Santa Ynez River Valley, Santa Maria Valley, and the south-coast basins.

In July 1943, the cooperation with the Los Angeles County Flood Control District virtually extended the Long Beach-Santa Ana investigation northwestward to the Torrance-Santa Monica area, which included the so-called West Basin. That investigation, which was made to evaluate replenishment to and salt-water encroachment in the West Basin, was completed in 1947 and a report entitled "Geology, hydrology, and chemical character of the ground waters in the Torrance-Santa Monica area, Los Angeles County, California" was made to the Flood Control District.

In the West Basin of Los Angeles County, the barrier faults of the Newport-Inglewood uplift are along its inland edge. They serve to restrain coastward movement of fresh water into the basin. The amount of replenishment that passes through them depends upon the difference in head on the two sides. In Orange County, on the other hand, the barrier features are close to the coast and now function to hold back salt water from entering the main ground-water basin. These barrier features are not water-tight in either area. Nevertheless, in Orange County, they are of great benefit; for the West Basin, they are an eternal problem.

The investigation along the Rio Hondo and lower Los Angeles River for the Army Engineers was started in December 1944. In connection with other flood-control measures, the Army Engineers were considering concrete pavement as a channel lining for the Rio Hondo from the Whittier Narrows to its confluence with the Los Angeles River at Imperial Highway, and for the latter stream from that place to the coast. Major problems of the investigation included the maximum possible hydrostatic pressure that might be exerted by the ground water on a concrete channel lining, the maximum rate at which water might have to be drained into the channels to relieve such pressure, and also the extent and quantity of ground-water replenishment that occurs by natural seepage loss from the channels.

The Army Engineers in the fall of 1944, after conferring with the Geological Survey, constructed 79 shallow observation wells along the reaches of the two streams, in lines normal to the river and a mile apart. Each line comprised four wells--two on each side of the river, one at the toe of the levee, and the other 500 feet distant. Owing to personnel shortage, the Survey was not able to assume responsibility for the water-level measurements in these wells until January 1945. As background for the studies, the results of other intensive investigations by the Survey in that area were utilized, and during the investigation an inventory of all water wells within most of the project area was made.

Hydrographs and profiles along the river, based on river levels and water levels in the shallow and nearby deep wells, showed that for about 6 miles downstream from the Whittier Narrows, the Rio Hondo flows across an intake area in which seepage loss supplies substantial recharge to a common water body, but that between the intake area and the coast, the streams are underlain by two separate and distinct water bodies. The principal water body is confined by relatively impermeable flood-plain silts and clays which contain the semiperched shallow body. The shallow body is hydraulicly continuous with the river, and might exert a maximum hydrostatic pressure which would range areally from zero to as much as 13 feet of water. The small rate of drainage necessary to relieve the destructive heads was estimated on the basis of permeability, cross section, and gradient. The permeability of the shallow aquifer was determined both by field and laboratory methods. The former consisted of three pumping tests made in the area of greatest potential hydrostatic uplift, and on a scale far smaller than any previously reported--the pumping rates ranged from one-fourth to two-thirds of a gallon per minute. The laboratory tests were made by the variable head permeameter on 103 samples of material obtained during the investigation. A progress report was made to the Army Engineers in January 1946, and a second progress report in April 1947.

The last investigation during the period was started in July 1946 in San Bernardino County, and was known as the study of the Lower Chino Basin Area in the Upper Santa Ana Valley. It was an appraisal of the ground water rising from the lower part of the Chino Basin and escaping into the Santa Ana River; also a study of geologic and hydrologic conditions controlling that escapement. In that study, the evapotranspiration losses in the area had previously been estimated by the Department of Agriculture. In a sense, this investigation which was confined to the valley portion of the area and that of H. C. Troxell,292/ which was confined to the mountain area in the San Bernardino County, are complementary. 293/ The investigation was in progress at the end of the period.

In 1943, the Army Engineers requested the Survey to review all available reports describing the ground-water conditions in the San

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292/ p. 188.
293/ Statement of Mr. Poland to author.

Joaquin Valley in Central California, and Mr. Piper assigned that review to Penn Livingston of the Texas District. A report entitled "Ground-water features of the San Joaquin Valley, California" was made in January 1944.

Mr. Piper's supervision of the California investigations ceased when he was detailed to the economic survey of the ex-Japanese mandated islands in the Western Pacific, April 1, 1946.[294] At that time, Mr. Poland was placed in charge of the California investigations. The following Civil Service technical assistants were in the Long Beach office during the period:

Name	Period
G. A. LaRocque, Jr.	Jan. 1940 to Jan. 24, 1941
J. F. Poland	Jan. 15, 1940 to June 30, 1947
A. A. Garrett	Oct. 17, 1940 to June 30, 1947
R. C. Newcomb	Jan. 6, 1941 to June 6, 1942[1]
A. L. Detweiler	Feb. 24, 1941 to Feb. 17, 1942
Leonard Phelps	May 19, 1941 to Apr. 26, 1942
Allen Sinnott	Mar. 25, 1942 to June 30, 1947
W. W. Paulsen	July 1, 1942 to June 15, 1943
B. H. Mashburn	Dec. 6, 1944 to Mar. 1, 1945
W. C. Reimund	Feb. 2, 1945 to Dec. 30, 1946
A. S. Sollid	May 23, 1945 to Aug. 23, 1946
H. G. Thomasson, Jr.	Aug. 26, 1946 to June 30, 1947
T. E. Eakin	Dec. 2, 1946 to June 30, 1947

1/ Military furlough; did not return to district.

Civil Service technical personnel in Santa Barbara Office:

G. A. LaRocque, Jr.	Jan. 25, 1941 to Feb. 1943[1]
G. F. Brown	Jan. 1941 to Oct. 6, 1941
C. A. Wahrhaftig	July 14, 1941 to Sept. 20, 1941
J. E. Upson	Oct. 6, 1941 to June 30, 1947
G. F. Worts, Jr.	Nov. 1941 to June 30, 1947
L. Porter, Jr.	July 1942 to Sept. 1944*
J. C. Fredericks	Jan. 1943 to Mar. 12, 1943*
Penn Livingston	Sept. 1944 to June 1945
V. H. Bartolome	June 19, 1945 to Mar. 1, 1946 W.A.E.
G. F. Gregg	July 17, 1945 to Jan. 16, 1946

1/ Military furlough; did not return to district.

The office clerk was Myrtle Holt until August 1944 when she was succeeded by Ann Peck.

294/ p. 237.

Hawaii. - At the beginning of the period, investigations on the islands of Maui and Molokai were in progress. The Maui investigation, which had been started in 1932, was so far advanced that the field work consisted chiefly in several months' geologic mapping by G. A. Macdonald in 1939 and 1940, the final field work being completed in the fall of 1940. By means of the Territorial Division of Hydrography drilling rig, two test holes were drilled under H. T. Stearn's supervision in 1940. The report was published by the Division of Hydrography as Bulletin 7, "Geology and ground-water resources of the island of Maui, Hawaii."

The Molokai investigation was suspended during the war years with their many special studies, and was not resumed until 1945 when Mr. Macdonald completed the geologic mapping and ground-water investigations. The County made 9 test borings. In addition to the inventory of 29 drilled wells and 13 tunnels, records of stream flow were presented. Various plans for tunnels to bring ground water from the windward valleys to the southern slopes for irrigation were discussed. The report was published as Bulletin 11, "Geology and ground-water resources of the island of Molokai."

The first investigation started during the period was on the island of Hawaii, the largest of the island group, having an area of 4,030 square miles. The need for additional water in the Kona district is acute during every dry period as the wells along the coast are brackish, and cannot be used for domestic purposes. Farther inland, the public and domestic supplies are obtained from rainfall collected on roofs and stored in tanks. Every few years, droughts occur when those supplies become exhausted and cause much hardship. To relieve that situation, the Territorial legislature passed a special act for a ground-water investigation of that district. The investigation was started in 1939 and continued intermittently until 1944. Test drilling was started by the Survey in 1940, but was stopped when well drillers became unavailable due to the war years. However, in connection with war-time investigations for the Armed Forces, drilling was resumed in cooperation with the Army Engineers in 1942 and in cooperation with the Navy in 1944.

Although started primarily to study the Kona district, the investigation was broadened to cover the entire Island of Hawaii. As the island was built up by 5 volcanos, only two of which, Mauna Loa (13,680') and Mauna Kea (13,784'), are active, much of the geologic study was devoted to the effects of volcanic action on the geology and descriptions of historic erruptions. A topographic map of the island was essential to the investigation, and the Ground Water Office compiled one from existing maps published by the National Park Service, and the Geological Survey. In addition to being used in Bulletin 9, it was published and released for distribution in March 1944.

Basal water, the unconfined ground water occurring in the lavas under the entire island, except the rift zones, is the chief source of the ground-water supplies and the depth to those supplies increases rapidly with the distance from the coast, due to the steep slopes. Contracts were let to sink diamond-drill holes to basal water, a distance of about 640 feet at one site and 245 feet at another, but due to inexperience, the contractors were unable to drill more than 80 feet.

During the investigation, numerous requests were received for assistance in locating ground-water supplies near Hilo and in February 1942, a report by Mr. Macdonald describing places where wells could be sunk to supply Hilo was released. Sites for one or more test holes were pointed out with the suggestion that the holes should be drilled to a depth of 1,500 feet before being abandoned. A type of well known as the Maui-type well was used at several locations. That well is a shaft sunk either vertically or diagonally on the mountain side. At the bottom is an enlarged chamber for the pump and from the sump beneath the pump chamber, one or more tunnels are driven horizontally. An inventory of 8 Maui-type wells, ranging in depth from 42 to 1,550 feet, was made; also, an inventory of all public water supplies, chiefly from ground water. Discharge records of springs, wells, and tunnels were obtained chiefly from water-users. It was found that in addition to the known discharge of ground water, huge amounts discharge from basal springs at sea level all around the island, and are practically unused. High level or perched water, above the basal water, is used in limited quantities, and the discharge of about 150 springs from that source was estimated. In the fiscal year 1945, test borings were completed near Kailua, Kona, Hawaii to determine the quality and head of the basal water in that area. The report was published in 1946 as Bulletin 11, "Geology and ground-water resources of the island of Hawaii."

During the war years, much of Mr. Stearns' time was taken up with special investigations for the Army and Navy, starting some time before Pearl Harbor, when both branches desired advice in ground-water supplies and location of quarries for the various establishments. Not only did requests for information regarding sites in the Territory continue but in the following years, answers to the requests widened his field of operations greatly. In 1942, he investigated the geology and ground-water resources of Samoa for the Navy, and in 1943, at the request of the Navy, he made two extensive airplane trips through the South Pacific, visiting all major and many minor Naval bases to locate ground-water and rock supplies. In September and October of that year, at the request of the War Department, an investigation of the possibility of obtaining fresh water from wells on Ascension Island, a stopping point on the air route to Africa in the Atlantic was made; sites for drilling wells were selected, and although the first test well found brackish water, indicating that fresh water prospects were not good, the brackish water could be used for bathing and sanitary purposes, thus making it unnecessary to continue bringing water for these purposes, by ship. While on that trip, Mr. Stearns obtained data on ground-water conditions on many South American bases, either by visiting the bases or contacting engineers who had been engaged in constructing water-supply facilities. A memorandum was prepared for the Survey on ground-water conditions in South American bases on October 23, 1943.

During the last half of 1944, he was engaged on a study of water, rock, and mineral supplies in the Mariana Islands for both the Army and Navy, and following that, he studied water supplies on the Pacific Islands where troops were based.

With the end of hostilities in 1945, it was possible to concentrate on the cooperative program in the Hawaiian Islands and complete investigations previously started. A brief investigation on the island of Niihau was made during the latter part of May 1945. That island has no perennial streams, and as the water from wells is brackish, the domestic supply is rainwater caught on the roofs and stored. A geologic study was made and also an inventory of 57 wells and water holes. Samples were collected from the latter and titrated for chloride by the Survey. The results of the investigation were published as Bulletin 12, "Geology and ground-water resources of the island of Niihau, Hawaii."

The investigation of the last of the principal islands and the second largest was that of the island of Kauai, started in the spring of 1945, and by June 30, 1947, half the geologic mapping and the field work for the investigation had been completed.

A special investigation covering the damage, effects, and possible means of warning of the seismic wave of April 1, 1946, which caused very considerable damage, was made by Mr. Macdonald.

Mr. Stearns resigned June 30, 1946, and was succeeded by Mr. Macdonald. On January 15, 1947, D. A. Davis was assigned to the office.

The preparation of the various reports made it necessary to utilize the following Territorial Civil-Service technical assistants:

Name	Period
S. H. Elbert	July 1, 1939 to Feb. 1942
J. H. Nitta	Mar. 1941 to June 30, 1942
Jean Braund	Feb. 1942 to Oct. 1945
Ethel McAfee	Sept. 1945 to June 30, 1947

Puerto Rico. - When cooperation became effective with the Puerto Rico Aqueduct and Sewer Service, C. L. McGuinness was detailed to Puerto Rico, and began field work in September 1945. The purpose of the investigation was to obtain general information on the quantity and quality of the ground water in all parts of the island, but on account of the limited time and funds available, it was necessary to confine the investigation to a reconnaissance survey in which observations of geologic and hydrologic conditions were those apparent from surface indications. However, previous geologic investigations made by various agencies had made available a more complete knowledge of the geology, than for any other island in the Antilles. In addition, A. G. Unkelsbay of the Geological Survey, a few months previous had made, at the request of the Puerto Rico Industrial Development Company, an investigation of the ground-water supplies in the San Juan area with reference to its industries.

The investigation was aided very greatly by the action of Sergio Cuevas Bustamente, the head of the cooperating agency, who provided the necessary services and facilities, some without cost. In addition to personal visits to many parts of Puerto Rico, data from the principal well drillers and representatives of most of the agencies, both governmental and private, which use large quantities of ground water. As a result, an inventory of the larger public water supplies, chiefly surface water, was made together with an inventory of about 950 wells. Field tests for hardness and chloride content for 62 wells and springs were made. Field work was completed in March 1946 and Mr. McGuinness returned to Washington to prepare his report, which was published by the Puerto Rico Aqueduct and Sewer Service as "Ground-water resources of Puerto Rico."

Washington Office personnel

The field personnel are listed in connection with the activities in each state and to complete the list, those in the Washington Office during all or a part of the period are presented here:

Name	Period	
O. E. Meinzer	July 1, 1939 to June 30, 1947	
A. G. Fiedler	July 1, 1939 to June 30, 1947	
V. T. Stringfield	July 1, 1939 to June 30, 1947	
A. N. Sayre	July 1, 1939 to June 30, 1947	1/
D. G. Thompson	July 1, 1939 to Feb. 19, 1943	Deceased
D. J. Cederstrom	July 1, 1939 to Nov. 14, 1940	
L. K. Wenzel	July 1, 1939 to Dec. 7, 1945	Retired for disability
V. C. Fishel	July 1, 1939 to July 21, 1941	
R. C. Cady	July 1, 1939 to Feb. 1, 1941	2/
C. L. McGuinness	July 1, 1939 to Jan. 24, 1942	
	Jan. 25, 1943 to June 30, 1947	3/
F. H. Klaer, Jr.	July 1, 1939 to July 19, 1943	
R. G. Kazmann	Mar. 13, 1940 to Nov. 11, 1943	
A. C. Byers	Jan. 17, 1940 to Aug. 25, 1942	
C. E. Jacob	Sept. 27, 1944 to June 30, 1947	
G. A. Waring	Apr. 22, 1941 to Nov. 25, 1946	1/

1/ For detail to Military Geology, see p. 234.
2/ Military furlough; died Jan. 15, 1943.
3/ Detailed to Puerto Rico Sept. 8, 1945 to Mar. 14, 1946.

Name	Period							
B. Fisher	Feb.	18, 1942	to	May	5, 1942	4/
R. B. Morrison	Sept.	1, 1942	to	Nov.	1, 1942	1/
F. A. Swenson	July	24, 1942	to	Mar.	1, 1947	1/
R. M. Jeffords	July	23, 1942	to	Sept.	15, 1942	1/
J. M. Berdan	Aug.	10, 1942	to	Oct.	15, 1946	
W. O. Smith	Dec.	4, 1945	to	June	30, 1947	
J. M. Birdsall	Dec.	13, 1943	to	Dec.	11, 1944	
R. C. Hart	July	1, 1939	to	Jan.	24, 1943	
	Oct.	22, 1945	to	June	30, 1947	
W. F. Guyton	May	1, 1945	to	Mar.	5, 1946	1/
	Mar.	10, 1947	to	June	30, 1947	
M. M. Saunders	Aug.	20, 1945	to	June	30, 1947	

1/ For detail to Military Geology, see p. 235.
4/ Military furlough; did not return.

QUALITY OF WATER DIVISION

The increasing interest in the quality of both surface and ground water on the part of industry brought about largely by the war, resulted in greater cooperation with the States which were seeking additional industrial plants. Also, post-war planning by Federal agencies making studies of the water resources, particularly in the western states, created greater interest in sedimentation with reference to existing and proposed reservoirs, and in the chemical quality of surface and ground water for irrigation. The increase in Federal funds was especially marked during the last two years when the intensive investigation of the Missouri River Basin-Departmental Program was in effect.

The result of these influences was an increase in the total annual funds for the Division from $86,678 in 1940 to $316,382 in 1947, an increase of more than 350 percent, most of which occurred during the last three years.

Perhaps the greatest effect on the Division was the decentralization which took place during the period. Previously, practically all the analytical work had been performed in Washington, except for a limited amount in the Austin laboratory which was set up in 1937; but the expansion made it possible as well as highly desirable, to establish 7 field laboratories, with permanent staffs, located much closer to their fields of operation and having a more intimate knowledge of their areas, and reducing the very considerable expense of transporting the water samples to the laboratory.

Washington Office

W. D. Collins continued in charge of the Division until his retirement on September 30, 1946, when he was succeeded by S. K. Love. C. S. Howard was in charge of the operation of the Washington laboratory until he established headquarters in Albuquerque, New Mexico, in July 1942 when Mr. Love succeeded him in charge of the laboratory. Mr. Howard was also in charge of the continuing investigations in the Colorado and Rio Grande Basins, and the Pecos River Joint Investigation with was started in the beginning of the period and continued until December 1941. Mr. Love was in charge of the sediment investigations for the Soil Conservation Service and the Flood Control Coordinating Committee of the Department of Agriculture, which were started in the previous period and continued during the first year or two of the present period; also of that part of the Southeastern Florida investigation relating to quality of water which was started in the fall of 1939, and continued during the period. When Mr. Love became chief of the division, E. W. Lohr took charge of the operation of the Washington laboratory.

Field

The first move in the decentralization which characterized the present period, was brought about in 1942 by the limitation on Washington Office salaries,[295] which required that some Washington Office personnel be transferred to permanent field headquarters. One of the principal areas of operation was the Colorado River, Gila, Rio Grande, and Pecos River Basins in the southwest and as C. S. Howard was in charge of those investigations, his headquarters were moved to Albuquerque, N. Mex. in July 1942, that city being selected not only because it was rather centrally located, but what was of equal importance, laboratory space was made available by the United Pueblos Agency. At that time, Mr. Howard's territory included all that west of the Mississippi River and west of Texas. When the Missouri River Basin-Departmental Program became effective in the 1946 fiscal year, that area was transferred to the newly established Lincoln Office, and when the Fayetteville Office was established in 1945, the Arkansas work was turned over to it.

<u>Laboratories</u>. - Prior to the establishment of the laboratory at Albuquerque, a permanent laboratory was established in Austin, Texas in 1937, and a temporary laboratory was maintained at Pecos, Texas from Aug. 1, 1939 to June 30, 1941 in connection with the Pecos River Joint Investigation. A temporary laboratory maintained at Roswell, N. Mex. from 1937 to June 1943, and another temporary laboratory maintained at Safford, Ariz. from July 1940 to March 1945, except for the period from June 1942 to June 1943, were under Mr. Howard's supervision.

Additional State cooperation made it possible to establish laboratories

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at Raleigh, North Carolina in September 1943, in charge of W. L. Lamar; at Charlottesville, Virginia in July 1945, also in charge of Mr. Lamar; at Fayetteville, Arkansas in September 1945, in charge of I. W. Walling and later of G. A. Billingsley; at Stillwater, Oklahoma in July 1946, in charge of I. W. Walling; (the Fayetteville and Stillwater laboratories were under the supervision of W. W. Hastings, who was in charge of the Austin laboratory); and in September 1946, at Philadelphia, Pennsylvania in charge of N. D. Beamer under the supervision of W. F. White. A temporary laboratory was maintained at Miami, Florida from February 1940 to September 1942.

The Missouri River Basin-Departmental Program which was placed in operation in the fall of 1945, required an intensive sediment study in the entire basin, with a less intensive study of quality, and a main office and laboratory were established at Lincoln, Nebraska, in March 1946, under the supervision of P. C. Benedict, who was in charge of the Division's investigations in the Basin. That program was so extensive, as well as intensive, that sediment laboratories were also established at Worland, Wyoming in March 1946, with T. F. Hanly in charge; at Dickinson, North Dakota in June 1946, with B. C. Colby in charge, followed by R. B. Vice; and at Norton, Kansas, in April 1947, with D. M. Culbertson in charge.

The first regional full-scale laboratory established for chemical analyses and sediment determination, was that at Salt Lake City, Utah, in January 1947, as a result of a specific appropriation by Congress. With the expansion of the Division's activities, it was recognized that regional laboratories would be necessary; the cost of equipping a laboratory in each state where investigations were being conducted, was in general too great for the available funds and the logical solution was a number of regional laboratories equipped by means of Federal funds appropriated for the purpose. With the establishment of regional laboratories, the expense of transporting water samples from the field to the laboratory would be much less than that required to send them to the fewer and more distant laboratories. Salt Lake City was selected as the site of the first regional laboratory, as the work had increased in the upper Colorado River Basin in Utah and Colorado, and in Idaho, and to a limited extent, the Pacific Northwest. It was established by Mr. Howard in quarters at Fort Douglas in a building of a former Army Post which had been acquired by the Public Buildings Administration. R. T. Kiser was sent from Albuquerque in January 1947, to set up the laboratory. He was assisted by W. M. Webster and beginning March 24, 1947, E. L. Singleton joined the staff.

State cooperation

The number of states cooperating in quality of water investigations increased from 3 to 13, the additions occurring chiefly during the last half of the period. That increase was due largely to the fact that in planning for the post-war period, many industrial firms were seeking new sites, and water of suitable quality was necessary. The many inquiries received by State and city officials, in consequence, called attention to the importance of a knowledge of the quality of the water, both surface and ground. There were practically no State organizations working independently on industrial and agricultural quality of water in a comprehensive way, and as competition was keen, especially in some sections of the country, the natural result was that offers of cooperation by additional States were received by the Survey.

Annual cooperative State funds:

1940	$23,500	1942	$13,209	1944	$13,550	1946	$45,031
1941	18,400	1943	11,150	1945	26,300	1947	59,540

The decrease during the first 4 years was due to the fact that a number of special investigations by the surface, ground, and quality of water divisions, started during the previous period, were completed and the quality studies either discontinued or greatly reduced. The increase during the last 4 years reflects the interest aroused chiefly by industrial needs.

The details of cooperation in each state are given under "Operations in each State."

Federal Cooperation

There were three principal reasons for Federal cooperation which consisted in transferring to the Survey sufficient funds for the Survey to do the work requested: (1) special investigations participated in by several agencies during the first two years, (2) investigations during the war years pertaining to the war effort, and (3) the investigations of the Bureau of Reclamation, requiring an intensive sediment program particularly in the Missouri River Basin during the last two years. The total annual amounts of Federal cooperation were:

1940	$12,964	1944	$ 3,096
1941	13,893	1945	6,320
1942	12,380	1946	103,630
1943	3,418	1947	148,640

The details of the activities for each agency follow.

Army Engineers. - Early in the period, the Army Engineers requested the Survey to make analyses for dissolved solids of 10-day deposits above Conchos Dam in the Canadian River in New Mexico, and above and below the John Martin Dam on the Arkansas River in Colorado.

During the war years, the Army Engineers requested the Survey to make analyses of water supplies for existing or proposed military establishments in various parts of the country. Those requests were made usually by the various district offices. To assist the Office of Chief of

Engineers in maintaining water supply systems at the various Army camps, the Repairs and Utilities Division was organized during the war, and in the fiscal year 1943, that agency requested the Survey, as the authorized agency for that purpose, to furnish a complete analytical service for Army camps as needed. That service was continued during the period, and analyses of the water supply at each camp were made at least once a year by the nearest Survey laboratory.

Annual amounts of Army funds available:

Year	Army Engrs.	Army camps	Total
1941	$ 1,168		$ 1,168
1942	980		980
1943	905	$ 2,513	3,418
1944	1,358	1,738	3,096
1945	784	536	1,320
1946		420	420
1947	2,131	5,519	7,650

Public Works Administration. - During the 1942 fiscal year, the Public Works Administration made a final transfer of funds to the Survey amounting to $23,500, of which $11,200 was allotted to the Quality of Water Division to continue the analyses that had been supported by that agency during the previous period. Of that amount, $8,650 was used in Texas, and $2,550 in New Mexico.

Defense Plant Corporation. - The second phase of the Gila River Investigation296/ made as a war measure, was financed by the Defense Plant Corporation, a war-time agency of the Reconstruction Finance Corporation, and required a large number of analyses which were made in the Safford laboratory297/. To meet the expense of that work, the following allotments were made available:

1944 $5,000 1945 $5,000

Bureau of Reclamation. - Of the $38,000 contributed to the Pecos River Joint Investigation by the Bureau of Reclamation, 298/ $5,800 was allotted to the Quality of Water Division for its work in the Texas portion of the Pecos River Basin during the Fiscal year 1940.

It was not until the fiscal year 1946 when the Bureau was investigating the Lower Rio Grande Valley Gravity Project that further funds were made available. At that time, the Bureau wished to know the amount of salts being applied to the irrigated lands by river water, and the amount leached out by the drains and wasteways. Funds were

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296/ p. 362.
297/ idem.
298/ p. 17.

provided for the analysis of the water samples which the Bureau collected. That agency also made the necessary discharge measurements. The investigation continued during the 1947 fiscal year. A small number of analyses were also made in the Upper Brazos River Basin.

During the fiscal year 1947, the Bureau's investigations of both surface-and ground-water projects were being expanded, and funds for the analysis of water for a number of new investigations in Oklahoma, New Mexico, and Colorado were provided. During the ground-water investigations in the Pecos Valley in Texas,299/ the sodium content of the water was an important factor, and samples from 522 wells and springs were analyzed. Sediment samples at three points in the Pecos River Basin, two on the main stream, and one on Alamagordo Creek above Alamagordo Reservoir. It was anticipated that records would be obtained showing loads during periods of summer storms, but unfortunately, no flow occurred in Alamagordo Creek and the flow of the Pecos was normal.

Daily dissolved solids samples were collected at the Rio Grande gaging stations near Lobatos, Colo., which is the State line station, and at Otowi Bridge, N. Mex.

The ground-water investigation of the sump drain in the closed basin portion of the San Luis Valley, Colo.,300/ required the chemical analyses of samples from some 200 wells.

Near the end of the year, funds were made available for the collection of daily sediment samples at four gaging stations in the Washita River Basin, Oklahoma. This was an inter-division undertaking; a local observer took the samples, which were collected by the Surface Water engineer by the Stillwater laboratory; and finally the Surface Water Division, in connection with the discharge records, computed the load in tons.

Total annual amounts of Bureau of Reclamation funds available:

1940	$5,800	1946	$5,210	1947	$23,900

Soil Conservation Service. - Of the eight projects in which sediment studies had been started during the previous period, those at Tarkio, Mo., Deep River, N. C., Coon Creek, Wis., and Pullman, Wash. were continued until 1941.

The collection of sediment samples in the field were made by the Surface Water Division which maintained the gaging stations at which the samples were collected, and funds were allotted the Surface Water Division for that purpose. The analyses of the sediment samples and

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299/ p. 317.
300/ p. 323.

computations of the sediment load was made by the Quality of Water Division, and for that purpose, the following amounts were available:

1940 $2,064 1941 $2,300

Flood Control Coordinating Committee. - The study of sediment on the Boise River, Idaho Project started in January 1939, was discontinued in November 1941, and the temporary project at St. Francis, Mo. started in February 1939 was discontinued in 1940.

The collection of sediment samples was made by the Surface Water Division which maintained the gaging stations at which the samples were collected, and funds were allotted the Surface Water Division for that purpose.

The analyses of the sediment samples and the computation of the sediment load was made by the Quality of Water Division, and for that purpose, the following amounts were available:

Year	Boise	St. Francis	Total
1940	$ 8,000	$ 1,200	$ 9,200
1941	4,400		4,400

For a description of the Boise River Project, see p. 896.

Navy Department. The Survey was called upon to analyze the water supplies at a few Naval establishments and the Navy Department funds expended were:

1941 $225 1942 $200 1947 $160

Veterans Administration. - Perhaps following the precedent set by the Army Engineers several years previous, the Veterans Administration near the end of the period entered into an agreement with the Survey to analyze, chiefly for corrosion and scale, the water supplies of Veterans hospitals as requested.

During 1947, the amount of Veterans Administration funds required was $330.

State Department. - As a result of the International Treaty with Mexico, the San Marcial gaging station on the Rio Grande was transferred from the International Boundary and Water Commission to the Survey on July 1, 1946. The San Marcial station is a comparatively short distance above Elephant Butte Reservoir and both stream-flow and sediment records were maintained. The State Department provided funds for the maintenance of the station of which $3,400 was allotted to the sediment studies.

Boise River Investigation

The Boise River Investigation was one of a number of similar investigations started toward the end of the previous period in cooperation either with the Soil Conservation Service or the Flood Control Coordinating Committee of the Department of Agriculture. It is here described as during the investigation, new methods of collecting and computing sediment records were used, methods which have become more or less standard in the Survey.

The investigation was started in January 1939, with the measurement of discharge at 13 points, the general locations of which were selected by the Soil Conservation Service to show the effect on erosion of placered areas, burned areas, cut-over areas, virgin timber areas, and range areas in three different stages of depletion. All stations, three of which were existing stations, were equipped with recorders and a number also had broad-crested controls. When the flow was too small to be measured by current meter, portable weirs were used. The field work of measuring the flow and collecting sediment samples was performed by the Boise District of the Surface Water Division, P. C. Benedict being in charge of the project under T. R. Newell's supervision. The development of the sediment sampling equipment, the collection of sediment samples and their analyses were under the direction of S. K. Love, who spent considerable time in the field. A temporary laboratory in charge of H. A. Swenson was maintained from July 1, 1939 to Oct. 30, 1940.

The frequency of the sampling depended upon the changes in sediment content. During spring runoff, samples were collected from 3 to 12 times daily. As changes in stage and sediment content usually occur more suddenly in small streams, samples were collected more frequently on the small tributary streams. During flood periods, the loads for most of the stations were computed in tons per hour and plotted in the form of continuous graphs for each day, and the daily loads determined by measuring with a planimeter the areas under the graphs. During periods of low flow and periods of low sediment content and the discharge fairly uniform, the daily loads were computed from daily samples and the average discharge for the day. A total of 43,900 sediment samples were collected at the 13 stations.

Field work was completed June 30, 1940, and the results of the investigation were published as Water-Supply Paper 1048.

Pecos River Joint Investigation

The work of the Quality of Water Division for the Pecos River Joint Investigation was a continuation of that started in 1937 in cooperation with the State of New Mexico, which had been confined chiefly to the New Mexico portion of the Pecos River Basin with samples from one gaging station in Texas. The analytical work was performed under supervision of C. S. Howard in a laboratory established at Roswell, in charge of

W. F. White, Jr. When the Joint Investigation was started in July 1939, additional work was performed in the Texas portion of the area with analyses being made in the laboratory at Pecos, Texas, established August 1, 1939, in charge of W. W. Hastings.

Daily samples were collected at 16 gaging stations on the Pecos River and less frequently at several intermediate points on the main stream. As the surface waters in the Basin are rather highly mineralized, collection of daily samples was necessary to obtain a clear understanding of changes in concentration and character of the river waters. At the station on the Pecos at Red Bluff, New Mexico, it was necessary to obtain 2 samples daily because of marked diurnal variation in concentration. The concentrates entered the river at Malaga Bend, downstream from the power plant below Carlsbad, and as that plant regulated the river, the percentage of concentrates varied. Samples of important tributaries were obtained at frequent intervals to evaluate the effects of tributary contributions on the composition of the waters in the Pecos River. Many wells were sampled throughout the basin to determine the character of the ground waters available for irrigation and to show the quality of the ground water, which is a large proportion of the low flow of the river. After the end of the Joint Investigation in June 1941, quality of water investigations were continued on a very reduced scale through cooperation with the states of New Mexico and Texas.

The Civil Service personnel in the Roswell laboratory were:

W. F. White	July 1, 1939 to Nov. 1, 1942
E. D. Parsons	Sept. 5, 1939 to Oct. 14, 1941
J. D. Hem	July 1942 to June 1943
W. L. Minton	June 24, 1942 to Jan. 5, 1943
A. R. McKinney	June 3, 1940 to Sept. 16, 1940
J. K. Lawson	June 15, 1940 to Sept. 30, 1940
R. J. Putman	Apr. 2, 1941 to July 26, 1941

The Roswell laboratory was merged with that at Albuquerque June 16, 1943.

The Pecos laboratory was opened August 1, 1939 and continued until June 30, 1941, after which date the small amount of analytical work being continued was performed in the Austin laboratory. The Civil Service technical employees were:

N. A. Talvitie	July 1, 1939 to June 30, 1941
W. W. Hastings	Aug. 1, 1939 to June 30, 1941
Burdge Irelan	Sept. 18, 1939 to June 30, 1941
R. G. Kerlin	June 25, 1940 to Dec. 28, 1940
N. L. Lewis	Jan. 2, 1941 to June 30, 1941

Gila River Investigation

At the request of S. F. Turner, a laboratory was set up at Safford, Arizona in July 1940, in charge of J. D. Hem. Its function was to analyze the water samples required by the ground-water inventory of Safford Valley, which were surface- and ground-water samples to determine the amounts of dissolved solids entering and leaving the valley, and the sources of the saline material. In addition, analyses of ground water in other parts of Arizona were made. The first phase of the investigation, during which about 2,000 analyses were made, was ended in June 1942 and the laboratory was closed in July.

The second and more intensive phase of the Gila River investigation, made at the request of the Defense Plant Corporation and financed by it, with funds furnished by the Phelps Dodge Corporation, was started in June 1943, and the laboratory was reopened by Mr. Hem on a more extensive scale. About 5,000 water samples were analyzed to determine the effect on the quality of water in the area by its use by irrigation, industry, and native vegetation. Some of the analyses of ground-water samples were used in a method of computing water use by native vegetation, which was devised during the investigation. The investigation lasted until the end of 1944 when the laboratory was closed. In addition to Mr. Hem, R. T. Kiser was there from August 16, 1943 to August 1944.

Colorado River Investigation

The program of sediment sampling on the Colorado River was virtually unchanged from that of the previous period. The gaging stations selected for sampling were at important points connected with plans for reservoirs, or those stations which would indicate the large sediment-producing areas. Sediment samples were collected at the following points:

Colorado River near Cisco, Utah
Green River at Green River, Utah
San Juan River near Bluff, Utah
Colorado River at Grand Canyon, Ariz.

The samples were analyzed in local laboratories by the resident engineers of the Surface Water Division. The computation of daily, monthly, and annual sediment loads were made in the Albuquerque laboratory.

During the period, the dissolved solids studies, however, were expanded. Their purpose was to determine the concentration in chemical character of the river waters at various points in the main stream and then ascertain the nature and quantity of the contributions of dissolved solids from tributary streams. The users of water in the lower basin became conscious of the need for quality of water information, particularly in anticipation that trans-mountain diversions out of the headwater areas of the basin would have a detrimental effect on the quality of the water available in the lower basin.

Dissolved solids studies were conducted at the following gaging stations:

Colorado River at Hot Sulphur Springs, Colo., Apr. to June 1947
Colorado River near Glenwood Springs, Colo., Oct. 1941 to June 1947
Colorado River near Cameo, Colo., Oct. 1933 to June 1947
Colorado River near Cisco, Utah, Oct. 1928 to June 1947
Colorado River near Lees Ferry, Ariz., Oct. 1942 to June 1947
Colorado River at Grand Canyon, Ariz., Aug. 1925 to June 1947
Colorado River below Hoover Dam, Oct. 1939 to June 1947
Colorado River near Yuma, Ariz., Oct. 1942 to June 1947
Green River at Green River, Utah, Oct. 1928 to June 1947
Gunnison River near Grand Junction, Colo., Oct. 1939 to June 1947
San Juan River near Blanco, N. Mex., Apr. 1945 to June 1947
San Juan River at Shiprock, N. Mex., Feb. 1941 to 1944
San Juan River near Bluff, Utah, Oct. 1929 to June 1947
Animas River at Farmington, N. Mex., June 1940 to June 1947
Eagle River below Gypsum, Colo., Apr. to June 1947

Daily samples were collected and the analyses made at first in Washington, but were made in Albuquerque after the laboratory was established in July 1942.

The Colorado River investigation was under the direction of C. S. Howard who furnished the foregoing information.

Annual Federal funds available were:

1940	$ 9,800	1944	$ 11,800
1941	9,720	1945	14,000
1942	9,620	1946	12,400
1943	10,780	1947	29,000

The increase for 1947 was made in recognition of the growing interest in and need for more sediment and dissolved solids data for the Colorado River.

Albuquerque Laboratory. - The Albuquerque laboratory was virtually of the type which came to be known later as a regional laboratory. It was maintained chiefly by Federal funds and analyzed samples of sediment and dissolved solids, from a large area in the southwest. At first, the samples analyzed were from the Colorado River but later samples from ground water investigations in the southwest were analyzed, and during the last year, sediment samples from the Rio Grande, Pecos, and Little Colorado River Basins were analyzed for the Bureau of Reclamation.

The laboratory had the following Civil Service technical personnel under Mr. Howard's supervision:

Name	Period
W. F. White, Jr.	Nov. 2, 1942 to Aug. 3, 1944
Trudell Downer	Aug. 2, 1943 to July 11, 1945
M. R. Cummings	Nov. 20, 1943 to Apr. 15, 1944
R. T. Kiser	Aug. 1944 to June 30, 1947
J. D. Hem	Jan. 1945 to June 30, 1947
M. E. Krausnick	Aug. 17, 1945 to Mar. 8, 1946
V. D. Arnold	June 7, 1946 to June 30, 1947
W. I. Ettleman	July 22, 1946 to May 29, 1947
W. M. Webster	Sept. 9, 1946 to June 30, 1947
E. F. Williams	Feb. 11, 1946 to June 30, 1947
E. L. Singleton	Mar. 24, 1947 to June 30, 1947

Missouri River Basin-Departmental Program

When plans for the Quality of Water Division's participation in the Departmental program were well advanced, P. C. Benedict, who had devoted a large part of his time in the Iowa District to the development of sediment sampling equipment as the Geological Survey representative,301/ was transferred September 21, 1945, from the Surface Water Division to the Quality of Water Division and placed in charge of the Division's activities in the Missouri River Basin. Those activities were concerned chiefly with the sediment discharge of streams, related to reservoirs proposed for construction by the Bureau of Reclamation, as well as studies of the mineral quality of surface and ground waters to meet the needs of all Federal agencies in the Missouri River Basin.

After a study of the probable investigations to be undertaken and transportation facilities available, S. K. Love and P. C. Benedict recommended the establishment of a central office and laboratory in Lincoln, Nebr., and when field work was being started, Mr. Benedict's headquarters were moved on March 6, 1946, to Lincoln.

The Army Engineers were obtaining sediment samples at Survey gaging stations in the Yellowstone River Basin in connection with their plans for constructing flood control reservoirs; sampling at 2 stations was discontinued, and the other stations were incorporated in the Survey's program. That program consisted of determining daily sediment discharge at 25 gaging stations and miscellaneous studies at several other stations. For the quality study, daily samples were obtained at 4 gaging stations, and samples were collected monthly and during floods at 38 other stations. Many of the latter samples were obtained by the Surface Water Division engineers while making discharge measurements.

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By June 30, 1947, the requested program had expanded to include 44 daily sediment stations, and 7 stations sampled periodically, and 13 quality stations sampled daily plus 61 stations sampled periodically. Water samples collected by the Ground Water Division in the Missouri River Basin were also analyzed, and discussions were prepared for inclusion in ground-water reports.

To carry on the investigation, offices and laboratories were established in Lincoln, March 1946; Worland, Wyoming, March 1946; Dickinson, North Dakota, June 1946; and Norton, Kansas, April 1947. An engineer with several assistants was in charge of each office and was responsible for the field office and laboratory work in his area and, at times, made needed water-discharge measurements. H. A. Swenson was in charge of the quality of water studies in the Lincoln Office. The Dickinson suboffice, which is carrying on both quality of water and surface water investigations, was jointly supervised by the respective district offices, Lincoln, and Bismarck. Surface water engineers in Kansas, Nebraska, South Dakota, and Wyoming also assisted with the program.

The following amounts from the Missouri River Basin funds were allotted to the Division:

1946	$ 98,000	1947	$115,450

Although not concerned solely with the Missouri River program, the Survey's participation in the development of the sediment samplers at the Hydraulic laboratory at Iowa City was under the supervision of the Lincoln Office as Mr. Benedict had previously been engaged in that study. Mr. Benedict had as Civil Service technical assistants the following:

Name	Period
Lincoln:	
F. T. Schaefer	Jan. 29, 1946 to June 30, 1947
H. A. Swenson	Feb. 1, 1946 to June 30, 1947
J. G. Connor	Feb. 25, 1946 to June 30, 1947
S. E. Emeson	June 3, 1946 to Aug. 29, 1946
R. H. Schaffer	Sept. 23, 1946 to June 30, 1947
J. J. Wright	Feb. 4, 1947 to June 30, 1947
S. E. Palmer	Apr. 21, 1947 to June 30, 1947
Mrs. W. M. Barr	June 2, 1947 to June 30, 1947
L. L. Thatcher	June 2, 1947 to June 30, 1947

Name	Period
Dickinson, N. Dak.:	
B. C. Colby 1/	Mar. 25, 1946 to Aug. 12, 1946
R. B. Vice 1/	June 19, 1946 to June 30, 1947
J. M. Stow	July 1, 1946 to June 30, 1947
Norton, Kans.:	
K. B. Johnson	Feb. 18, 1947 to June 30, 1947
D. M. Culbertson	Mar. 17, 1947 to June 30, 1947
Worland, Wyo.:	
T. F. Hanly	Jan. 15, 1946 to June 30, 1947
S. G. Heidel	Mar. 18, 1946 to June 30, 1947
A. R. Robinson, Jr.	June 2, 1947 to June 30, 1947

1/ Surface Water Division.

In addition, the Surface Water Division's sub-office at Cambridge, Nebr. supervised the sediment work in that area.

Research projects

Prior to the fiscal year 1947, the division's activities in research had been largely concentrated on methods of chemical analysis as applied to the chemistry of natural waters, but with increasing demands for actual analyses, less time and funds were available for research. However, with $7,000 available for research,302/ it was planned to participate in further research and development of sediment sampling equipment and technique at the Iowa City laboratory, and the initiation of a program for studying geochemical problems in connection with studies of ground water resources.303/

The funds were used for five new projects and for one of two projects started previously. The new projects were:

A detailed study of the flame photometer for the routine determination of sodium and potassium, conducted by a graduate student at Oklahoma A & M College in Stillwater, under joint supervision of the Chemistry faculty of the college, and I. W. Walling, the Survey's resident chemist.

An improved electrometric method for determining boron developed in the Lincoln laboratory, under the general supervision of P. C. Benedict.

302/ p. 21.

303/ S. K. Love: Proc. Southern Branch Conference, Dec. 5-7, 1946, p. 134.

W. L. Lamar supervised in the Raleigh laboratory a method to determine color in turbid water by introducing a concentrated solution of sodium chloride, which would precipitate the turbidity without affecting the color.

A study of methods for determining high nitrate content in natural waters was made in the Austin laboratory under the direction of Burdge Irelan.

A study of analytical methods needed for pollution investigations was made by W. L. Lamar, who visited the Tennessee Valley Authority in Knoxville and the Public Health Service in Cincinnati, and obtained a large amount of information on the pollution problem.

Of the two projects started previously, one was the development of sediment samplers,304/ and funds were used to help finance the activities of the Survey's representative, B. C. Colby.

The other project was a study of zinc uranyl acetate for the determination of sodium, which had been started a year or so previously by the Albuquerque laboratory under the supervision of C. S. Howard. No research funds were devoted to that project during 1947.

Sedimentation Studies

Increasing attention to the sediment loads in streams was being given not only by the Survey but also by the Army Engineers, Bureau of Reclamation, TVA, Soil Conservation Service, and other agencies concerned with the shortage of water, and soil erosion. The accuracy of the computation of sediment load depended largely upon the degree with which the sediment samples collected gave a true measure of the sediment in the stream cross section at the time of sampling. For collecting the samples, no standard type of equipment known as a sampler had been developed; the Survey was using the so-called Colorado-type, the Army Engineers were using various types devised by the different district offices, and the other agencies had their own samplers. Also, there was no standard method of analysis of the sediment loads.

To make a study of the various types in use, and develop satisfactory types for various conditions, Gail Hathaway, Special Assistant to the Chief of Engineers, U.S.A., contacted Prof. E. W. Lane at the University of Iowa's Hydraulic Laboratory in Iowa City in 1939; the Army Engineers were carrying on a study of lock models at the time and had a sub-office there. Prof. Lane expressed a willingness to undertake a research project, and to guide that research, an inter-agency committee, consisting of representatives from the Army Engineers, Bureau of Reclamation, TVA, Soil Conservation Service, and

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304/ p. 368.

Office of Indian Affairs, was formed in 1939. Headquarters for the project were established at the Hydraulic Laboratory in the spring of 1939. At first, the project was actively participated in by personnel of the Army Engineers, Soil Conservation Service, and the Geological Survey; somewhat later the Bureau of Reclamation and TVA detailed men to the project for a relatively short time. Prof. Lane guided the project until the summer of 1942 when he left the Hydraulic Laboratory. Although preliminary models had been made, no tangible results had been obtained, and there was a disposition on the part of some of the agencies to discontinue the project. L. C. Crawford was most insistent that the study continue until a satisfactory sampler was developed. The Army Engineers also desired the continuation and thereafter the development work was carried on by P. C. Benedict of the Survey and M. E. Nelson of the Army Engineers in charge of the Army Engineer sub-office at the laboratory. The Survey's participation was financed from Federal station funds, and V. A. Koelzer of the Iowa District was the Survey's full-time representative, under the supervision of R. G. Kasel, district engineer, who was succeeded by L. C. Crawford April 1, 1940. Mr. Koelzer resigned November 12, 1940, and the Survey had no representative until the following June when P. C. Benedict was transferred to the Iowa District. Thereafter, he devoted half his time to the joint investigation until he was transferred to Lincoln, Nebraska, to head the Quality of Water Division's participation in the Missouri River Basin-Departmental Program on March 6, 1946, and was succeeded by B. C. Colby on a full-time basis to complete certain important phases of the remaining work of particular interest both to the Army Engineers and the Survey. From then on, the Survey's share of the project was financed by Missouri River Basin, Colorado River, and Research funds, and general supervision was exercised by Mr. Benedict from the Lincoln Office.

The first phase of the investigation was a review of field practice, and equipment used in sampling suspended sediment. More than 50 samplers in use, not only in the United States, but also in Europe and India were studied, together with the current field practices which varied considerably. As a result of that study, the requirements for an ideal sampler were set forth, as were also the frequency with which samples should be taken, and the selection of sampling points. The results were published by the Army Engineers' sub-office at Iowa City as "Report No. 1, Field practice and equipment used in sampling suspended sediment, August 1940." It formed the basis for the subsequent investigation.

As the most unsatisfactory phase of sediment sampling was the determination of bed load and bed material, a study of existing samplers was made, and the requirements for an ideal sampler outlined. Report No. 2, "Equipment used for sampling bed load and bed material, September 1940," gave the results. It appeared to be almost impossible to develop a bed load sampler for streams having sandy channels, and as that type of stream carries the heaviest concentrates, the type of stream of greatest concern to the cooperating agencies, no work was done on a bed load sampler.

A study of the various sampling methods in use was made to determine their inherent errors when used in streams where the sediment concentrations and velocities vary between the surface and stream bed. As a basis for subsequent field work, a laboratory study of the problem was made both by analytical methods and use of many field samples. It was termed a "quantitative analytical study" and the results were published as Report No. 3, "Analytical study of methods of sampling suspended sediment, November 1941."

As a part of that study, or perhaps it would be more accurate to state, being carried on at the same time, was a study of methods to determine concentrations of sediment in the samples. There was a lack of uniformity in the methods in use, as was shown by Report No. 4, "Methods of Analyzing Sediment Samples" was also published in November 1941.

With the background of existing samplers and the study of sources of error through the sample collected being non-representative of the conditions in the stream, the next step was to eliminate by laboratory tests the sources of those errors. The chief sources were (1) due to adverse sampler intake conditions, (2) accumulation of sediment in the sample container, and (3) loss of sediment in transferring a sample, Report No. 5, "Laboratory investigations of suspended sediment samplers, December 1941," gave the results.

Having determined the sources of error in existing types of samplers, the next step was to design samplers which would eliminate those errors, and that work was started early in 1941. To meet the wide range of field conditions, two types of samplers were needed, one the depth-integrating sampler which, as its name implies, would obtain an integrated result as the sampler was moved uniformly from the top to the bottom and return, and the other, a point sampler to be held at a fixed point in the vertical. The depth integrator was the more complex, and it was studied first. Working drawings for a sampler were prepared from which plaster models were made, the latter being changed until size and shape appeared satisfactory. Then a finished metal sampler was constructed, which was subject to laboratory and field tests. The tests disclosed weaknesses which resulted in further revisions. That procedure continued with more exhaustive tests on each succeeding model, until the fifth model was completed early in 1943. In May 1943, 10 test models were made, and distributed among the Office of Indian Affairs, Bureau of Reclamation, Army Engineers, and Survey offices for comparisons with samplers in use. Reports received from 13 field offices indicated that the sampler proved to be satisfactory for average conditions, but needed some modification to satisfy extremes of depth and velocity. The comparisons also showed that in some instances, the discrepant results of the existing samplers were due in part to the methods used in sampling. Thus, it was apparent that there was a need to standardize the methods used in sampling.

A progress report containing the results of the various field tests was published in December 1944. It was transmitted to the Interdepartmental Committee for study of methods used in measurement and analysis of sediment loads in streams, as that agency had directed that such study be made. As a result of all the studies, report No. 6 was prepared having the title, "The design of improved types of sediment samples."

While the depth-integrating sampler was being developed, work was started on the point sampler in which the Army Engineers were particularly interested. Work was suspended before more than the one laboratory sampler was made, as the Interdepartmental Committee on July 3, 1942, agreed to defer further development until after the war.

With an apparently satisfactory sampler of the depth-integrating type and a workable laboratory sampler of the point type, Mr. Benedict took both samplers to the 5 sampling stations in the Colorado River Basin to test them under rigorous field conditions, and also with the samplers then in use at those stations. A few days were spent at each station and the experimental samplers were found to operate satisfactorily.

On March 28, 1944, the Interdepartmental Committee, adopted the name "U. S. Sediment Sampler D-43" for the depth integrator, 43 being the year when it was developed, and "U. S. Sediment Sampler P-43," for the point sampler. Experiments with the P-43 sampler were continued and in 1946, it was redesigned as the P-46.

During the remainder of the period, contracts were let for 162 P-43 samplers which were used chiefly by the Survey. At an interagency conference on sediment held in Denver May 6-8, 1947, the advantages of the new samplers were recognized and the agencies concerned generally agreed to use them in the future.

Following the development of the two samplers in 1943, attention was turned again to the size analysis of suspended sediment samples; as none of the methods in use could be applied satisfactorily to all sizes and concentrations existing in streams, it was hoped to remedy that deficiency by developing a device suitable for analyzing suspended sediment samples with a wider range of sizes and concentrations, than any known methods. War conditions curtailed the study before its completion, but the results actually obtained were published as Report No. 7, "A study of new methods for size analysis of suspended sediment samples," in June 1943.

The material leading up to and discussed in the reports of this series was summarized in Report No. 8 entitled "Measurement of the sediment discharge of streams." This report was prepared to help the field men in their selection of equipment and methods for measuring sediment loads.

One of the chief needs for sediment studies was to determine the rate at which reservoir capacities would be depleted. As the quantity of sediment carried by a stream is usually expressed by weight, it is necessary to convert that weight into volume, and as no thorough study has ever been made for such conversion, the estimated densities cover a wide and indiscriminate range of values. Early in the research project, Prof. Lane and Mr. Koelzer compiled all available data and drew certain conclusions from their analysis. The study was published as Report No. 9, "Density of sediments deposited in reservoirs."

Sediment-discharge measurements. - Messrs. Love and Benedict, on the Boise project, the field work for which lasted from January 1939 to June 1940, used methods which, with subsequent refinement, based somewhat on the studies at the Iowa Hydraulic Laboratory, were used in the Missouri River Basin-Departmental Program. The methods included the hydrographing of daily concentration on the gage-height chart. So-called sediment-discharge measurements included the collection of samples from 3 to 5 vertical points using the D-43 sampler. The location of the verticals was obtained from current-meter measurements and represent equal points of discharge. The local observer took his daily samples at one point in the cross section except in streams having wide variations in concentrates in the cross section. Observer's results were compared with the engineer's sediment-discharge measurements and corrected by a shifting channel method, when necessary.

Special Reports

With the increase in the number of analyses of surface water, both for dissolved solids and sediment, and the greater interest in the results, the need arose for a series of annual publications containing the analyses. Accordingly, for the water year 1941, the series was started under the title "Quality of Surface Waters in the United States," the first being Water-Supply Paper 942. In the report for 1943, a summary for the previous years was included.

The results of the sediment studies in the Colorado River, started in 1925, had previously been made available to Federal agencies by means of typewritten reports, but to make then available to the public, the results from October 1, 1925, to September 30, 1941, were published as Water-Supply Paper 998. Records at the Grand Canyon gaging station were given for the entire period, and for shorter periods at other stations. They included records of the mean daily discharge and daily sediment load for many stations. Records for subsequent years were included in the annual "Quality of Surface Waters of the United States."

In connection with an investigation of the Boise River drainage basin made in cooperation with the Flood Control Coordinating

Committee, in 1939 and 1940,[305] the results of the sediment loads were published as Water-Supply Paper 1048.

State cooperative programs

Delaware. - In connection with the investigation of the Brandywine Creek Basin, by several Survey divisions cooperating with the Newcastle Conservation District, daily sediment samples were collected at the gaging station on the Brandywine Creek at Wilmington, to measure the erosion from that area, starting in December 1946. The samples were analyzed for sediment in the Philadelphia laboratory, but the computation of the sediment load was performed in Washington.

Cooperative funds available during the 1947 fiscal year were $1,250.

Pennsylvania. - The Pennsylvania Department of Commerce, like similar agencies in other states during the later years of the war, was advertising the industrial advantages of Pennsylvania, and quality of available water supplies was an important factor to industries seeking new locations. J. W. Mangan, in charge of the surface-water investigations, called the Department's attention to the need for a study of the quality of the surface water of the state, as little information was available. As a result, a cooperative agreement with the State Planning Board of the Department of Commerce was signed in June 1944, the beginning of the State's fiscal year, for the purpose of studying, in the State's phraseology, "the industrial utility of the surface waters." The work was placed in charge of W. F. White, Jr., who retained his headquarters in Washington. Mr. Mangan, who had sponsored the new program and was anxious to put it into effect, had the surface-water field men take spot samples at 120 gaging stations during the low-water period in the spring of 1945, the samples being analyzed in Washington. The results of those analyses, together with the temperatures at the time the samples were taken, were published by the Department of Commerce in August 1947, as "Chemical Character of Surface Water, 1944 to 1946."

October 1, 1944, a regular program of daily sampling at 10 gaging stations, selected to show differences in quality, was started, complete analyses of 10-day composites being made in Washington. At the station on the Susquehanna at Harrisburg where the total channel was nearly a mile wide and the quality of water was so different throughout the cross section, as the eastern and western tributaries were radically different in quality, the samples were taken at 11 points in the cross section.

It had been the custom, chiefly on account of insufficient funds, to

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discontinue daily sampling stations at the end of one year, and select new stations. However, Mr. White decided to make only partial analyses for 3 or 4 elements at those stations, and keep them on the active list. By so doing, sufficient funds were saved to enable him to establish on October 1, 1945, 5 additional daily sampling stations at which complete analyses were made. By means of the same procedure, and possible additional funds, 4 more stations were established October 1, 1946, making a total of 19 daily sampling stations at the end of the period.

The increased load on the Washington Office laboratory and the space required for the storage of the daily samples became so great that means to relieve that situation were sought, and on September 18, 1946, a small laboratory was established in unutilized space in the laboratory at Philadelphia's northeast sewage disposal plant, in direct charge of N. H. Beamer. As the available space was limited, the samples from only 7 stations in eastern Pennsylvania were analyzed in the Philadelphia laboratory, the remainder continuing to be analyzed in Washington. A few samples of ground-water were also analyzed in Philadelphia.

Annual State cooperative funds available:

1945	$18,000
1946	25,000
1947	25,000

The increase in funds after the first year indicates the recognition of the value of the work and its appreciation.

Mr. Beamer continued in charge of the laboratory and had as Civil Service assistant, J. W. McGuire.

A special investigation made at the request of the State agency and financed wholly from State funds was that for the Pennsylvania Turnpike Commission in 1940. In the early days of railroading, the Vanderbilt interests had planned to build a railroad through central Pennsylvania and went so far as to obtain the right-of-way and bore a number of tunnels. The Turnpike Commission selected much the same route as being the best, and completed the boring of the old tunnels. They were to be lined with concrete, and in that connection, the Commission requested the Survey to analyze the water in them. The Survey collected samples in the various tunnels and analyzed them in the Washington laboratory. The Commission allotted $1,700 for the investigation.

Virginia. - Prior to the present period, there had been a two-year cooperative program during the years 1929-1931.[306] Cooperation was resumed in the fiscal year 1945; D. S. Wallace, who had the dual role

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306/ p. 360 (1928-1939).

of Survey District Engineer in charge of surface water investigation, and also Chief Engineer of the Virginia Conservation Commission's Division of Water Resources and Power, found that a shortage of personnel was curtailing the surface water investigations to such an extent that $4,000 during 1945 could be made available for quality of water investigations of the streams in which industrial concerns were greatly interested. On his recommendation, the Conservation Commission began cooperation with the Quality of Water Division. Thereafter, funds were allocated annually for that work. A laboratory was established at the University of Virginia in Charlottesville in July 1945, by W. L. Lamar. He was assisted by Martha Carr beginning September 17, 1945. In March 1947, G. W. Whetstone was transferred from the Raleigh laboratory and placed in charge, under Mr. Lamar's supervision. D. G. Walker was assigned to the Charlottesville laboratory January 6, 1947.

During the first year of operation, 7 daily and 4 monthly sampling stations were established at or near gaging stations. Analyses were made on spot samples collected at other gaging stations. The results of the surface water investigations to September 30, 1946, were published by the State.307/

To provide additional funds to analyze samples required by the ground-water investigations, the Virginia Geological Survey began cooperation in the fiscal year 1947.

Annual State cooperative funds available:

Year	Virginia Conservation Commission: Division of Water Resources and Power	Virginia Conservation Commission: Geological Survey Division
1945	$ 4,000	.
1946	4,500	
1947	4,500	$ 500

North Carolina. - Fearing the let-down of industrial activity after the war, the State Department of Development and Conservation, increased its advertising of North Carolina's advantages to industries seeking new locations. As the quality of available water supplies was an important consideration, the State Department in cooperation with the North Carolina State College in Raleigh, conducted an intermittent quality of water investigation until 1943, when the chemist in charge of that work joined the military forces, and the work stopped. Realizing the importance of continuing the quality of water investigations and placing them on a continuing and coordinated basis, the Department

307/ Lamar, William L., and Whetstone, George W., Chemical Character of surface waters of Virginia: Va. Conservation Comm., Bull. No. 8, 1947.

made a request for cooperation to E. D. Burchard, who was cooperating with that agency in surface-water investigations. That request was referred to the Washington Office and W. D. Collins and W. L. Lamar went to Raleigh. In pointing out the advantages of cooperation, Mr. Collins explained that the Survey had the country-wide view and method of approach, and that the State officials knew the local needs, resulting in mutual contributions in planning the work of cooperative quality of water investigations. After listening to the advantage of cooperation, one State official turned to another and said, "Did you hear that guy from Washington admit that sometimes the State people knew something?" The advantages of cooperation were recognized and became effective in the fiscal year 1944. Mr. Lamar established a laboratory at the State College where the State had formerly made its analyses.

In the fall of 1945, the State Board of Health began cooperation in order that the investigations might be expanded to cover the quality of public water supplies; one agreement covered the cooperation with the two State agencies. The expanded program required new laboratory space, and the Board of Health's State Laboratory of Hygiene in Raleigh, furnished both laboratory and office space.

The first year, daily sampling stations were established at or near 3 gaging stations; the second year, at 4 stations; and the third year at 6 stations. Monthly samples were also collected at 4 stations, spot samples at all gaging stations, and at particular points desired by industry. The results for the first year were published by the Survey as "Chemical character of surface waters of North Carolina 1943-44," and by the Department of Conservation and Development for the three succeeding years, 1944-45, 1945-46, and 1946-47, as Bulletin 52, Volumes 1, 2, and 3. Information about the public water supplies obtained from surface waters was issued in multilith form by the Survey as Progress Report No. 1, "Public surface-water supplies in North Carolina, descriptions and chemical character." As a result of cooperation with the State Board of Health, all public surface-water supplies numbering 116, serving 139 communities, were inventoried and analyzed.

A program of river-basin studies was started to determine the character of the water throughout each basin, the change in character from headwaters to mouth, and the extent of industrial pollution. To obtain comparative samples, those were collected throughout each basin from headwaters to mouth over a period ranging from one to three days for each basin. Data were obtained for 10 basins and published by the State with the records for 1946-47 as Bulletin 52, Volume 3. In addition, the investigations for each basin, together with the investigation of the Surface and Ground Water Divisions, were included in basin reports of which two were published during the period.308/

308/ Hydrologic data in the Cape Fear River Basin, 1920-1945; and Hydrologic data in the Neuse River Basin, 1866-1945.

Mr. Lamar was in charge of the North Carolina investigations and had the following Civil Service technical assistants:

Name	Period
Evelyn Holloman	Sept. 27, 1943 to Nov. 15, 1946
G. H. Whetstone	June 1945 to Mar. 1947
F. H. Pauszek	Mar. 21, 1946 to June 30, 1947
J. B. Floyd	Sept. 3, 1946 to Feb. 14, 1947
B. F. Joyner	Sept. 18, 1946 to June 30, 1947

Annual State cooperative funds available:

Year	Dept. Cons. & Devel.	State Bd. of Health	Total
1944	$ 4,000		$ 4,000
1945	4,000		4,000
1946	4,856	$ 2,500	7,356
1947	6,340	2,500	8,840

In addition, the Division of Mineral Resources of the Department of Conservation and Development, cooperated through the Survey's Ground Water Division in a study of the quality of ground water.

South Carolina. - Like her sister states, South Carolina was looking for new industries after the war and likewise realized that information on the quality of available water supplies would be required. Accordingly, the South Carolina Research Planning and Development Board, through A. E. Johnson and W. L. Lamar, the former in charge of surface water investigations in the state, the latter in charge of quality of water work in North Carolina, arranged a small cooperative program beginning in the fiscal year 1946. Daily samples at one gaging station the first year, and two the second year, obtained by local observers, as well as spot samples from practically all gaging stations were collected by the Surface Water Division in connection with its regular field work. Funds were not available to establish a laboratory in South Carolina, and the nearest Survey laboratories in North Carolina and Virginia, were primarily for the analyses of samples in those states. Therefore, to avoid too much outside work for either laboratory, the 10-day composite analyses of the daily samples were made in Virginia, and the analyses of spot samples were made in North Carolina.

Annual State cooperative funds available:

1946 $ 600 1947 $1,500

The results of the analyses were published by the State agency. 309/

309/ Chemical character of surface waters of South Carolina, 1945-47, by William L. Lamar: Bulletin 16.

Georgia. - There was one cooperative agreement with the State covering the various investigations of the Branch; the division of funds was varied to meet the wishes of the State officials, and as ground water was becoming increasingly important during the period, it was necessary to reduce the funds for the quality of water investigations.

At the beginning of the period, the salinity study of the Savannah River was in progress, and daily samples at the selected sampling points were collected from July 21 to September 30, 1939. They were analyzed in the temporary laboratory in Savannah, which was maintained by W. L. Lamar until December 1939. Cooperative funds were not adequate to complete the computation of the records, and as a result of a contribution of $500 by the City of Savannah, a WPA project under Survey supervision was set up for that purpose, but the report was not finished before WPA funds became exhausted. A brief summary of the work was published in an article by W. L. Lamar in the Transactions of the American Geophysical Union for 1940, pages 463-470. In 1943, the City of Savannah made an appeal for the completion of the Savannah River investigation, but through lack of personnel, the Survey was unable to do so.

Analyses of the public water supplies were continued through 1940. Also during 1940 and 1941, daily samples were collected at two gaging stations on the Chattahoochee River, and 52 spot samples of surface water analyzed. During the remainder of the period, one daily sampling station was established and operated each year. Other analyses were confined chiefly to ground-water samples furnished by that division, including the checking of the chloride content in key wells in the Savannah area.

Until the establishment of the Raleigh laboratory in 1943, the field work was performed by Mr. Lamar and the analytical work, except that in connection with the Savannah River investigation, was performed in the Washington laboratory. Between 1943 and 1945, it was performed in Raleigh, and with the establishment of the Charlottesville laboratory in July 1945, it was divided between Raleigh and Charlottesville.

The data collected from 1937 to 1941, which included 470 analyses of surface water at 96 sampling points were published as Water Supply Paper 889-E, "Chemical character of surface waters of Georgia," and those for 66 public water supplies were published as Water Supply Paper 912, "Industrial quality of public water supplies in Georgia."

Prior to the 1945 fiscal year, the cooperating State agency was the Division of Mines, Mining, and Geology, but subsequently, it was changed to the Department of Mines, Mining, and Geology.

Annual State cooperative funds available:

1940	$3,500	1942	$2,645
1941	2,400	1943	1,000

1944	$ 300	1946	$ 800
1945	400	1947	800

Florida. - The comprehensive investigation of the water resources of southeastern Florida, started in December 1939,310/ required an analysis of the surface and ground waters, and the City of Miami co-operated with the Quality of Water Division during that period. A laboratory was established in space made available in the city laboratory, and was maintained by H. A. Swenson from December 29, 1940 until August 13, 1942, when he joined the military forces. Thereafter, the laboratory was closed, and as the scope of the work was decreasing, the relatively few analyses were made in the Washington laboratory. S. K. Love supervised the Miami quality of water studies.

Not only were the usual surface and ground water samples analyzed, but the study of salt water encroachment required many extra analyses to define the movement of salt water up and down the tidal reaches of the coastal streams and canals. So numerous were those samples that a method of rapid determination was required, and a special electrical field salinity meter was developed by S. K. Love, A. H. Frazier, and H. C. Spicer, the latter of the Geologic Branch. It was an adaptation of a laboratory instrument to field use for the measurement of electrical conductance of water. As the ratio of the electrical conductance to the total salinity of sea water is fairly constant, the salinity meter was invaluable in tracing the amount of salt water contamination in the tidal canals.

The Florida Geological Survey was cooperating with the Surface Water Division in a study of the larger springs in the State, and beginning with the fiscal year 1946, the cooperation was extended to the Quality of Water Division for the purpose of determining the quality of spring water. By that time, the State survey had been interested in the springs, and to complete the picture, needed chemical analyses, and what was equally potent, had the available funds.

Annual State and municipal cooperative funds available:

Year	Miami	State Geological Survey
1940	$2,500	
1941	5,500	
1942	4,564	
1943	4,300	
1944	500	
1945	500	
1946	500	$500
1947	500	500

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Louisiana. - State cooperation was in effect during the fiscal years 1944 and 1945. There were two programs covering different fields, but carried on during much of the same period. They were under the supervision of W. W. Hastings, in charge of the Austin laboratory where the analyses were made.

In October 1943, to help meet the many requests for non-existent information concerning the quality of the surface water, R. E. Marsh, in charge of the surface water investigations, set aside $2,700 from the State's cooperative stream-gaging funds for the purpose of analyzing water samples from 52 gaging stations during both low and high water periods. The surface-water field men collected the samples in connection with their regular field work. Two daily sampling stations were also established. That program was discontinued in October 1944, at the end of one year.

Cooperation with the State Department of Conservation was started in February 1944 for the purpose of determining the characteristics of Calcasieu River and its lower tributaries in the vicinity of Lake Charles, with reference to the salt water encroachment from the Gulf, industrial wastes, and oil field brines. Seven stations for weekly sampling were established, only one being at a gaging station. The slopes were so flat that suitable gaging station sites were practically non-existent. Local observers were employed. The interests concerned desired the information chiefly during the low-water period, and also during the period of maximum diversion from the river for rice culture. The program was discontinued in December 1944.

State cooperative funds available were:

1944	$1,600	1945	$1,750

Ohio. - The purpose of the Ohio Water Resources Board, created in October 1945, was a study of the State's water resources, and in that highly industrialized state, the quality of the surface water was an important factor. C. V. Youngquist, the Board's chief engineer, was familiar with the program recently started in Pennsylvania, and desired a similar one for Ohio. He discussed the situation with W. F. White, Jr., in charge of the Pennsylvania work, and cooperation was started in the spring of 1946 under Mr. White's supervision. For the first fiscal year, samples were collected at 60 gaging stations during April and May during the normal high water season and again during the low water period in September and October. Beginning in July, daily samples were collected at 2 gaging stations, and in October, 2 more daily stations were added. The Surface Water Division, in connection with its regular field work, collected the spot samples, made measurements and read temperatures at the same time, and sent the samples to Washington for analysis. At the daily sampling stations, local observers took the samples and sent them to Washington.

Annual State cooperative funds available:

1946	$1,500	1947	$9,152

Because of the many requests for the data, the Water Resources Board issued a preliminary report January 1947.[311]

Arkansas. - When the University of Arkansas Bureau of Research was created by the Legislature in 1944 and funds made available for research, Dr. C. O. Brannen, Director, Bureau of Research, and Dr. Harrison Hale, head of the University's Chemistry Department, proposed an investigation of the quality of the water resources of the state as there had been many inquiries from prospective industries regarding the quality of available supplies. The Bureau of Research recognized the value of such an investigation and cooperation with the Survey was started in the fiscal year 1946, $6,000 being allotted each year. When the cooperative agreement was prepared, it covered both the quality of water, and ground-water investigations which were to be started, specifying the amounts for each division.

An office was established in the Chemistry Building at the University of Arkansas in Fayetteville in September 1945. I. W. Walling, a chemist employed by the Texas Bureau of Economic Geology, was given a Survey appointment and placed in charge of the Fayetteville office.

For the first year's program, three objectives were outlined: (1) inventory and analyses of all public water supplies; (2) daily samples of surface water at 6 gaging stations with analyses of 10-day composites, and at 6-month intervals, analyses of samples from all Survey gaging samples; and (3) analyses of water samples from all ground-water investigations.

The 6 sampling stations selected were in the northern part of the state where the streams were not affected by industrial wastes. During the second year, 3 of the original stations were dropped, and 4 stations in the southern part added. The southern streams were being increasingly polluted by such wastes, and it was felt that the analyses should be started before the pollution became any worse.

In addition to the analyses of the surface water, analyses were made for El Dorado and Ashley County ground-water investigations.[312] The inventory and analyses of the public water supplies were published by the Bureau of Research as Research Series No. 11, June 30, 1947. The results of the analyses for the ground-water investigations were included in the reports of these investigations.

Mr. Walling continued the Arkansas investigation until July 1946, when he was transferred to Stillwater, Oklahoma, to initiate the quality

311/ The Industrial Utility of the Surface Waters of Ohio, Bull. 4.
312/ p. 294.

of water studies in that state. He was succeeded by G. A. Billingsley, who was assisted by Dorothy M. Parrish.

Oklahoma. - In connection with the compilation of quality of water data for the report, "Oklahoma Water,"[313] the Oklahoma Planning and Resources Board provided $850 during the fiscal year 1944 for the purpose of making a reconnaissance survey of chemical character of Oklahoma waters. From September to December 1944, daily samples were collected at 6 gaging stations, and spot samples were collected at all other gaging stations in the State. The daily samples were sent to the Survey's Austin laboratory for complete analyses, and partial analyses of the spot samples were made in a temporary Survey laboratory at the Oklahoma A & M College. The results of the analyses were issued by the Survey in mimeograph form under the title "Chemical Analyses of Surface Water in Oklahoma, September to December 1944."

During the war years, industry became increasingly interested in the quality of available water supplies, both surface and ground, and with a view to answering the many requests from municipalities, individuals and existing as well as prospective industrial plants, State agencies in the fiscal year 1947 united in contributing funds for cooperation with the Survey for continuing on a state-wide scale the quality-of-water studies started in 1944. The cooperative agreement was with the Experiment Stations, the State Geological Survey and the Planning and Resources Board both contributed to that agency, making the total State cooperative funds $6,250 for the 1947 fiscal year.

A laboratory was established in the Chemistry Building at the A & M College at Stillwater, July 15, 1946. I. W. Walling was transferred from the Fayetteville, Arkansas, laboratory and placed in charge. Dr. Dunn, vice-director of the Experiment Station, represented the State in formulating the work program. Daily samples of surface water collected at 10 gaging stations were analyzed by 10-day composites, as well as samples of ground water collected in connection with the ground-water investigations. The results of the analyses at 5 gaging stations in the Washita River Basin during 1946-47 were published by the State agency.[314]

One special investigation was wholly financed by the City of Miami. The Goodrich Rubber Plant was lowering the water table to such an extent that the city was looking for a standby surface supply; weekly samples from three possible sources were analyzed for a period of four months. In addition to Oklahoma samples, those from the Arkansas River Basin in Kansas were also analyzed in the Stillwater laboratory.

313/ p. 57.
314/ Chemical character of surface waters in the Washita River Basin of Oklahoma, 1946-47: Bull. 4.

Texas. - At the beginning of the period, there were two quality of water programs in Texas, one started in 1937 with a WPA grant for the purpose of analyzing the ground-water samples in connection with the state-wide ground-water investigation, and the other, cooperation with the Red Bluff Water Power Control District and the State of Texas, as a part of the Pecos River Joint Investigation.315/ The latter program consisted of collecting daily samples from 5 stations on the main stream and 3 on tributary streams for analysis by 10-day composites; also, the analyses of a large number of spot samples collected from the Pecos River, the main tributaries and ground-water sources. 316/ After the conclusion of that investigation December 1940, the Red Bluff District continued cooperation on a greatly reduced scale, maintaining a sampling station on the Pecos River at Orla below the reservoir.

When the WPA project ended in January 1942, there was a drastic reduction in available funds, and consequently in laboratory operations. To make more analyses possible, the Ground Water Division made available additional funds for the continued analysis of ground-water samples, collected in connection with extensive ground-water investigations. The State was becoming steadily more conscious of the value of data on the quality of its surface waters, and began cooperative studies in a small way in the fiscal year 1942. The great industrial movement into the state was in full swing by 1944 and the data being collected at widely scattered areas called attention to the need for a more complete coverage, so that during the last two years, the State cooperation was greatly increased.

Under the State-cooperative program, augmented by funds of the Ground Water Division which wished to help establish the quality of water program, and funds contributed by several local agencies, during the fiscal years 1942 to 1944, daily samples for analysis by 10-day composites were gradually started at 4 gaging stations. The daily sampling program was expanded to 20 stations at the end of the period.

From 1943 to 1945, special work connected with industrial plants and military establishments occupied a large part of the quality of water personnel. W. W. Hastings was at that time the only experienced chemist, because of loss of trained personnel to the Army and to industrial war plants.

In the fiscal year 1945, the Cities of Denison and Sherman were considering taking water from the Denison Reservoir with its capacity of 5,700,000 acre-feet, and asked the Board of Water Engineers for information regarding its quality. No information was available and

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315/ pp. 15-17.

316/ Pecos River Joint Investigation, Reports of participating agencies, p. 102: National Resources Planning Board, June 1942.

the Board asked Mr. Hastings to suggest a sampling program. That program, which consisted of daily sampling stations on the 2 principal contributary streams to the reservoir, and 1 station on the Red River below the reservoir, was agreed upon and the cities began cooperation.

The City of Childress needed an improved water supply and considered the possibility of interesting the Bureau of Reclamation in a reservoir on Quitaque Creek, and cooperated one year for the purpose of having the water of that stream analyzed. The Surface Water Division established a gaging station on that stream to determine its discharge. While the quality was adequate, it was found that stream flow was insufficient, and the city dropped its project.

During the fiscal years 1942 to 1944, the Pease River Flood Control District, the Cameron County Water Control and Improvement District No. 5, the Brazos River Conservation and Reclamation District, and the Lower Colorado River Authority, contributed funds to the State Board of Water Engineers for the purpose of obtaining quality studies of the proposed water supplies for their individual projects. One or more daily sampling stations were maintained at stream gaging stations for each project.

The study of the quality of the Pecos River and its tributaries made during the Joint Investigation was not carried on for a sufficient length of time to obtain complete information on the salinity of the tributaries in Texas. In the fiscal year 1944, the Pecos River Compact Commission, a state agency, contributed funds which were used to establish 2 daily sampling stations on tributaries, one of which contributed water only during a few days in the year.

Beginning in May 1946, the Colorado River Municipal Water Association and the Texas Electric Service Company contributed funds to the Board of Water Engineers for the purpose of determining the quantity and quality of water in the Upper Colorado River with a view to possible storage of water near Colorado City, for the use of 5 rapidly growing cities in that general area. Three daily sampling stations were maintained, and samples on tributary streams obtained at less frequent intervals.

E. W. Lohr was in charge of the Austin laboratory from its establishment in 1937 until July 1, 1941, when W. W. Hastings, formerly in charge of the Pecos laboratory, was placed in charge of the Quality of Water work in Texas and also in Arkansas, Louisiana, Mississippi, and Oklahoma, when investigations were started in those states later in the period. Other Civil Service technical employees in Texas were:

Name	Period	Military Furlough
E. W. Lohr	July 1, 1939 to June 30, 1941	
B. Irelan	July 1, 1941 to June 30, 1947	Sept. 24, 1942 to Mar. 1, 1946

Name	Period	Military Furlough
N. A. Talvitie	July 1, 1941 to Nov. 15, 1942	
P. A. Witt	Sept. 1, 1942 to June 6, 1943	
J. H. Rowley	Mar. 1, 1943 to July 3, 1946	
M. L. Begley	June 27, 1944 to May 20, 1946	
J. H. Raby	May 3, 1944 to June 30, 1947	
D. M. Parrish	Aug. 28, 1944 to Nov. 26, 1945	
G. A. Billingsley	Oct. 12, 1945 to Sept. 3, 1946	
J. R. Avrett	Jan. 13, 1947 to June 30, 1947	
R. M. Collier	Jan. 13, 1947 to June 30, 1947	

Annual State and municipal cooperative funds available were:

Agency	1940	1941	1942	1943	1944	1945	1946	1947
Board of Water Engrs.			$ 700	$450	$ 950	$ 600	$2,950	$2,600
Red Bluff Water Power Cont. Dist.	$9,000	$2,000	300	400	400	400	400	400
Pecos River Compact Comm.					800			
Denison & Sherman						800	800	400
Childress							125	
Total	$9,000	$2,000	$1,000	$850	$2,150	$1,800	$4,275	$3,400

New Mexico. - The study of the salinity of the Pecos River started in 1937 was merged with the Pecos River Joint Investigation. The program consisted of collecting daily samples from 11 stations on the main river, and 4 on tributary streams for analysis by 10-day composites; also, the analysis of a large number of spot samples collected not only from the Pecos River and main tributaries, but also from ground-water sources. 317/

After the completion of that investigation in December 1940, the state of New Mexico desired the continuation of the analyses of daily samples from 6 Pecos River stations. The state thought there was a possibility of a new law suit by individuals who claimed that the quality of the Pecos River had deteriorated because of use in New Mexico and that the State might be made a defendent. Also, there was a possibility that the hoped-for Pecos River Compact would have provisions of

317/ Pecos River Joint Investigation, Reports of participating agencies, p. 102: National Resources Planning Board, June 1942.

quality of water similar to those included in the Rio Grande Compact. 318/ In view of those possibilities, the State desired a continuation of the quality of water studies.319/ Also, in 1941, analyses of daily samples from the Rio Grande at San Acacia were desired. The samples were obtained by local observers and analyzed in the Albuquerque laboratory. In that connection, it may be stated that one observer, to avoid Sunday work, was taking 2 samples on Saturday and marking one for Sunday. After being told that a Sunday sample was required, he took 2 samples on Saturday and 2 on Monday, mixed one Saturday and one Monday sample, and marked it Sunday.

The investigations were in charge of C. S. Howard, who moved his headquarters to Albuquerque in July 1942 and established the laboratory.

In the fiscal year 1946, cooperation with Colfax County became effective. The program included surface- and ground-water investigations in addition to those of quality of water. The specific quality of water problem areas were in the vicinity of Raton and on the Maxwell project south of Raton. A daily sampling station was established on the Cimarron River at Ute Park. Periodic samples were collected from the Vermijo River and other irrigation sources for the Maxwell project.320/

The State's share of the cost of the Pecos River Joint Investigation, as well as of the subsequent investigations, was borne by the State Engineer in his capacity as Secretary of the Interstate Streams Commission, as funds for that purpose were available to the Commission only for studies of interstate streams.

Annual State and County cooperative funds available:

Year	State	County	Year	State	County
1940	$8,500		1944	$5,000	
1941	8,500		1945	5,000	
1942	5,000		1946	5,000	$1,500
1943	5,000		1947	5,000	1,500

Washington Office personnel

The Civil Service field personnel are listed under the various field activities, and to complete the Division's personnel, those in the Washington Office during all or a part of the period are presented herewith.

318/ p. 374 (1928-1939).

319/ Letter from C. S. Howard to author.

320/ Idem.

The Civil Service technical personnel in the Washington Office were:

W. D. Collins	July 1, 1939 to Sept. 30, 1946
C. S. Howard	July 1, 1939 to June 30, 1942
S. K. Love	July 1, 1939 to June 30, 1947
W. L. Lamar	July 1, 1939 to Sept. 1943
Margaret Foster	July 1, 1939 to June 30, 1942
E. W. Lohr	July 1, 1941 to June 30, 1947
F. H. Davis	July 1, 1939 to Apr. 30, 1941
W. W. Hastings	July 1, 1939 to Aug. 1, 1939
A. T. Ness	July 1, 1939 to Aug. 15, 1939
W. W. Brannock	July 1, 1939 to Aug. 31, 1942
W. M. Noble	July 1, 1939 to Oct. 31, 1940
M. H. Silberman	July 1, 1939 to Oct. 10, 1939
G. J. Petretic	July 1, 1939 to May 30, 1942
M. D. Reeves	July 1, 1939 to Mar. 16, 1941
J. D. Hem	July 1, 1939 to July 1940
T. W. Dakin	May 27, 1940 to Sept. 26, 1940
L. W. Miller	July 8, 1940 to Apr. 22, 1942
H. A. Swenson	Nov. 2, 1940 to Dec. 28, 1940
	Dec. 11, 1945 to Jan. 30, 1946
C. G. Seegmiller	Jan. 21, 1941 to Jan. 21, 1942
W. F. White, Jr.	Aug. 4, 1944 to June 30, 1947 1/
Margaret Thomas	Nov. 2, 1942 to July 20, 1944
J. D. Boreman	Aug. 20, 1942 to Nov. 21, 1943
W. A. Henderson	June 15, 1942 to Nov. 23, 1942
D. M. Derrick	Mar. 26, 1944 to Sept. 28, 1945
E. M. Burchard	June 9, 1944 to Sept. 21, 1944
A. A. Vlisidis	July 27, 1944 to June 30, 1947
M. K. Wood	Sept. 5, 1944 to Oct. 5, 1944
E. D. Manfredi	Nov. 1, 1944 to Feb. 28, 1945
G. W. Whetstone	Nov. 16, 1944 to June 1945
J. H. White	Feb. 25, 1945 to Sept. 6, 1945
E. J. Barton	Mar. 22, 1945 to Sept. 21, 1945
S. E. Brien	May 18, 1945 to June 30, 1947
Annette Theriault	Sept. 24, 1945 to June 30, 1947
N. H. Beamer	Jan. 22, 1946 to Sept. 17, 1946
W. T. Platt	Feb. 18, 1946 to June 30, 1947
N. K. McShane	Apr. 12, 1946 to June 30, 1947
M. E. Schroeder	July 18, 1946 to June 30, 1947
I. H. Barlow	Nov. 8, 1946 to June 30, 1947
A. L. White	Dec. 10, 1946 to June 30, 1947
R. H. Dellett	Dec. 18, 1946 to June 27, 1947

1/ In charge of Pennsylvania and Ohio programs.

Mrs. A. J. Reynolds performed the duties of district clerk during the entire period.

WATER UTILIZATION DIVISION

The Water Utilization Division occupies a unique position in the activities of the Water Resources Branch. The three other divisions emphasize basic fact-finding programs in their respective activities and operate from numerous field offices. In addition, each field office is to a large extent, on account of its close contact with cooperating State and Federal officials, engaged in making available its services to those agencies. By contrast, the Water Utilization Division has only a limited basic fact-finding program, but is engaged largely in coordinating the studies of the fact-finding divisions and in improving the general analytical methods used.

Expanding Activities

In previous years, the activities had related largely to studies along the Canadian Border, required by the International Joint Commission, financed by State Department funds, to supervising activities relating to Federal Power Commission projects, and to coordinating and supervising special flood studies. An entrance was made into the interpretative field in the special rainfall-runoff studies.321/ During the present period, the Branch broadened the scope of its activities and entered farther into the field of interpretation. The division spearheaded the establishment of the Water Resources Review. The broadening of branch policy was given impetus by the view of the new Director that the Survey should be more than a statistical fact-finding agency, and should make interpretative studies of those facts along with the coordination of field data.

Along with interpretative studies came a movement to improve analytical methods and techniques, and train selected personnel of the Surface Water Division in the use of such methods and techniques for use in their field districts. In addition and as an incident of the preparation of the 16 basin reports for the Bureau of Reclamation,322/ division personnel were assigned to some of the major river basins in the west, for the purpose of making overall water-supply studies. With funds appropriated for research in the last year of the period, the division stimulated and coordinated the suggested subjects for research by the other divisions, and guided such research. Another activity that came into the picture was participation in the Department's Soil and Moisture Conservation Program.

Organization

R. W. Davenport, the division's chief, in describing the activities of the division, stated:323/

321/ p. 76 (1928-1939).

322/ p. 19.

323/ Proc. East-Central Branch Conference, Nov. 7-9, 1946, Indianapolis, Ind., p. 21.

The Division has collected a small group of specialists and men believed to be particularly qualified in directing, coordinating, and stimulating technical work in hydrology and hydraulics. In addition to the coordinative function, we wish to perform a clearing house function, that is, to be responsible for collecting new and worthwhile ideas with (the) view to disseminating them so that all may have the advantage of them.

In the previous period, the division's activities were carried on chiefly by the Washington Office personnel with certain studies made by R. R. Woolley in Salt Lake City and other studies for a short time by W. E. Dickinson in Los Angeles. Additional duties, however, changed the picture somewhat during the present period.

When the work relating to the Soil and Moisture Conservation Program was placed under the division's supervision in 1941, H. V. Peterson was given charge of field operations with headquarters in Los Angeles. With the creation of the Missouri River Basin-Departmental Plan, B. R. Colby was assigned to the Branch Office in Lincoln in April 1946, and with the intensive studies of the Columbia River Basin being undertaken, C. C. McDonald was assigned to Tacoma early in 1946. 324/

Development of methods and techniques

In the Washington Office, W. B. Langbein devoted a large part of his time to the development of the science of hydrology in the Branch and about 1946, modern statistical methods began to be used. Those afford valuable tools for analyzing masses of basic data, and by eliminating largely individual judgment, are straightforward in reaching the solution of a problem. A notable example was the determination of normal flow at index stations used in the Water Resources Review where the length of the index records varied widely. It had been the practice to use the mean of the years of record, and that required a recomputation each year. To obtain a uniform and stable basis, a study by statistical methods was started by Mr. Langbein in 1946. A 25-year period, 1921 to 1945, was chosen and the median computed for each index station. Records not covering the entire period were extended by correlation with comparable stations and rainfall-runoff studies. That was the longest period for which stream-flow records were available at a sufficient number of index gaging stations. However, that period is believed to be fairly representative for the entire region, as it contained the abnormally wet years of 1927 and 1928 and the extremely dry years of the nineteen-thirties. 325/ The 25-year mean was not used for the Water Resources Review until October 1947. As a matter of passing

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324/ p. 391.
325/ Water Resources Review, Sup. 2: Normals and variations in runoff, 1921-1945, p. 2.

interest, it may be stated that the Thames Conservancy, which furnishes London's water supply, uses the records for the 35-year period 1881 to 1915 in computing the "standard averages." Statistical methods were also applied to the analyses of flood frequencies, trends in runoff, effects of reforestation on stream flow, and similar problems involving three or more variables.

The study of statistical methods was not usually included in engineering curricula, and few engineers of the Branch were familiar with them or their uses. To insure that each district office would eventually have at least one engineer trained in these methods, the procedure was started in the fall of 1946 of supplementing the work of field engineers detailed to the Section of Review, Surface Water Division, by a month's detail to the Water Utilization Division. In addition, the practice was started in 1947 of detailing to the Division in Washington for 3 or 4 months, engineers from other divisions having suitable qualifications; they worked on projects designed to instruct them in analytical techniques that would be useful in their field offices. So popular did the theory of statistics become that evening courses offered by the Graduate School of the Department of Agriculture were attended by a number of the engineers on detail.

In response to several requests, a pamphlet of methods of "Flood frequency compilations" was prepared by Mr. Langbein. A little later, it became apparent that manuals on the following subjects were prepared: Flood-frequency compilations; median-discharge computation methods; abstracting topographic characteristics of drainage basins; channel storage and flood routing; extending stream-flow records; double mass curves; analyses of low flow; flood frequency analyses. Some of the manuals were not completed until after the end of the period. The designation "Handbook for Hydrologists," which was under Mr. Langbein's editorship, was assigned to the series to avoid any implication that they were complete text books on hydrology. The manuals have been frequently revised to include additional experience.

W. G. Hoyt, although nominally attached to the Conservation Branch, devoted practically his entire time to the Water Utilization Division until July 1944, when he became Vice-Chairman and Executive Officer of the Department's Water Resources Committee. After the work leading to the publication of Water-Supply Paper 772 in the previous period, Mr. Hoyt played a major role in the origin and development of the Water Resources Review, being virtually its editor, and was responsible for important contributions to a number of flood reports. In addition, he was called upon for a wide variety of very important work, including consultation and review of reports for the agencies with which the division's activities were concerned.

Special Flood Studies

As an important phase of the Branch activities, the district engineers in whose districts major floods occurred, made investigations and prepared reports. If the floods were sufficiently wide-spread to cover more than one district, especially if unusual methods of determining peak discharges were necessary, arrangements were made for the detail of an especially qualified engineer of the Branch to assist as consultant and coordinator. Hollister Johnson made especially noteworthy contributions along this line. All flood reports to be published by the Survey were reviewed and arranged for publication by the Water Utilization Division, W. S. Eisenlohr, Jr., being detailed to that activity.

The most wide-spread floods during the period were those of August 1940 in the southeastern states. There were two major floods that took the lives of about 30 persons and caused damage of some $30,000,000. The Survey lost 6 recorder shelters and 6 cableways. On the Roanoke River, the flood was the greatest known since settlement in the seventeenth century, and in western North Carolina the greatest known, except on some streams where the flood of July 1916 was greater. An outstanding feature of the storms causing both floods was the large number of earth slides on the steeper hillsides, more than 150 being reported within an area of about 150 square miles. The field studies started in October and continued through December were made by the Asheville, Atlanta, Charlottesville, Chattanooga, Columbia, and Charlestown Districts. The organization of the work in the early stages was arranged by Hollister Johnson, who contacted for rainfall records all Army Engineer and Soil Conservation Service offices concerned. He also advised on the evaluation of the flood discharges at various points. By means of $8,000 contributed by the Soil Conservation Service, it was possible to enlarge the scope of the work and include measurements of peak discharge on a greater number of streams. The Army Engineers, Forest Service, and Flood Control Coordinating Committee furnished field parties to determine peak discharges in certain areas. Mr. Langbein prepared the section on rainfall and runoff studies, and made the hydrologic analyses. Mr. Eisenlohr reviewed the report and prepared it for publication which appeared as Water-Supply Paper 1066.

International Joint Commission

The studies of water supply connected with treaty obligations were extended during the period by the increasing investigations of the Columbia River Basin being made both by American and Canadian agencies.

The International Columbia River Control Board created by the Commission on December 15, 1941, had the Chief Hydraulic Engineer as the American member. The duty of the Board was to report to the Commission the facts regarding backwater in Canada caused by the operation of the reservoir at the Grand Coulee Dam, 150 miles downstream from the Boundary. An International Station at the Boundary had been maintained since 1938 but the completion of the dam had required the installation of a second gage to determine the slope. F. M. Veatch analyzed the stream-flow records to determine the amount of backwater at the Boundary, and the report was prepared in Washington.

The International Joint Commission on July 12, 1943, created the International Osoyoos Lake Engineering Board, of which F. M. Veatch was one of the two American members. Certain obstructions in the channel of the Okanogan River caused backwater on Osoyoos Lake, located on the Boundary, and thereby raised questions requiring attention of the International Joint Commission.

In 1944, the International Joint Commission appointed the International Columbia River Engineering Board to conduct investigations and advise the Commission regarding harmonizing plans of projects within the basin in the United States and Canada. The American members were the Assistant Chief of Engineers of the Army, and the Survey's Chief Hydraulic Engineer. The Canadian members were the Controller of the Dominion Water and Power Bureau, and the Superintending Engineer, Department of Public Works. A field committee was appointed, the representative of the Interior Department being F. A. Banks of the Bureau of Reclamation, with F. M. Veatch as alternate. Mr. Veatch assisted Mr. Banks, particularly concerning the participation of the Survey in the investigations, and most of the Survey contributions were channeled through him.

The comprehensive investigation made by the International Columbia River Engineering Board required an intensive study of the hydrology of the Basin and C. C. McDonald was assigned to Tacoma in January 1946, to carry on this work. Mr. McDonald cooperated with the Canadian engineers of the Committee in preparing a map and index of all gaging station records in the Upper Columbia River Basin above Snake River. He also made a study of flood frequencies. W. F. Kennon was his assistant.

An account of the increase in the number of International gaging stations is given on p. 76.

The operations of the Kootenai Lake Board of Control, of which T. R. Newell was a member, are described under the activities of the Boise, Idaho, District. 326/

The Water Utilization Division assisted the Chief Hydraulic Engineer in conducting activities relating to the international program and was in large measure, responsible for the details of administration and supervision. W. S. Eisenlohr, Jr. was particularly active in the computations required.

Missouri River Basin-Departmental Program

Among features of the Missouri River Basin Departmental Program

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326/ p. 173.

with which the Water Utilization Division was directly concerned was an inventory of the water resources of the Basin, and improvement studies of the range in which water is the limiting factor. For the inventory, B. R. Colby was assigned to the newly established Branch Office at Lincoln, April 1946, and the range studies were made under the direct supervision of H. V. Peterson, District Geologist, from his headquarters in Los Angeles. K. R. Melin was in direct charge of those studies with headquarters in Billings.

The inventory consisted of a table of gaging station data showing for each of several hundred stations, the drainage area, period of record, number of years with complete records, average discharge based on years of complete water-year records, maximum and minimum discharges with dates, approximate acreage of land irrigated by divisions above each station, and the approximate developed capacity of reservoirs. Average discharge of streams and average annual depth of runoff were shown on maps. For some years, the Army Engineers had collected sediment samples at a number of Survey gaging stations on the Missouri and principal tributaries, and from the concentration of those samples, monthly and annual records of sediment discharge were computed. A study of changes in the bed of the Missouri River at Omaha with sediment load was started and was in progress at the end of the period. It was hoped that the investigation might show whether the sediment at Omaha came from the main river or from the tributaries.

An important objective of the range-improvement studies was the proper location of surface tanks or small reservoirs having capacities ranging from 1 to 5 acre-feet each for livestock, where ground water was not available from wells. Being usually on small drainage areas for which discharge records were not available, data were obtained on precipitation, and size and character of drainage area necessary to give reasonable assurance of periodic filling of the tanks; also studies were made of silting and evaporation and seepage losses.

Soil and Moisture Conservation Program

Under the President's reorganization plan 4, dated April 11, 1940, the planning for the conservation of soil and moisture on lands in the jurisdiction of the Interior Department, formerly carried on by the Department of Agriculture, was transferred to the Interior Department as a more logical grouping of activities. The Secretary's Office set up the Office of Land Utilization, under Lee Muck, assistant to the Secretary, to administer the program. Largely at the suggestion of W. G. Hoyt, the Geological Survey was selected to act as adviser or consultant to the active agencies which carry on the work; Office of Indian Affairs, Grazing Service, General Land Office, Bureau of Reclamation, National Park Service, and Fish and Wildlife Service, all in the Interior Department. The administration of the new service was lodged with the Water

Utilization Division,[327] and Mr. Hoyt was especially identified with its development.

To have field charge of the new activity, H. V. Peterson, a geologist having experience with the effect of geology on runoff, accepted transfer from the Army Engineer's Office in Los Angeles, and established his headquarters in the same city Oct. 1, 1941. The chief functions of the new unit were to advise on range-water development, erosion and sedimentation, from both surface and ground sources.

In May 1941, Mr. Peterson and Mr. Langbein made a reconnaissance over the public domain to obtain first hand information on actual conditions; during the trip, the principal offices of the action agencies were visited, and cordial relations established.

During the first year, in preparation for later operations, reference files of pertinent data were compiled; reference showing the general relation of geology, water, soils, cover, erosion, and climate to soil and moisture conservation; a file showing by states and specific areas, the availability of ground water, and geologic maps, and stream flow and meteorologic records; a manual showing essential features of about 150 experimental areas being maintained by Federal agencies, to determine soil-water-climatic relationships. In addition, the action agencies were supplied with topographic maps and reports on availability of ground water and other data as requested. Having assembled all available information in shape for ready reference, the new unit was ready to function as adviser to the action agencies.

The first request came from the Grazing Service to investigate the flood problem and geology in the lower Moapa Valley, Nevada. Mr. Peterson and the chief engineer of the Grazing Service spent several weeks making a study. A report was made to the Grazing Service in 1942.

As a further example of the service supplied, in 1942 the superintendent of the Navajo Indian Reservation at Window Rock, Arizona, requested information regarding prospective sites for stock-water wells. Mr. Peterson assisted by R. W. Revell, spent June 15-23, 1942, in making an examination of well sites, and collected data relative to soil and moisture conservation. Four prospective well sites were investigated and rejected, but a new site was suggested. The log of one well was obtained and the discharge estimated. The report to the Indian Reservation dated August 18, 1942, in addition to recommending a well site, contained comments on erosion and a discussion of the small log dams in existence, and suggested sites for small flood-control dams.

Also, the Regional Grazier at Phoenix, Arizona, in September 1942, requested an investigation to determine the possibility of establishing a

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327/ Memo to Lee Muck June 26, 1941.

feed center of some 20,000 acres near Wickenburg; a local promoter had a plan to irrigate the land from ground water, and wished to have it withdrawn from grazing. The only possible water supply was ground water, and a brief investigation and geologic study indicated that the required ground water was not there.

Beginning in 1943, weekly records of stage of several small reservoirs in Arizona were kept in order that data on the hydrology of those reservoirs (stock tanks) might be used in the improvement of that source of supply.

During the winter of 1943-44, the Division made erosion studies in the southwest by Hollister Johnson, under Mr. Peterson's supervision. These studies were essentially, (1) field surveys of washes near Shiprock, N. Mex. to determine amount of erosion and head cutting which had taken place since the original surveys by the Conservation Branch in 1936, and (2) field surveys to determine the area and capacity of stock tanks on the Hualpai Indian Reservation in Arizona. In addition, experimental work for the determination of the elevation of the ground-water table for use of geophysical methods. It was carried on in various parts of Arizona and was participated in by the Conservation Branch.

Also, as a result of the various investigations, of which those mentioned are typical, Mr. Peterson prepared a memorandum to Lee Muck, describing the various mechanical measures to combat soil erosion used during the nineteen-thirties and commenting particularly on their deficiencies.328/

The Bureau of Reclamation in the fiscal year 1947, requested an appraisal of the erosion structures installed in the southwest some ten years previously, and transferred $15,000 for that purpose. Three areas in the Gila River Basin were investigated in detail, the striking result of the investigation being the lack of results previously obtained. Many structures (erosion dams) had failed largely through lack of maintenance, and where failure had not occurred, there was little evidence that the structures had fulfilled their mission.

In an attempt to determine the basic cause of erosion, a study of the past cycles of erosion was started in 1946, with an investigation of Moneta Reservoir, Wyoming, in cooperation with the Bureau of Land Management. Records were kept of water levels and silt levels in the reservoir, together with those of precipitation, and conditions of vegetation and erosion in the basin.

The last request received during the period was from the Regional Grazier at Albuquerque to examine proposed sites for stock-well sites in New Mexico. Fifty-one sites were examined by C. F. Hains from

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328/ Water Resources Bull., May 1944, pp. 106-111.

March 17 to April 26, 1947, who recommended either that the sites be drilled to determine the ground-water possibilities or that they be abandoned.

Until the beginning of the Missouri River Basin-Departmental Program in 1945, the Soil and Moisture Conservation activities were confined chiefly to the southwest from lack of personnel. But upon being included in that program, and sharing in the available funds, the activities were extended to the Missouri River Basin.329/

The Soil and Moisture Conservation activities were financed by appropriations made by Congress to the Office of Land Utilization in the Secretary's Office. Annual funds transferred to the Survey for this work were:

1941	$15,000	1945	$17,600
1942	11,500	1946	17,200
1943	11,000	1947	33,300
1944	16,400		

The increase in funds during 1947 was due to the fact that the services rendered were becoming better known, and it was believed there was a greater need for those services.

H. V. Peterson continued in charge of the activities and had the following assistants:

R. W. Revell	Jan. 15, 1942 to Mar. 15, 1946
K. R. Melin	Feb. 1, 1944 to June 30, 1947
C. F. Hains	Jan. 20, 1946 to June 30, 1947

Of the Missouri River Basin-Departmental funds allotted to the Division, $8,732 were expended.

Salt Lake City Office

R. R. Woolley continued to supervise Federal Power Commission permits and licenses. A large part of his time was devoted to an intensive water utilization study of the Great Basin, including: a hydrologic study of streams with relation to physiographic and climatic conditions pertaining to floods and their occurrences over the entire basin; analysis of trends in stream flow over the periods of records; hydrologic studies of Great Salt Lake and trends relating to stream flow; analyses of total precipitation in drainage basins and the relation to various uses, and to measured runoff; and from the legal side, a study of state control over water resources and its relation to the public domain. Those various studies were being continued at the end of the period.

329/ pp. 391, 392.

Los Angeles Office

W. E. Dickinson's study of the water supply of the Colorado River Basin, which had started in 1938, was continued during the early years of the period. It resulted chiefly in the revision and bringing down to date of the records for key stations on the Colorado River. The records were published as Water-Supply Paper 918.

Special Studies Supervised

There were a number of studies carried on by Surface Water Districts and otherwise, under the general supervision of the Water Utilization Division. Although those studies are described in connection with the districts operations, brief descriptions are presented.

In 1938, since floods in the metropolitan areas in New Jersey caused heavy damage, as the cities had encroached on the natural river channels. The State was requested to prepare a map showing the allowable limits of riparian encroachment. G. R. Shanklin, a State employee, was detailed to the study under the technical supervision of the Water Utilization Division. Interrupted by the war, it was resumed in July 1946, and expanded to a state-wide basis, when an engineer of the New Jersey district was assigned to it.

In 1939, the Water Utilization Division, with the Weather Bureau, sponsored a WPA project in Pittsburgh where there were a large number of unemployed draftsmen and technicians. Its purpose was to determine the topographic characteristics of drainage basins from topographic maps, limited to those basins completely mapped in the states east and north of Ohio and Virginia. The results are published in Water-Supply Paper 968C.

In 1940, the Boston District started a similar project for Massachusetts, dealing with floods. A special appropriation was obtained from the State, and B. R. Colby was detailed to it, working under H. B. Kinnison's supervision. The investigation was completed at the beginning of the war. Flood formulae, based on area, slope, average distance of water travel, and valley storage obtained from topographic maps, were developed. They were published in the A.S.C.E. Proceedings for March 1944.

Soon after the creation of the Ohio Water Resources Board in 1945, C. V. Youngquist, chief engineer, and formerly the Survey's district engineer in Ohio, suggested Survey cooperation in a general hydrologic study of the state by W. P. Cross. The first study was that of floods from small areas, those of June 1946 in Wayne and Holmes Counties being selected. A list of past floods at existing gaging stations was compiled and a study of their frequencies made. Both studies were published by the State agency.

Cooperation with the Division of Waterways and the Illinois

Department of Public Works and Buildings was begun in 1945 on a study of unit hydrographs. This work was under the technical supervision of W. D. Mitchell of the Urbana District and was completed in 1947. The Water Utilization Division gave advice and support to the investigation.

Cooperation was begun in 1941 with the San Bernardino County Flood Control District of California, on a study of the hydrology of the streams draining the San Bernardino Mountains. This work was under the technical direction of H. C. Troxell. The work was completed in 1948. The results are scheduled for publication in a water-supply paper. The Water Utilization Division reviewed the work to the same extent as similar projects in other field offices.

Miscellaneous

In addition to the major activities described, there were a number of short studies pertaining to runoff of specific streams in various parts of the country, rainfall-runoff relations, median discharge methods, maximum flood flows from small areas in the western part of the country, analyses of variation in annual flow in the Columbia River Basin, relative effect of variations in rainfall on runoff, and effect of droughts on hydro-electric power generation, by various members of the Branch, made under the supervision of the Division. The Bulletin of August 1947 listed 29 such studies at the end of the period.

Division Personnel

Mr. Davenport's technical assistants, with the exception of the personnel of the Soil and Moisture Conservation Program which are listed under that program, were as follows:

Name	Period
R. R. Woolley	July 1, 1939 to June 30, 1947
W. B. Langbein	July 1, 1939 to June 30, 1947
W. S. Eisenlohr, Jr.	July 1, 1939 to June 30, 1947
W. E. Dickinson	July 1, 1939 to Sept. 30, 1943
D. F. Peterson, Jr.	July 1, 1939 to Sept. 15, 1939
J. M. Fox	July 1, 1939 to Aug. 31, 1939
L. C. Crawford	July 1, 1939 to Apr. 29, 1940
Alphonso Wilson	July 1, 1939 to Sept. 9, 1939
M. D. Brands	Apr. 12, 1940 to Sept. 21, 1942
Sean O'Deorean	Mar. 19, 1941 to Dec. 31, 1944
M. I. Rorabaugh	Sept. 1, 1944 to May 5, 1945
Mrs. E. M. Patton	May 3, 1945 to June 30, 1947
Hollister Johnson	June 28, 1945 to June 30, 1947 1/
Miss E. M. Wilson	Jan. 5, 1946 to June 30, 1947
G. E. Harbeck	Jan. 13, 1946 to June 30, 1947

1/ On detail from Albany District previously.

Name	Period
R. E. Oltman	Apr. 3, 1946 to June 30, 1947
F. W. Kennon	Apr. 25, 1946 to June 30, 1947
B. R. Colby	Apr. 29, 1946 to June 30, 1947
C. C. McDonald	May 22, 1946 to June 30, 1947
F. D. Spencer	Dec. 2, 1946 to June 30, 1947
Irving Sherman	Jan. 1, 1947 to June 30, 1947
C. F. Hains	Jan. 20, 1947 to June 30, 1947

The division clerk was Miss Loula Salter until June 1942, Miss Martha J. Karres from July 1942 to April 1945, and Mrs. May E. Thiesen from July 1945 to June 1947.