HISTORICAL PROFILE OF QUALITY OF WATER LABORATORIES AND ACTIVITIES, 1879–1973

U.S.G.S. WATER QUALITY LABORATORIES

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

1879 CENTENNIAL 1979

U.S. GEOLOGICAL SURVEY
Open-File Report 78—432

U.S. DEPARTMENT OF THE INTERIOR
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Ann,

We received 6 copies of this report -
one to keep
" " Shelle
4 to you.

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA. 22092

4351-6016
QW Branch

January 13, 1979

QUALITY OF WATER BRANCH TECHNICAL MEMORANDUM NO. 79.08

Subject: PUBLICATIONS--"Historical profile of quality of water laboratories and activities, 1879-1973"

Enclosed is a copy of open-file report 78-432 entitled "Historical Profile of Quality of Water Laboratories and Activities, 1879-1973". This report was prepared by W. H. Durum with input from many individuals throughout the Division. It is one of a series of planned reports aimed at documenting the history of water-quality data collection activities within the Water Resources Division. District personnel and other data users have found this type of information to be essential for the proper analysis of water-quality data for long-term trends.

Two additonal reports are in preparation. They will present: (1) a profile of cooperator-or other State-supported laboratories that have contributed significant bodies of historical water-quality data through our district programs and (2) a history of analytical methods used to acquire water-quality data for Division programs that will include a statement on the precision associated with each method. The many changes that have taken place in the water-quality field make it imperative that we document the water-quality methodology and techniques that were used by Division hydrologists in the past before that information is lost to us, so that these factors can be considered when making evaluations of historical water-quality data.

We feel that Walt Durum has done a very fine job of documenting the 95 years of water quality activities from 1879-1973. Of necessity, the level of effort was such that some important details may have been omitted and some statements may need correction or expansion. We would appreciate comments that will help us correct the historical documentation found in this report. After the next two reports have been completed, a final summary report will be prepared which will incorporate all needed revisions. Please send any comments you may have to the Analytical Services Coordinator, Mail Stop 412, Reston, Virginia 22092. We encourage district offices to give copies of this report to their cooperators with a request for comments on the correctness of the data in the report that pertain to their programs or facilities. Between our cooperators and our WRD field personnel, we hope to be able to identify all State-supported or cooperator laboratories that should be interviewed and written up. Our intention is to cover 85 percent of the historical water-quality data collected through WRD programs in that state.

This report is also being made available to selected former WRD employees, who will be asked to comment on it and assist in further corrections to the report. Additional copies needed to satisfy the needs of districts, cooperators, direct service laboratories, retirees interested in commenting, and others are available from the Quality of Water Branch, Mail Stop 412, Reston, Virginia 22092.

R. J. Pickering

R. J. Pickering
Chief, Quality of Water Branch

Enclosure

Distribution: A, B, S, FO, PO

DEDICATION

Dedicated to those intrepid pioneers in water quality investigations: M. O. Leighton, F. W. Clark, R. B. Dole, Walton Van Winkle, W. D. Collins, and S. K. Love--who did the field work, performed the analyses, wrote the reports, and raised the money. And to my co-workers who made a life-long activity in the field of water quality thoroughly enjoyable and all too brief.

HISTORICAL PROFILE OF QUALITY OF WATER LABORATORIES AND ACTIVITIES, 1879–1973

PART 1: HISTORICAL PROFILE OF WATER QUALITY LABORATORIES

By W.H. DURUM

U.S. GEOLOGICAL SURVEY
Open—File Report 78—432

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

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ABSTRACT

During the period 1918 to 1973 the Water Resources Division established 22 District-type water quality laboratories. These facilities provided the analytical capability and water quality information for hydrologic investigations and the national baseline inventory of chemical, physical, fluvial sediment, and biological characteristics of surface and ground waters in the United States.

The first laboratory was established in 1918 at Washington, D.C., and the second in 1937 at Austin, Texas. Eleven additional facilities were established during the 1940's when a major stimulus to water quality investigations came during World War II and the postwar period when numerous State and municipal water resources agencies sought an appraisal of water resources to attract industries. State agencies became major cooperators with the Survey in the 1940's and 1950's. Six additional laboratories were placed in operation in the 1950's and four in the 1960's.

Prior to 1950 most methods used in the laboratory were gravimetric, colorimetric, or titrimetric. Flame photometric equipment was common to most laboratories in the 1950's and the atomic absorption spectrophotometer was added to larger laboratories in the 1960's for greater productivity, improved quality control, and an aftermath of increasing concern with the spreading of potentially hazardous levels of constituents in water systems along with recent legislation that placed stringent requirements on laboratory analytical measurement techniques.

In the late 1960's the first of the automatic analyzers was installed to keep pace with rapidly increasing volume of analyses and a growing public interest in trace elements, nutrients and other water quality measurements.

Most laboratories analyzed fluvial sediment at some time during their operation.

Prior to 1950 analytical methods used were monitored by the Washington laboratory and office. Thereafter, standard procedures evolved in a rapid sucession of methods manuals published in Survey's TWRI series beginning in the 1970's.

The first techniques for quality control included a difference in cation-anion balance ranging from 1 to 5

percent. Rechecks of suspect analysis, second analyst approval, and a national standard reference program beginning in 1962 were common to all laboratories.

Total annual production averaged about 480 adjusted complete analyses during the early years 1919-28, about 7,800 in 1946, and about 50,000 in 1970. Analyst production rate rose dramatically from 1950 to 1970 benefitting from advanced analytical equipment.

Starting about 1968 chemical quality data were stored in the Division's Water Data and Storage and Retrieval System (WATSTORE). All data are published in the annual series of water supply papers beginning in 1941 (WSP 942). State compilations and special hydrologic reports for specific areas also include many basic data.

Budget estimates for the majority of laboratories ranged from $25,000 to $50,000 (1940-50) to $75,000 to $300,000 (1965-73).

Beginning in 1972 the major functions of the 22 laboratories have been combined into two comprehensive, highly automated facilities that comprise the Central Laboratory System. These facilities are located at Denver (Arvada), Colo., and Atlanta (Doraville), Ga.

INTRODUCTION

Quality of water laboratories and facilities of the U.S. Geological Survey have been intimately associated with the Nation's rich heritage and rapid growth in population and economy during the last centennial. The Survey's water-quality activity can be traced nearly a century to 1879 when the first chemical quality of water resources information was made available. The laboratories have supported Water Resources Division programs that evolved with the development of vast public works and concern with the intensity of pollution problems in the first decade of the century and again in the 1960's.

The rapid growth of water science in recent years provides incentives to reexamine historical water quality data in light of our improved understanding of normal earth-water processes and how they are affected by man.

This document considers certain aspects of the operational features and historical development of the laboratories and associated programs.

In addition to the historic significance of the Survey's information source, future investigators may want to evaluate the precision and reliability of data (inorganic, organic, biological, and sediment) that were reported through the historic period as more and more information is stored and retrieved in the Water Resources Division data system. The first part of the report is a summary that highlights the principal operating features of the laboratories prior to the 1973-74 period, including dates of operation, purpose or objective, manpower, analytical facilities, data output, budget, and relation to district or national programs. The second part consists of a brief documentation of the individual laboratory. For convenience, the facility appears in alphabetical order of the city in which the laboratory was last located.

The operational program of the Water Resources Division is conducted largely through 48 district offices across the country. Prior to 1972, twenty-two of the district offices included water-analysis laboratories, that furnished the analytical support to all the districts (fig.1.)

Laboratory operations have undergone major change in the last 30 years mainly through advancement in instrumentation. Technical development in spectrometry and flame photometry during the 1940's and 1950's and automation in the 1960's and 1970's had a major impact on Water Resources Division laboratories. These facilities now require major capital investment, specialized techniques, a short time-frame for analysis, and a large volume workload in cooperative programs.

Beginning in 1972, major functions of the 22 laboratories have been combined into two comprehensive highly-automated facilities located at Denver (Arvada), Colo., and Atlanta (Doraville), Ga. The two laboratories comprise the Central laboratory System and are not considered in detail in this report.

At the turn of the century stream pollution problems were attracting interstate attention and Survey investigations of water quality were directed toward pollution problems for several years. Data on stream sanitary (biochemical) quality (i.e., bacterial, oxygen consumed, nitrogen compounds, turbidity, color and other measurements taken from State Board of Health reports) commonly were summarized in reports. By the end of the first decade, national interest in conserving water resources and the impact of industrial interests brought a shift in emphasis in water quality studies. Studies in the next few years following 1913 were almost exclusively of the mineral content of water. This restriction was caused by a lack of funds to cover a wider field and by the entrance of the Public Health Service into stream pollution investigations.

The first systematic nationwide monitoring program for assessing the mineral characteristics of rivers and lakes was begun in 1903 by the Survey's Hydrographic Division (now the Water Resources Division). Daily samples were obtained on a year-around basis at selected sites of the principal rivers and at four of the Great Lakes. Ten daily samples were composited to provide a single sample for the determination of some fourteen different parameters and constituents (Dole, 1909).

On January 2, 1918, the Division of Quality of Water was reestablished as an independent unit and the Survey established in Washington D.C., its first separate water analysis laboratory.

During the years 1921 to 1946 the suitability of the Nation's water supplies for public use and for agricultural

WATER RESOURCES DIVISION LABORATORIES, 1918—1973
GEOGRAPHIC AREAS AND FIELD CENTER LOCATIONS

Figure 1.--Water Resources Division Laboratories, 1918-1973

and industrial purposes was stressed. Many reports were prepared about industrial and domestic utility of water supplies, hardness, indices of analyses, water temperature, methods of analysis, and other contributions to hydrology.

Survey's studies in water quality moved westward to Arizona in 1925 when a continuing program for the measurement of fluvial sediment in the Colorado River began. Increasing attention was being given to the study of Colorado River flow and its utilization. Storage reservoirs were needed. The awesome sediment load transported by the stream affected the life of the reservoir, and data were necessary for design plans.

Analytical services and technical support for the Colorado River studies were provided by the Washington laboratory and again when cooperation was arranged with four States during the 1930's. The Virginia State Commission on Conservation and Development, in 1929, cooperated with the Survey in a two-year study of the State's water resources. A cooperative program with the Georgia State Division of Mines, Mining, and Geology began March 1, 1937 initially with daily sampling at stream gaging stations. A comprehensive salinity study of the Connecticut River was made cooperatively with Connecticut State Water Commission from 1934 to 1939 to cover tide and stream-flow conditions.

Nearly two decades were to elapse before a second permanent laboratory was established at Austin, Texas, in 1937, to facilitate continuing ground-water studies in Texas and in the Pecos River Joint Investigation.

The investigation of the source of salinity in the Pecos River begun in April 1937 by the Ground Water Division resulted in a separate agreement with the State of New Mexico and the Quality of Water Division. A field laboratory was established at Roswell, N.Mex.

A major stimulus to water-quality investigations came during World War II and the postwar period when numerous water resources oriented agencies were either created or existing ones sought an appraisal of water resources to attract industries. Federal-State cooperative programs with the Geological Survey grew rapidly, either as an expansion of existing traditional surface water or ground water investigations with the Water Resources Division or as entirely new ones. These began as modest activities, often to establish a data base of seasonal high and low-flow surface water quality. The few existing laboratories, of which the Washington D.C. facility was the mainstay, were unable to maintain the new analytical loads. Shipping cost of water samples, equipment, and materials were formidable, and some State officials preferred a local facility for better control of analytical schedules and the State share of cooperative funds. These factors, among others, contributed to a rapid development of small District laboratories serving, generally, one or more Federal-State cooperative programs.

River development in the west and southwest beginning in the early 1940's fostered joint investigations in New Mexico, the Arkansas River basin, the Middle Rio Grande basin, and the Lower Colorado River basin. The Albuquerque, New Mexico Laboratory was created in 1942 to provide analytical services for these new programs of the Geological Survey and of other Federal agencies. In 1947 the first regional laboratory for chemical quality and sedimentation studies was established at Salt Lake City by specific appropriation of Congress. This action by Congress came because the cost of equipping a laboratory in each State where programs had developed was too costly for available funds. It was recognized that selected regional facilities equipped by means of Federal funds appropriated for that purpose would be an alternative solution.

In 1944, Congress approved the Missouri River Plan and vested joint execution of the Plan with the Department of Interior's Bureau of Reclamation and the Army Corps of Engineers. A Geological Survey laboratory at Lincoln, Nebr., began operations in 1946 to provide water-quality information for studies of water resources by Interior and other Federal agencies. The Survey's Water Resources Division also was assigned the responsibility for conducting numerous investigations to provide hydrologic information for other Interior agencies.

In these western drainage basins, the principal water-quality problems were the naturally-occurring high salinity of surface and ground water and the suspended-sediment content and discharge of streams. The main scope of activities in the Missouri basin was with the sediment load of streams related to reservoirs and desilting basins proposed for construction by the Bureau of Reclamation and studies of chemical quality of surface and ground water to meet requirements of other Federal agencies in the basin.

Following the enactment of the Water Quality Act of

1965 increasing attention has been given to man-induced water quality problems and the potential proliferation in water resources of "exotic" chemicals including pesticides and organics, trace elements, nutrients, and biochemical substances. Highly sophisticated instruments for routine determinations in the laboratory replaced older laborious methods. Also, during the late 1950's and 1960's the Water Resources Division field offices and headquarter specialists were hard at work with systems for insitu field monitoring and digitally recording water-quality parameters. By 1966 the Division was ready to report that the digital recording of water quality parameters is a link in the automated data collection and processing system of the USGS.

Despite a ragged start, the age of on-site automation had begun.

During fiscal years 1973 to 1976 nearly one-half of the new offerings of State and local agencies in the Water Resources Division cooperative program involved studies with water quality aspects, largely in response to new environmental responsibilities mandated by recent Federal laws. Specifically, these are the Federal Water Pollution Control Act amendments of 1972 (Public Law 92500) and related research and monitoring activities. The bulk of them have been coordinated through the Environmental Protection Agency and the Department of Interior's Office of Water Resources Research and have stimulated many of the recent technological advances in several aspects of water quality.

SUMMARY

DATES OF OPERATION

In January, 1918, the Division of Quality of Water established in Washington, D.C., its first separate water analysis laboratory, having first begun operations on F Street in 1906 (Jointly with the Geologic Division). In 1919, the laboratory was moved to Room G241C in the present General Services Administration Building (then the Interior Building). The laboratory again moved to the Old Post Office Building, 12th and Pennsylvania Ave., N.W. on June 25, 1951 where it remained in the ornate, imposing landmark in downtown Washington for the next 22 years.

No additional full-time facilities were developed until 1937 when the Austin, Tex., laboratory began operations. This was followed 5-years later, in 1942, with a facility at Albuquerque, N.Mex., then in rapid succession in the 1940's at Raleigh, N.C.; Little Rock, (Fayetteville), Ark.; Columbus, Ohio; Harrisburg (Philadelphia), Pa.; Lincoln, Nebr.; Oklahoma City (Stillwater), Okla.; Charlottesville, Va.; Salt Lake City, Utah; and Anchorage (Palmer), Alaska. Six additional laboratories were placed in operation in the 1950's--Sacramento, Calif.; Ocala, Fla.; Albany, N.Y.; Portland, Oreg.; Baton Rouge, La.; and San Juan, P.R. The last group of facilities to be started in the 1960's, included Yuma, Ariz.; Tuscaloosa, Ala.; Tacoma, Wash.; and Honolulu, Hawaii.

All 22 District facilities were discontinued as full-scale laboratories in the 1973-74 period and converted to District service units when the Central Laboratory System began full time operation at Denver, Colo.; Atlanta, Ga.; and temporarily at Albany, N.Y.

PURPOSE OR OBJECTIVES

Most of the laboratories functioned as a support facility for the quality-of-water district operation in which they were located and in adjacent States. They provided the analytical capability and water quality information for hydrologic investigations, and the national baseline inventory of chemical, physical, fluvial sediment, and biological characteristics of surface and ground waters in the United States. From 1973 to the present, the existing data base has been expanded for National water-quality programs under PL (Public Law) 92-500 and PL

93-523 such as National Stream-Quality Accounting Network (NASQAN), National Water-Quality Surveillance System (NWQSS) and others.

MANPOWER

Most of the facilities began with 2 or 3 analysts during the first few years of operation. The size of the staff varied according to the workload, but only 6 laboratories averaged more than 10 personnel during the period of operation (Austin, Albuquerque, Ocala, Columbus, Harrisburg, and Salt Lake City). Including field facilities at project offices in the State of Texas, the Austin Laboratory had a roster of 35 to 50 analysts during the early 70's. But the number of analysts averaged about 6 to 7 for all laboratories, indicative that the facilities generally were small.

The typical 2-man older laboratories initially included a chemist and technician, or in the instance of a sediment laboratory, sometimes an engineer or soil scientist. As biochemical interests grew in the 60's biologists were added to some staffs. Beginning in the 1950's as instrumentation gradually replaced standard gravimetric and other procedures, the composition of laboratory personnel shifted increasingly to a high proportion of technician-analysts. In University towns this was facilitated by the available supply of advanced science students for part or full-time employment. The laboratory supervisor, a designated full-time professional, was responsible for adequate quality control, training, and the maintenance of a smooth work schedule. Historically, the quality-of-water laboratories have earned a considerable national reputation in career development as training grounds for analysts, hydrologists, and other professionals preparing for field and research project studies, and for district and national leadership positions.

To some extent this unique approach in the Water Resources Division career development program for training of hydrologists in the laboratory accounts for a rather short tenure of the laboratory supervisor, generally from a few months to a few years in most of the laboratories. Noteworthly is that C. S. Howard supervised the Washington Laboratory from 1920-1942--22 years, and in recent years, James R. Avrett supervised the Tuscaloosa, Ala. Laboratory for the period of its operation, 1962-1975.

ANALYTICAL FACILITIES

Equipment: Prior to 1950, most methods in the laboratories were gravimetric, colorimetric, or titrimetric. Electronic equipment consisted chiefly of line operated pH meters, colorimeters, a spectrophotometer and a electrophotometer.

In the 1950's a model DU or equivalent spectrophotometer for flame measurements of sodium and potassium was common to most laboratories. This was followed by the addition of the Model "B" spectrophotometer for measurements such as iron, nitrate, boron, and manganese.

By 1964, the atomic absorption spectrophotometer (P.E. Model 303, or equivalent) for measurement of minor elements were added to the larger laboratories. A second atomic absorption spectrometer with refinements for measurement of calcium and magnesium was purchased by a few laboratories. In 1967-68, the first of the automatic analyzers ("Autoanalyzer") was installed at the Salt Lake City laboratory and a few other facilities to keep pace with the rapidly increasing volume of analyses and the growing public interest in minor elements, nutrients, and other special measurements.

Other highly specialized equipment such as the infrared spectrophotometer and/or the carbon analyzer were added in the late 1960's as special case situations in a few facilities.

In 1939, an Interdepartmental Committee composed of representatives of interested Federal agencies and the Iowa Institute of Hydraulic Research directed a joint study of fluvial sediments at the University of Iowa. In 1948 the project was moved to the St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, Minn. Under the Committee's direction 14 numbered reports and "Lettered Reports", A through T, have been published on the design and development of field equipment for sampling suspended sediment and bed material, methods for making particle size analyses, and field procedures for the determination of fluvial sediment discharge (Report 14, Determination of fluvial sediment discharge 1963).

The Geological Survey has participated directly in the technical phases of the Federal Inter-agency Project, including project personnel, and utilized and modified the sampling equipment as it became available for field studies.

Most laboratories had capabilities for analyzing fluvial sediments at some time during their operation. The standard equipment beginning about 1946 was the bottom-withdrawal tube for particle-size analysis and sieve analysis for sands. About 1950 the pipet method for particle-size analysis was added.

In addition to a principal laboratory, some operations like the Missouri basin program at Lincoln, Nebr., required separate field units (i.e. Norton, Kans.; Dickinson, N.Dak., and Worland, Wyo.) for handling a large volume of sediment analysis during the peak of operating programs.

Highly specialized analytical equipment for pesticide and other organic analysis by gas chromatograph were centered in Washington, D.C. and Austin, Tex., laboratories, and the Menlo Park Calif. and Denver Colo., research centers beginning with the period 1964 to 1967.

Aquatic biological and microbiological studies, historically a small, but significant part of some district laboratory operations began to expand rapidly about 1970 as the broad scope of environmental concerns in natural resources in the late 60's unfolded and the impact was felt in the Division programs. Laboratories on the East Coast, particularly at Albany, Harrisburg, Washington, D.C., and Ocala tooled up for small-volume biochemical and biological analysis principally through leadership and facilities at Albany.

The first recording of multiparameter water quality characteristics occurred in 1959-60 when a water-quality monitor was installed in the Delaware estuary at Philadelphia. The Philadelphia district tested and made innovative improvements to monitoring equipment for the next several years in cooperation with the City of Philadelphia and equipment manufacturers. In November 1962, a water-quality monitor was installed on the Cuyahoga River at Center Street in Cleveland in cooperation with the Ohio Department of Health.

Methods: Prior to 1950, there was no standard compendium of water analysis procedures used by all laboratories. Collins "Notes on practical water analysis," (WSP 596 H, 1928) and procedures monitored by the

Washington, D.C. headquarters were the principal references. Standard Methods and others were source material. But the ever-widening problems in composition and concentrations of substances in different parts of the country often left the selection of procedures to the experienced skilled analyst. Some facilities compiled the best of time-tested procedures applicable to the specific water problems of the area.

As advances in instrumentation were announced in the late 1940's, the laboratories shifted from tedious and time-consuming gravimetric procedures which depended to a large extent on considerable skill by the experienced analyst to obtain reliable results. "Methods of water analysis," (1950) was the first attempt to standardize procedures in the District laboratories. This was updated in 1960 with the public- released WSP 1454, "Methods for collection and analysis of water samples." In 1970 there began a rapid succession of methods manuals in the TWRI series, "Methods for collection and analysis of water samples for dissolved minerals and gases, "book 5 chapter A1; "Methods for organic substances" (1972); "Methods of water analysis for trace constituents"; "Methods for aquatic biological and microbiological samples"; "Methods for sediment analysis" (1960, 1969), and others.

PRECISION OR ACCURACY

Historically, the hallmark of Geological Survey analysts is reliable data. During the early life of the organization, and particularly during the period 1902 to 1906 when an increasing assemblage of data were published, practically no analyses other than field assays were made by Water Resources Division facilities. The bulk of the analytical work was performed through cooperation with university and State laboratories. Quality control probably was difficult to attain.

In the period 1905-08, comprehensive studies of water quality were underway for example, in California, Illinois, and North Carolina, by principal analysts F. W. Clarke, W. D. Collins, R. B. Dole, F. M. Eaton, M. G. Roberts, Chase Palmer, Walton Van Winkle, and others. For most studies daily samples were composited, generally for 10-day periods. Results of analysis typically were reported for turbidity, suspended matter, silica, iron, calcium, magnesium, sodium and potassium carbonate, bicarbonate, sulfate, nitrate, chloride, and total solids.

From these early comprehensive analyses came the first techniques for quality control including a cation-anion balance ranging from 1 to 5 percent depending on the composition of the waters. These techniques persisted in all Survey laboratories through the 1940 to 1970 period together with careful comparison with other relative analyses where possible.

Standard solutions were prepared by experienced chemists and compared aganist solutions of known reliability. Laboratory and portable field instruments were inspected and calibrations checked at regular intervals in accordance with manufacturers specifications. Water-quality monitors were visted on a regular schedule, generally weekly, for calibration and maintenance.

The method of careful checking the laboratory analysis sheets against the final data tabulations seems to be an adequate control over records prior to data storage.

Rechecks of suspect analysis and second analyst approval were standard procedure in all laboratories.

Beginning in 1962, the Methods Development Unit at Denver, directed by Marvin Skougstad, undertook a Standard Reference Program in which prepared samples of a single element were analyzed by participating laboratories. The results and performance of each laboratory in comparison with the mean values obtained by all laboratories were reported.

Additionally, beginning about 1973, Survey laboratories have followed established procedures for nutrients outlined in the EPA Analytical Quality Control Manual, and have participated in regular blind analysis of EPA reference samples.

Table 1 is a summary of general analytical methods, references, and estimated precision for data in the historical period, 1918-1973.

Data output: During the early years of the Washington, D.C. laboratory, 1919-28, total annual production averaged about 480 adjusted complete analyses annually. The addition of the second facility, Austin, in 1937, and the increase in the number of analysts in the two laboratories (total about 20) increased production to an estimated 2400 complete analyses by 1940.

About ten years later, in 1946, total analyses

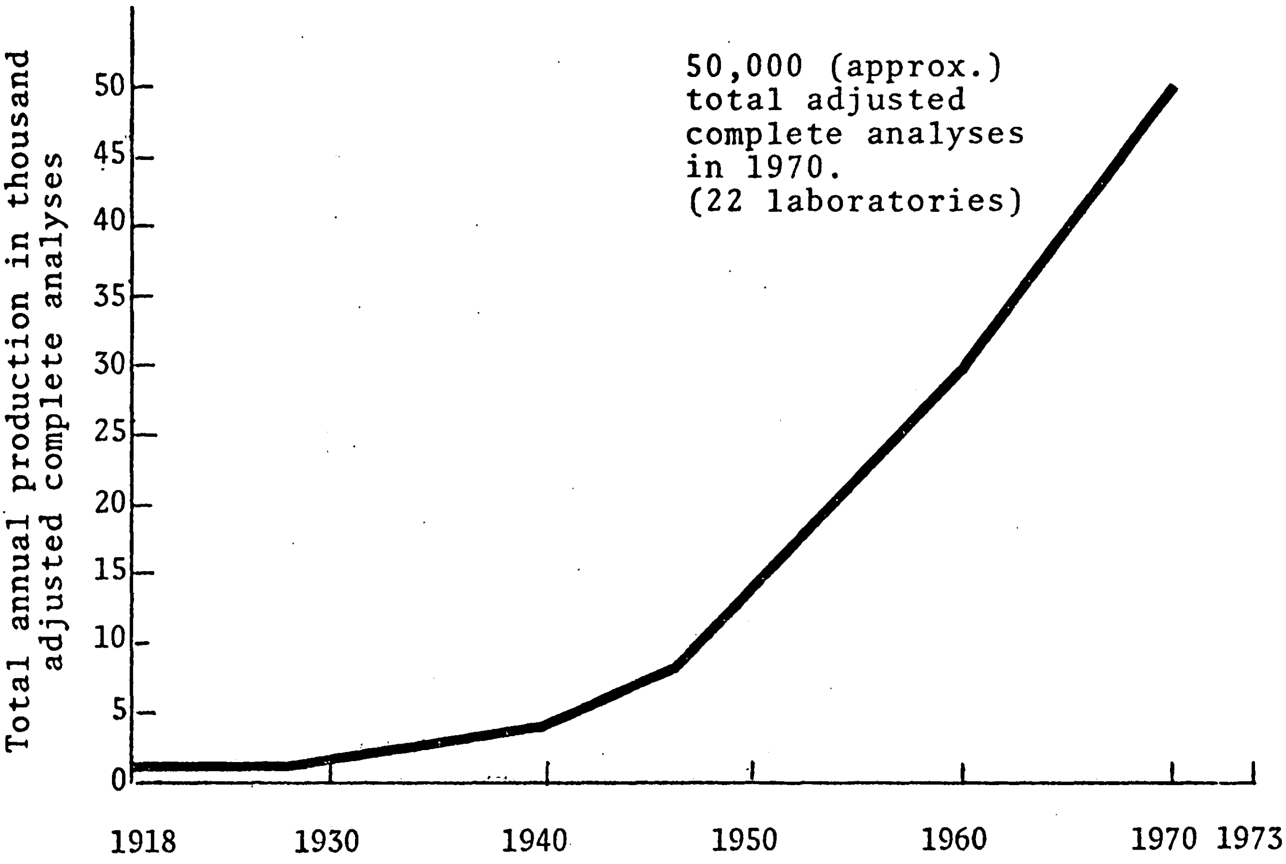
Table 1.--Summary of analytical methods, references, and estimated precision, historical period 1918-1973

Historical period	General method of instrumentation	Reference	Precision (estimated)	Constituents
1918-1950	Gravimetric, volumetric and titrimetric (all laboratories)	USGS: WSP 236 (1909) WSP 596 (1928) Methods of water analysis (1950) reported	±5 percent, where dissolved solids (DS) is less than 100 mg/L ±20 percent for individual constituents reported in mg/L.	Acidity, alkalinity, aluminum (Al), arsenic (As), barium (Ba), boron (B), bromide (Br), calcium (Ca), carbon dioxide (CO_2), chloride (Cl), chromium (Cr), color, specific conductance, copper (Cu), dissolved solids, fluoride (F), hardness as $CaCO_3$, hydrogen sulfide (H_2S), iodide (I), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nitrate (NO_3), oxygen consumed, pH, phosphate (PO_4), potassium (K), selenium (Se), silica (SiO_2), sodium (Na), specific gravity, strontium (Sr), sulfate (SO_4), sum of determined constituents, suspended matter, turbidity, and zinc (Zn).
1951-1973	Flame photometer	USGS: WSP 1954 (1960) TWRI book 5 chapter A1 (1970)	±5 percent for individual constituents reported in mg/L.	Calcium (Ca), lithium (Li), maganesium (Mg), potassium (K), and sodium (Na).
1956-1973	Emission spectrograph (applicable only to special studies, Sacramento, CA, Denver, CO, & Washington, DC laboratories)	USGS: WSP 1540A (1960) TWRI book 5 chapter A2 (1971)	±16 percent (Based on average geometric deviation, 1.16, the factor by which amount found may be multiplied & divided to find the range of one of the standard deviations.)	Aluminum (Al), barium (Ba), beryllium (Be), bismuth (Bi), boron (B), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), gallium (Ga), germanium (Ge), iron (Fe), lead (Pb), manganese (Mn), molybdemum (Mo), nickel (Ni), silver (Ag), strontium (Sr), tin (Sn), titanium (Ti), vanadium (V), & zinc (Zn).
1962-1973	Atomic absorption spectrophotometer (13 laboratories)	USGS: TWRI book 5, chapter A1 (1970)	±15 percent where constituent is less than 20 ug/L.	Barium (Ba), beryllium (Be), cadmium, chromium (Cr), cobalt (Co), copper (C), iron (Fe), lead (Pb), lithium (Li), maganesium (Mg), manganese (Mn), nickel (Ni), potassium (K), silica (SiO2), silver (Ag), sodium (Na), strontium (Sr), & zinc (Zn).
1968-1973	Technicon Auto Analyzer (8 laboratories)	Methods as released by Technicon.		Chloride (Cl), chemical oxygen demand (CO), ferrous iron (Fe+2), ferric iron (Fe+3), iodide (I), ammonia nitrogen (NH_4), nitrate (NO_3), nitrite (NO_2), phosphate (PO_4), and silica (SiO_2).
1969-1973	Fisher Titralyzer (2 laboratories)	Methods as released by Fisher Co.		Chloride (Cl) and sulfate (SO_4).
1964-1973	Gas chromtography	USGS: TWRI book 5, chapter A3 (1972)	±3 percent (single component under ideal conditions) ± 15 percent (chlorinated hydrocarbon extracted from water with m-hexane, 0.01 to 0.10 ug/L).	Pesticides.
1964-1973	General organic methods	USGS: TWRI book 5, chapter A3 (1972)	±1 percent to 100 ug/L level. Where precision is known, range is ± 5 to ±10 percent of 1 to 5 mg/L range	Carbon, chlorophylls, color, extractable organic matter, methane blue active substances (MBAS), and phenolic material.
1960-1973	Continuous recording electronic water-quality monitors	Manufacturers specifications	±2 percent, ±2 percent, ±5 percent, ±2 percent, ±5 percent, respectively.	Dissolved oxygen (DO), specific conductance, turbidity, temperature, and pH.
1955-1973	Radioactive substances	USGS: TWRI book, chapter A5 (1977)	±100yr at 10,000yr range, ±800yr at 30,000yr range; ±20 percent, ±2 percent above 15 pCi/L, ±10 percent lower concentrations; ±20 percent, ±15 percent; ±10 percent, respectively.	Carbon 14, Lead 210, Cesium 137 and cesium 134, radium, ruthenium 106 and ruthenium 103, and tritium. uranium; and strontium.

Table 1.--Continued--Summary of analytical methods, references, and estimated precision, historical period 1918-1973

PRECISION OF AUTOMATED DETERMINATIONS

No.	Determination	Method	Precision
		Technicon AutoAnalyzer	
1	Chloride (Cl)	I-2187 Ferric thiocyanate	±2 percent (26.8 mg/L); ±1 percent (72.9 mg/L).
2	Chemical oxygen demand (COD)	I-1561 Dichromate oxidation	±3 percent to ±1 percent (50 to 500 mg/L).
3	Ferrous iron (Fe+2)		(See iron, ferrous-plus-ferric)
4	Ferric iron (Fe+3)		(See iron, ferrous-plus-ferric)
5	Iron, ferrous-plus ferric	I-2379 Biphyridine	±5 percent (124 ug/L); ±2 percent (854 ug/L).
6	Iodide (I)	I-1371 Ceric-arsenious oxidation	Precision data not available; precision estimated to be in the range of from 3 percent to 5 percent.
7	Ammonia nitrogen (NH_3)	I-2353 Indophenol	±20 percent (0.05 mg/L); ±2 percent (0.43 mg/L); ±1 percent (1.46 mg/L); ±5 percent (3.47 mg/L).
8	Nitrate nitrogen (NO_3)		(See nitrite plus nitrate)
9	Nitrite nitrogen (NO_2)		(See nitrite plus nitrate)
10	Nitrite (NO_2) plus nitrate (NO_3)	I-2545 Cadmium reduction-diaxotization	±3 percent (2.86 mg/L); ±5 percent (5.77 mg/L).
11	Phosphate (PO_4)	I-2600 phosphomolybdate	Precision estimated to be in the range of from 3 to 5 percent.
12	Silica (SiO_2)	I-2700 Molybdate blue	±5 percent (7.24 mg/L); ±3 percent (23.9 mg/L).
		Fisher Tiralyzer and Radiometer Analyzer	
13	Bicarbonate (HCO_3)		±6 percent (50 mg/L); ±5 percent (100 mg/L); ±5 percent (200 mg/L).
14	Chloride (Cl)		Precision estimated to be 4 percent.
15	Sulfate (SO_4)		Precision estimated to be 4 percent.



50,000 (approx.)
total adjusted
complete analyses
in 1970.
(22 laboratories)

Figure 2.--Total annual production, adjusted complete analyses (approx.) for all laboratories, 1918 to 1970

performed in six facilities rose to 7,800 adjusted complete analyses. By 1960 total output had increased four-fold to more than 30,000 complete analysis and by 1970 when 22 facilities were operating, the national total was estimated to be about 50,000 complete analyses (fig. 2).

As late as the 1950's a good production rate for a well trained analyst was about 240 adjusted complete inorganic analyses, annually. In 1976, benefitting from advanced analytical and automated equipment, the individual analyst's production rate for the year increased dramatically to 1,570 adjusted complete analyses.

The significant increases in production for the 3-decade period 1940-70 clearly indicate that as instrumentation techniques improved several-fold the production efficiency of analytical procedures, so also the demand for water quality information increased dramatically and led to decisions on consolidation into the Central Laboratory System in the early 70's.

In 1960 water quality data were obtained at 907 surface water sites. About one-third of these river observation stations were east of the Mississippi River. In 1963, the quality of water basic data network included 1,372 river sampling stations throughout the U.S. and Puerto Rico. Chemical quality was measured at 942 of these sites, sediment concentration and loads at 306 sites, and water temperature at 1,127 locations.

Public interest in water-quality information grew rapidly in the 1960's and by 1971 a total of 4,344 stations were operated. Chemical quality observations were made at 3,546 river locations, sediment concentrations at 873 locations, and temperature at 3,586 places.

Noteworthy in the reporting from individual facilities was that the Raleigh laboratory in the course of its 29-year operation performed about 50,000 water analyses estimated to be equivalent to 30,000 adjusted completes. About 75 percent of the analyses were of surface waters.

From 1950 to 1971 the Sacramento Laboratory analyzed about 62,000 water samples--an estimated 2,000 adjusted complete analysis annually for the period of operation.

The only available information on sediment analyses were for the Harrisburg and Sacramento laboratories which reported an average yearly sediment analyses of 20,000 and 24,000 sediment concentrations, respectively. Sediment data programs probably peaked and leveled off sometime during the 1950's, but the chemical quality programs have grown steadily with a major upsurge occurring about 1968 when environmental questions evolved into a national concern.

DATA PRESENTATION

Prior to about 1964, analyses were transcribed from laboratory notes to 4" x 6" analytical statement cards which were filed in the District laboratory. The laboratory worksheets where redesigned to serve as the official file document and the analytical cards were eliminated during the period 1964 to 1971. Beginning in 1971, the Central Laboratory analysis report has been used as the official file document.

Starting about 1968 all chemical quality data were stored in the Division's Water Data and Storage and Retrieval System (WATSTORE). All data are published in the annual series of water supply papers beginning in 1941. State compilations and bulletins or special hydrologic reports for specific counties or areas also include many basic data.

BUDGET

Budget information was difficult to compile because the assortment of programs and sources did not always separate funds for water quality activities or laboratory service functions. Some of the estimates given include cost of sediment field activities, administration, and report preparation.

The following ranges of budget estimates for the majority of the laboratories are considered a reasonable guideline:

1940-50	$25,000 to $ 50,000
1951-65	$50,000 to $ 75,000
1965-73	$75,000 to $300,000

A few of the smaller facilities reported an operating budget of about $30,000 through 1973, and four operated in the general range of $200,000 to $670,000 in the 1970's. Generally the budget increased two-to-six-fold during the lifetime of most laboratories, and two larger facilities reported increases nearly 20-fold during the period of operation (fig. 3).

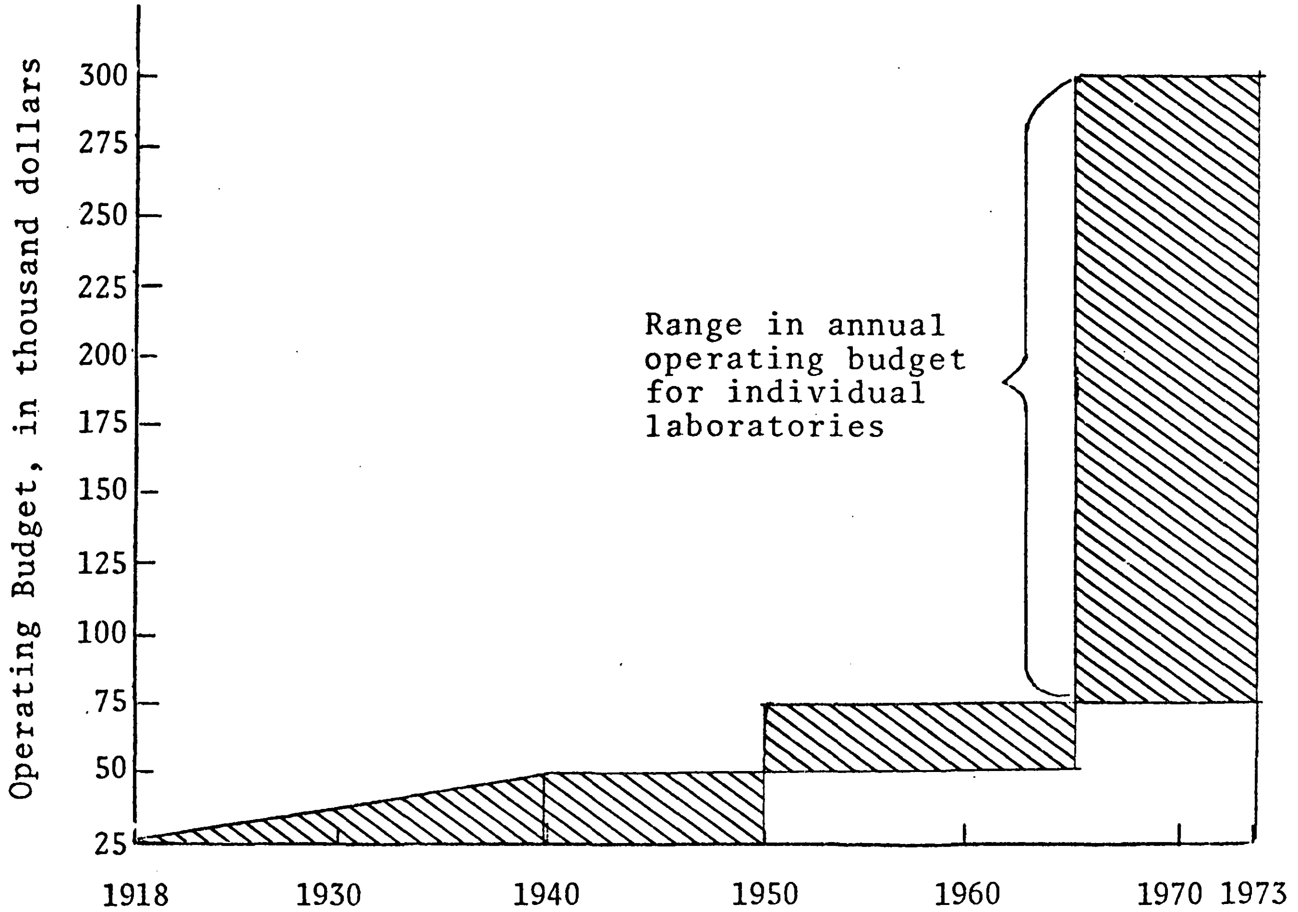


Figure 3.--Range in annual operation budget (estimate) for individual laboratories during several periods, 1918 to 1973

RELATION TO DISTRICT OR NATIONAL PROGRAM

The laboratory operation was mainly analytical support for the basic data network and for District projects as water quality programs developed with State and Federal agencies.

State agencies became major cooperators in water-quality projects with the Survey in the 1940's and 1950's when most of the laboratories in eastern United States were started. These cooperative programs have expanded and continued generally to the present.

During the years prior to about 1950 the laboratories in western United States supported primarily the national programs of USGS in obtaining basic records for surface water and ground water. Thereafter, the laboratories have functioned in support of Federal-State cooperative programs and with other Federal agencies such as the Corps of Engineers, the Armed Forces, Soil Conservation Service, U.S. Bureau of Reclamation, Bureau of Land Management, U.S. Fish and Wildlife Service, and the Environmental Protection Agency.

Historically, beginning with the establishment of the first Geological Survey independent water-quality laboratory in 1918 at Washington, D.C., the Division's laboratories have been associated directly with the public sector, principally with local cooperators and cooperative problems.

As the Central Laboratory System becomes completely operational one should expect with more efficient and larger volume production some loss in the traditional "grass roots" service that has characterized the smaller laboratories. Thus, one of the objectives in management of the Central Laboratory System should be to ensure that traditional public service is maintained. The quality of that public service will have a great deal to do with the success of the system, particularly in the role of a larger laboratory in a rapidly changing technological society.

Judging from achievement to date there is no cause to lament that the Water Resources Division laboratories will not be sensitive to the public needs.

PROFILE OF QUALITY OF WATER LABORATORIES

ALBANY, NEW YORK LABORATORY

[Background material prepared by R. J. Archer
and A. L. Mattingly]

Dates of operation: 1953-76 - The laboratory continued operations as a Central Laboratory beginning April 1973. A sediment laboratory was established with a 2-man staff at Saratoga in September 1952 and the facility was moved to Albany in 1953.

Location: Albany: 343 U.S. Postoffice and Courthouse.

Purpose: Throughout the period of operation, the laboratory was primarily a support facility for the District quality-of-water operations in New York, the New England District (Massachusetts, Maine, New Hampshire, Rhode Island, Vermont), and Connecticut.

Manpower: Leadership: 1953-54, W. F. White (from Washington, D. C.) supervised operations. 1955-69, F. H. Pauszek, district chemist. 1969-73, A. L. Mattingly, supervising chemist. 1973-__, B. A. Malo. 1967-72, P. E. Greeson headed the water-quality section and was responsible for laboratory biological investigations. Personnel: Personnel in the laboratory at startup time included two full-time analysts and varied from 5 to 18 analysts thereafter. The staff included part-time students who performed many of the analyses.

Analytical facilities: Equipment: In starting years major pieces of equipment included two Model "B" spectrophotometers, a flame photometer, and a line-operated pH meter. In the middle 1960's, two Perkin-Elmer 303 atomic absorption spectrophotometers and a digital readout were added. A Technicon "Auto Analyzer" was put in operation in 1968.

Analytical methods: 1953-57, Methods of water analysis (1950); Standard methods. 1958-68, WSP 1454, Methods for collection and analysis of water samples (1960). 1969-76, TWRI series, book 5, chap A1, Methods for organic substances (1972). TWRI book 5, chapter A4, Methods for collection and analysis of aquatic biological and microbiological samples (1973). Laboratory theory and methods for sediment analysis (1941, revised 1960, TWRI, book 5, chap C1, 1969).

Precision or accuracy: Cation balance, 1 to 5 percent; analyst recheck and second analyst approval; supervisor review of analysis; trace constituents (See methods of water analysis, 1960, 1970; Denver Standard Reference Program beginning in 1972.

Data output: Constituent: Major ions and physical measurements. Trace (minor) elements by atomic absorption spectrophotometer, beginning in 1966. Biochemical (BOD, DO, nitrogen and phosphorus cycle, nutrients). Bacteriological (coliform and streptococci fecal), and several pathogenic measurements, i.e., samonella, etc. beginning in 1967. Biological (plankton, periphyton, benthic invertebrates). Production: Number of adjusted complete analyses per year: 1962-66, 785 to 1,500; 1967-69, 1,850 to 2,070.

Data presentation: 1950's Laboratory card (analytical statement cards). Water-Supply Paper annual series beginning in 1953. All historical quality of surface water data in National Water Data Storage and Retrieval System (WATSTORE) by 1970.

Budget: 1968, $64,700. Budget information for other years is not available.

Relation to District or National Program: Mainly district, Federal-State cooperative and other Federal agencies project support including New York, New England District, and Connecticut.

ALBUQUERQUE, NEW MEXICO LABORATORY

[Background material prepared by Kim Ong; some dates are approximate]

Dates of operation: 1937-76.

Location: Roswell - 1937-43; Laboratory space was provided at the New Mexico Military Institute for use by the Pecos River Joint Investigation Committee, in a study of salinity in the Pecos River. Albuquerque- 1942-53; A regional Laboratory for chemical and sediment analyses was located at Second and New York Streets (1942-51) and at 10th and Park Streets (1951-53). Field laboratories operated in Tucumcari, N. Mex., (1949-52) and Safford, Ariz. (1939-40 and 1943-45). 1953-71; The laboratory was moved to the University of New Mexico campus with larger facilities to accomodate an expanding QW program. 1971-76; The chemical-quality laboratory converted to a "District Field Service Laboratory" following the organization of a Salt Lake City Regional Central Laboratory (temporary). However, the Albuquerque Sediment Laboratory continued to operate after 1971. 1976; District offices were moved to a downtown location in Western Bank Building.

Purpose: To determine and study the quality of water resources of New Mexico and to provide analytical services to regional parts of the Arkansas River basin, the middle Rio Grande basin, and the lower Colorado River basin. The laboratory also provides analytical services for the U.S. Geological Survey programs, other government agencies, and for determining the effects of manmade changes in the quality of the water resources, such as mining, urban development, and irrigation. The principal water-quality problems in this area are the naturally occurring high surface- and ground-water salinity and suspended-sediment concentrations and loads in the streams.

Manpower: Leadership: District chief or district chemists: 1942-48 - C. S. Howard. 1949-53, J. D. Hem. 1953-64, J. M. Stow. 1964, J. D. Culbertson (acting chief). 1964-66, Robert Shupp. 1966-76, W. E. Hale. Chemical quality laboratory supervisors: 1952-48, C. S. Howard. 1948-54, L. S. Hughes. 1954-58, A. M. Diaz. 1958-60, H. R. Feltz. 1960-64, H. E. Koester. 1964-72, Kim Ong. 1972-76, R. L. Lepp. 1948-51, J. L. Kunkler (Tucumcari sediment laboratory). 1939-43, W. F. White (Roswell

Laboratory). Sediment laboratory supervisors: 1943-48, Bill Bratchi. 1948-53, J. K. Culbertson. 1953-57, Darrel Sloan. 1957-64, W. F. Curtis. 1964-72, J. D. Dewey. 1972-76, B. M. Delaney. Personnel: Until and engineers with a limited number of technicians. Technicians worked primarily on the sediment program. An increasing part of the chemical-quality work was accomplished with instruments and established standard procedures. During the 1960's, technicians began to replace chemists and engineers who were reassigned to multidisciplinary studies in hydrology. 1943-49 - Chemical quality - 2 or 3 chemists assisted by 2 or 3 aides; Sediment, 2 or 3 engineers assisted by 2 or 3 aides. 1949-60 - Chemical quality, 4 to 7 chemists assisted by 2 to 4 aides; Sediment, 4 to 7 engineers assisted by 5 to 10 aides. 1960-71 - Chemical quality, 2 to 3 chemists assisted by 4 to 6 aides; Sediment, 2 to 4 engineers assisted by 5 to 10 aides. 1971-76 - Chemical quality, 1 chemist or 1 biologist assisted by 4 to 6 aides; Sediment, 1 engineer or 1 hydrologic technician assisted by 4 to 6 aides.

Analytical facilities: Equipment: During the early years of operation (1937-1950), most of the equipment in use in the laboratory was the standard laboratory ware of an "assay" laboratory using gravimetric and volumetric techniques. The laboratory was equipped with chainomatic pan balances, funnel filtering assemblies, centrifuges, drying ovens, burettes, crude colorimeters, and a still for producing distilled water. Advances in instrument development, particularly in spectrophotometry and flame photometry, created many changes in the laboratory during the 1940's and 1950's. Some equipment acquisition dates are: 1940's and 50's: First field type conductivity meter - 1937. Laboratory wheatstone bridge (Leed-Northrop) - about 1943. Beckman Model "B" spectrophotometer - 1940, 1959, 1962. Analytical balance (mechanical-electronic) - 1957. Flame photometer (PE 52c) - 1954. Particle-size VA apparatus - about 1954. Resin water de-ionizer system - 1956. pH meter (Beckman zeromatic) - 1957. Kjeldahl still - 1957. Atomic absorption flame photometer - about 1964. Field DO meter (YSI) - 1968. Field bacteria incubator (Millipore) - 1968. Field filter apparatus - 1967.

Analytical methods: Methods used were those prescribed by the Quality of Water Branch and published in administrative or official analytical documents of the

Water Resources, U.S. Geological Survey. An exception was boron by the curcumin method (1964-70).

Precision or accuracy: 1937-64 - Laboratory policy was to obtain a cation-anion balance of 1 percent or less. 1964-70 - With an increase laboratory workload and a greater variety of samples, the 1 percent goal was relaxed to 2 to 5 percent depending on the type of water. It was felt that the difference in accuracy was not significant for most uses of the data. All analytical results are reviewed by a chemist, and any determinations suspected to be in error are re-determined or deleted.

Data output: Constituent: The bulk of the chemical analyses were performed on major constituents. The more expensive "complete" analyses were not performed on most samples until the acquisition of the flame photometer (1954) which provided less expensive and more precise methods for the sodium and potassium analyses. The determination of special constituents for water supply (fluoride) and irrigation (boron) were added to the routine suite of constituents about 1955. A limited number of trace elements were analyzed after the purchase of the atomic absorption meter in 1964. After the Water Quality Act of 1964, more trace elements were determined and routine field determination of dissolved oxygen, biochemical oxygen demand, pH, and bacteria were introduced as an integral part of the collection program. Production: The demand for water-quality data grew steadily from 1940 to the present time. This was reflected in the laboratory's output of adjusted analyses. The sediment data program probably peaked and leveled off sometime during the early 1950's; but the chemical quality program grew steadily and experienced a large upsurge about 1968 when the environment became a national concern. Annual production of chemical analyses in adjusted-completes (AA) is estimated as follows: 1940-50 - 500 to 1000 AA; 1951-68 - 1000 to 1700 AA; 1968-76 - 1700 to 2500 AA with the Central Laboratory producing most of the analyses beginning in 1971.

Data presentation: The early analyses were transcribed from laboratory notes onto 4" x 6" analytical statement cards which are filed in the District Laboratory. This system was used on any analyses performed prior to 1964. In 1964, the analytical statement cards were eliminated, and the laboratory work-sheet was re-designed and used as the official file document. The Central Laboratory analyses reports have served as the official district file document since 1971. Beginning about 1968, all chemical-quality data were stored in the National Water Data Storage and Retrieval System (WASTORE). Surface water-quality data have been published in Water-Supply papers up through the 1970 water year. Surface and ground water-quality data have been published in State reports since 1964, and special hydrologic reports such as county studies have been published since 1939.

Budget: Budget information is difficult to compile because of the assortment of programs and cooperators which the chemical quality program serves. The best estimates for the total chemical quality budget in the District is as follows: 1940-50 - 25,000 to 50,000; 1951-68 - 50,000 to 75,000; 1968-76 - 75,000 to 150,000.

Relation to District or National Program: During the early years prior to 1950, the laboratory supported primarily the national program of the U.S. Geological Survey in collecting "basic" records in both New Mexico and Arizona. During the 1950's, the laboratory began serving other Federal agencies such as the Corps of Engineers, U.S. Army, the Soil Conservation Service, U.S. Department of Agriculture, the Bureau of Reclamation and Bureau of Land Management, U.S. Department of the Interior, and the Environmental Protection Agency. The State of New Mexico also became a major cooperator in the chemical-quality program through the New Mexico Interstate Streams Commission, the Pecos River Commission, the State Engineer's Office, and the New Mexico Bureau of Mines. The State has continued to be a major cooperator during the 1960's to the present time. The State Engineer's Office has cooperated with the U.S. Geological Survey on general hydrologic studies in various parts of the State since 1940, and the laboratory provides analytical support and consultation to these studies.

ANCHORAGE, ALASKA LABORATORY

[Background material prepared by Harry Hulsing]

Dates of operation: 1948-73 - Analytical work transfered to Central Laboratory System in early 1974.

Locations: Palmer, Alaska - 1948-65. Anchorage, Alaska - 1966-73.

Purpose: Through the 1960's, most of the analytical work was in support of federally funded programs to provide base line water-quality information on Alaska waters and analysis of State and Federal water supply installations. During the 1970's, development of programs with the State and expansion of the Federal Program resulted in analytical requirements of projects for expanded chemical, sediment, and biological data for water supply, fisheries enhancement, planning and environmental impact analysis.

Manpower: Leadership: 1948-52, G. W. Whetstone. 1953-61, F. B. Walling. 1962-65, R. G. Shupp. 1966-69, C. G. Angelo. 1969-72, B. Irelan. Personnel: Number of employees: 1958-63 - One professional, two technicians. 1964-67 - Two professionals, one technician. 1968-73 - Four professionals, two technicians.

Analytical facilities: Equipment: 1967-73: Standard suspended-sediment and particle-size analysis; Perkin Elmer atomic absorption spectrophotometer; Beckman Model "B" spectrophotometers (colorimetric and flame); Beckman zeromatic pH; USGS conductivity meter; L & N field meter; Beckman "R" series field conductivity; Yellow Springs D.O.; Turner fluorometer (chlorophyll).

Analytical methods: 1948-58 - WSP 596H. Methods of water analysis (1950), Standard methods. 1958-59 - WSP 1454. 1970-73 - TWRI series.

Precision or accuracy: 1969-73: Cation-anion balance; sum conductivity; cation-anion conductivity; supervisor review of analysis and same chemist rerun; computation and analysis check by second analyst; Denver Standard Reference program beginning in 1962.

Data output: Constituent: Through the 1960's determinations included major ions, physical measurements, and suspended sediment. Through the 1970's analyses included major ions, physical measurements, minor elements, sediment, biochemical oxygen demand, chemical oxygen demand, benthic invertebrates, and chlorophyll. Production: Number of adjusted complete analyses per year: 1967 - Approximately 750. 1968-69 - Approximately 1,000. 1972 - Approximately 900.

Data presentation: Water-Supply annual series began in 1950. All historical surface water is in the computer system (WATSTORE). Historical ground water data is being processed into the computer system.

Budget: 1958 - $30,000 (estimated). 1967 - $59,000. 1969 - $73,000. 1972 - $79,000.

Relation to District or National Program: Through the 1960's the activity consisted mostly of Federal program support; collection of basic records (CBR); and other Federal agencies (OFA) service work. Through the 1970's, analytical support was requested for District projects as water-quality programs developed with State and Federal agencies.

AUSTIN, TEXAS LABORATORY

[Background material prepared by Jack Rawson,
L. S. Hughes, and I. D. Yost]

Dates of operation: 1937-74.

Location: E. W. Lohr of the U.S. Geological Survey was transferred from Washington to Austin to supervise a WPA laboratory in 1937. During 1939-41 the USGS operated a chemical laboratory at Pecos, Texas. The laboratory was moved to Austin in 1941 where it continued to function until 1974 when it was converted to a field laboratory. A regional pesticides laboratory was operated in Austin during the period 1967-74.

Purpose: Inventory of chemical, physical, fluvial sediment, and biological quality of the Nation's water resources. Published reports include discussions of the quality of surface and ground waters, environmental factors that affect the quality of the water, and the suitability of the water for various uses.

Manpower: Leadership: 1937-39, E. W. Lohr. 1941-48, W. W. Hastings. 1948-61, B. Irelan. 1961-65, C. H. Hembree. 1965, L. S. Hughes. Personnel: Number of employees: 1937-50 - 5 to 10 (including WPA employees). 1950-55 - 10 to 15. 1950-65 - 20 to 25. 1965-70 - 25 to 35. 1970-74 - 35 to 50 (including employees in field laboratories at Houston and Fort Worth).

Analytical facilities: Equipment: Gravimetric, colorimetric, conductivity bridge, potentiometric (pH), flame photometric (after 1952). 1945 - Coleman spectrometer. 1952 - Perkin-Elmer atomic absorption spectrophotometer (cations). 1967-74 - Gas chromatographs (Micro, Tek, Tracor, Varian) for pesticides. 1970 - Perkin-Elmer IR spectrophotometer for pesticides. 1972 - Beckman Model 915 carbon analyzer.

Analytical methods: 1928 - WSP 596 H (Collins). 1950 - Methods of water analyses (Quality of Water Branch). 1960 - WSP 1454 (Rainwater and Thatcher). 1970 - TWRI series (Brown, et. al.). 1972 - Methods of organic substances (Goerlitz and Brown). 1973 - Methods for aquatic biological and microbiological samples. 1941 - Methods for sediment analysis (Guy, et. al, revised in 1960 and 1969).

Precision or accuracy: Cation-anion balance for major constituents with 1 percent objective. Recheck, and second analyst approval. Trace elements - See Methods of water analysis (1960, 1970). Pesticides - See Methods for organic substances (1972).

Data output: Constituent: 1937-74 - Major ions, physical parameters, suspended sediment. 1967-74 - Pesticides, minor elements. 1972-74 - Organic carbon. Production: Number of adjusted complete analyses per year: 1937-50 - 250 to 800 (estimated). 1950-55 - 800 to 1700. 1955-60 - 1700 to 1900. 1960-65 - 3000 to 5000. 1970-74 - 5000 to 8500.

Data presentation: 1937-41 - Laboratory cards; WSP project studies. 1941 - Beginning WSP annual series. 1938-63 - Texas Development Board reports, annual series. 1963 - USGS reports. 1965 - National Water Data Storage and Retrieval System (WATSTORE).

Budget: The following estimates include all water-quality activities: 1937-50 - $10,000 to $30,000. 1950-55 - $30,000 to $70,000. 1955-60 - $70,000 to $100,000. 1960-65 $100,000 to $200,000. 1965-70 - $200,000 to $670,000. 1970-74 - $67,000 to $1,000,000.

Relation to District or National Program: Mainly district, Federal-State cooperation, and other Federal agencies project support. The laboratory performed chemical and physical analyses of water from streams, reservoirs, estuaries, springs, and wells. The unit was a service facility for the pesticides program for States west of the Mississippi River (1967-74).

BATON ROUGE, LOUISIANA LABORATORY

[Background material prepared by D. E. Everett]

Dates of operation: The water-quality laboratory was established March 1957 and discontinued in 1973. The sediment laboratory was established in 1973 and is currently in operation.

Location: Leach Bldg., Main St., 1957 to January 1962. 6554 Florida Blvd., January 1962 to 1973.

Purpose: The purpose of the laboratory was to analyze surface and ground-water samples collected in Louisiana. The data gathered were used to determine the suitability of the water for various uses and to better define the water resources of the State.

Manpower: Leadership: 1957-61, S. F. Kapustka, chemist in charge. 1961-64, S. F. Kapustka, district chemist. 1964-66, R. L. McAvoy, district chemist. 1966-71, R. R. Meyer, District Chief. 1971 to present, A. N. Cameron, District Chief. Personnel: Number of employees: 1957-60 - 3 technical employees. 1961-65 - 5 technical employees. 1966-68 - 6 technical employees. 1969-73 - 6 technical employees.

Analytical facilities: Equipment: Model "B" spectrophotometer, flame photometer, Kjeldahl equipment, atomic absorption equipment, assorted pH, specific conductance and dissolved oxygen meters.

Analytical methods: WSP 1450, Standard methods, TWRI series.

Precision or accuracy: Cation-anion balance, ± 2 percent. Standard reference sample program (Denver 1967-73)

Data output: Constituent: 1957-66 - Major ions and physical measurements. 1966-73 - Major ions, minor elements, and physical measurements. Production: Number of adjusted complete analyses per year: 1958-61 - 800. 1962-68 - 1,600. 1969-73 - 2,000.

Data presentation: 1957-64 - Laboratory cards were typed from original laboratory sheets and the original laboratory sheets stored. Data are published in the annual Water-Supply Paper series and State basic data publications. 1965-73 - The original laboratory sheets were stored and data published in State basic data publications. 1957-76 - All data are stored in WATSTORE.

Budget: 1957-61 - approximately $80,000 per year. 1961-68 - approximately $160,000 per year. 1969-73 - approximately $200,000 per year.

Relation to District or National Program: The principal activities included Federal-State cooperation with Louisiana, Mississippi, and Alabama; service facility for Armed Forces water-sampling, ground water program, Environmental Protection Agency, Corps of Engineers, U.S. Army, National Stream-Quality Accounting Network, and other Federal agencies.

CHARLOTTESVILLE, VIRGINIA LABORATORY

[Background material prepared by S. M. Rogers]

Dates of operation: July 1945 to July 1956; July 1967 to June 1974 as a combined Federal-State cooperative facility; in June 1974 laboratory functions were transferred to the Central Laboratory System.

Location: At the University of Virginia in Charlottesville.

Purpose: In order to make available needed data on the chemical character of surface water in Virginia, systematic studies were resumed in 1945 by the U.S. Geological Survey in cooperation with the Virginia Conservation Commission. Laboratory functions were transferred to the Raleigh N.C. district during the period 1956 to 1967. A previous investigation by the two agencies was made cooperatively during the period 1929-31 and analyses were performed in Washington, D.C. Ten-day composites of daily samples were obtained at 16 gaging stations the first year and 17 stations the second year. Suspended sediment concentrations and loads were determined at three stations, two being supported by the U.S. Corps of Engineers and one in the Federal basic data program.

Manpower: Leadership: 1945-47, W. L. Lamar. 1947-48, G. W. Whetstone. 1949-53, J. G. Connor. 1952-57, S. F. Kapustka. 1953-55, M. E. Schroeder. 1967-__, S. M. Rogers. 196_-74, J. D. Thomas. Personnel: Number of employees: 1929-31 - Washington, D.C. 1945-51 - 2. 1952-57 - 3. 1967-74 - 4.

Analytical facilities: Equipment: 1945-51 - Gravimetric, colorimetric, conductivity bridge, potentiometric (pH). 1952-57 - Flame photometer (sodium and potassium), Model "B" spectrophotometer.

Analytical methods: WSP 596H (Collins 1928). American Public Health Assoc., 1946. Methods of water analysis (1950). WSP 1454, 1960 and revisions in TWRI series, 1970. Methods for sediment analysis, 1941 (rev. 1960, 1969).

Precision or accuracy: Cation-anion balance for major constituents, 1 percent objective; imbalance 5 percent on diluted waters. Recheck and second analyst approval. Denver Standard reference program beginning 1962.

Data output: Elements: Major ions; physical parameters; suspended sediment. Production: Number of adjusted complete analyses per year: 1945-57 - 250 to 400 (estimated). 1968-74 - 600 to 700 (estimated).

Data presentation: 1945-56 - Laboratory card. Virginia Conservation Commission annual bulletin series, beginning 1945. Data for the 1929-31 study, including 1,340 complete analyses were published in Bulletin 3. At the time it was described as "the most comprehensive and adequate report so far published on the industrial quality of surface waters in a State. 1945-56 - Water-Supply Paper series beginning 1941. 1968-74 - USGS reports, WATSTORE.

Budget: 1945-47 - $4000 - $5000. No recent budget information is available.

Relation to District or National Program: Mainly District, Federal-State cooperation, and other Federal agencies project support.

COLUMBUS, OHIO LABORATORY

[Background material prepared by N. J. Stewart, E. L. Skinner, and C. R. Collier]

Dates of operation: Water-quality studies were started in Ohio in 1946 at the following four stations for daily chemical quality analysis: Mahoning River at Warren, Ohio, Miami River at Dayton, Ohio above Stillwater Dam, Cuyahoga River at Botzum, Ohio, and Tuscarawas River at Newcomerstown, Ohio. The first analyses were run in the Washington Laboratory. In 1947 the Toledo, Ohio, Sewage Treatment Plant Laboratory was used until the Columbus laboratory was operational. M. E. Schroeder transferred to Toledo and was in charge of the laboratory operations. The Water Resources Division established a laboratory in Columbus, Ohio in August 1948. W. L. Lamar was the District Chemist and M. E. Schroeder was his assistant.

Quality of water laboratory analyses were performed for West Virginia until 1969 when that district activities were transferred to the Atlantic Coast Region. Laboratory analyses for the States of Indiana, Illinois, Kentucky, Michigan, and Wisconsin were performed until the Columbus laboratory was closed in 1973.

In 1950, the water-quality program was expanded to include sediment investigations. Sediment laboratory work also was done for the States of Indiana, Kentucky, Michigan, and Wisconsin. This service work continues except for the Wisconsin district which established a sediment laboratory in 1974. The first recording of multiparameter water-quality characteristics occurred in November 1962 when a water-quality monitor was installed on the Cuyahoga River at Center Street in Cleveland, in cooperation with the Ohio Department of Health. The Ohio District water-quality network consists presently of 42 stations of which 33 are 4-parameter stations (conductance, temperature, pH, and dissolved oxygen). At one time the network consisted of 51 stations. Most of the discontinued stations were 2-parameter (conductance and temperature) with no gage at site.

Purpose: The chemical quality laboratory functioned as a support facility for the Quality of Water District Operations in Ohio and States of West Virginia, Kentucky, Indiana, Michigan, and Wisconsin. Analytical services also were provided for the Ohio Ground Water and Surface Water Districts.

Manpower: Leadership: 1948-56, W. L. Lamar. 1956-64, G. W. Whetstone. 1964-65, C. R. Collier, acting District Chemist. 1965-67, J. J. Malloy. The district functions then were transfered to the Atlanta and Albany regional laboratories. Personnel: In 1956, the laboratory operated with 15 professional chemists and engineers and 3 technicians; in 1960; with 14 professionals and 5 technicians. There were 30 employees in 1966 in water quality laboratory functions, including 10 professionals and 9 technicians. Most technicians worked in the sediment laboratory.

Analytical facilities: Equipment: Following is a list of dates and laboratory capabilities: 1948 - Conductivity common ions, and physical measurements. 1950's - Reaeration (dissolved oxygen) studies. 1952 - Atomic absorption spectrophotometer determination of trace metals and heavy metals. 1954 - Nitrogen cycle. 1960 - Radiological samples for tritium were collected from the laboratory roof for the Washington Laboratory. 1962 - Electronic water-quality monitor (5 parameter) installed. 1964 - Pesticides. 1969 - Bacteriological analysis for Benchmark and NASQAN Programs. 1969 - Technicon Auto Analyzer. 1964 - Dissolved oxygen field determinations. 1975 - Environmental and limnology studies.

Analytical methods: 1948-53, WSP 596H, 1928. 1953-57, Methods of water analysis (1950). 1957-68, WSP 1454, Methods for collection and analyses of water samples. 1969 to present, TWRI series book 5, chap. A1., Methods for organic substances, 1972; Methods for aquatic biological and microbiological samples; Methods for sediment analysis (1941), revised 1960 and 1969.

Precision or accuracy: Precision for common constituent analyses (cation-anion balance) ranged from 1 to 5 percent. An interlaboratory check was used prior to 1962. From 1962 Standard Reference Samples were interspersed for quality control.

Data output: Production: Records of sample analyses show a range from about 1,800 (1956) to 5,400 (1973). Col-1 was for the composite period March 11-20, 1949, Tuscarawas River at Newcomerstown. The last analysis in 1973 was number 69,092.

Data presentation: In the 1963 an ADP Center was established in the Columbus QW office and basic data reports for the States of Arkansas, Illinois, Indiana, Kentucky, Louisiana, Michigan, Mississippi, Ohio, Pennsylvania, Teneessee, Texas, West Virginia, and Wisconsin, were processed for publication. This activity was transferred from the Ohio District office in 1969.

In December 1969, a telemetering network was established in cooperation with the Ohio Department of Natural Resources. As of June 1972, the system consisted of 18 remote stations, a master receiver in the office of the cooperator, and a supplementary receiver in the Ohio District office. This activity was discontinued in June 1973 for lack of funds. Water quality data are published in the Water Supply Paper annual series beginning in 1946 and in individual State reports. Most historic data are in WATSTORE.

Budget (estimated): 1956 - $107,000; 1960 - $163,000; 1966 - $202,000.

Relation to District or National Program: Measurements were made of chemical and physical properties and sediment from streams, wells, and springs in Ohio, Indiana, Illinois, Kentucky Michigan, West Virginia, and Wisconsin. Samples were also analyzed for various agencies--Air Force, Army, Veterans Administration, Corps of Engineers, U.S. Environmental Protection Agency, and Atomic Energy Commission. For several years the Ohio District had cooperative programs with ORSANCO, Agricultural Research Service and Soil Conservation Service, Department of Agriculture.

HARRISBURG (PHILADELPHIA), PENNSYLVANIA LABORATORY

[Background material prepared by D. McCartney]

Dates of operation: 1947-73.

Locations: Philadelphia, 1947-68, initially at the U.S. Navy Yard, then the N.E. Sewage Disposal Plant, and in later years at U.S. Customs House, 2nd and Chestnut Sts; Harrisburg, 1968-73 4th Floor, Federal Bldg. 228 Walnut St. Sediment - Schuylkill Haven, 1947-57; Harrisburg, 1957-76.

Purpose: To provide chemical, sediment, sanitary, and biological services for water resources studies in Pennsylvania, Delaware, New Jersey, and Maryland.

Manpower: Leadship: 1944, W. F. White, district chemist (from Washington, D.C.). 1947, N. H. Heamer resident chemist - Established and supervised Philadelphia water-quality laboratory. 1947, C. F. Lindholm - Operated and supervised sediment laboratory in Schyulkill Haven. 1953, N. H. Beamer, district chemist, Pa. 1954, J. Eiler, engineer-in-charge, sediment laboratory Schuylkill Haven. 1956, J. K. Culbertson, engineer-in charge, sediment laboratory, Harrisburg and Schuylkill Haven, laboratory, 1957. 1958, J. W. Wark, engineer-in-charge, sediment laboratory, Harrisburg. 1960, D. McCartney, chemist-in-charge, Philadelphia laboratory. 1964, J. R. George, hydrologist-in-charge, sediment laboratory, Harrisburg. 1967, A. N. Ott, hydrologist-in-charge, sediment laboratory, Harrisburg. 1968, B. A. Malo, chemist-in-charge, chemical and sediment laboratory, Harrisburg. Personnel: Number of employees: 1947 - 3. 1948 - 8. 1951 - 7. 1953 - 12. 1973 - 14.

Analytical facilities: Equipment: Beckman Model "B" spectrophotometer; B & L spectronic 20; Orion & Beckman pH meter, Beckman specific conductance meters, Perkin-Elmer flame photometer, Perkin-Elmer 303 atomic absorption spectrophotometer, Beckman 115 total organic carbon analyzer.

Analytical methods: Methods of water analysis (1950 rev. 1960) and procedures monitored by the Washington, D.C. Laboratory. WSP 1454, Methods for collection and analysis of water samples.

Precision or accuracy: Most waters, 3 percent difference in ionic balance. Problem waters, rain waters, etc., 5 percent difference. Member of Public Health Service. Analytical Reference Service (1963) and standard reference program (1967).

Data output: Constituent: All major ions through 1965. Many minor elements determined by atomic absorption spectrometer were added after 1965 and total organic carbon analysis was performed frequently. Production: Range in number of complete analyses: 1947 - 500. 1973 - 1800. Average yearly sediment analyses, 20,000 concentrations.

Data presentation: 1947 - Typewritten laboratory cards or sheets. 1964 - IBM cards, Computer printouts, data, interpretive reports.

Budget: 1947 - $40,000. 1973 - $330,000.

Relation to District or National Program: Provided the data collection programs for interpretive studies in Pennsylvania, New Jersey, Delaware, and Maryland with suitable water-quality information.

Highlights: Operated the largest sediment laboratory east of the Mississippi. Operated the oldest sediment station in the east Brandywine Creek at Chadds Fork (Washington, D. C.), established December 1946. It was the first sediment station in the country in the Federal-State cooperative program (with support other than a Federal agency). Then, sediment was considered a "Western problem", and it is significant that a local agency supported a sediment program in the "non-problem Eastern area". Developed and performed the first coal analysis on sediment samples. Installed the first conductivity recorder to study salt-water movement in the Delaware River estuary (Durfor 1955). Assembled and installed the first integrated multi-variable water-quality monitor, 1959-60 (McCartney). Tested, and cost evaluated plastic throw-away bottles now in use by the Survey (McCartney 1966). Tested first conductivity probe and battery-operated dissolved oxygen meter 1964, and the first battery-operated conductivity recorders, 1965. Developed automatic sediment sampler (Spots 1968), and installed digital Telemetry, 1969. Tested first ERTS platforms in the Delaware River Estuary (Paulson, 1971).

HONOLULU, HAWAII LABORATORY

[Background material prepared by John Yee]

Dates of operation: 1967-76. 1967 - Sediment laboratory established for sediment concentration and particle size determinations. 1969 - Chemical laboratory established for analysis of surface and ground water. 1973 - Chemical laboratory discontinued; converted to field unit; sediment laboratory capability continued.

Location: 1833 Kalakaua Avenue, Honolulu.

Purpose: At startup through 1968 the program was mainly the determination of fluvial sediment characteristics of Hawaiian and Okinawan streams. From 1969 to 1972 the principal emphasis was the baseline inventory of chemical and physical characteristics of surface and ground waters.

Manpower: Leadership: 1967-68, R. Busch, hydrologist-in-charge. 1969-72, J. Yee, chemist in charge.

Analytical facilities: Equipment: 1967-68 - Suspended-sediment filtration units, visual accumulation tube, pipet, rotap, oven. 1969-72 - Perkin-Elmer atomic absorption spectrophotometer, Beckman Model "B" spectrophotometer, Sargent pH, Beckman specific conductance and Hach 2100 meters, Heilige colorimeter, Mettler, etc.

Analytical methods: 1967-68 - Laboratory theory and methods for sediment analysis (1967) published later as TWRI series, book 5, chap C1. 1969-72 - WSP 1454, TWRI series book 5, chap A1.

Precision or accuracy: Cation-ion balance + 1 percent or <0.05 milliequivalent objective for samples under 250 micromhos conductivity; Denver Standard reference program.

Data output: Constituent: 1967-68 - Sediment concentration and particle size. 1967-68 - Sediment concentration and particle size. 1969-72 - Major ions, minor elements by atomic absorption spectrophotometer, physical measurements. Production: Number of adjusted complete analyses per year: 1969 - 100. 1970 - 120.

Data presentation: WRD data system, WATSTORE, State annual report.

Budget: 1967-68 - $30,000 per year (approximately).
1969-72 - $40,000 per year (approximately).

Relation to District or National Program: Cooperation (See Purpose); Cooperation and National Program (See Purpose).

LINCOLN, NEBRASKA LABORATORY

[Background material prepared by L. R. Petri]

Dates of operation: 1946 to June 1971. Phased down to District water-quality unit, June 1971.

Location: 1946 - 510 Rudge Guenzel Bldg; 1964 - 225 N. Cotner Blvd; 1975 - 406 Federal Bldg, U.S. Courthouse, 100 Centennial Mall No.

Purpose: In 1944, Congress approved the Missouri River Basin Plan (known as the Pick-Sloan Plan) with joint execution of the plan to be by the Department of Interior's Bureau of Reclamation (USBR) and the Corps of Engineers, U.S. Army. The plan envisioned more than 100 new dams, about 150 irrigation projects involving about 5,000,000 acres not previously irrigated, more than 30 power plants, water supplies for at least 19 communities, hundreds of miles of flood-control levees and dikes, and more than 700 miles of channelization work to provide for navigation.

Whereas the USBR was the principal agency of the Department of the Interior involved in this plan, other agencies of the Department also became involved including the Bureaus of Land Management, Indian Affairs, Mines, the Fish and Wildlife Service, and the National Parks Service. The Geological Survey was assigned the responsibility of conducting numerous investigations to provide hydrologic information needed by other Interior agencies.

The chemical laboratory of the Lincoln District was placed in operation in 1946. Its principal purpose was to provide water-quality information requested by the Interior agencies or by USGS investigators conducting hydrologic investigations on water resources of the Missouri River basin. Because it served a 10-State area, the laboratory eventually was designated as a Regional Laboratory.

Manpower: Leadership: 1946-49, District Engineer; 1950-57, Regional Engineer, Paul C. Benedict; Chemical laboratory supervisors: 1946-51, H. A. Swenson; 1951-52, F. A. Rainwater; 1952-54, R. H. Langford; 1954-59, L. R. Petri; 1955-56, V. L. Bell; 1957-58, B. V. Salotto; 1960-71, S. C. Downs; Sediment laboratory supervisors (Lincoln):

1949-51, J. E. Adams; 1952-64, J. C. Mundorff; 1965-69, B. L. Day; 1970-76, C. G. Hoy; Area offices: Worland, Wyoming, 1946(?)-57, T. F. Hanly, Area Engineer (District Engineer, 1958-); Norton, Kansas, 1947-57, D. M. Culbertson, Area Engineer (District Engineer, Lincoln, Nebraska, 1958-65). Personnel: The Missouri River Basin Program which began operation in the fall of 1945 required an intensive study of sediment in the entire basin, a less intensive study of chemical quality, and a main office and laboratory at Lincoln, Nebr., March 6, 1946. The Quality of Water Division activities in the Basin grew rapidly under the leadership of P. C. Benedict and required additional sediment laboratories at Worland, Wyo., March 1946; at Dickinson, N.Dak., June 1946; and at Norton, Kans., April 1947.

The number of laboratory personnel fluctuated greatly during the 25 years of the laboratory's existence. The laboratory in the Rudge-Guenzel Building had space for about 12 workers. From 1946 to the Korean War, the number averaged about 10. Thereafter, it decreased gradually and, because of severe budget cuts, in 1953 personnel was reduced to 2 or 3. Generally, the number at personnel paralleled the need for data by the action agencies of the Department. In the first decade of its existence, work by the laboratory was almost exclusively related to MRB project planning.

In the mid-fifties, cooperative programs with local agencies involved in planning were developed and the number of laboratory personnel increased to an average of about six with slight varations from year to year thereafter.

Analytical facilities: Equipment: In 1946 most methods were gravimetric, volumetric, or titrimetric. Electronic equipment consisted chiefly of line-operated pH meters, colorimeters, Coleman Model 11 spectrophotometer, and Fisher A.C. Model electrophotometer. Filtration was through Whatman paper, Gooch crucibles, or hollow ceramic filters. 1946 - Bottom-withdrawal tube for particle-size analysis and sieve analysis for sands. 1950 - Pipet method for particle-size analysis at Lincoln, Norton, and Worland. 1950 - Beckman Model "D.U." spectrophotometer for flame spectrophotometer measurements of sodium and potassium. 1953 - Beckman Model "B" spectrophotometers for measurement of iron, nitrate, boron, manganese. 1958 - Beckman Model "B" with burner as replacement for DU in measurement of sodium and potassium. 1964 - Perkin-Elmer 303 atomic absorption spectrophotometer for measurement of minor elements. 1966 - Fisher Automatic Titralizer System. 1969 - Hach Turbidimeters, Model 2100. Methods: 1946-50 - Selected Procedures for the Chemical Analysis of Water, Part 2, Methods of Analysis, June 1949 by U.S. Geological Survey, Lincoln, Nebr. 1950-53 - Methods of Water Analysis, January 1950, by Quality of Water Branch. 1953-65 - WSP 1454 by Rainwater and Thatcher. 1965-71 - TWRI, book 5, chap. A1, by Brown, Skougstad, and Fishman, WSP 1540C, by Fishman and Downs.

Precision or accuracy: Cation-anion balance for major constituents within 2 percent, except when dissolved solids were less than 100 mg/L. Imbalance of 5 percent allowable on dilute samples. Essentially all chemical quality samples were composited by volume in proportion to stream discharge or analyzed during extreme changes in flow.

Data output: Constituent: Principal ions and physical measurements; suspended sediment and particle-size analysis. Production: Number of adjusted complete analyses per year: Estimate, 2,000 to 2,500.

Data presentation: Essentially all data on surface waters, except daily specific conductance prior to 1969, are published either in Water-Supply Papers or individual State reports. All data on streamflow form 1961 have been updated by individual districts. For the Nebraska District, essentially all water-quality data on both streamflow and on ground water obtained through the laboratory beginning in 1946 are now in the WATSTORE data file. Results of investigation and research during the Missouri Basin program are found in more than 75 Geological Survey publications and 10 technical journals. One major applied research result was the development of a turbulence flume to measure total sediment load in sandbed streams. This break through facilitated design of storage reservoirs and diversion works in the Loup River basin, Nebraska and elsewhere in the sand hills country.

Budget: No information by which the budget for the laboratory could be extracted could be found in the present district files.

LITTLE ROCK, ARKANSAS LABORATORY

[Background material prepared by J. H. Hubble
and R. T. Sniegocki]

Dates of operation: 1945 to 1972. Phased down to District Water-Quality Service Unit 1972.

Location: An office and laboratory was established in the Chemistry Building, University of Arkansas at Fayetteville, September 1945. The laboratory was moved to the Federal Office Bldg., 700 West Capitol Ave, Little Rock in 1962.

Purpose: To provide water-quality information for cooperative hydrologic investigations in Arkansas. The initial program objectives were 3-fold: (1) Inventory and analyses of all public water supplies; (2) Daily chemical quality sampling at selected stations and semi-annual sampling at all Survey gaging stations; and (3) Chemical quality sampling and analyses from all ground-water investigations.

Manpower: Leadership: 1945-46, I. W. Walling. 1946-53, G. A. Billingsley. 1953-55, J. W. Guerin. 1955-61, M. E. Schroeder. 1961-65, J. H. Hubble. 1965-76, R. T. Sniegocki, District Chief. Personnel: Number of employees: 1945-63 - 4 to 7. 1964-70 - 5 to 8. 1971-76 - 7 ± 2.

Analytical facilities: Equipment: 1945-50 - Gravimetric procedures except Fisher colorimetric for iron and nitrate. Turbidity, color, and flouride were determined by visual comparison methods. 1952 - Silica determination changed from gravimetric to colorimetric. Hardness was determined by versenate method and sodium and potassium by Perkin-Elmer flame photometer. 1953-72 - Beckman Model "B" and instrument determination of calcium, magnesium, and sulfate, including colorimeter methods for fluoride and metals were added at about the same time as at other U.S. Geological Survey Laboratories.

Analytical methods: 1950-53 - "Methods of Water Analysis, January 1950." by Quality of Water Branch. 1953-65 - WSP 1454 by Rainwater and Thatcher. 1965-71 - TWRI book 5, chap A1 by Brown, Skougstad, and Fishman.

Precision or accuracy: Cation-anion balance for major constituents within 2 percent, except when dissolved solids were less than 100 mg/L. Ion balance of 5 percent allowable on dilute samples. Denver reference samples were used beginning in 1962.

Data output: Production: Average number of adjusted complete analyses per year: 1950-60 - 3,000 to 4,000. 1961-73 - 3,000.

Data presenation: Essentially all data on surface waters, except daily specific conductance prior to 1969, are published either in Water-Supply Papers or individual State reports. Essentially all water-quality data on both streamflow and on ground water obtained through the laboratory beginning in 1945 are now in the WATSTORE data file.

Budget: 1945-63 - $15,000 to $35,000. 1964-70 - $35,000 to $60,000. 1971-73 - $100,000 to $125,000 (all QW activities). 1974 - $125,000. 1975 - $132,000. 1976 - $193,000. The last three years include central laboratory costs.

Relation to District or National Program: 1961-72 - Service facility for Missouri and Tennessee Districts: Army and Air Force analyses for Arkansas, Missouri, and Tennessee.

OCALA, FLORIDA LABORATORY

[Background material prepared by C. S. Conover and D. A. Goolsby]

Dates of operation: Established October 1952. Phased down to District Water-quality Service Unit, November 1973.

Location: During the period 1952-61 the laboratory was located at Roosevelt Village U.S. Highway 441S. In 1961 it was moved to Room 244, Federal Bldg.

Purpose: To provide water-quality information for cooperative hydrologic investigation in Florida. Earlier, the city of Miami collaborated with the Quality of Water Division as part of a comprehensive investigation of Florida, begun in December 1939. S. K. Love supervised the water-quality stations, and a laboratory was established in the city laboratory from December 1940 until August 1942, H. A. Swenson in charge.

Manpower: Leadership: 1952-57, E. Brown; J. W. Geurin. 1958-63, J. W. Geurin; K. A. MacKichan. 1964-68, K. A. MacKichan; B. F. Joyner. 1969-73, B. F. Joyner. Personnel: Number of employees: 1952-57 - 2 to 9. 1958-63 - 9 to 12. 1964-68 - 12 to 16.

Analytical facilities: Equipment: 1952-65 - Beckman Model "B", L & M Wheatstone bridge, Muffle furnace, PE flame photometer. 1952-65 - Serfass conductance meter, Lumetron colorimeter, Hellige turbidimeter, Beckman pH meters. 1965 - Atomic absorption (Pe 303)-(1), Mobile laboratory, YSI oxygen meter, Kjeldahl digestor. 1969 - Technicon autoanalyzer (1) Millipore. 1970 - Technicon autoanalyzer (2), 1971 - Atomic absorption spectrophotometer, PE 303 (2). 1972 - Beckman 915 carbon analyzer.

Analytical methods: 1953-65 - WSP 1454, by Rainwater and Thatcher. 1965-71 - TWRI book 5, chap A1 by Brown et al.

Precision or accuracy: Cation-anion balance ± 2-3 percent. Trace metals, 1:10 duplicate analysis. Denver Reference Samples since 1962.

Data output: Production: Average number of adjusted complete analyses per year: 1952-57 - 500. 1958-63 - 2,000. 1964-68 - 2,500. 1969-73 - 5,000.

Data presentation: Essentially all data on surface waters, except daily specific conductance, prior to 1969, are published either in Water-Supply Papers or individual State reports. Essentially all water-quality data on both streamflow and on ground water obtained through the laboratory beginning in 1952 are now in the WATSTORE file.

Budget: Approximate amounts per year: 1958 - $30,000. 1962 - $55,000. 1965 - $100,000. 1973 - $120,000. 1976 - $153,000.

Relation of District or National Program: 1953-68 - Project support facility for Federal-State cooperative programs in Florida and Georgia, Armed Forces analysis, Corps of Engineers, National Park Service, and Georgia sediment program. 1968-73 - Service and project support facility for Federal-State cooperative and Federal programs in Florida, Corps or Engineers, National Park Service, Environmental Protection Agency, Armed Forces. The laboratory also provides some analytical service for Georgia, Alabama, South Carolina, and North Carolina, district porgrams.

OKLAHOMA CITY, OKLAHOMA LABORATORY

[Background material prepared by R. L. Hanson]

Dates of operation: The District Laboratory began operation in 1946 and ceased in July 1973, when its functions were transferred to the Salt Lake City Central Laboratory.

Location: 201 N.W. 3rd, Oklahoma City. (See discussion under Purpose.)

Purpose: The laboratory was primarily a support facility for the Quality of Water District Operations. It also was the analytical facility for the Okalhoma Ground and Surface Water Districts. Initially the Oklahoma Planning and Resources Board as part of a compilation of quality-of-water data for the report "Oklahoma Water" provided funds to the Survey in fiscal year 1944 for a reconnaissance survey of Oklahoma waters. From September to December 1944, daily samples from selected stations were sent to Austin, Tex., for analyses. Spot samples elsewhere were analyzed in a temporary Survey laboratory at Oklahoma A & M College, Stillwater, Okla. Growing interest of industry in water quality prompted the Experiment Station's State Geological Survey and Planning Resources Board in 1947 to pool funds for cooperation with the U.S. Geological Survey for a statewide scale of quality-of-water studies began in 1944. A laboratory was established in Stillwater at Oklahoma A & M College.

Manpower: Leadership: The laboratory operated under the supervision of three District Chemists: Beginning about 1946 with I. W. Walling; about 1951 with T. B. Dover; and from 1959 with R. P. Orth. After the consolidation to Division status in 1967, R. P. Orth served as the District water-quality specialists and in that capacity was responsible for laboratory operations. Personnel: The manpower in the laboratory varied from 7 to 12 equivalent Part-time students performed many of the analyses; therefore, the permanent staff was generally less than the 7 to 12 previously stated.

Analytical facilities: Equipment: Very little information is available on the equipment used during the early operation; however, it probably was very typical of laboratories of that time, 1946. At the time of closure the laboratory has in operation a Fisher Titralyzer for sulfates, a Perkin Elmer 303 atomic absorption spectrophotomer, a Beckman Model "B" spectrophotometer and a flame photometer. In addition, the normal equipment, turbidimeter, pH meter, etc., associated with this type of operation were available.

Analytical methods: 1946-56 - Notes on practical water analysis, by W. D. Collins WSP 596-H. Standards Methods, 9th edition. 1957-68 - WSP 1454. 1969-73 - TWRI series book 5, chap. A1, Brown et al.

Precision or accuracy: Cation-anion balance to ± 2 percent. Beginning in 1967, the USGS standard reference program was also used to check the accuracy of analysis.

Data output: Constituent: The primary analytical work was for common constituents. Some determinations of phenols and oxygen consumed was down during the period 1959-70, and trace-element analyses were performed during the later years, post 1968. Production: During the period of operation the laboratory analyzed from 2,000 to 3,000 adjusted complete analyses per year. At the time of closure the number of adjusted complete analyses per year was 2,250.

Data presentation: The early storage of data was on 3 by 5 laboratory cards. Basic data were published by the Oklahoma Water Resources Board from 1946 to 1963 in the series Chemical Characteristics of Surface Waters of Oklahoma. From 1964 to 1974 the basic data were published in Part II of the State report series, and in 1975, the data were published in a combined State report on Surface- and ground-water data. The data also has been stored in the WATSTORE files.

Budget: Information on the budget for the early years was not readily available. In 1959, the annual budget was approximately $60,000 and in 1973, the annual budget was approximately $120,000.

Relation to District or National Program: The laboratory operation was mainly support for the basic data network and project activities. The District served as a major advisor to the Oklahoma Water Resources Board for water-quality problems. In this capacity analytical work was done for many special projects. The primary function of the laboratory from its inception was to support the basic data collection program. Since 1946 water-quality data at more than 400 surface-water sites in the State of Oklahoma have been collected, analyzed and published.

PORTLAND, OREGON LABORATORY

[Background material prepared by S. F. Kapustka]

Location: 830 N.E. Holladay, Portland, Oregon.

Purpose: From its inception in 1953 to about 1960 the objective of the laboratory was to appraise the chemical and physical quality of the State's water resources with special reference to ground-water quality.

Identification of water quality problems in the Willamette River basin was a major objective during the period 1960-68. The study was extended to the Columbia River basin in 1968. Thereafter, a cooperative program was developed with the Oregon State Sanitary Authority to provide data for compliance with State river quality standards.

Recently, cooperative programs have included a progressive study for monitoring the effects of logging operations on turbidity and sedimentation downstream. Multiparameter water quality monitors provide continuous information.

From 1973 to the present the existing data base has been expanded for national water-quality programs under PL 92-500 and PL 93-523 such as NASQAN, NWQSS, and others.

Manpower: Leadership: 1953-58, H. A. Swenson, Chief. 1958-63, L. B. Laird, Chief. 1953-60, J. F. Santos, chemist. 1960-, R. J. Madison. 1963-66, G. L. Bodhaine, Chief. 1966-76, S. F. Kapustka, District Chief. 1967-68 J. Yee. 1968-70, D. A. Curtiss. Personnel: Number of employees: 1953-58 - 2 chemists. 1962 - 4 chemists, 2 technicians. 1965 - 15 (all personnel). 1970 - 5 (all personnel).

Analytical facilities: Equipment: 1953-60 - Beckman Model "B" spectrophotometer and flame photometer, Beckman pH, and conductivity meters. 1960 - Suspended-sediment and particle-size equipment. 1966 - Perkin-Elmer atomic absorption spectrophotometer.

Analystical methods: 1953-60 - Methods of water analyses, 1950, revised 1960, WSP 1454. 1961-70 - WSP 1954, USGS approved atomic absorption methods.

Precision or accuracy: 1953-63 - Cation-ion balance, 1 percent objective 0.1 ppm (mg/l) precision, Supervisor approval. 1961-70 - Atomic absorption - 1 microgram precision, Standard Reference Program (Denver beginning 1967).

Data output: Constituent: 1953-60 - Major ions and select minor elements by colorimetric spectrophometer. 1961-70 - Suspended-sediment and particle-size distribution, Total nitrogen, phenols. 1966 - Trace elements, atomic absorption spectrophotometer. 1968 - Trace elements AA expanded. Production: Average number od adjusted complete analyses per year (estimated): 1953-58 - 200. 1966 - 1,800 plus sediment. 1967 - 1,200 plus sediment. 1969 - 900 plus sediment.

Data presentation: 1953-60 - Laboratory cards, annual WSP series. 1965-70 - State reports, WRD data system. 1971 - Data placed in historic file of WATSTORE.

Budget: 1953 - $37,000. 1955 - $26,000. 1957 - $27,000. 1959 - $45,000. 1961 - $120,000. 1963 - $500,000. 1965 - $61,000 (chemical), $15,000 (sediment). 1967 - $60,000 (chemical), $15,000 (sediment). 1969 - 46,000 (chemical), $15,000 (sediment).

Relation to District or National Program: Mainly National Program support in earlier years. Activity was expanded to include services for Armed Forces, including all Far East, and Federal-State cooperation for Oregon, Washington, and Idaho. It included analytical support for ground-water projects in Tri-State area. 1962 - Support of Atomic Energy Commission project on Columbia River estuary. 1965 - Washington was established as Division district and 50 percent of the program was alloted to Tacoma. 1969 - FWPCA Surveillance Program (Idaho) and support of other Federal agencies projects.

RALEIGH, NORTH CAROLINA LABORATORY

[Background material prepared by H. B. Wilder]

Dates of operation: 1944-73. The laboratory was established in 1944 by W. L. Lamar. The first USGS water analyses in North Carolina were done in 1907 by R. B. Dole, et al. They analyzed 10-day composited samples from the Neuse River, Pee Dee River, and Cape Fear River. During the period 1925-27, Margaret D. Foster performed major constituent analyses of waters from streams in the western one half of the State. So far as is known both Dole, et al and Foster performed their analyses in Washington, D.C.

Location: 1944 - On Campus of North Carolina State University. (then North Carolina State College). 1946- Moved to North Carolina Department of Hygiene. 1952 - Moved to Oberlin Road in Raleigh. 1954 - Moved to Century Building on Fayetteville Street in Raleigh.

Purpose: Quality of available water supplies was an important consideration in post World War II planning of industrial development by the North Carolina Department of Development and Conservation. Mutual contributions in planning the work of cooperative studies led to a cooperative program of quality-of-water investigations by the Department and the U.S. Geological Survey in 1944.

An expanded cooperative program to include the quality of public water supplies began with the State Board of Health in the fall of 1945.

Manpower: Leadership: 1907, R. B. Dole, et al. 1925-27, M. D. Foster. 1944-48, W. L. Lamar. 1948-53, F. H. Pauszek. 1954-63, G. A. Billingsley. 1964-73, H. B. Wilder. Personnel: Number of employees: 1907 - 4 (Washington, D.C. Laboratory). 1925-27 - 1 (Washington, D.C. Laboratory). 1944-53 - 2 to 8. 1954-63 - 10 to 16. 1964-74 - 4 to 10.

Analytical facilities: Equipment: 1907, 1925-27 - Gravimetric. 1944-53 - Colorimetric, pontentiometric (pH), conductivity bridge, 1954-73 - Spectrophotometer, flame photometer, sodium and potassium, volumetric, calcium and magnesium.

Analytical methods: 1944-53 - WSP 1454, Methods of water analyses (1950), Standard Methods. 1954-63 - WSP 1454, TWRI series.

Precision or accuracy: Cation-anion balance, 5 percent; second analysis approval; comparison with other relative analyses. Standard reference program, Denver, beginning 1962.

Data output: Constituent: 1907, 1925-27 - Major mineral constituents, turbidity, suspended matter coefficient of fineness. 1944-73 - Expanded capabilities to include major and minor elements, nutrients, etc. 1951 - Suspended-sediment program established. The first station was Yadkin River at Yadkin College, N.C. Production: During its operation, the laboratory performed slightly more than 50,000 water analyses estimated to be 30,000 adjusted completed. About 75 percent were surface waters. Number of adjusted complete analyses per year: 1925-27 - 248 (for western streams). 1944 - 298. 1945 - 504. 1954-63 - 600 to 800 per analyst (5,000 to 7,000 total annual). 1964-73 - 2,500 to 3,500 total annual.

Data presentation: 1907, 1925-27 - Laboratory cards, North Carolina Department of Conservation, and Development Bulletin 61, 1928. 1944-63 - Annual Water-Supply Papers (Series beginning in 1941). 1944-63 - North Carolina Department of Conservation and Development Bulletin series (Bull. 52, vol. 1, 2 and 3). etc. 1964-73 - Water-Supply Papers and State reports, WATSTORE system started in 1965.

Budget: 1944-47 - $4,000 to $8,800. 1950's - $50,000 to $60,000. 1964-74 - $150,000 to $175,000 (Principally data analysis after 1968).

Relation to District or National Program: Mainly district and Federal and Federal-State cooperative program support.

SACRAMENTO, CALIFORNIA LABORATORY

[Background material prepared by George Porterfield, C. F. Berkstresser, and J. W. Helms]

Dates of operation: 1950-71 - Chemical laboratory (discontinued). 1956-76 - Sediment laboratory.

Locations: September 1950 to April 1952 - Davis, Calif. April 1952 to May 1962 - 2120 Fulton Ave., Sacramento. May 1962 to October 1968 - 650 Capitol Mall, Sacramento. October 1968 to March 1971 - 2800 Cottage Way, Sacramento. March 1971 - Operations were discontinued and transferred to Salt Lake City, Utah.

Purpose: A cooperative program was established to define in a general way the water quality of California's resources. The water quality program was financed by project funds disbursed by the various district offices of the California Department of Water Resources. Almost all records were of local interest -- obtained on a periodic or monthly basis with daily sampling maintained at 15 sites.

Manpower: Leadership: 1950-56, I. W. Walling. 1956-64, Eugene Brown. 1964-65, S.F. Kapustka. Following reorganization from QW Branch to California District lines, April 1965, district laboratory leadership was maintained as follows: 1965-67, George Porterfield (Assistant Sub-district Chief for chemical-quality and sediment. Porterfield was Assistant District Chief for sediment operations 1958-65. 1965-71 - J. W. Helms, Supervising chemist. Personnel: Initial operation included three chemists-analyists, increasing to five in 1951. The number of analysts fluctuated from 5 to 10 until the peak of operations, in 1961, when 13 analysts were employed. Changes in methodology and decreases in budget resulted in a reduction to five analysts in 1971 when the laboratory was closed. In 1956 the sediment program included two laboratory technicians. Personnel increased to three in 1958, then to 15 engineers, soil scientists, mathematicians, geologists, and technicians by April 1965.

Analytical facilities: Equipment: 1950-55 - Partial analyses were by traditional gravimetric and volumetric methods to include hardness, sodium and potassium by difference, alkalinity, chloride, and boron. Dissolved solids, sulfate, fluoride, nitrate and specific conductance were determined as required. 1956-71 - An emission spectrograph was operational for trace elements. The laboratory had capacity for standard analysis and special determinations through acquisition of the following equipment: Model "B" spectrophotometer, U.V. spectrophotometer, I.R. spectrophotometer, gas chromatograph for pesticide analysis installed in 1966 and equipment transferred to Austin about December 1967, carbon analyzer, PE 303 atomic absorption spectrophotometer, Alpha-beta radioactive counting equipment. COD, BOD, TOC, phenols, ABS were determined by request. Standard sediment equipment, visual accumulation tube, pipet bottom withdrawal tube, and sieve were installed.

Analytical methods: 1950-60 - Methods of water analysis, (rev. 1960), Standard Methods, special procedures, developed locally. 1960-69 - WSP 1454. 1970-71 - TWRI series.

Precision or accuracy: 1950-61 - ± 2 percent cation-anion balance, second analysts check and supervisor review of analysis. 1962-71 - Denver Standard reference program in addition to above.

Data output: Constituent: 1950-55 - Partial analysis including major ions, physical measurements, and standard suspended sediment determinations. 1956-71 - Major ions, physical measurements, minor elements by emission spectrograph and atomic absorption spectrophotometer, organic carbon, pesticides (1967), BOD, COD, chlorophyll, coliform, etc. Production: From 1950 to 1971 a total of about 62,400 samples were analyzed -- an estimated 2,000 adjusted complete analysis annually for the period of operation. Additionally many spectrographic analyses were performed. The sediment laboratory continues operations in Sacramento with 4 analysts. Analyses include concentrations of suspended sediment, specific conductance, pH, turbidity, and particle-size analyses by visual accumulation tube pipet, bottom-withdrawal tube, and sieve. About 24,000 sediment concentration analysis and 1,200 particle-size analysis are performed annually.

Data presentation: Water-Supply Paper series 1950-70. All historical quality of surface water data are in WATSTORE. Historical ground water data are being entered.

Budget: Chemical quality (estimated): 1963 - $170,000. 1964 - $187,000. 1965 - $104,000. 1967 - $52,000. Fluvial sediment: 1956 - $10,000. 1957-63 - $63,000 to $97,000. 1964-67 - $142,000 to $260,000. 1968-69 - $309,000 to $332,000.

Relation to District or National Program: Mainly district, Federal-State cooperative and other Federal agencies project support. Fluvial sediment operations included areal studies, channel morphology, beach erosion, reservoir surveys, and collection of basic data.

SALT LAKE CITY, UTAH LABORATORY

[Background material prepared by A. H. Handy and J. C. Mundorff]

Dates of operation: 1947-64 - The first regional laboratory for chemical quality and sedimentation was established at Salt Lake City by specific appropriation of Congress. C. S. Howard established the laboratory at Fort Douglas in a former Army Post building acquired by the Public Buildings Administration. During this time the States of Utah, Colorado, Idaho, Washington, Oregon, and Nevada were served. 1964-70 - The laboratory was moved to the Old Remington Arms Plant Administration Building located at 1750 South Redwood Road in Salt Lake City. It was necessary to move due to the condition of the old building at Fort Douglas, and to accommodate the expanding program. During this period the States of Utah, Colorado, and Wyoming were served. 1970-72 - Operations were converted in November 1970 to a pilot test facility for the Water Resources Division's Central Laboratory system and continued until March 1972 when results were evaluated and the pilot study declared a success. All of the States west of the Mississippi River were served at this time except Texas, Arkansas, Missouri, and Oklahoma. 1972-76 - The laboratory functioned as one of three national laboratories in the Central Laboratory System. In June 1976, the laboratory was moved to Denver, (Arvada) Colo., and greatly expanded to handle an ever-increasing workload. Basically the same States were served during this period as in the previous period.

Purpose: Action by Congress to establish the regional facility came because the cost of equipping a laboratory in each State where programs has developed were too costly for available funds and it was recognized that selected regional facilities equipped by means of Federal funds appropriated for that purpose would be an alternative solution. Cost of transporting water samples from the field to the laboratory at that time also appeared to be a factor favoring regional facilities.

Salt Lake City was selected as the site of the first regional laboratory as the program has increased in the upper Colorado River basin in Utah and Colorado, and in Idaho, and to a limited extent, the Pacific Northwest. Salt Lake City was selected as the pilot site because of the availability of a trained staff, existing space to expand and central location in the area to be served. The purpose of the laboratory from then on was to complete laboratory analyses as efficiently and reasonable as possible.

Manpower: Leadership: District chemists: 1947-53, C. S. Howard. 1953-61, J. G. Connor. 1961-66, R. H. Langford. District chief: 1966-70, Theodore Arnow. Laboratory supervisors: 1947-53, C. S. Howard. 1953-55, J. G. Connor. 1955-60, C. G. Mitchel. 1960-65, Osamu Hattori. 1965-70, A. H. Handy. Sediment section supervisors: 1952-65, R. E. Cabell. 1965-74, G. E. Johnson. Personnel: Number of employees: 1947-64 - 10 to 20 (engineers, chemists, and technicians). 1964-70 - 12 to 16 (engineers, chemists, and technicians). 1970-72 - 35 to 45 (chemists and technicians). 1973-76 - 45 to 60 (chemists and technicians).

Analytical facilities: Equipment: From about 1948 to 1954, the equipment used was basically the type used for gravimetric and volumetric analysis. In the late 1940's and early 1950's the Beckman Model "B" (colorimetric) and Beckman Model DU (flame photometric) made the determination of trace elements (metals and ions) possible. In 1964, the Perkin-Elmer model 303 atomic absorption spectrophotometer was purchased allowing faster and more reliable trace-metal determinations. In 1970, technicon analytical systems were introduced for rapid determination of colorimetric analysis. In addition, gas chromatography, fluorimetric analyses mass spectrometry, and autotitration equipment was utilized.

Analytical methods: Methods used were found, in WSP 1454, TWRI book 5, chap A1 and their fore runners until 1970, and then EPA manual, ASTM manual and provisional releases also were accepted.

Precision or accuracy: 1947-64 - The laboratory policy, was, to obtain a cation-anion balance of 1 percent or less. 1964-70 - With an increase laboratory workload and a greater variety of samples, the 1 percent goal was relaxed to 2 to 5 percent depending on the type of water. In addition, each analysis was reviewed and all calculations checked by a colleague before review by the laboratory supervisor. In 1970 a quality control program based on replicate standard reference samples (Denver Standard Reference Program) was developed. This system is still used.

Data output: Constituent: The bulk of the chemical analyses were performed on major constituents. The more expensive "complete" analyses were not performed on most samples until the acquisition of the flame photometer (1954) which provided less expensive and more precise methods for the sodium and potassium analyses. The determination of special constituents for water supply (fluoride), and for irrigation (boron), were added to the routine suite of constituents about 1955. A limited number of trace elements were analyzed after the purchase of the atomic absorption meter in 1964. After the Water Quality Act of 1964, more trace elements were determined and routine field determinations of dissolved oxygen, biochemical oxygen demand, pH, and bacteria were introduced as an integral part of the collection program. Production: Number 1,000. 1960-65 - 1,000 to 1,500. 1965-70 - 1,500 to 2,000. 1970-72 - 20,000 to 25,000. 1973-76 - 25,000 to 35,000.

Data presentation: The early analyses were transcribed from laboratory notes onto 4" x 6" analytical statement cards which are filed in the Laboratory. This system was used on any analyses performed prior to 1964. In 1964, the analytical statement cards were eliminated, and the laboratory work-sheet was re-designed and used as the official file document. The Central Laboatory analyses reports have served as the official file document since 1971. Beginning about 1968, all chemical-quality data were stored in WATSTORE. Surface water-quality data have been published in Water-Supply Papers up through the 1970 water year. Surface and ground water-quality data have been published in State reports since 1964, and special hydrologic reports such as county studies also have been published.

Budget: Budget is estimated for periods that the output also has been estimated. 1947-60 - $20,000 to $50,000. 1960-65 - 50,000 to $75,000. 1965-70 - $50,000 to $75,000.

SAN JUAN, PUERTO RICO LABORATORY

[Background material prepared by Ferdinand Quinones.Marques]

Dates of operation: 1959-76 - Phased down to District QW Unit 1973.

Location: Building 652, Ft. Buchanan, P.R.

Purpose: 1958 - Due to the rapid economic growth of Puerto Rico, the demand for water for municipal, industrial, and agricultural uses increased significantly. Therefore, quality-of-water studies were necessary to determine the suitability of the available water for the different uses.

Manpower: Leadership: 1959-62, J. R. Crooks, J. R. Diaz. 1962-66, J. J. Murphy, J. R. Diaz. 1966-69, J. P. Reed. 1969-72, J. P. Reed, R. T. Kiser. 1972-73, Sherman Ellis. 1973-76, Ferdinand Quinones. Personnel: Number of employees: 1958-60 - 2. 1960-62 - 3. 1962-67 - 4. 1967-72 - 5. 1972-73 - 4. 1973-76 - 5.

Analytical facilities: Equipment: 1959 - Partial analysis, sediment analysis, Beckman Model "B" spectrophotometer, Lumetron (colorimeter), sulfate determinations. 1960 - Partial complete - same equipment. 1967 - Complete analysis, Perkin-Elmer atomic absorption spectrophoto spectrophotometer. 1969 - Complete analysis, bacteriological and biochemical analyses. 1973 - District Water Quality Unit.

Analytical methods: WSP, Methods for collection and analysis of water samples (1960). TWRI, book 5, chap A1, Methods for collection and analysis of water samples for dissolved minerals and gases (1970). Standard methods (1971).

Precision or accuracy: Cation-anion balance, ± 5 percent, recheck, second analyst approval. Denver Standard Reference Program beginning 1962.

Data output: Constituent: 1959-67 - Major ions. 1967-73 - Major ions and metals, biochemical (coliforms, BOD, COD). Production: Number of complete adjusted analyses per year: 1959-60 - ± 300. 1961-67 - ± 500. 1968-73 - ± 800.

Data presentation: Water resources data into WATSTORE.

Budget: 1961 - $40,200. 1962 - $47,400. 1967 - $77,000. 1968 - $89,000. 1970 - $119,000. 1975 - $160,000.

Relation to District or National Program: Federal-Commonwealth cooperative program. Chemical and physical properties of water including "mineral" analyses of water from wells, springs, streams, and estuaries. Extent of pollution of surface water.

TACOMA, WASHINGTON LABORATORY

[Background material prepared by J. E. McCall]

Dates of operation: Started in May 1964 and is still operating.

Location: 1305 Tacoma Avenue South.

Purpose: The first year of operation was simply as a small project support facility to provide specific analyses for cooperative projects. From 1965 to 1972, the major objective of the laboratory was to provide an inventory of the physical-chemical quality of the surface waters of the State, and to a lesser emphasis, the ground waters also. From 1973 to the present, the objectives have been to expand the existing data base to include nutrient and bacterial assessment also, and to meet the ever-increasing service demands of special water-quality projects and national water-quality programs such as National Stream-Quality Accounting Network (NASQAN), National Water-Quality Surveillance System (NWQSS), and ground-water programs demanded by Public Laws 92-500 and 93-523.

Manpower: Leadership: May 1964 to July 1965, Gene Welch. August 1965 to June 1971, Norman Leibbrand. July 1971 to May 1975, Marvin Fretwell. June 1975 to present, J. C. Ebbert (laboratory supervisor). Personnel: Number of employees: 1964-65 - one operator. 1965-71 - 3 chemists, 2 technicians. 1971-75 - 1 to 2 chemists, 1 to 2 technicians. 1975 - 1 chemist, 1 biologist, 2 technicians.

Analytical facilities: Equipment: 1964 - Beckman Model "B" spectrophotometer, Leads & Northrup galvanometer/conductance unit, necessary balances, bottles, crucibles, ovens, etc. for sediment analysis. 1965-72 - Several spectrophotometers, pH meters, flame photometer, atomic absorption spectrophotometer, Fisher titralizer, sediment pipet, visual-accumulation tube, total carbon analyzer. Field equipment, specific conductance meters, pH meters, bacteriological kits, filtration units. Technicon Autoanalyzer for nutrient analysis (purchased in May 1970). 1972 - Technicon Autoanalyzer (dual-channel). Suspended sediment concentration apparatus, pipet, visual-accumulation tube, size equipment, BOD and bacteria incubators, saturometers, and miscellaneous field equipment.

Analytical methods: Methods of analysis have been according to the general accepted WRD methodology of the time. In general, WSP 1454 was followed until the TWRI series began. Technicon Autoanalyzer procedures initiated with Technicon methodology, and now coincide with current WRD, EPA, and Standard Methods (14th edition) procedures.

Precision or accuracy: Precision for common-constituent analyses was generally very good, with less than 3 percent error in cation-anion balance, for the period 1965-72. Quality control was through careful review and standard reference samples. From 1973 to the present, nutrients are the main output, with the following well established precision, as determined by methods outlined in the EPA Analytical Quality Control Manual: O-PO4 0.001 mg/L, T-PO4 .002 mg/L, NO2 .01 mg/L, NO3 .01 mg/L, NH3 .01 mg/L, T-KjN .02 mg/L. Quality control now includes regular blind analysis of EPA reference samples, occasional blind analysis of WRD standard reference samples, and regular interspersing of WRD standard reference samples with each sample run.

Data output: Constituent: In 1964, facilities were limited to a small project support capable of limited analysis of chlorophyll, plankton, specific conductance, chloride, and suspended-sediment concentration. From 1965 to 1972, analytical capabilities included common constituents, trace metals, bacteria, sediment concentration, and particle size, and after 1970, nutrients. After 1972, all common constituents and trace element analyses were transferred to the new Salt Lake City Central Laboratory and much of the existing equipment went into storage. Operations changed to analysis of only the so-called "nonconservative" constituents. Production: Production averaged about 1,000 to 1,200 adjusted complete analyses per year from 1965 through 1972. From 1973 to the present, production has ranged from 1,400 to 1,800 adjusted complete analyses per year.

Data presentation: Data presentation consists of card storage and publication in State reports and Water-Supply Papers. Most historic data and all data since 1971 are in WATSTORE.

Budget: Laboratory budget was in the approximate $20,000 to $25,000 per year range for the years 1965-72. From 1973 to the present, the budget has ranged from $25,700 to $30,700 per year.

Relation to District and or National Program: The laboratory was established, and has functioned historically for support of Federal-State cooperative programs. In the past three to four years, however, it has become more and more a support unit for special projects and programs, including the Federal NASQAN and NWQSS programs.

TUSCALOOSA, ALABAMA LABORATORY

[Background material prepared by J. R. Avrett]

Dates of operation: July 1962 to November 1975.

Location: Oil and Gas Board Building, University, Alabama.

Purpose: A large increase in funds for water-quality oriented programs resulted in the need for a large increase in chemical and physical quality information. The establishment of a District laboratory was necessary owing (1) to the large increase in number of analyses required, (2) to reduce turn-around time and number of analyses, and (3) to provide more flexibility in the type of analyses made.

Manpower: Leadership: 1964-72, W. L. Broadhurst, District Chief. 1972-75, W. J. Powell, District Chief. 1962 to present, J. R. Avrett, Laboratory Supervisor. Personnel: Number of employees: 1963-69 - 1 to 3 part-time technicians, 1 to 3 part-time chemists. 1970-75 - 4 to 5 technicians, 1 to 3 part-time chemists.

Analytical facilities: Equipment: 1963-69 - Beckman Model "B" spectrophotometer, Beckman pH meter, Wheatstone bridge, and galvanometer for specific conductance. 1970-75 - Atomic absorption spectrophotometer, Kjeldahl distillation unit, turbidimeter.

Analytical methods: WSP 1454, "Methods for collection and analysis of water samples," TWRI series, book 5, chap A1, "Methods for collection and analysis of water samples for dissolved minerals and gases."

Precision or accuracy: One percent objective; Denver standard reference program beginning 1962.

Data output: Constituents: Generally the amount of work performed in the laboratory increased each year. The greatest change in operation occurred in fiscal year 1970 after the equipment to determine the major ions had been acquired. 1963-69 - Partial analysis plus iron. 1970-75 - Major ions and physical measurements. Production: Number of adjusted complete analyses per year: 1963-69 - 300 to 700. 1970-75 - 1,200 to 1,800.

Data presentation: Water-Supply Papers and Water Resources Data annual series, Water Resources Data file (WATSTORE).

Budget: 1963-69 - $11,000 to $40,000. 1970-75 - $70,000 to $125,000.

Relation to District or National Program: Measurements of chemical and physical quality of water from wells, springs, and streams as part of Federal-State cooperative programs; service facilities for National programs.

WASHINGTON, D.C. LABORATORY

[Background material prepared by D. E. Weaver]

Dates of operation: 1903-73.

Location: 1906 - F. Street (jointly with Geologic Division). 1919-51 - Room G241 - C GSA Bldg., 18th and F. st. 1951-73 - Old Post Office Building, 12th and Pennsylvania Ave. NW.

Purpose: From its inception the Washington laboratory has functioned as a source of information on chemical and physical properties of water resources. In the early years, particularly, the laboratory provided analytical services and technical support for national and Federal-State cooperative programs and for other government agencies.

The Division of Quality of Water was reestablished as an independent unit on January 2, 1918 and the Geological Survey established in Washington it's first separate water analysis laboratory. During the years 1921 to 1940, the suitability of the U.S. water supplies for public use and for agricultural and industrial purposes was stressed.

Persistent requests for additional specific quality-of-water data and information resulted in preparation of papers on the industrial utility of public water supplies in the United States, published in 1923 and updated in 1932.

Interest was growing in the early 1920's for information on temperature of river waters on which power sites were available. Extensive temperature data were published by the Survey.

A continuing program for the measurement of sediment concentrations and loads of streams began in 1925 when a study under the direction of C. S. Howard was started in Arizona on the Colorado River. All analyses for chemical and sediment content were made in the Washington laboratory.

Analytical services were provided by the laboratory when cooperation was arranged with four States during the 1930's.

The Virginia State Commission on Conservation and Development, in 1929, cooperated with the Survey in a two-year study of the State's waters.

A cooperative program with the Georgia State Division of Mines, Mining, and Geology began March 1, 1937 initially with daily sampling at gaging stations. Within the year, interest shifted to public water supplies for industry, and analyses were made of water supplies for principal cities and towns.

A study of the intrusion of sea water in ground water supplies in the tidal reaches of the Connecticut River began in 1933 by the Ground Water Division resulted in a cooperative agreement with the State Water Commission. A comprehensive salinity study of the river was made from 1934 to 1939 to cover tide and stream-flow conditions.

A laboratory was established at Austin, Texas, in 1937, to facilitate ground-water studies in Texas and in the Pecos River (joint Investigation).

In addition to these four programs an investigation of the source of salinity in the Pecos River, begun in April 1937 by the Ground Water Division, resulted in a separate agreement with the State of New Mexico and the Quality-of-Water Division and field laboratories at Roswell, N.Mex., and ultimately at Albuquerque were established.

The Division was called upon for cooperative studies by numerous Federal agencies beginning in 1933. Among these were Public Works Administration, Indian Service, Soil Conservation Service, Flood Control Coordinating Committee. National Resources Committee, Public Health Service, National Park Service, Veterans Administration, and the State Department.

As cooperative-programs continued to develop and District-type laboratories were established in the 1940's the Washington laboratory functioned increasingly as the center for new instrument and methods testing and monitoring for use in field laboratories. Radiochemical studies such as tritium monitoring of water resources during U.S. and other nuclear tests in the 1950's and the examination of water resources for potential proliferation of pesticides and trace metals in the 1960's, were major activities.

Subsequently, in the 1960's and 1970's, these activities were transferred to research centers or operational programs.

Manpower: Leadership: September 1903 to July 1907, M. O. Leighton. July 1906 to June 1910, R. B. Dole. January 1918 to July 1919, A. A. Chambers. July 1919 to May 1920, C. A. Kidwell. June 1920, H. Stabler (acting). July 1920 to September 1946, W. D. Collins, Q.W. Branch Chief. June 1920 to July 1942, C. S. Howard. July 1942 to September 1946, S. K. Love. September 1946 to March

1968, S. K. Love, Q.W. Branch Chief. October 1946 to June 1951, E. W. Lohr. June 1951 to June 1960, D. E. Weaver. June 1960 to February 1969 H. R. Feltz. February 1969 to August 1971, D. W. Fisher. August 1971 to September 1973, H. Crump-Weisner. Personnel: Number of employees: 1903-18 - 6 technical. 1919-20 - 3 technical. 1920's - 6 technical. 1939-60 - 14 technical. 1960-73 - 14 employees.

Analytical facilities: Equipment: 1902-06 - Most analyses other than assays were made in cooperation with university and State laboratories. 1919-20 - Gravimetric and titrimetric procedures for major cations and anions; physical measurements; field kit used for Mississippi River studies. 1921-46 - Colorimetric equipment and specific conductance added. 1946-60 - Flame photometer purchased (1951) for routine determination of sodium and potassium. Suspended sediment (1954), Beckman Model "B" spectrophotometer, Perkin-Elmer flame photometer, Beckman pH meter, etc., radiochemical. 1960-73 - Perkin-Elmer atomic absorption spectrophotometer (1965); gas chromotograph, Wilkins herograph 600 series for pesticide determination (1964), Technicon Autoanalyzer (1967), PE infrared spectrophotometer (1968), Beckman carbon analyzer-915 (1968), Dohrman microcoulometer (1968).

Analytical methods: 1921-46 - WSP 596H (1928), Specific conductance and fluoride added (1945). 1946-60 - Methods of Water Analysis (1950), revised 1960. 1960-73 - WSP 1454, TWRI series, book 5, chap A1.

Precision or accuracy: 1918-46 - Cation-anion balance, ± 5 percent, recheck by second analyst, supervisor approval. 1946-60 - One percent objective, 1955; 0.1 ppm precision; interlaboratory sample check. 1960-73 - Standard reference program (Denver 1967); AA 1 microgram precision.

Data output: Constituent: 1918-46 - Major ions and physical measurements. 1946-60 - Radiochemical (1955); spectrograph, carbon arc for minor elements (1958). 1960-73 - Pesticides; carbon compounds; minor elements; atomic absorption spectrophotometer broadened, to include additional ions. Production: Number of adjusted complete analyses per year: 1919-28 - 275 to 819 (average per year 477). 1954 - 2,460. 1960 - 2,300. 1970 - 4,000.

Data presentation: 1918-20 - Laboratory cards; Water-Supply Paper project studies. 1921-70 - Annual Water-Supply Paper series beginning in 1941; Colorado River studies, WSP 998 (1925-41), WSP 1048, Boise River (1939-40), 1965-73 - WRD Data system (WATSTORE).

Budget: 1920 - $7,350. 1920's - $20,000 (including all water-quality activities). 1951 - $35,000. 1944 - $106,000 (probable range during period 1944-60). 1960 - $104,000 (including research). 1965 - $61,000. 1970 - $140,000. 1971 - $120,000.

Relation to District or National Program: 1918-20 - Mainly National project support for chemical and physical properties of water, "mineral" analyses of water from wells, springs, and streams. 1921-46 - Principally a service facility for National programs; Armed Forces; D.C. and Maryland cooperative programs. Federal-State cooperative programs for Georgia, Ohio, Virginia, New York and other State and Federal agencies have at various times utilized the services and facilities of the laboratory.

YUMA, ARIZONA LABORATORY

[Background material prepared by L. R. Kister, and J. D. Hem]

Gila River investigations: An inventory of inflows and outflows of water and solutes in the irrigated Safford Valley Ariz., was begun in 1940 and a laboratory was set up in Safford in July of that year, with J. D. Hem in charge. During the ensuing two years the laboratory analyzed about 2,000 samples, not only from the Safford Valley but also from other areas in Arizona that were being investigated by the Ground Water Branch at that time. At the completion of the Safford Valley study the laboratory was closed, in June 1942.

With financing by the Defense Plant Corporation, a more intensive study of water quality and availability in the Gila River Valley above San Carlos Reservoir was begun in 1943 and the Safford laboratory was reestablished in June of that year, again with J. D. Hem in charge. A large expansion of copper mining and smelting operations at Morenci had begun to meet war-related requirements for the metal; and additional water supplies were needed. The earlier Safford Valley studies had indicated that clearing of native vegetation, mainly salt-cedar, which grew luxuriantly along the river, might salvage substantial amounts of water. The laboratory analyzed about 5,000 samples before the project was terminated at the end of 1944, and the laboratory was closed and merged with the Albuquerque facility early in 1945.

The Arizona district has not included a full-fledged water laboratory as part of its operations in recent years. Samples for chemical analyses and particle-size determinations were sent to Albuquerque, N. Mex., until the establishment of the Central Laboratory system. Currently, all water samples are sent through the Central Laboratory system, with the exception of a small number of samples from stations on the lower Colorado River. Samples from these stations are analyzed in the Yuma Water Resources subdistrict facility.

Dates of operation: 1961-66.

Location: Federal Building, 301 W. Congress St.

Purpose: In 1961 the laboratory was established to provide field laboratory facilities in support of the Lower Colorado River Project. From 1966 to the present, the laboratory has provided analyses of daily and weekly water samples from about 5 to 7 stations on and along the Colorado River below Imperial Dam for regulation of the quality of water entering Mexico.

Manpower: Leadership: 1940-42 (Safford), J. D. Hem. 1961-66, Burdge Irelan. 1962-72, W. J. Welbourne. 1970, Ethel Linville. Personnel: Number of employees: 1940-42 - 3 technicians. 1961-66 - 2 technicians. 1966 - 2 technicians.

Analytical facilities: Equipment: 1961-66 - Field kit, specific conductance meter, pH meter, analytical balance. 1966 - Added steam bath, Beckman Model "B" spectrophotometers with flame attachment, dissolved oxygen meter, turbidimeter, incubators, and oven.

Analytical methods: 1961-66 - Wet chemical methods from WSP 1454, Methods of Water Analysis (1960). 1966 - Same as above plus TWRI, book 5, chap A1 (1970).

Precision or accuracy: 1961 to present - One percent objective.

Data output: Constituent: 1961-66 - Major ions, except nitrate, physical measurements, calcium, sodium and potassium, and silica. 1966 - Major ions, silica, physical measurements, coliform, streptococci bacteria, dissolved solids (residue at 180°C), dissolved oxygen, turbidity. In addition, standard NASQAN parameters, exclusive of those run in Yuma, are determined at the Central Laboratories.

Data presentation: 1961-66 - Laboratory cards. 1966 - Laboratory cards, Water Resources Data File (WATSTORE), Annual report, Water-Quality Data for Arizona.

Budget: 1974 - $30,000 (approximately). 1977 - $50,000 (approximately).

Relation to District or National Program: Support of Lower Colorado River research project. District took over operation in 1966. Currently, the laboratory provides the Bureau of Reclamation, and the International Boundary and Water Commission the real-time chemical data needed to manage the quality of water at the United States-Mexico boundary.

HISTORICAL PROFILE OF QUALITY OF WATER LABORATORIES AND ACTIVITIES, 1879—1973

PART 2: HISTORY OF WATER QUALITY ACTIVITIES

By W.H. DURUM

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INTRODUCTION

There are perhaps few places in the Geological Survey where so much history and change goes daily unnoticed as the quality-of-water laboratories, Water Resources Division. These facilities have been intimately associated with the Nation's rapid growth in population and economy during the last centennial and with the development of vast public works and concern with the intensity of pollution problems in the first decade of the century and again in the 1960's. Few technical persons, however, have had time to notice or appreciate the past developments except as a fleeting glimpse or passing episode.

In the broadest sense historical programs in water quality reflect what is going on in the American society--its moods, mores, industrial and public actions, and social concerns.

The report is divided into five periods: 1879-1913, 1914-1920, 1921-1946, 1947-1959, and 1960-1973. These were chosen because events or leadership made them logical units for discussion. Owing to many details and for convenience to the reader a summary follows in the next section.

This document, hopefully, will capture some of the highlights in the historical development of the quality of water facilities and associated programs.

SUMMARY

A brief chronicle of nearly 100 years of evolving quality-of-water activities is certain to have many shortcomings and inadequacies. Lost records, hazy recollection or forgotten episodes, and unintentional bias are certain assurance that many important events or developments have been overlooked. Nevertheless, certain key events, personalities or a combination of factors formed an impression with the writer that in his judgment were milestones in Geological Survey's multidiscipline, difficult to define, and sometimes maligned science of water quality.

Throughout nearly a century in water quality activities the Survey has shown remarkable constraint in maintaining a national leadership in this field of science. Limitations in program monies and lack of identity in the public sector probably were contributing factors. However, it is a tribute to its leadership and personnel that at times of national stress or disquieting events the Survey has provided a firm technical hand and continuing source of scientific information on water resources.

Water quality problems emerged in the first decade of the century, again with State and local water resources development of the post World War II period of the 1940's, and with the Nation's search for environmental quality and subsequent Federal and State legislation in the 1960's. The Survey, through its Water Resources Division, never deviated in its assigned responsibility for public service in placing water data on record. In this respect, Survey's technical contributions are likely to be judged immeasurable.

In the early years, particularly in the period 1900 to 1910, investigators demonstrated marked ability to report their findings rapidly and with clarity of style. During his short period of leadership as Chief Hydrographer, M. O. Leighton (1903-1906) insisted that water quality embraces more than dissolved minerals. By his actions in charting pollution problems in rivers of the Northeast, Leighton provided the early incentive for maintaining scientific leadership in documenting water quality problems of concern to the general public.

Survey investigations of water quality were directed toward pollution problems for several years and sanitary and biochemical quality measurements taken from State Board of Health reports were included along with chemical analysis in reports.

By the end of the first decade, national interest in conserving water resources and the impact of industrial uses of water brought a shift in emphasis in water quality studies.

Several quality-of-water investigations made for the Reclamation Service at the turn of the century influenced the decision that in the western United States mineral studies would focus on the amount of alkali (salinity) in stream waters used for irrigation. The examination of water quality for industrial uses began in 1905 when a contract was negotiated with the State Engineer of California for a study of natural waters of California, their composition and the damage "sustained by reason of pollution." The San Francisco earthquake, April 1906, caused suspension of the project which was later resumed and results were published in 1910.

A similar agreement with the State of Illinois, 1906, provided for the investigation of mineral and organic constituents of the surface and ground water, corrosion of waters in steam boilers, and purification of waters for industrial and domestic uses, and related problems. W. D. Collins was the principal investigator.

Studies in the years following 1913 and World War I were almost exclusively of the mineral content of water. This restriction was caused by a lack of funds to cover a wider field and the entry of the Public Health Service into stream pollution investigations.

On January 2, 1918, the Division of Quality of Water was established as an independent unit within the Survey's Water Resources Branch. Soon thereafter the first laboratory devoted entirely to water analysis was established in Washington, D.C. As development of State-Federal cooperative studies in the southeast and southwest showed increasing interest in quality-of-water studies, the need grew for more analytical capability.

In the years 1914 to 1920, the Survey published more than 50 reports containing discussion or data on water quality, mostly describing mineral quality in relation to geologic environment of the waters and their suitability for use. From 1921 to 1946 the suitability of the Nation's water supplies for public use and for agriculture and industrial purposes was stressed. Many reports were prepared about industrial utility and domestic utility of water supplies, methods of analysis, and other contributions to hydrology.

The interval, 1921-46, included the depression years of the 30's when the investigations authorized solely from Federal funds were severely limited. Cooperative programs supported most of the investigations.

The Survey's studies in water quality extended to Arizona in 1925 when a continuing program for the measurement of fluvial sediment in the Colorado River began. Storage reservoirs were needed. The large sediment load transported by the stream affected the life of the reservoir, and data were essential for planning purposes.

Cooperative programs were arranged with four States during the 1930's. The Virginia State Commission on Conservation and Development, in 1929, cooperated with the Survey in a two-year study of the State's water resources. A cooperative program with the Georgia State Division of Mines, Mining, and Geology began in March 1937, initially with daily sampling at stream gaging stations. A comprehensive salinity study of the Connecticut River was made cooperatively with the Connecticut State Water Commission, from 1934 to 1939, to cover tide and stream-flow conditions.

The investigation of the source of salinity in the Pecos River begun in April 1937 by the Ground Water Division resulted in a separate agreement with the State of New Mexico and the Quality of Water Division. A field laboratory was established at Roswell, N. Mex. A permanent laboratory was established at Austin, Tex. in 1937 (initially a WPA facility) to facilitate continuing ground-water studies in Texas and in the Pecos River Joint Investigation.

In Arizona, ground water inventory of Safford Valley, was begun in 1936, to determine the amounts of dissolved solids entering and leaving the valley, and the source of salts.

The Division was called upon for cooperative water-quality studies by numerous Federal agencies beginning in 1933. Among these were the Public Works Administration, Indian Service, Soil Conservation Service, Flood Control Coordinating Committee, National Resources Committee, and Public Health Service.

The Boise River, Idaho, investigation begun in 1939 was one of several cooperative studies with either the Soil Conservation Service or the Flood Control Coordinating Committee of the Department of Agriculture. It became a key study for obtaining sediment records which eventually led to the Survey's development of improved equipment and standardization of stream sediment sampling methods.

A major stimulus to water-quality investigations came during World War II and the postwar period when numerous water resources oriented agencies were either created or existing ones sought an appraisal of water resources to attract industries. Federal-State cooperative programs with the Survey grew rapidly, either by the expansion of existing traditional surface water or ground water investigations with the Water Resources Division or by the establishment of entirely new ones. These programs began as modest activities, often to establish a data base of seasonal high and low-flow surface water quality. As development of State-Federal cooperative studies in the Southeast and Southwest showed increasing interest in quality of water problems, it was necessary to establish District laboratories for additional analytical capability serving, generally, one or more cooperative programs.

With the rapid increase in basic data both for chemical quality and sediment, and public interest in the results, a need arose for an annual report containing the information and data. Beginning with water year 1941 the annual series was started under the title, "Quality of surface waters in the United States," the first being Water-Supply Paper 942.

Noteworthy program advances came in the mid 1940's with the Colorado River studies and the Missouri River basin program. These called for intensive studies of sediment for entire basins in addition to work in chemical quality. In 1947, the first regional laboratory for chemical-quality and sedimentation studies was established at Salt Lake City, Utah, by specific appropriation of Congress. In 1944, Congress approved the Missouri River Plan, and a Survey regional laboratory at Lincoln, Nebr., began operations in 1946 to provide water-quality information for studies of water resources by the Interior Department and other Federal agencies. To simplify sediment data collection, four field laboratories were established at selected locations.

In these western drainage basins, where the principal water-quality problems are the naturally-occurring high salinity of surface and ground water, the suspended sediment content, and discharge of streams, the main scope of activities in the Missouri basin program was the sediment load of streams related to reservoirs and desilting basins proposed for construction by the Bureau of Reclamation and studies of chemical quality of surface and ground water to meet requirements the Bureau of Reclamation, and of other Federal agencies in the basin.

A third regional laboratory was established at Columbus, Ohio, August 1948, by the Quality of Water Branch (previously called Division). In addition during 1946-58, eight District offices for quality of water activities were created. This brought the number of District offices and laboratories to 13. To foster advanced studies, four field research centers were authorized. The first of these centers was activated at Minneapolis June 1948. Other centers at Denver, Menlo Park, and Fort Collins followed during 1953-57.

Advances in laboratory instrumentation were announced in the late 1940's, and by the early 1950's Division laboratories adapted the flame spectrophotometer to routine determinations of sodium, calcium, and selected elements. It was the forerunner of future major equipment development.

Growth in water quality activities was striking in the period 1946-60. In 1946, the Quality of Water Branch had 42 employees on its rolls. In 1958, the roster included 338 employees of which 78 were employed part-time. During the 1945 fiscal year, $107,400 was allocated to quality of water programs, and by 1960, the funds totalled $2.7 million--an increase of more than 25-fold. Surface water quality station operation more than doubled: from 455 in 1946 to 1,170 in 1960.

In 1953, the Division published a series of nine preliminary reports containing data pertaining to public water supplies of more than 1,200 large cities of the United States. The reports filled a significant need in the field of water supply engineering by updating the information contained in WSP 658, "The industrial utility of public water supplies in the United States, 1932."

A program to determine and interpret the radioactivity of natural waters was begun. And, assistance to the Atomic Energy Commission on problems of water supply and waste disposal at established sites was continued. By 1953, increasing recognition was being given by State, Federal, and private agencies to the impairment of the quality of natural waters by industrial wastes mine drainage, irrigation return flows, and other sources of pollution. The Division broadened the scope of its studies in order that the effect of pollutants on natural waters could be properly evaluated. Attention was given to analytical capabilities for new determinations and the deviation and frequency of periods of low flow in streams.

Methods of water analysis was released in January 1950, to establish analytical methods used by the Geological Survey and to standardize procedures in the District laboratories. This was updated in 1960 with the public-released WSP 1454, "Methods for collection and analysis of water samples." Technology advanced rapidly and called for a simpler form for release and updating new approved procedures. In 1970, there began a rapid succession of methods manuals in the Technical Water Resources Investigation (TWRI) series, Methods for collection and analysis of water samples.

New Division program thrusts in the 1950's conveyed the need for broad technical training in hydrology to supplement that given new employees in the District office. The first Quality of Water Branch Tecnnical Training School convened at Charlottesville, Va., May 1956.

The extensive quality of water studies of the Water Resources Division by 1955 included several principal projects. The deposition of sediment in the Middle Rio Grande Valley had raised the valley flow to such an extent that the economy of the valley was seriously threatened. Intensive studies of the sediment transported by the river and its major tributaries were providing data for planning remedial measures. Continuing investigations of sediment discharge and chemical quality of streams in the Colorado River basin were developing data for planning of Federal projects on that basin and for meeting the requirements of the Upper Colorado River Compact. Sediment transport and chemical quality studies continued in the Pecos River basin to meet the requirements of the Pecos River Compact Commission. A sediment-index station program was developed through the Federal Inter-agency River Basin Committee (now the Federal Inter-Agency Committee on Water Resources) involving the collection of sediment discharge records over long periods at sites throughout the United States, in order to provide nationwide information on sediment protection. Six stations in this network were supported under this program in 1955. Periodic measurement of sediment in many streams in Alaska continued during this period.

An observation network on western streams was operated to determine changes in chemical quality over long periods as a result of return flows from irrigation projects.

A reconnaissance study of chemical and sediment characteristics of streams in the New York-New England area and a sediment-transport investigation on the Mississippi River at St. Louis, Mo., in collaboration with the Corps of Engineers provided data on sediment loads. The development and testing of methods and equipment used in measurement of sediment loads in streams were continued at the St. Anthony Falls Laboratory in collaboration with the Corps of Engineers and the University of Minnesota.

Analysis and evaluation of various procedures for collection of sediment load data directed to more effective field operations was begun in 1955.

Studies of the inland saline water resources were begun on a limited basis during 1954 to determine the availability of water of inferior quality that might be made potable by treatment process developed through the Department's Saline Water Conversion Program.

Studies of the radioactivity were continued in 1955, jointly with the Ground Water Branch, to determine background radioactivity of natural waters and to relate occurrence of such activity to hydrologic and geologic factors.

Chemical quality and sedimentation studies were in progress in cooperation with 20 States. Notable among these were investigations of oil-field brine pollution in the Ouachita River basin, Ark.; inorganic pollutants in streams in the Central Valley, Calif.; along the Suwanee and Withlacoochee Rivers, Fla.; sediment-load data on major streams of Kentucky; evaluation of the ground- and surface-water quality of northwest Minnesota; chemical characteristics of ground and surface waters of New York as part of a program to evaluate the industrial utility of the State's water resources; in the Little Miami River basin and the Ohio River, Ohio; along the North Canadian River and Salt Fork Arkansas River, Okla.; the lower Delaware River, Pa.; and sedimentation studies in Black Earth Creek and elsewhere in Wisconsin as part of hydrologic studies of a watershed improvement area.

In 1956 detailed chemical quality investigations were continued in the basins of the Colorado, Missouri, Pecos, Yadkin-Pee Dee, and Columbia Rivers; in New York and the New England States, and in Alaska.

A sampling network was maintained on 75 western streams to determine trends in mineral content that would affect successful continued operation of irrigation projects.

An appraisal of water quality of the Upper Colorado River began in October 1957.

In 1958, the Survey began a study of major worldwide contributions of dissolved solids being carried from land surfaces to the oceans. The Survey also considered the significance and potential use of tritium as a tracer and age determinant in water investigations.

During the spring months of 1958 the Division was involved in an intensive study of the effects of strip mining in the Beaver Creek Watershed project in McCreary County, Ky.

Other reports on water quality of special interest during the 1950's included those on the Colorado River basin for the period 1925-40, the chemical characteristics of surface waters in the Devils Lake basin, N. Dak., and the quality of surface waters in the Wind River basin, Wyo. Reports describing chemical characteristics of South Carolina, Texas, New York, Kentucky, North Carolina, Virginia, Arkansas, and Oklahoma were prepared in cooperation with these States.

As research activities broadened both in scope and in number in late 1950's, studies were begun on the uranium and radium content of ground water in several areas of the West, and reports were released for the Llano Estacado, Texas and New Mexico. Radiochemical studies evolved with tritium monitoring of water resources during U.S. and other nuclear tests in the 1950's. Other noteworthy reports included hydrologic and tracer studies in Mohawk River at Knolls Atomic Power Laboratory, "Chemistry of iron in natural waters, and the Study and interpretation of water analyses."

During the period 1955 to 1959 comprehensive investigations of waterborne sediments were continued in the Missouri, Middle Rio Grande, and Colorado River basins. These studies provided information about the sources of sediment, rates of discharge and other factors to aid extensive Federal programs of water development in these areas. Results of sediment investigations in the Wind River basin were published in WSP 1373. The results of water resources investigations and research for the Missouri River Basin Program are found in more than 75 Geological Survey publications and 10 technical journals.

The program of the U.S. Soil Conservation Service was assisted by studies of sediment yields and trapping efficiency of reservoirs on small watersheds in North Carolina, West Virginia, Kentucky, Georgia, Nebraska, Oklahoma, and Texas. Special studies were made for the Bureau of Reclamation in the Rio Grande and Colorado River basins and in the watershed of Medicine Creek, Nebr.

Investigations of sedimentation were continued in cooperation with the States of Iowa, Wisconsin, Kentucky, Ohio, Pennsylvania, and Virginia. These included several small watersheds to measure and explain changes in runoff and discharge of sediment induced by conservation practices.

By 1959 sedimentation studies had broadened to include the relationship of sediment transport to roughness and shape of stream channels; bedload discharge of sediment; development of automatic equipment for measuring sediment discharge of streams; and improved techniques and standards for analyzing and interpreting sediment data and records. Fluvial sediment experimental studies were done collaboratively with Colorado State University, Fort Collins, Colo. Equipment development studies were centered at the St. Anthony Falls Hydraulics Laboratory, University of Minnesota, Minneapolis, Minn., jointly with the Federal Inter-Agency Committee on Sedimentation.

National concern about environmental quality in the 1960's was expressed in Federal legislation such as the Water Quality Act of 1965, the National Environmental Policy Act of 1969, the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) the Safe Drinking Water Act (Public Law 93-523), and the Toxic Substances Control Act.

Increasing responsibilities in the 1960's for providing water quality data to meet the changing priorities of water management and pollution control agencies allowed the Survey to extend its capabilities to include routine determinations of pesticides, nutrients, bacteria and aquatic biology materials, minor elements, and others. Water Resources Division laboratories had undergone radical change as highly sophisticated instruments and specialized techniques were required for routine determinations.

By 1964, the atomic absorption spectrophotometer for measurement of minor elements was added to the larger laboratories. In 1967-68 the first of the automatic analyzers (Autoanalyzer) was installed at the Salt Lake City laboratory to keep pace with the rapidly increasing volume of analyses. After further testing in 1969 the Division approved the use of automated systems in large District laboratories. Highly specialized analytical equipment for pesticide and other organic analysis by gas chromatograph and mass spectrograph were centered in Washington, D. C., and Austin, Tex., laboratories and in the Menlo Park, Calif., and Denver, Colo., research centers beginning with the period 1964 to 1967.

Aquatic biological and microbiological studies expanded rapidly about 1970 as the broad scope of environmental concerns in natural resources in the late 1960's brought new priorities in the Division program for parameters such as biochemical oxygen demand, coliform, fecal coliform, and macroinvertebrates.

By the end of the 1960 decade the increasing requests from cooperators for analyses of a broader spectrum of substances in water and associated with sediment underscored the need to further automated laboratories. In April 1970 a Water Resources Division Task Group prepared guidelines and detailed studies for a Central Laboratory System. A pilot centralized laboratory was established at Salt Lake City in November 1970, and continued until March 1972 when results were evaluated and demonstrated the advantages and effectiveness of the system.

In February 1973, the Division proceeded to establish the Central Laboratory System with two large scale, highly automated laboratories at Denver, Colo., and Atlanta, Ga., as immediate goals. A third site, tentatively at Albany, N.Y., was to be designated later. All 22 District facilities were discontinued as full-scale laboratories in the 1973-74 period when the Central Laboratory System began full-time operation.

Also, during the 1960's the Division was developing electronic systems for on-site field monitoring and digitally recording water-quality parameters. In November 1962, a water-quality monitor was installed on the Cuyahoga River at Center Street in Cleveland, Ohio in cooperation with the Ohio Department of Health. By 1966 the Division reported that the digital recording of water quality parameters is a link in the automated data collection and processing system of the Geological Survey.

The annual growth in water-quality program both in operating stations and total funds increased rapidly from 1960 to 1974.

In 1960, water-quality data were obtained at 1,120 surface-water sites. About one-third of these river observation stations were east of the Mississippi River. The number of operating stations increased nearly 2-fold between 1967 and 1970 (2,102 to 4,195 stations). Total program funds doubled in the 5-year period 1960-65 from about $2.7 million to $5.4 million and increased steadily to $6.6 million by the close of the period, 1973.

The Moore-Pecora Agreement, July 1968, defined the working relationship between Interior's Federal Water Pollution Control Administration (FWPCA) and the Geological Survey. It summarized agreements regarding responsibilities and work relations between the two agencies relative to water data activities directed by Bureau of Budget Circular No. A-67, and coordinated Federal activities in the acquisition of certain water data. Division representatives worked effectively with FWPCA (later the Water Quality Office of Environmental Protection Agency (EPA) in implementing EPA's National Water Quality Surveillance System beginning in fiscal year 1970. In 1969, the USGS and FWPCA (EPA) issued by mutual agreement, a list of parameters to be determined and guidelines for the collection of samples and specific analytical procedures.

Plans were outlined and initiated in the fall of 1968 for the technical review of water-quality activities at the District level. Reviews were conducted by technical specialists from the Branch and Regional staffs for the purpose of strengthening quality-of-water activities within the framework of Division objectives and goals and coping with emergent problems in environmental quality. Assurance of quality control of data was a major issue in the review.

In November 1971, the Quality of Water Branch submitted a detailed plan for the National Stream Quality Accounting Network (NASQAN) to be implemented during the 1973 fiscal year. The plan evolved after lengthy discussions and coordination with the Office of Water Data Coordination (OWDC) and other participants over a period of several years. The network is based on the river-basin accounting units designated by OWDC in consultation with the Water Resources Council. It is designed to provide a measure of the quality of water moving from one accounting unit to another in terms of physical, chemical, and biological aspects of water quality. This was done by the selection of one or more stations in each accounting unit at which the bulk of the outflow from that unit can be sampled. The planned network includes about 525 locations.

A series of pilot river-quality assessments of selected river basins in the United States was started in 1972. These are to provide a product dedicated to those aspects of the rivers that are of most interest and concern to the general public. The studies consider not only the physical and chemical properties of the water as they relate to water use, but also to the condition of streams as reflected by their biota and by their attractiveness and recreational appeal.

In the 1960's some Districts encouraged by State cooperators and Division headquarters shifted their cooperative programs to attain greater areal coverage and to augment information for different seasonal flow conditions. The Florida District was active in Survey's nationwide program to evaluate the effects of underground waste disposal on the Nation's subsurface environment, and to report on the hydrochemical effects of injecting wastes into a limestone aquifer near Pensacola, Fla..

As a first step in updating the water-quality basic data program, the North Carolina District assessed historical information as a necessary part of program design. Mine drainage, thermal pollution, urban studies, and eutrophication were some of the environmental problems dealt with by the Pennsylvania District. And, innovative improvements were made to field instruments such as automatic sediment samplers and electronic chemical monitors.

Quality of the ground water in the Red River alluvium and time-of-travel studies to determine how pollutants move in the lower Mississippi River were noteworthy activities of the Louisiana District. A statewide water quality reconnaissance of streams affected by coal and metal mining, and a project study concerned with potential problems involved in pending oil-shale development of the Piceance basin were highlights of the diverse program of the Colorado District.

In addition to the continuing network of data collection sites, the Texas District program includes studies of the quality of water of Texas bays and estuaries, the quality of urban runoff in Houston and San Antonio, and quality of water is a significant part of the Edwards Underground Aquifer in the San Antonio area.

Following discovery of oil at Prudhoe Bay on Alaska's North Slope, in March 1968, comprehensive plans for data collection along the prospective transportation corridor, Prudhoe Bay to Valdez, were developed by the Alaska District. Hydrologic investigations also were underway at Anchorage, Juneau, Kenai, and Kodiak.

The California District operates about 30 sediment stations extending from the Oregon border to near San Luis Obispo. These stations provide useful sediment data for a variety of hydrologic and cultural environments. Among projects involving water quality, several of which are strongly oriented toward problems in aquatic biology, are the studies of the hydrology of Bollinas Lagoon, the Sacramento River, Lopez Reservoir, and the Bay Area Storm Runoff.

Lakes of Washington is a continuing project to describe the potential for accelerated eutrophication of lakes. The Washington District also is developing a model for predicting the effects of treatment plant effluent on water quality in Puget Sound and its estuary. A study of the water resources of the Lummi Indian Reservation involves potential problems for developing aqua-culture.

During the early 1970's the Water Resources Division expanded research and special studies to relate to problems encountered in operating programs as rapidly as funds and personnel allowed. Principal published studies were those for laboratory methods, trace elements and nutrients, organic solutes, forms of ions and rates of reaction, water quality modeling, and evaluation of long-term trends.

During fiscal years 1973 to 1976 nearly one-half of the new offerings of State and local agencies in the Water Resources Division cooperative program involved studies with water quality aspects, largely in response to new environmental responsibilities mandated by recent Federal laws.

Commenting on the situation as much better now, V. E. McKelvey, Director, U.S. Geological Survey, said at the dedication of the Survey's National Water Quality Laboratory, Denver, Colo., November 12, 1976, the stalwart pioneers in water quality "would all agree on one counsel to those who continue their work today: There's a big job to be done. Let's get on with it!"

THE YEARS 1879 TO 1913

Nearly a century of Geological Survey's interest in water quality can be traced as early as 1879 when the first water-quality data was reported. In the period 1884 to 1901, the Survey published 25 reports containing information on chemical and physical properties of natural waters and their geologic environment.

The field of sedimentation did not go unnoted 90 years ago. A report by Carl Barus, in 1886, speaks of the suspension of finely-powdered material in aqueous media and describes relationships of electrical conductivity to the settling rates of sediment particles.

The early investigations show a direct response to a public concern or interest, and this led to a stated need for a separate unit to study water quality and related matters (USGS Bulletin 227, p. 89), "Owing to the increased demand for information on water powers, municipal water supplies, sanitary conditions of rivers, flood preventions, and other allied questions, the Division of Hydro-Economics was established in January 1902. At that time its work was confined to reviewing chemical and board-of-health reports and extracting therefrom such matter as applied directly to the quality of natural waters."

To head the new Division of Hydro-economics, F. H. Newell, Chief Hydrographer, selected M. O. Leighton, former health officer at Monclair, N. J. Leighton, an engineer with a strong technical background in chemistry and biology also was an excellent public relations man. His training and experience in sanitary engineering influenced the course of activities of the new Division. F. W. Clarke, Chief Chemist of the Geologic Branch favored emphasis on studies of the chemical character and properties of water in relation to its geologic environment. Leighton was concerned from an economic viewpoint about pollution of water. He maintained that pollution studies were a proper activity of the Survey in its inventory of water resources because sewage and industrial wastes down graded the quality of water for many uses.

The stage was set for Leighton and his small professional staff of six persons to attack stream pollution problems attracting interstate attention. The first of a series of reports, "Sewage pollution in the metropolitan area near New York City and its effect on inland water source," published as WSP 72 in 1902, was the beginning of many investigations of water quality directed toward pollution problems for the next 10 years.

By 1906, when Leighton became chief hydrographer, the Survey had published 13 reports on water quality, of which 9 related to pollution studies -- disposal of industrial wastes, lake and stream pollution and its prevention, and purification of municipal sewage (Swenson, personal correspondence).

The contents of selected papers during the period are noteworthy:

WSP 72 is mainly a discussion of the water supply and sewage treatment facilities for towns and cities and the extent of pollution in the Raritan River, Passaic River, and Hudson River drainage systems in the metropolitan area near New York City. Some daily and monthly flow records are given and three brief tables of chemical and bacterial analyses of a few samples or annual averages in the 1890's for waters of the Hudson River, Hoosic River, and the Mohawk River. Measurements include albumenoid ammonia, free ammonia, nitrogen as nitrates and as nitrites, oxygen consumed, required oxygen, chloride, turbidity, color, total residue, hardness, and number of bacteria per cubic centimeter. Data are taken from State Board of Health reports and are reported in either parts per million or parts per 100,000. Sampling procedures and methods of analyses are not given.

Leighton concludes that natural resources of the Passaic system are severely damaged by pollution but that "It is not possible to estimate, with any degree of accuracy, the amount of damage that has been done to the Hudson River system by sewage pollution--when consideration is taken of the fact that runoff water in this basin is sufficiently large to dilute this sewage so that in places it almost escapes detection, the actual damage done appears to be greatly modified, or in the opinion of many, it becomes almost nil (p. 60)."

That Leighton was sensitive to the problem is evident when he states, "A municipality made miserable by polluted water from another State is deplorably helpless to obtain remedy. There is no national authority over such matters (p. 11)."

The investigation shows in a striking manner the effect of pollution upon the waters ot the Mohawk. Starting above Rome, where the water is practically normal both from a chemical and bacteriological standpoint, the 42 samples taken at different points along the river to the mouth show greater or less pollution according as the points from which they were taken were near to or some distance below the outlet of sewers of the different cities (p. 54)."

The following year, 1903, Leighton authored WSP 79, "Normal and polluted waters in Northeastern United States." The paper reviewed the more readily available records, published and unpublished, of examinations made of water supplies derived from streams in the northeastern part of the United States, the principal streams examined being the Merrimac, Connecticut, Housatonic, Delaware, and Ohio Rivers and their branches. The report includes 148 tables, mostly turbidity, color, nitrogen compounds, chlorine, and generally include hardness and total residue where this information is available from the data sources, the State Board of Health in the 1890's.

Leighton describes the origin of impurities in natural waters and attempts to differentiate between a "normal" and a "polluted" water on the basis of turbidity, color, nitrogen compounds, chlorine, and total residue.

F. H. Newell, Hydrographer in Charge, states in his Letter of Transmittal, Nov. 13, 1902, "This paper forms one of a series of reports on examinations made as to the character of the natural waters of the United States and the pecuniary damage to municipal water supply occasioned by city and industrial wastes. It is expected that examinations of like nature will be undertaken by the Survey in cooperation with the universities and State laboratories in the country, the character of the work differing according to conditions and demands in each case."

Urged on by Clarke to focus attention on the mineral examination of natural waters, Leighton decided from a practical consideration that any study of the mineral content of waters should be related to hardness with reference to use--in boilers, laundries, textile plants, and in the home.

Several quality-of-water investigations made for the Reclamation Service influenced Leighton's decision that in the western United States, mineral studies would focus on the amount of alkali in stream waters used for irrigation. Determination of mineral content of the water for industrial uses was begun July 1, 1905 when a contract was negotiated with the State Engineer of California for a study of: "---natural waters of the State of California, their seasonal variations in composition and in physical characteristics and the damage which they have sustained by reasons of pollution."

The San Francisco earthquake, April 1906, caused suspension of the California project. The study was resumed and results were published in 1910 (WSP 237).

In the California study 37 river-sampling stations were established during the period 1905-08. Daily samples were composited, generally for 10-day periods. Results of analysis were reported for turbidity, suspended matter, silica, iron, calcium, magnesium, sodium and potassium, carbonate, becarbonate, sulphate, nitrate, chlorine, and total solids. F. M. Eaton and Walton Van Winkle were the principal analysts using procedures with few exceptions, those outlined in WSP 236.

The authors' reported that the average mineral content of the 37 rivers studied in detail was 368 parts per million, the average in the humid regions 165 parts, and in the semiarid regions 628 parts.

Some data were given for lakes and springs. Noteworthy was that "organic matter" was reported for Sulphur Springs, Tulare Lake, and Owens Lake, both from independent analysis and from those by USGS analysts. The USGS laboratory space was provided by the Univeristy of California in the basement of the University's chemical laboratory.

River sampling studies for California and others during this period gave meticulous attention to recording of river flow including the tabulation of mean discharge for the sample composite period. No attempt was made to distinguish between high flow and low flow in either discrete single sample analysis or in the length of the composite period. For this reason the reader should exercise judgment in comparing chemical analyses for two unlike periods of flow.

The method of 10-day compositing also tends to mask or flatten out day-to-day fluctuations in concentrations of a constituent, and some changes are to be expected owing to the length of time the composite samples were stored before analysis. Nevertheless, within these limitations and restraints the body of chemical data reported in the early part of the 1900's is of incalculable technical and historical value, and mean values can be relied on with the reservations noted.

A similar agreement with the State of Illinois, July 1, 1906, provided for the investigation of mineral and organic constituents of the surface and ground water, corrosion of waters in steam boilers, and purification of waters for industrial and domestic uses, and related problems. The 1910 report (WSP 239) by W. D. Collins shows ever broadening concern about water-quality problems.

Messers Van Winkle and Eaton wanted the report to contain statistical information regarding municipal water supply, and replies to inquiries were received from 155 incorporated cities and towns. A table by George D. Leslie, statistician of the California State Board of Health was inserted to show the prevalence of water-borne diseases in some of the towns and cities in California, 1906.

	Deaths	Proportion per 1,000 total deaths
Typhoid fever	657	22.4
Malarial fever	111	3.8
Diarrhea and enteritis, under 2 years	930	31.7
Diarrhea and enteritis, 2 years and over	338	14.4

Today's health-oriented society finds these statistics cause for reflection as well as compassion.

Collins writes; "In time past the attention of those concerned with the quality of water has been directed very largely to the question of its fitness for drinking, but within the last few years corporations and communities have awakened to a great waste occasioned by the industrial use of unsuitable waters. The railroads of the country are spending thousands of dollars every year in treating their boiler feed waters---. Many laundries find it profitable to install expensive apparatus for softening water---. Water must be purified for use in many woolen mills, breweries, and other establishments---".

A Large amount of work had been done on the water quality of rivers in Illinois before the beginning of the 1906 study. In WSP 194 (1907) Leighton had given a digest of the testimony in the suit of the State of Missouri against the State of Illinois and the sanitary district of Chicago. As evidence in this case, results were presented from several thousand analyses of samples of water from Illinois River and its tributaries, with many analyses of Missouri and Mississippi River water. The analyses were not of mineral constituents, but were mainly determinations of the amounts of certain substances present in very small quantities, usually less than 1 percent of the total dissolved material. These results merely indicated the purity of the water as regards sewage contamination and had little value for determining the value of the water for any use other than for drinking.

Collins was assigned to the investigation of surface waters and began work in Illinois July 16, 1906, in the laboratory of the Illinois State Water Survey, Urbana. The program ended the following summer. Daily samples of water were obtained for 1 year from 17 rivers and reservoirs at 27 places in the State either from pumps taking water from the river or reservoir, dipped from near the surface, or the bottle was weighted with a sinker and filled some distance below the surface. The last method would give the most representative sample if the bottle were filled at exactly the right position in the cross section of the river, but the samples from pumps represented the water actually obtained in practice.

Analyses of the composite samples for each 10-day period together with averages for the year Aug. 1, 1906 to July 31, 1907 and gage readings are given in 27 tables in WSP 239 including turbidity, suspended matter, coefficient of fineness, silica, iron, calcium, magnesium, sodium and potassium, carbonate, bicarbonate, sulfate, nitrate, chlorine, and total solids.

When analyzing data for the Mississippi River at Chester, Mo., Collins noted a discrepancy in the average value for dissolved solids as compared to a value computed from the sums of the contribution from the Missouri River, Illinois River, and Mississippi River above St. Louis. His first concern was that of possible lack of complete mixing of Missouri River with Mississippi River waters at the place where the samples were collected. Collins then proceeded to plot curves of dissolved solids calculated from the analyses and discharges of upper Mississippi, Illinois, and Missouri

Rivers. Inspection of these curves indicated that the dissolved solids found at Chester followed closely the calculated dissolved solids. Collins concluded that the dissolved solids from Missouri River were much higher than the average value for dissolved solids in Mississippi River. This then would cause an increase in Mississippi River at the same time that the discharge increased.

These observations were to have a profound effect on future design of field sampling programs and procedures for handling samples in the laboratory.

The first systematic nationwide monitoring program for assessing the mineral characteristics of rivers and lakes was begun in 1903 by Richard B. Dole, a chemist with the Hydrographic Division (now the Water Resources Division) of the U.S. Geological Survey (Clark 1924). Dole arranged for the collection of daily samples on a year-around basis at selected sites of the principal rivers and for monthly samples at four of the Great Lakes. Ten daily samples were composited to provide a single sample for the determination of some fourteen different parameters and constituents. Parameters and constituents determined in Dole's water-quality monitoring program, 1906-1907, included: turbidity, suspended matter, total iron (Fe), silica (SiO_2), iron (Fe), calcium (Ca), magnesium (Mg), sodium and potassium (Na + K), carbonate (CO_2), bicarbonate (HCO_3), sulfate (SO_4), nitrate (NO_3), chlorine (Cl), and total dissolved solids.

Dole's data for samples collected east of the one-hundreth meridian during the period from September 1906 to September 1907 were published in 1909 as U.S. Geological Survey Water-Supply Paper 236 (Dole 1909).

Analysts during the first decade of the century used, with few exception, procedures outlined in WSP 236. They are summarized as follows:

1. Turbidity was determined with the Jackson electric turbidimeter for values over 100 parts per million (ppm). For values between 100 parts and 50 parts comparison was made with silica standards in 500 cc clear-glass bottles.

2. Suspended matter was determined by filtering from 100 to 500 cc through an asbestos mat and in a procelain Gooch crucible, drying for an hour at 180°C and weighing.

3. Dissolved solids were obtained by weighing the residue from the evaporation in platinum of 500 cubic centimeters (cc) of filtered water.

4. Silica, iron, and aluminum were separated from the total residue in the usual manner. The silica was weighed and volatilized with hydrofluoric acid.

5. Calcium and magnesium were determined in half the filtrate from the iron and aluminum precipitate. The calcium was precipitated as oxalate, dissolved in sulfuric acid, and filtrated hot with potassium permanganate. Magnesium was precipitated as ammonium-magnesium phosphate, dissolved in dilute nitric acid. Sodium acetate was added and the phosphoric acid filtrated with uranium nitrate, with potassium ferrocyanide indicator.

6. Sulfate and alkalies were determined in the other half of the filtrate. Sulfate was precipitated and weighed as barium sulfate. The sodium and potassium were not separated.

7. Nitrate was determined by the phenol-sulphonic acid method.

8. Chlorine was determined by evaporating 100 cc filtered water down to 25 cc, adding potassium chromate, and filtrating with silver nitrate solution.

9. Carbonates and bicarbonates were determined by filtration with fiftieth-normal acid potassium sulphate solution, using phenolphthalein and methyl orange indicators.

In 1906, the Division of Hydro-Economics changed its name to Division of Quality of Water, with R. B. Dole, chemist-in-charge.

During the life of the earlier organization (1902-06) practically no analyses, other than field assays, were made by Division facilities. The bulk of the analytical work was performed through cooperation with university and State laboratories.

Pollution studies continued to hold an important position until about 1912. On August 14, 1912 by act of Congress effective July 1913, the Federal Public Health Service was authorized to study sanitary quality. The Act sanctions investigations of: "---diseases of man and conditions influencing the propagation and spread thereof including sanitation and sewage and the pollution either directly or indirectly of the navigable streams and lakes of the United States."

During the period 1902-13 the Survey issued 100 reports containing information on water quality at which 33 were written by personnel assigned to water-quality activities. Of the 33 reports, about one half (16) were classed in the subject category stream pollution, purification, and waste disposal.and the bulk of the remainder (12) were area studies on water quality.

By the end of the first decade national interest in conserving water resources led to a summary report in 1909, WSP 234, "Papers on the conservation of water resources." Dole and Stabler's summary paper, Denudation, (p. 78-93) gave computations on the amount of dissolved and sediment transported by U. S. rivers, the areas tributary to the streams, and the quantity of water discharged to the oceans. Their carefully prepared estimates, 270 million tons of dissolved solids and 513 million tons of suspended sediment, were the forerunner of similar studies 50 years later during the International Hydrological Decade.

The results led Dole to remark, "Though this amount seems trivial when spread over the surface of the country, it becomes stupendous when considered as a total---."

Most of the chemical data were based on about 5,000 analyses by the water resources branch under Dole's direction. Daily samples of water were collected for one year and composited for 10-day periods for about 150 rivers and lakes in California and the States east of the one hundredth meridian. Sediment data were largely from records in the west of the U.S. Reclamation Service and in the east of the U.S. Corps of Engineers.

By combining solid but limited field observations of the principal U.S. rivers with experienced, intuitive judgment for the unmeasured runoff, Dole and Stabler produced an excellent summary of the national inorganic water quality situation.

The impact of industrial interests in water quality are clearly evident in Dole's comments in WSP 236, "The quality of surface waters in the United States, (1909).---" During the last twenty years the practical man has been obliged to modify his views, previously limited only by the quantity of available water by considering the part of his manufacturing cost that is due to the use of water unsuited to his processes.--The hygienic quality, as well as the physical and chemical characteristics in some industries such as starch making, brewing, distilling, and ice manufacture, but the industrial water problem is primarily a consideration of the minimal substances contained in the supplies."

Chase Palmer's report "The geochemical interpretation of water analyses" (USGS Bull. 479, 1911) considers dissolved salts in natural water as a chemical system of balanced values. With limitations the report was widely used by analysts for interpreting data well into the 1940's.

Concurrently, the Reclamation Service, like Hydro-Economics, a unit formed in the reorganization to the Hydrographic Division in 1902, was active in studies of western streams.

A systematic study of 55 western stream waters was begun by the Reclamation Service early in 1905 in order to determine the influence of the salinity of the waters on the growth of vegetation and the effect of suspended sediment in silting canals and reservoirs. After completion of the field study in May 1907, Herman Stabler, assistant engineer, compiled the results of analyses and the associated USGS stream flow data and computed daily discharge of suspended sediment and dissolved solids (USGS Water-Supply Paper 274, 1911).

The analyses were made in a laboratory established at quarters provided by the University of California at Berkeley, Calif.

Four-ounce water samples were taken daily at each of the regular stations. Occasionally samples were taken in the cross section to determine any variation in water quality. Equal volumes of the individual samples were composited to represent the average quality of each stream for a week, and analyzed quantitatively for total solids, dissolved solids, carbonate, bicarbonate, and chloride. Sulfate was determined qualitatively.

Remainders of the weekly composites were combined in sets of four representing the collections for a month. The monthly composites were analyzed for dissolved solids, calcium, magnesium, sodium, and potassium, carbonate, bicarbonate, sulfate, chloride, and nitrate.

Of the weekly composites 50 cubic centimeters was taken and total solids were determined by evaporating to dryness on a steam bath, drying for one hour at 110°C, cooling in a desiccator, and weighing. Solids were estimated on both filtered and unfiltered samples, and the difference between the two determinations was tabulated as suspended matter. For the period 1905-07, Rio Grande at San Marcial, N. Mex., Stabler compiled the daily discharge of water, in acre-feet, and the percent by weight of suspended matter, estimates of percent, by volume, of sediment for each day (assuming a cubic foot of sediment weighs 85 pounds). He extended this information to the period 1897 to 1908 and computed the mean annual sediment discharge for the period at the San Marcial station to be 6,110 acre-feet.

Stabler qualifies the accuracy of his estimates by stating, "The mean monthly values for discharge of water are probably not in error by more than 10 or 15 percent. The sediment determinations are probably equally accurate. The chief opportunity for error is--samples used for sediment determinations do not include material rolled along the bottom of the stream and that a single sample will not represent the true mean condition for the entire cross section,--monthly averages of the silt carried and the water-to-sediment ratio are likely to be correct within 10 or 15 percent. The yearly results and those for the entire period of 2 years may reasonally be expected to be still more accurate."

THE YEARS 1914 TO 1920

Studies in the next few years following 1913 were almost exclusively of the mineral content of water. This restriction was caused by lack of funds to cover a wider field and by the entrance of the Public Health Service into stream pollution investigations.

On January 2, 1918, the Division of Quality of Water was reestablished as an independent unit having been merged in 1910 with the Division of Ground Water, chiefly for administrative purposes. A. A. Chambers, was placed in charge of the Division of Quality of Water in 1918, and in January of that year the Survey established in Washington its first separate water analysis laboratory. C. H. Kidwell succeeded Chambers who resigned July 31, 1919, and in turn was succeeded by W. D. Collins as chemist-in-charge, July 10, 1920. Collins transferred from the Department of Agriculture, Bureau of Chemistry. A former member of the Hydro-Economics Division he had been with the Bureau of Chemistry from 1908 to 1920.

In the years 1914 to 1920 the Survey published 56 reports containing discussion or data on water quality. Eight reports discussed water quality on an areal basis describing the character and geologic environment of the waters and their suitability for use. Of two reports relating to mineral waters, one discussed radioactivity, and one compared the chemical character of American and European mineral waters (Swenson, personal communication).

THE YEARS 1921 TO 1946

GENERAL

With laboratory facilities under its control, the QW Division assumed full responsibility for analyses of water in its own investigations and additionally, other units of the Survey. Collins and his colleagues prepared many reports about industrial and domestic utility of water supplies, hardness, indices of analyses, water temperature, methods of analysis, and other contributions to hydrology.

In addition to the Division's investigations, analyses were made of the mineral content of waters for the Division of Ground Water and Geologic Branch. Kidwell used the "field kit," developed earlier by the Hydro-Economics Division for field tests of the Mississippi River, in 1919. Studies of methods were made and changes introduced in investigations of river waters reported in Water-Supply Papers 236, 237, 239, 273, 339, and 363. The number of analyses reported annually varied from 275 to 819 and averaged 477 for the period 1920 to 1928.

The suitability of the Nation's water supplies for public use and for agricultural and industrial purposes was stressed during much of this period. Many inquiries about the hardness of water led Collins to prepare an article, "Hardness of surface waters of the United States" which was published in the Journal of Industrial and Engineering Chemistry, December 1920. The article was based largely on the analyses in the earlier series of papers on the quality of surface waters.

The large number and persistent requests for more information and specific quality of water data prompted the preparation of WSP 496, "The industrial utility of the public water supplies in the United States," published in 1923.

This report included the results of 64 series of analyses, 190 complete, and 74 partial analyses by the Survey, State, and municipal water works and commercial laboratories. The data represented water supplies for 287 cities, each having a population in excess of 25,000.

A popular feature of the report was the hardness map based on the weighted average hardness, by States, of the water supplied to consumers in the cities included in the report. This illustration and later revisions have been widely used in magazine articles, in books, and in advertising literature relating to products whose distribution and use are affected by hardness of water.

An updated report, WSP 658, "The industrial utility of public water supplies in the United States, 1932," was issued August 21, 1934, reprinted four times and sold almost 8,000 copies--a record for Survey book publications on water quality.

Interest was growing in the early 1920's for information on temperature of the water in certain rivers on which sites for steam-power plants were available. F. H. Newell, now in private practice, came to Collins for data, and from waterworks officials the latter obtained temperatures of surface waters at 21 locations. Daily and hourly fluctuations of water and air temperatures are not equal, but Collins found reasonable agreement between the monthly mean water and air temperatures. He also compiled data on ground water temperatures. From a study of more than 3,000 records C. E. Van Orstrand, Geologic Branch, concluded that under normal conditions the temperature of ground water obtained at a depth of 30 to 60 feet will generally exceed by 2° or 3°F the mean annual air temperature. Data were published in WSP 520-F and issued in 1925.

A growing body of water-quality data by State and other agencies was scattered in State publications and technical journals. For a quick reference to these information sources, Collins compiled an index of analyses of natural waters in the United States (1925).

The Survey had no continuing program for the measurement of sediment in streams until 1925 when work under the direction of C. S. Howard began in Arizona on the Colorado River where increasing attention was being given to the study of Colorado River flow and its utilization. Storage reservations were needed. The large sediment load transported by the stream affected the life of the reservoir, and data were necessary for design plans.

An earlier study by Herman Stabler of sediment transported by the Rio Grande was published in 1911 (WSP 274). Stabler's study and similar early sediment investigations in other parts of the country were brief, reconnaissance type. He proposed the study of the Colorado River and Howard made a trip to the basin in 1925, and arranged for the resident engineers at the Tapock and Grand Canyon gaging stations to obtain samples for determinations of sediment content and chemical analysis. The Reclamation Service took samples at the Yuma station. For the Topock and Grand Canyon stations, Howard fashioned a sediment sampler designed to be attached to the meter cable which consisted of a metal frame holding a milk bottle. The sampler was lowered to the desired depth and a small weight allowed to slide down the line until it struck the sampler arm, forcing knife edges to puncture the paper cap on the milk bottle, and allowing water to enter the bottle.

Except at shallow depths the hydrostatic head would sometimes break the paper seal allowing water to rush into the bottle. This problem was overcome by using a rubber stopper as a closure which could be extracted by a following-weight technique.

Generally samples were taken at each of three points in the cross section--at the bottom, 1-foot below the surface, and a so-called average sample, where the bottle was lowered to the bottom, the cap punched, and the bottle drawn up at a rate that would allow filling when the bottle surfaced.

All analyses for chemical and sediment content were made in the Washington laboratory. Sediment samples numbered 539--which disclosed only the suspended sediment, there being no known method by which the bed load or material rolled along the bottom of a stream could be measured.

Howard, in direct charge of the investigations, attempted to approximate the amount of bed load at the Grand Canyon stations by taping the pint milk bottles to the fins of the weights on the sampler so the bottles would be near the bottom with their mouths pointed upstream. Care was taken to avoid stirring up mud when the weight touched bottom. The mean of 16 samples collected in this way was about 35 percent higher than the mean of 10 samples collected in bottles.

Chemical data for 1925 and 1926 were published in WSP 596-B, 1928 and sediment data for the years 1925-28 appeared in WSP 636-B, also published in 1928.

The Washington office roster during the period July 1, 1919 and June 30, 1928 included at various times the names A. A. Chambers, C. H. Kidwell, Margaret D. Foster, Addie T. Geiger, Nathaniel Tuchs, H. B. Riffenburg, C. S. Howard, W. D. Collins, and S. K. Love. Annual support for Division work during the years 1920-28, almost entirely from Survey allotments, ranged from $7,850 to $14,400.

Increasing interest in quality of water supplies for industry, and the continuation of sediment studies of the Colorado River boosted the Quality of Water Division activities several-fold during the period 1929-1939. Annual amounts of funds from all sources ranged from $15,000 to $66,876 during the period.

The total number of analyses, another measure of the Division activities, was 20,900 for the period 1928 to 1939 as compared to 4,300 for the period 1919 to 1928.

During the period 1929 to 1939 W. D. Collins continued as Division Chief and C. S. Howard as his principal assistant.

LABORATORY FACILITIES AND METHODS

Fluoride interest: The occurrence of the dental effect known as mottled enamel was established in 1930 when physiological chemists at the University of Arizona fed experimental animals residues from evaporated drinking water from St. Davids, Ariz., where mottled enamel was prevalent. They successfully correlated the occurrence of fluoride in the water with mottled enamel.

The Survey became interested in fluoride analyses when examination in the laboratory of the Aluminum Company of America of a new public water supply from deep wells at Bauxite, Ark. revealed excessive concentration of fluoride. Children using exclusively water from the new supply began to show the effects of mottled enamel in a few years.

Margaret Foster developed a method for determination of fluoride, an adaptation of one used by the Aluminum Company, and was found generally reliable by the careful analyst. But the method was not used much by other laboratories and, in 1941, Lamar and Seegmiller published a version of the most generally used method. This improved method was adopted in the Water Resources laboratories and was published by Lamar in 1945 (Analytical Edition Industrial and Engineering Chemistry, Vol. 17, p. 148-9, March 1945) with slight revision based on laboratory experience.

About the time that Foster began using the fluoride method, there was opposition to the use of Colorado River water on the premise that it would cause mottled enamel on the teeth of Los Angeles residents. Survey records showed that the Colorado River water almost never contained as much as 0.5 ppm of fluoride, generally considered the safe upper limit to avoid mottled enamel. The fact quieted the fears of Los Angeles residents.

Electrical conductivity: Following the practice of the Department of Agriculture for measuring electrical conductivity of waters and soil solutions, the Survey continued this procedure in the Rio Grande Joint

Investigation, begun in 1936, and subsequent studies in the Southwest. Conductivity is computed from the measurement of the electrical resistance between two platinum electrodes immersed in water. Breakage of the glass cell was common in course of field measurements. C. S. Howard and R. L. Atkinson of Survey's Division of Field Equipment developed a cell made of lucite and eliminated this trouble.

Laboratory instruction: Inexperienced chemists on a WPA project in Monroe County, N.Y., attempted to make complete analyses of water samples, and the analyses were found to be of little value. Lamar went to Rochester in August 1934, gave instruction, and returned a few months later to observe excellent results including the Survey method of performing partial analyses.

In the spring of 1936 a chemist of an eastern State Geological Survey wrote the Survey requesting instructions for analyzing brines. After a few months of unsuccessful effort with brine determinations in his laboratory, the analyst called Margaret Foster for a month's instruction in the State laboratory using Survey procedures.

The need for adequate supervision appeared in other WSP projects, a part of the difficulty being that in some cases the original plan proposed a larger volume of analytical work than should have been expected from the available personnel and supervision. In the struggle to maintain the schedule, accuracy was sacrificed. As part of continuing ground-water studies in Texas, the Survey sponsored a WPA project for obtaining well data, water levels, and water quality. Chemical studies were done by a WPA group not experienced in water analysis. Results of a large amount of work were wanted speedily and some of the analyses, when checked in Washington, were found to be seriously in error.

In order to bring all the work on the project up to the standard of the best of it, Lohr and Collins went to Austin in October 1937 to confer with State and Federal personnel interested in the project. Lohr undertook some of the analytical load with such assistants as he could employ directly, a system of checks and duplications was set up for handling the mass of WPA samples, and he inspected all results before they were released. He remained there after June 1939, able to give more prompt service than could be given by the Washington laboratory (Water Resources Bulletin, Aug. 10, 1937).

Decentralization and regional laboratories: The first step in decentralization which took place during the period since World War II occurred in 1942. Limitation on Washington Office salaries required that some Washington Office personnel be transferred to permanent field headquarters. One of the principal areas of operation was the Colorado River, Rio Grande, and Pecos River basins in the Southwest. C. S. Howard was in charge of the investigations, and his headquarters were moved to Albuquerque, N.Mex., in July 1942. The location was selected as central to operations and because laboratory space was made available by the United Pueblos Agency.

The space provided has been described as resembling a hay loft, but it was standard procedure during the period to improvise with such benches, tables, and other special chemical laboratory equipment were rarely available in acquired space.

Howard's territory included all that west of the Mississippi River and west of Texas. When the Missouri River basin Departmental Program began in 1946, that area was placed under the responsibility of the newly established Lincoln Office. When the Fayetteville Office was established in 1945, the Arkansas studies were assigned to it.

A permanent laboratory was established in Austin, Tex., in 1937, and a temporary laboratory was maintained at Pecos, Tex., from Aug. 1, 1939 to June 30, 1941 as part of the Pecos River Joint Investigation.

Temporary laboratories were maintained at Roswell, N.Mex., from 1937 to June 1943 and at Safford, Ariz., from July 1940 to March 1945. J. D. Hem succeeded Howard in charge of the facilities.

Additional State cooperation made it possible to establish laboratories in rapid succession: At Raleigh, N.C., September 1943 and at Charlottesville, Va., July 1945, both in charge of W. L. Lamar; at Fayetteville, Ark., September 1945, in charge of I. W. Walling succeeded by G. A. Billingsley; and at Stillwater, Okla., in July 1946 in charge of I. W. Walling. Both the Fayetteville and Stillwater facilities were under the general supervision of W. W. Hastings at Austin, Tex.

In September 1946 a laboratory was established at Philadelphia, Pa., in charge of N. D. Beamer under the supervision of W. F. White and a temporary facility was maintained at Miami, Fla., from February 1940 to September 1942.

FEDERAL-STATE COOPERATIVE PROGRAMS IN THE 1930'S

Cooperation was arranged with four States during the 30's highlights of which are as follows:

Virginia: The progressive State Commission on Conservation and Development, in 1929, cooperated with the Survey in a two-year study of the quality of the States' waters. Ten-day composites of daily samples were obtained at 16 gaging stations the first year and 17 stations the second year. Together with high and low flow samples, a total of 1,340 complete analyses were published in State Commission on Conservation and Development Bulletin 3. Collins described this as "The most comprehensive and adequate report so far published on the industrial quality of surface waters in a State."

Funds expended were:

Year	State	Survey
1930	$5,089	$1,839
1931	4,967	4,500

Georgia: Cooperation with the State Division of Mines, Mining, and Geology began March 1, 1937 initially with daily sampling at gaging stations and the analytical work performed in the Washington laboratory. Within the year W. L. Lamar the project leader, found a shift in interest to public water supplies for industry. He reduced the river sampling program, visited 66 cities and towns and arranged for shipment of samples to the Survey.

Concurrently, ground-water supplies of Savannah had become seriously depleted and the city proposed additional water from the Savannah River which is tidal in its lower reaches. The Survey was urged to study the extent of salt-water penetration to determine the location of the proposed intake--a unique study at the time.

A laboratory was established in a storeroom in the Savannah post office. Lamar arranged for sampling to cover the greatest salinity during daylight hours daily - during some tide cycles every half hour or hour for a period of 28 hours. Although computations were not completed for the period December 1, 1937 to November 30, 1938, Lamar published a summary of the work in Transactions, American Geophysical Union, 1940, p. 463-470.

Funds expended were:

Year	State	Survey
1937	$ 889	$2,197
1938	5,711	4,357
1939	3,376	3,617

New Mexico: Studies of the Rio Grande waters which were planned for discontinuance in January 1937 were placed on a reduced scale for the remainder of 1937. The reductions included were electrical conductivity and 10-day composites of daily samples for three mainstem stations, weekly samples at two other sites, and at seven places on tributaries.

An investigation of the source of salinity in the Pecos River begun in April 1937 by the Ground Water Division resulted in a separate agreement with the State Engineer and the Quality of Water Division. C. S. Howard organized the analytical work with headquarters first at Carlsbad, then Roswell where laboratory space was provided at the New Mexico Institute. W. F. White, Jr. was in charge of the laboratory. Begun in July 1937 the study later merged with the Pecos River Joint Investigations.

One notation concerning the field studies was that local field observers hired to obtain daily water samples were generally reliable. Occassionally, however, daily conductance measurements of the samples at the laboratory indicated identical samples, when, in fact, chemical concentrations were changing rapidly. This would indicate that several samples were obtained on the same day. A reminder to the observer usually sufficed to correct the situation, but some observers had to be replaced or the station abandoned. The situation was not unique to this study.

Funds expended were:

Year	State	Survey
1937	$ 1,139	$ 2,288
1938	12,000	10,593
1939	10,000	10,070

Connecticut: A study of the intrusion of sea water in ground-water supplies in the tidal reaches of the Connecticut River begun in 1933 by the Ground Water Division resulted in a cooperative agreement with the State Water Commission. A comprehensive salinity study of the river to cover tide and stream-flow conditions was made under Howard's direction from 1934 to 1939. With unlimited supply of WPA assistance in sampling and laboratory analysis, about 150,000 water samples were obtained and the results published in mimeograph form by the State Commission under the title, "The salinity of the Connecticut River," October 1, 1934 to Sept. 30, 1937, Bull. S.1.

Funds expended were:

Year	State	Survey
1938	$700	$609
1939	550	552

FEDERAL PROGRAM IN THE 1930'S

The Division was called upon for cooperative studies by numerous Federal agencies beginning in 1933. Through the period 1933 to 1939, cooperative Federal funds ranged annually from $700 to $26,700. The following is a capsule description of some activities.

Public Works Administration: In addition to Public Works Administration (PWA) support of sediment measurements for streams on eight Soil Conservation Service projects, the Division made a study of temperature and chemical conditions in the vicinity of Warm Springs, Ga. Lamar arranged for field and laboratory analyses in Washington.

In 1935 PWA referred a sample from a well under consideration to supply a small western town with water. When analyzed for fluoride by a method modified by Margaret Foster for use by the Survey the water contained excessive fluoride, sufficient to cause mottled enamel of children drinking the water. As there was no practical method then known to remove the fluoride the project was rejected in favor of one providing a surface supply.

Indian Service: Expenditures of $2,000 were made in 1937 for the Rio Grande Joint Investigation.

Soil Conservation Service: Equipment was furnished by the Division for measurement of sediment in streams on eight soil erosion projects, funded chiefly from PWA funds from 1934 to 1937. Thereafter Soil Conservation funds were used. Sediment analyses supervised by the Division were made at laboratories on each project and the results discussed with officials.

In describing this work Collins insisted that the weight of transported material would be good enough to show any differences as great as 25 percent, but that changes of 2 or probably 5 percent in the measured loads might easily be due to experimental uncertainties.

Flood Control Coordinating Committee: First of two projects with the Flood Control Coordinating Committee was on the Boise River, Idaho beginning November 1938. A project laboratory at Boise for analysis of sediment occupied space in a rented store and was frequently mistaken as a milk station owing to numerous cases of samples in milk bottles. H. A. Swenson was the analyst under supervision of S. K. Love.

A second, temporary project was started in February 1939 on the St. Francis River, and a few sediment samples were analyzed in a local laboratory at Rolla, Mo.

National Resources Committee: As early as 1936 the National Resources Committee attached importance to a national base of water quality. It recommended that 200 base stations should be established for determinations of mineral content, oxygen, and sediment load and be maintained at existing gaging stations for at least 10 years. Additionally, at least 400 secondary stations should be operated each year for a one-year period, their locations to be changed annually. The Committee's recommendations for funds were not approved by Congress and the proposed program was deferred. (Deficiencies in basic hydrologic data: Nat'l Res. Com. Sept. 1936, p. 37).

Public Health Service: In 1938 the Public Health Service made an investigation in Giles County, Tenn. and Coffee County, Ala. to determine whether natural conditions were a factor in the differing death rate from tuberculosis in the two counties. Margaret Foster was assigned to the project. She inspected water supplies, and analyzed more than 400 water samples, and found no relation between quality of water and the incidence of tuberculosis.

National Park Service: Analyses performed in Washington of waters proposed for use at Shenandoah National Park camp or cabin sites were so corrosive that prior treatment was required before the water could flow through the planned copper pipeing.

Other Federal agencies such as the Federal Housing Authority also consulted the records and publications of the Survey in connection with specifications for plumbing supplies for housing projects or other structures. During the hectic days of Public Works Administration (PWA) there were many applications for grants and loans for water works projects. After completion of some projects, revenue from water sales did not materialize from prospective consumers who chose not to use the supply owing to undesirable quality such as the excessive iron in the water. In order to determine the cost of water treatment, the Reconstruction Finance Corporation (RFC) required knowledge of water quality and its probable chemical action on metals which are used in well equipment and pipelines. The Survey furnished this information.

During the period 1928-29 analytical procedures continued along conventional lines following Water Supply Paper 596(h) which was published in 1928.

An improved procedure for determining fluoride was developed, and specific conductance as an aid for preliminary examination of the mineral content of water was use more prevalently.

Veterans Administration: During 1947 the Veterans Administration entered into an agreement with the Survey to analyze, chiefly for corrosion and scale, the water supplies for Veterans hospitals. Funds amounted to $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, July 1, 1946. The State Department allotted $3,400 for sediment studies.

Boise River Investigation: The Boise River investigation was one of several cooperative studies with either the Soil Conservation Service or the Flood Control Coordinating Committee of the Department of Agriculture. It became a key study for obtaining sediment records which led eventually to the Survey's development of improved equipment and standardization of field and laboratory methods.

Placering in the Boise River drainage area was the "cause celebre" for studying the effects of gold dredging in Moore Creek and other Boise River tributaries. The U.S. Department of Agriculture wanted to find out how much sediment in the streams resulted from dredging. So, in January 1939, measurements of discharge were obtained at 13 sites, locations of which were selected by the Soil Conservation Service to show the effect of placered, burned, cutover, virgin timber, and range areas in three different stages of depletion. All stations were equipped with recorders and some had broad-crested controls. When the flow was too small to be measured by current meter, a portable weir was used.

P. C. Benedict was in charge of the project under T. R. Newell's supervision. The development of sediment sampling equipment, sample collection, and analysis were directed by S. K. Love. H. A. Swenson maintained a temporary laboratory in Boise from July 1939 to October 30, 1946.

Ken Love came to Boise in the fall of 1939 having previously shipped Colorado River sampling equipment including the brass bucket sediment sampler. After getting the first stations operating, Benedict (personal communication, Nov. 4, 1977) decided that the brass bucket sample was of no value for natural shallow streams. After he explained to Love, the "physics of the System" as he viewed it, Love agreed that the changes were justified. After returning to Washington he was able to convince W. D. Collins of the situation and that it was time for a change.

In June 1941 Mr. Benedict was transferred to Iowa City to do research work on the Federal Inter-Agency Sediment Project and other field streamgaging assignments.

The field group under Benedict was innovative in the design of artificial controls and gage houses, operation of both stream flow and sediment stations, and most important, the development of sediment sampling equipment. The field group pinpointed and documented sources of sediment and deposits of sediment in drainage pools, as well as in Arrowrock Reservoir.

Frequency of sampling depended upon the changes in sediment content. During spring runoff, samples were obtained from 3 to 12 times daily and more frequently on 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 were determined by measuring with a planimeter the areas under the graphs. During periods of low uniform flow and low sediment content, daily loads were computed from daily samples and the average discharge for the day.

A total of 43,900 sediment samples were obtained at the 13 stations. Field work was completed June 30, 1940 and the results of the study were published as WSP 1048, "Discharge and sediment loads in Boise River drainage basin, Idaho."

One valuable conclusion was that a systematic study should be made of all sediment sampling equipment--not only USGS equipment but that of all Federal agencies.

Pecos River Joint Investigation: The Pecos River Joint Investigation was a continuation of that which started in 1937 in cooperation with the State of New Mexico, and was mostly confined to the New Mexico portion of the Pecos River basin. W. F. White was in charge of the laboratory at Roswell. Additional work in the Texas portion of the Joint Investigation was performed in the laboratory at Pecos, Tex., established August 1, 1939, W. W. Hastings in charge.

The program included daily sampling at 16 gaging stations on the highly mineralized Pecos River and less frequently at intermediate places. At Red Bluff, N.Mex., twice-daily sampling was necessary because of marked diurnal variation as salt water entered the river below Malaga Bend.

Many wells were sampled to determine the quality of ground water available for irrigation and in relation to low flow of the river.

The Joint Investigation ended June 1941. Thereafter quality of water studies were continued on a reduced scale in cooperation with New Mexico and Texas.

The Roswell laboratory merged with the laboratory at Albuquerque June 16, 1943, and the Pecos laboratory continued until June 30, 1941 when a small amount of analytical work continued at Austin.

Gila River investigation: An inventory of inflows and outflows of water and solutes in the irrigated Safford Valley was begun in 1940 and a laboratory was set up in Safford in July of that year, with J. D. Hem in charge. During the ensuing two years the laboratory analyzed about 2,000 samples, not only from the Safford Valley but also from other areas in Arizona that were being investigated by the Ground Water Branch at that time. At the completion of the Safford Valley study the laboratory was closed, in June 1942.

With financing by the Defense Plant Corporation, a more intensive study of water quality and availability in the Gila River Valley above San Carlos Reservoir was begun in 1943 and the Safford laboratory was reestablished in June of that year, again with J. D. Hem in charge. A large expansion of copper mining and smelting operations at Morenci had begun to meet war-related requirements for the metal, and additional water supplies were needed. The earlier Safford Valley studies had indicated that clearing of native vegetation, mainly salt-cedar, which grew luxuriantly along the river, might salvage substantial amounts of water. The laboratory analyzed about 5,000 samples before the project was terminated at the end of 1944, and the laboratory was closed and merged with the Albuquerque facility early in 1945. Hem later wrote (personal communication, Sept. 23, 1977):

"The close integration of chemical quality studies with other aspects of ground and surface water hydrology that characterized the Safford laboratory operation was unique in its day. Techniques and approaches for geochemical interpretation of water quality data that were first devised there have strongly influenced the subsequent development of science."

Colorado River Investigation: Study of the chemical quality and suspended sediment in the Colorado River, begun in 1925, and continued throughout the 1930's. Bright Angel Creek near Grand Canyon Ariz., was the key station because excellent discharge records and cooperative resident engineers made it possible to obtain a reliable record of chemical quality and suspended sediment. The basic plan for the study at each station included the collection of daily samples for chemical analyses, sediment, and adequate measurements for computation of the suspended-sediment load (Water Resources Bulletin, May 10, 1939). For 4 years ending September 30, 1935, analyses were made of composites of daily samples from the Colorado and Gunnison Rivers at

Grand Junction, Colo. Daily samples were collected at Lees Ferry for 2 years ending September 30, 1930. Data revealed little difference in composition of the Colorado River water from Bright Angel Creek to Yuma. The Topock and Yuma stations were discontinued September 30, 1928.

Daily sampling from the Colorado River at Cisco, Utah and the Green River at Green River, Utah was begun October 1, 1928 and was discontinued September 30, 1935.

As construction of Boulder Dam progressed, it became desirable to check again the relation between the composition of the water at Bright Angel Creek and at Topock and the latter station was reactivated October 1, 1932. On July 1, chemical quality studies began at the Colorado River, Willow Beach, Ariz., station, and continued through June 1939.

Now some disturbing features began to show in the stratification of Lake Mead when at times turbid water was released. At first these occurrences were attributed to work progressing behind the dam, but later observations showed that at times turbid water was flowing 70 to 80 miles through the lake under the clear water and coming out through the tunnels at the dam. N. C. Grover and C. S. Howard discussed this observation in a paper published in the Proceedings of the American Society of Civil Engineers, April 1937, and this was followed by lively discussion from 18 contributors (Trans. Am. Soc. C. E., vol. 103, p. 720-790, 1938).

Interest aroused by this contribution led the Division of Geology and Geography of the National Research Council to establish a committee on density currents to coordinate the efforts of various agencies concerned with the study of stratification and currents in lakes. Examination of water from different depths at various places in Lake Mead has been part of the Colorado River studies since 1937.

Prior to the construction of Hoover Dam, it was assumed that water in the reservoir behind the dam would be well mixed and that users of water would consistently receive water having a chemical composition shown by the weighted average analyses of that passing the Bright Angel Creek station. For the 5-year period ending September 30, 1930 the weighted average dissolved solids was 571 ppm. (USGS Water Supply Paper 638, p. 145-148).

Beginning with the closing of the dam, February 1,1935, the composition of the river water at Willow Beach and Grand Canyon was similar until July when the inflow water became more concentrated than the outflow. By October 1935 the outflow began to increase progressively from 290 ppm of dissolved solids during September 21-30, 1935 to 890 ppm February 1-10, 1936. This was followed by a decrease to about 400 ppm by July 11-20 where it remained until October 1-30, 1936. Then dissolved solids increased to 750 ppm, January 11-20, 1937 where it remained in the range 700 to 750 ppm most of the time.

The 25 to 30 percent higher than expected dissolved-solids content was a serious matter to users of the water and also, in the cost of water treatment. The experience at Lake Mead altered the procedure for forecasting water quality from a large artificial lake.

A noteworthy observation in the Colorado River studies occurred during the summer of 1929 at the station San Juan River near Bluff, Utah. Following heavy rains, S. K. Love took the series of samples in the section that gave an average of 42 percent of suspended sediment--one of the highest of reliable known values.

Annual expenditures for water quality studies for the period 1929 to 1939, paid from annual appropriations for the Colorado River stations, ranged from $2,000 to $10,297.

In the 1940's chemical quality studies in the Colorado River basin expanded as users of water in the lower basin grew conscious of the need for water-quality information. Transmountain diversions out of the headwaters areas of the basin were anticipated and concern was expressed about the detrimental effect on the quality of the water available in the lower basin.

By June 1947 chemical quality studies had extended to 8 locations on the Colorado River mainstem, and 6 stations on tributaries including the rivers Gunnison, San Juan, Animas, and Eagle.

Analyses of daily samples were performed in the Washington laboratory and in Albuquerque after that laboratory was established in July 1942.

Annual Federal funds available were:

1940	$9800
1941	$9720
1942	$9620
1943	$10,780
1944	$11,800
1945	$14,000
1946	$12,400
1947	$29,000

Of the many Colorado River basin personalities who provided local color and hospitality for U.S. Geological Survey field parties Norman Nevills, Mexican Hat, N. Mex., is legendary for his boat trips down the San Juan River.

Paul Benedict (personal communication, "Tall tales from the San Juan River") describes one boat trip that he and Charlie Howard made with Mr. Nevills on May 10, 1943 from Bluff to Mexican Hat, N. Mex., a distance of about 30 miles:

> "The sand waves were getting higher and the water getting faster if anything. We glide around several more bends and there dead ahead is a high cliff with the current striking it at nearly right angles; woe is me. Norman grins and says, "If you hit this spot just right you can land in the slackwater pool, otherwise the boat is piled up against the cliff and turned over." I should mention here that the boat moves downstream generally at right angles to the direction of the current. In other words, the rowing is usually towards one bank or the other. The velocity picks up, Norman grins and makes a few leisurely strokes toward the right bank. I find myself eyeing the "Mae West" in the bottom of the boat and wondering how to manage it and the camera just in case the boat hits the cliff. Just about the time I am convinced that this boat ride is all a mistake, Norman goes into action and the boat shoots into the slackwater about 30 feet from the face of the cliff. The water was moving at 10 to 12 feet a second, Charlie didn't turn around so I can't say just where his stomach was. Then to impress us as to just how good he was, Norman let the boat, at right angles to the current now, almost scratch the cliff. Charlie began to shift around a bit as it was his end of the boat. We both admitted that he was very good but it was too cold in the shade of the cliff. Norman is happy now that he has really demonstrated to our satisfaction(?) that he can handle a boat in any kind of water and still keep us dry. I must admit that I am still just a bit dubious at this time. -- We glide on with the canyon walls getting steeper. Can't say as to Charlie's thoughts but I'm wondering how many more right angle turns there are between us and the "Hat".

"Now and then we had been hearing a definite hissing or crackling noise. We hadn't given it too much thought--now it was louder and definitely of considerable moment. Norman grins and explains that sometimes the bottom of the boat gets loose and breaks up. After this comment has created its maximum effect he further explains that it is the sand moving past the bottom of the boat or vice versa. Several attempts were made to collect samples just below the bottom of the boat with a gallon bucket in order to determine if the particle size was any larger than normal. The resulting samples did not lead to any conclusions as it was impossible to collect them satisfactorily with the equipment at hand. Apparently the movement of the boat in relation to the velocity of the water was slow enough to create flow underneath it and the sand particles in suspension made the noise as they moved over the bottom surface. The fact that the hissing noise only occured now and then with no regularity or similarity of surface conditions indicated that the sound was produced by a particular type of flow condition which could not be described by surface observations.

"After several more nice and easy turns we come to a straight stretch of channel with some extra-super sand waves in the distance. By this time both Charlie and I had gotten to a point where we rather "relished" riding the boat over the top of said waves. Also, it was almost heartbreaking for Norman to go by without going over the crest, so with slightly enforced exuberance we committed ourselves to the whims of the ever-rolling San Juan. The boat was performing nicely, and needless to say I was holding on with both hands, when without warning Norman started to turn the boat parallel with the current. The waves were at least 4 feet high and on looking downstream there was a 6-footer just about to break. When we hit it, the boat was parallel to the current and Charlie took the crest of the wave with no more than a shudder and a look as to the necessity. Norman explained that since he agreed to take me down "dry" it was necessary to turn the boat or the wave would have broken over all three of us, and of course I cheered lustily at such a adept handling of the oars, while Charlie wiped the water off his glasses. After this last wave we passengers felt equal to what might come assuming the waves did not break over the boat."

Rio Grande Joint Investigation: The Rio Grande Joint Investigation, planned in 1936, enlisted the services of all Federal agencies concerned with water for irrigation. The water from many irrigation drains entering the river progressively increased the salinity of the water downstream. The Bureau of Plant Industry was assigned the analyses of waters for salinity at the Bureau's Rubidoux laboratory at Riverside, Calif., and the Survey made many of the electrical conductivity measurements in field laboratories at Albuquerque and Alamosa, N.Mex., and at the Washington laboratory - all under supervision of C. S. Howard.

More than 5,000 measurements were made in Colorado and New Mexico, and the Rio Grande data were published in WSP 839. As Collins expressed it, the results "went in with others to build up the picture which resulted in the section of the Rio Grande Compact defining limits of chemical character beyond which water would not be water." Article III of the Compact states "In event any works are constructed after 1937 for the purpose of delivering water into the Rio Grande from the Closed Basin, Colorado shall not be credited with the amount of such water delivered, unless the proportion of sodium ions shall be less than forty-five percent of the total positive ions in that water when the total dissolved solids in such water exceeds three hundred fifty parts per million."

OTHER SIGNIFICANT EVENTS

In 1932, responding to the interest in the index of analyses of natural waters in the United States published in 1925, Collins and Howard prepared an updated supplement for the period 1926-1932. WSP 659-C included indexes of analyses of surface and ground waters and so-called mineral waters. Regarding the latter Collins writes: "For many of the best known of these waters there is nothing in the analytical results to suggest any explanation for their supposed remarkable characteristics.--Many of the statements regarding the therapeutic properties of the waters appear to have been taken from the authors of the books from advertising circulars--and have not been confirmed by observation and experience of the authors."

Thermal springs: Springs of Virginia, particularly hot springs, were of special interest to the State Geologist during the period. The Virginia Hot Springs Co. contributed $2,000 to the State Geological Survey for analyses of Hot Springs and elsewhere in Virginia and spent an additional $2,000 for a gaging station, recording temperature, and an apparatus for measuring radioactivity of the waters at Warm Springs.

Beginning February 1928 Frank Reeves, Geologic Branch, visited 337 springs in the southern part of the "Great Valley," he noted geologic formations, estimated flows, measured temperatures, and obtained samples. R. P. Meacham visited 229 springs in northwestern Virginia. From this field work 527 analyses were made by Margaret Foster during 1929 to 1931, and the results published by the State Commission on Conservation and Development as Bull. 1, "Division of water resources and power, springs of Virginia, 1930" and Bull. 36, "Virginia Geological Survey, thermal springs of Virginia."

Collins and Lamar measured the radioactivity of the waters of the springs and found them in agreement with observations by the Bureau of Chemistry, 1911. Collins states, "The waters were slightly more radioactive than most ground or surface waters. The radioactivity was, however, much below the limit commonly reported to have any physiological effect, either good or bad."

California surface waters: Extensive irrigation development occurred in California following the Survey's 1906-1908 investigations of water quality. In 1930, Edward Pyatt, State Engineer, under the general cooperative agreement, requested the Survey to make a preliminary investigation to determine any changes in the quality of surface waters. A total of 145 samples were obtained at 69 places on 56 streams and sent to Washington for partial analysis by the Survey.

The Survey's report containing these data (Calif. Div. of Water Resources: Bull. 29, appendix E, p. 637-8, 1931) stated: "These partial analyses are almost as valuable as complete analyses for single samples of surface waters--they give reasonably clear indication of changes or lack of changes in composition of the water since the earlier work was done."

Following these investigations, the study was continued with twice-weekly sampling of Sacramento River at Sacramento, July 20 to December 31, 1931 and weekly from January to July 1932. Complete analyses were made in Washington, probably with some greater accuracy because analytical methods improved over the 25-year period.

For some streams no change in quality was noted, but for others material change had occurred. Costs for the Sacramento River study, $1,500, came from surface water funds allocated for cooperation with the State Engineer and transferred to the Quality of Water Division.

Foreign water supplies: In 1932 and 1933 S. K. Love compiled material on foreign water supplies which was obtained largely in 1925 through a questionnaire sent to all consular offices through the cooperation of the Department of State. Analyses, expressed in many different units and styles, was obtained from all but three countries - USSR, Germany, and Japan. At that time, the United States had not recognized the current government of USSR and had no representative there. Officials of Germany and Japan were unwilling to supply the detailed information requested because of its military significance. A principal source of information was published journal-articles describing improvement in public water supplies. The information was not published but was used extensively by the Survey Military Geology Unit and by other Federal agencies before and during the participation of the United States in World War II.

The number of technical personnel on the Division roster increased from five in 1928 to 16 in 1939.

FLUVIAL SEDIMENT STUDIES

The following discussion is based on Robert Follansbee's, "A history of the Water Resources Branch of the United States Geological Survey" (vol. 4, p. 367), which describes in detail the increasing attention being given by Federal agencies to the sediment loads in streams and the events surrounding the development of sampling equipment.

The accuracy of the sediment load computations depended partly upon the degree with which the sediment samples gave a true measure of the sediment in the stream cross section at the time of sampling. But no standard type of sampling equipment had been devised. The Survey was using the so-called Colorado type and other agencies had their own samplers. There was no standard method for determining sediment concentrations or for computing sediment loads.

In 1939, Gail Hathaway, Special Assistant to the Chief of Engineers, USA, asked Prof. E. W. Lane of the University of Iowa Hydraulic Laboratory, Iowa City to make a study of the various types of methods in use, and to develop satisfactory equipment for various conditions. Prof. Lane agreed to undertake a research project and to guide that research. An interagency committee consisting of representatives from the Army Corps of Engineers, Bureau of Reclamation, Tennessee Valley Authority (TVA), Soil Conservation Service, and Office of Indian Affairs was formed in 1939. At first, the project was actively participated in by personnel of the Army Corps of Engineers, Soil Conservation Service and the Geological Survey. Later, the Bureau of Reclamation and TVA detailed men to the project. Prof. Lane guided the study until the summer of 1942 when he left the Hydraulic Laboratory. Thereafter the development work was carried on by P. C. Benedict of the Survey and Martin Nelson of the Army Corps of Engineers. Benedict devoted half time to the joint investigation until he was transferred to Lincoln, Nebr. to head the Quality of Water Division's participation in the Missouri River Basin Program in March 6, 1946. He was succeeded by B. C. Colby who completed certain phases of study for the Army Corps of Engineers and the Survey.

The first phase of the 4-year investigation was a review of field practices and the equipment used in sampling suspended sediment. More than 50 samplers used in the United States and foreign countries and current field practices were studied. The results were published by the Army Engineers as Report No. 1, "Field practice and equipment used in sampling suspended sediment, August 1940." It formed the basis for the subsequent investigation.

Report No. 2 "Equipment used for sampling bed load and bed material, September 1940" showed that it was nearly impossible to develop a bed load sampler for streams having channels. There was greatest concern to the cooperating agencies but no work was done on a bed load sampler.

A study of the various sampling methods in use was made to determine their interest errors when used in streams where the sediment concentrations and velocities vary between the surface and stream bed. The results were published as Report No. 3, "Analytical study of methods of sampling suspended sediment, November 1941."

There was a lack of uniformity in the methods to determine concentrations of sediment in the samples as was shown by Report No. 4, "Methods of analyzing sediment samples, November 1941."

With the background of existing samplers and the study of sources of error, the next step was to eliminate by laboratory tests the sources of those errors. Principal sources were (1) 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.

To meet the wide range of field conditions, two types of samplers were needed, one, the depth-integrating sampler would obtain an integrated result as the sampler was moved uniformly from the top to the bottom and returned, and the other a point sampler to be held at a fixed position in the vertical. The depth integrater was the more complex and it was started first, early in 1941. From working drawings, plaster models were made until size and shape appeared satisfactory. A metal sampler was constructed, subjected to exhaustive laboratory and field tests and the procedure repeated until a fifth model was completed early in 1943.

In May 1943, 10 test models were distributed among the Office of Indian Affairs, Bureau of Reclamation, Army Corps of Engineers, and Survey offices for comparisons with existing samplers. Reports received from 13 field offices indicated a satisfactory performance for average conditions but some modification was needed for extremes of depth and velocity. Some discrepancies in results were noted, due in part to the sampling methods, and indicated a need to standardize procedures used in sampling.

A progress report of field tests was transmitted to the Interdepartmental Committee for study of methods used in measurement and analysis of sediment loads in streams, in December 1944. Report No. 6, giving all results of the studies was prepared under title, "The design of improved types of sediment samples."

Work was suspended on the point sampler before more than one sampler was completed as the Interdepartmental Committee on July 3, 1942 agreed to defer development until after the war.

With a satisfactory depth-integrating sampler and a workable laboratory point-integrating sampler available, Mr. Benedict tested both under rigorous field conditions at five sampling stations in the Colorado River basin. The experimental samplers operated satisfactorily.

Recognizing the desirability of perfecting methods for measuring the quantity and for determining the character of sediment loads in streams, interested Federal agencies sponsored, in 1939, a project in cooperation with the Iowa Institute of Hydraulic Research at the Hydraulics Laboratory State University at Iowa City, Iowa. The project entitled "A Study of Methods Used in the Measurement."

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.

At an interagency conference on sediment held in Denver, May 6-8, 1947 the agencies concerned generally agreed to use them in the future. Contracts were let for 162 P-43 samplers during the period through 1947.

Following the development of the two samplers in 1943, attention was turned again to a device suitable for analyzing suspended-sediment samples with a wider range of sizes and concentrations than any known method. War conditions curtailed the study before completion, but the results were published in June 1943 as Report No. 7, "A study of new methods for size analysis of suspended-sediment samples."

The reports in this series were summarized in Report No. 8, "Measurement of the sediment discharge of streams." The report was prepared to aid field men in the selection of equipment and methods for measuring sediment loads.

Report 8 was replaced by Report No. 14, published in 1963. Others in the series include the following:

Report No.	Title
9*	Density of Sediments Deposited in Reservoirs, November 1943
--	Measurement and Analysis of Suspended Sediment Loads in Streams, by Martin E. Nelson and Paul C. Benedict, Transactions, ASCE, Vol. 116, Paper No. 2540, 1951, pp. 891-918
10	Accuracy of Sediment Size Analyses Made by the Bottom-Withdrawal-Tube Method, April 1953
11	The Development and Calibration of the Visual-Accumulation-Tube, 1957
12	Some Fundamentals of Particle-Size Analysis, December 1957
13	Single-Stage Sampler for Suspended Sediment, 1961
14	Determination of Fluvial Sediment Discharge, 1963
Catalog	Instruments and reports for fluvial sediment investigation, 1974, and titles to "Lettered Reports," A through T

In the Boise River project, field work for which lasted from January 1939 to 1940, Love and Benedict used methods and equipment developed for the Colorado River Program collecting samples at vertical sections approximately one-fourth, one-half and three-fourths of the distance across the stream. Because of shallow depths and overfall sections, Benedict developed a sampler which permitted sampling parrallel to the axis of flow. (See page 26 and Plate 5A and B, WSP 1048)

In the Missouri River Basin program Benedict used the new methods and equipment developed at the Iowa Hydraulic Laboratory. Suspended-sediment measurements were made at 3 to 5 vertical points using depth-integrating sampling equipment. The position of the verticals was obtained from current meter measurements and represent equal sections of discharge. The local observer obtained samples at one vertical in the cross section, except in streams having wide variations in suspended-sediment concentration in the cross section.

Observers' results were compared with the engineer's sediment-discharge measurements and corrected when necessary by a shift correction similar to that used for water discharge measurements. Mean daily concentrations were obtained by plotting concentration on daily gage-height charts. (See pages 55-56 Federal Inter-Agency Sedimentation Conference, January 1948 for technical paper by Benedict.)

ANNUAL WATER QUALITY PUBLICATIONS

With the rapid increase in basic data both for chemical quality and sediment, and public interest in the results, a need arose for an annual report containing the information and data. Beginning with water year 1941 the annual series was started under the title, "Quality of surface waters in the United States," the first being Water-Supply Paper 942. A summary for years prior to 1941 were included in the report for 1943, WSP 970.

Results of the sediment studies for the Colorado River, begun in 1925, had been distributed to Federal agencies by means of informal reports. To make them available to the public, results for selected periods from October 1, 1925 to September 30, 1941 were published as WSP 998. Records for subsequent years were included in the annual quality of water series.

FEDERAL-STATE COOPERATIVE PROGRAMS IN THE 1940'S

During the period 1941 to 1945 the following water quality stations were maintained by the Survey in cooperation with State and other agencies for the collection of basic data on the chemical, biological, and physical characteristics of streams, lakes, and reservoirs in the United States and its territories.

Water Year	Number of Stations
1941	73
1942	74
1943	188
1944	413
1945	416

During the later years of the war and afterwards industries, now very mobile, began seeking new locations. Quality of water supplies was an important factor in relocation, and cooperative agreements with State agencies grew rapidly. The following are highlights of these events:

Delaware: Starting in December 1946, a cooperative program with the Newcastle Conservation District provided for the measurement of erosion in the Brandywine Creek basin. Daily sediment samples were obtained at the Brandywine Creek at Wilmington, analyzed in the Philadelphia laboratory, and the computation of sediment load 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, was promoting the industrial advantages of locating in Pennsylvania. J. W. Mangan, in charge of surface-water investigations, urged the Department to study the State's quality of surface water. A cooperative agreement with the State Planning Board began June 1944 to study "the industrial utility of the surface waters."

W. F. White, Jr. headed the program and retained his headquarters in Washington where spot samples taken at 120 gaging stations during low flow in the spring of 1945 were analyzed in the laboratory. Beginning October 1, 1944 daily sampling at 10 river stations was started, analyses of 10-day composites being made in Washington. The channel of the Susquehanna River at Harrisburg, nearly a mile wide, required sampling at 11 places in the cross section owing to large differences in water quality.

Mr. White reduced the analyses to 3 or 4 determinations and was able to add 9 additional stations by October 1, 1946, for a total of 19 daily stations by the end of the period. Results together with field temperatures of water were published by the Department of Commerce in August 1947, as "Chemical character of surface water, 1944 to 1946."

To relieve the increased analytical load on the Washington laboratory and the space required for sample storage, on September 18, 1946, a small laboratory in direct charge of N. H. Beamer was established at Philadelphia's northeast sewage disposal plant. As the space was limited the laboratory handled samples from 7 stations in eastern

Pennsylvania; the remainder continued to be sent to the Washington Laboratory.

Annual State cooperative funds available:

1945	$18,000
1946	25,000
1947	25,000

In 1940, the Pennsylvania Turnpike Commission completed borings of the old railroad tunnels through central Pennsylvania. These were to be lined with concrete. The Commission requested the Survey to analyze the water in the tunnels. The Washington laboratory performed the analyses and the Commission allotted $1,700 for the investigation.

Virginia: After a lapse from 1931, on recommendation of D. S. Wallace, cooperation was resumed with the Virginia Conservation Commission Division of Water Resources and Power in fiscal year 1945. A laboratory was established in 1945 by Mr. Lamar at the University of Virginia, Charlottesville. In March 1947 G. W. Whetstone was transferred from the Raleigh laboratory and placed in charge under Mr. Lamar's supervision.

During the first year of operation, 7 daily and 4 monthly sampling stations were established and spot samples were obtained at other river gaging stations. The results of the investigation up to September 30, 1946 were published by the State (Lamar, William L. and Whetstone, George W., "Chemical character of surface waters of Virginia: Va. Conservation Comm. Bull. No. 8., 1947)." Subsequent data were published in the Bulletin series through 1956.

Funds to supplement ground-water investigations came from cooperation with the Virginia Geological Survey beginning fiscal year 1947.

Annual State cooperative funds available:

Virginia Conservation Commission

Year	Division of Water Resources and Power	Geological Survey Division
1945	$4,000	-
1946	4,500	-
1947	4,500	$500

North Carolina: Concern about a postwar letdown of industrial activity, led the State Department of Development and Conservation to promote the advantages of industrial location in North Carolina. Quality of available water supplies was an important consideration and the Department in cooperation with the North Carolina State College in Raleigh conducted an intermittent water-quality investigation until 1943.

Recognizing the importance of continuing and coordinated quality-of-water investigations the Department referred the matter to the Survey and W. D. Collins and W. L. Lamar went to Raleigh. In pointing out the advantages of cooperation Collins explained that the Survey had the national view and method of approach and the State officials knew the local needs. This resulted in mutual contributions in planning the work for cooperative studies. State officials liked this argument and cooperation was begun in fiscal year 1944. Lamar established a laboratory at State College where previous analytical work had been performed.

An expanded cooperative program to include the quality of public water supplies began with the State Board of Health in the fall of 1945. A new laboratory space and office was furnished by the Board of Health's State Laboratory of Hygiene in Raleigh.

By the third year, daily samples were obtained at six stations, monthly samples at four, and spot samples elsewhere. 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 in the three succeeding years as Bulletin 52, volumes 1, 2, and 3.

All public surface-water supplies, numbering 116, serving 139 communities were inventoried and analyzed and the results published as Progress Report No. 1, "Public surface-water supplies in North Carolina, descriptions and chemical character."

A program of river basin studies to determine the water quality from headwaters to mouth, including industrial pollution, was conducted for a period of 1 to 3 days in each basin. Data were obtained for 10 basins and published with records for 1946-47 as Bull. 52, vol. 3. Basin reports were published separately as Hydrologic data in the Cape Fear River basin, 1920-1945 and Hydrologic data in the Neuse River basin, 1866-1945. Lamar was in charge of the investigations.

Annual State Cooperative funds available:

Year	Department of Conservation and Development	State Board of Health	Total
1944	$4,000	------	------
1945	4,000	------	------
1946	4,856	$2,500	$7,356
1947	6,340	2,500	8,840

South Carolina: Like her neighboring States, South Carolina was looking for new industries after the war. Quality of available water supplies would be required and a small cooperative program was started in the fiscal year 1946. Two daily sampling stations were established by 1947 and spot samples were obtained at nearly all gaging stations. Funds were not available to establish a laboratory; so to divide the workload, 10-day composite samples were sent to Survey's Virginia laboratory and analyses of spot samples were made in North Carolina. Results were published in South Carolina Bull. 16, "Chemical character of surface waters of South Carolina, 1945-47" by William L. Lamar.

Annual State cooperative funds available:

1946	$600	1947	$1,500

Georgia: The salinity study of the Savannah River continued from July 21 to September 30, 1939, and Lamar maintained a temporary laboratory in Savannah until December 1939. Local and WPA funds were exhausted and the report was not completed. Lamar published a summary of the work in Transactions of the American Geophysical Union, 1940 (p. 463-470).

The public water supply study continued during the period 1940-41, as well as two daily sampling stations on the Chattahoochee River and spot samples of surface and ground water elsewhere.

Until the Raleigh laboratory was established in 1943, Lamar did the field and analytical work for the Savannah study. All other analytical work was done by the Washington laboratory. Raleigh performed the analyses between 1943 and 1945 until the Charlottesville laboratory was started in July 1945 when the work was divided between Raleigh and Charlottesville.

The data obtained from 1937 and 1941, which included 470 analyses of surface water at 96 locations, 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."

Annual State cooperative funds available:

1940	$3,500	1944	$300
1941	2,400	1945	400
1942	2,645	1946	800
1943	1,000	1947	800

Florida: The city of Miami collaborated with the Quality of Water Division as part of a comprehensive investigation of the water resources investigation of Florida which began in December 1939. S. K. Love supervised the Miami quality-of-water studies, and a laboratory was established in the city laboratory from December 29, 1940 until August 13, 1942, H. A. Swenson in charge.

A method of rapid determination of salinity was needed to define the movement of salt water in the tidal reaches of the coastal streams and canals. A field salinity meter, an adaptation of the laboratory electrical conductance meter, was developed by S. K. Love, A, H, Frazier, and H. C. Spicer. The meter was invaluable in tracing salt-water contamination in the tidal canals.

Interest in the quality of Florida's spring waters had been growing and, in 1946, the Florida Geological Survey extended cooperation with the Quality of Water Division for a chemical quality study.

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

Louisiana: Two cooperative studies were underway during fiscal years 1944 and 1945 under the supervision of W. W. Hastings at the Austin, Tex. laboratory.

Low- and high-water chemical quality samples were obtained at 52 gaging stations, including 2 daily stations for the period October 1943 to October 1944.

In February 1944, cooperation began with the State Department of Conservation to determine salt-water encroachment from the Gulf in the lower reaches of the Calcasieu River in the vicinity of Lake Charles. Interest was focused on pollution by industrial wastes and oil-field brines and potential effect on diversions from the river for rice cultivation.

State cooperative funds available were:

1944	$1,600	1945	$1,750

Ohio: The Ohio Water Resources Board, created in October 1945 to study the State's water resources, was the stimulus for water quality studies in that highly industrialized State. C. V. Youngquist, the Board's chief engineer, wanted to develop a program similar to that in Pennsylvania. He discussed plans with W. F. White, and cooperation was started in the spring of 1946. Initially high- and low-water chemical quality samples were obtained during spring and fall at 60 gaging stations. Subsequently, daily stations were added, and the analytical work was performed at the Washington D.C. laboratory.

The Water Resources Board issued a preliminary data report January 1947; "The industrial utility of surface waters of Ohio, Bull. 4."

Annual State cooperative funds available:

1946	$1,500	1947	$9,152

Arkansas: Creation of the University of Arkansas Bureau of Research by legislative action, in 1944, provided funds for an investigation of the quality of the water resources. Many inquiries were received from prospective industries in this regard.

Cooperation was started with the Survey in 1946, and $6,000 was allotted each year. An office and laboratory was established in the Chemistry Building at the University of Arkansas in Fayetteville, September 1945, I. W. Walling in charge.

The initial program objectives were 3-fold: (1) inventory and analyses of all public water supplies; (2) daily chemical quality sampling at 6 stations and the analysis of 10-day composites; semi-annual sampling at all Survey gaging stations; and (3) chemical quality sampling and analyses from all ground water investigations.

Emphasis at first was on the unpolluted streams of northern Arkansas, but more attention was directed to waters in the southern part of the State as industrial waste pollution increased.

The inventory and analyses of public water supplies were published by the Bureau as Research Series No. 11, June 30, 1947.

G. A. Billingsley succeeded Mr. Walling, July 1946.

Oklahoma: The Oklahoma Planning and Resources Board, as part of a compilation of quality of water data for the report "Oklahoma Water" provided $850 to the Survey in fiscal year 1944 for a reconnaissance survey of Oklahoma waters. From September to December 1944, daily samples were obtained at 6 gaging stations and sent to Austin for analyses. Spot samples at all other stations were analyzed in a temporary Survey laboratory at Oklahoma A&M College. The Survey issued the results in mimeograph form under the title, "Chemical analyses of surface waters in Oklahoma, September to December, 1944."

The growing interest of industry in water quality prompted the State agencies in 1947 to pool funds for cooperation with the Survey, and a State-wide scale of quality-of-water studies began in 1944. The Experiment Stations, State Geological Survey and Planning Resources Board funds totaled $6,250 for the 1947 fiscal year. A laboratory was established in Stillwater at Oklahoma A&M College, I. W. Walling in charge.

Daily samples obtained at 10 gaging stations were analyzed as 10-day composites in addition to quality of ground water studies. Data for the Washita River basin during 1946-47 were published by the State as, "Chemical character of surface waters in the Washita River basin of Oklahoma, 1946-47, Bull. 1."

Concurrently the city of Miami, Okla., looking for a standby surface water supply owing to the lowering of the ground water table by the Goodrich Rubber Plant, required water quality information from three possible sources.

The Stillwater laboratory also analyzed samples from the Arkansas River basin in Kansas.

Texas: In addition to the WPA project for study of ground water quality which began in 1937, a cooperative water quality study was underway with the Red Bluff Water Power Control District and the State of Texas as part of the Pecos River-Joint Investigation. This program included daily sampling of the Pecos at 5 stations on the mainstem, and 3 tributary streams, for analysis of 10-day composites; spot samples elsewhere on streams, and from ground water sources. The WPA project ended in 1942, and the loss in laboratory operations was partly offset by more extensive quality-of- ground-water investigations.

By 1942 small cooperative studies were underway as the State became aware of the value of information on quality of surface waters. The great industrial movement in the State was in full swing by 1944, more water quality coverage was needed, and the State cooperation greatly increased. By the late 40's the daily sampling program was expanded to 20 stations.

In 1945 the cities of Denison and Sherman were considering taking water from Denison Reservoir, capacity 5.7 million acre-feet. Inquiries were made to the Board of Water Engineers about water quality. W. W. Hastings recommended a program of daily sampling stations on 2 contributary streams to the reservoir and 1 station on the Red River below the reservoir. The cities began a cooperative study.

The city of Childress needed an improved water supply and cooperated in a one year study of water quality at Quitaue. Streamflow was insufficient and the city dropped the 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 funded quality studies of the proposed water supplies for their individual projects.

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 quantity and quality of water in the upper Colorado River. Possible storage of water was considered near Colorado City for the use of 5 rapidly growing cities in the area.

E. W. Lohr was in charge of the Austin laboratory from its establishment in 1937 until July 1941. He was succeeded by W. W. Hastings who headed the water quality program in Texas and in Arkansas, Louisiana, Mississippi, and Oklahoma when investigations were begun in those States later in the period.

During 1939-41 the Survey operated a laboratory at Pecos, Tex., and the facility was moved to Austin in 1941.

Annual State and municipal cooperative funds available were:

Year	Board of Water Engineers	Red Bluff Water Power Control District	Pecos River Compact Commission	Denison & Sherman	Childress	Total
1940	$-----	$9,000	$-----	$-----	$-----	$9,000
1941	-----	2,000	-----	-----	-----	2,000
1942	700	300	-----	-----	-----	1,000
1943	450	400	-----	-----	-----	850
1944	950	400	800	-----	-----	2,150
1945	600	400	-----	800	-----	1,800
1946	2,950	400	-----	800	-----	4,275
1947	2,600	400	-----	400	125	3,400

New Mexico: Following the completion of the Pecos River Joint Investigation in December 1940, the State continued a cooperative program for quality of the Pecos River at 6 river stations (Pecos River Joint Investigation, Reports of participating agencies, p. 102.-National Resources Planning Board, June 1942.) State officials were concerned about being a defendant in possible law suits by individuals claiming deterioration of quality of the water from its use in New Mexico. Also there was a possibility for a Pecos River Compact.

C. S. Howard continued in charge of investigations and moved his headquarters to Albuquerque in July 1942 and established the laboratory.

Cooperation began with Colfax County in fiscal year 1946 to consider quality of water problem areas in the vicinity of Raton and on the Maxwell irrigation project to the south. A daily station was established on the Cimmaron River at Ute Park, and spot samples were obtained from the Vermijo River and other irrigation sources for the Maxwell project.

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

THE YEARS 1947 TO 1959

GENERAL

Following the end of World War II, studies of chemical quality of water, fluvial sediments, and water temperature accelerated. The Quality of Water Branch (previously called Division) established regional offices in Lincoln, Nebr., February 1946; in Salt Lake City, Utah January 1947; and in Columbus, Ohio August 1948. In addition during 1946-58, eight district offices for quality-of-water operations were created. This brought the number of district offices to 13, five offices--Charlottesville, Va., Austin, Tex., Albuquerque, N.Mex., Raleigh, N.C., and Fayetteville, Ark., having been established in the years 1937-45.

To foster advanced studies, four field research centers were authorized. The first of these centers at Minneapolis, Minn., was activated June 1948. Other centers at Denver, Colo., Menlo Park, Calif., and Fort Collins, Colo., followed during 1953-57.

Upon Mr. Collins retirement September 30, 1946, S. K. Love assumed responsibility as Branch Chief.

W. W. Hastings was appointed Assistant Branch Chief, and he was succeeded by H. A. Swenson. W. L. Lamar was designated Branch Area Chief, Pacific Coast Area, Menlo Park, Calif., August 12, 1957 and T. B. Dover was appointed Branch Area Chief, Midcontinent Area, Denver, Colo., October 15, 1958.

In 1946 the Quality of Water Branch had 42 employees on its rolls. In 1958, the roster listed 338 employees of which 78 were employed part-time.

Growth was striking: During the 1945 fiscal year $107,400 had been allocated to quality-of-water programs. In 1960 funds available were $2,716,000--an increase more than 25-fold.

STATISTICAL SUMMARY OF PROGRAM

During the period 1946 to 1960, the following water quality stations were maintained by the Survey in cooperation with other agencies for the collection of basic data on the chemical and physical characteristics of streams, lakes, and reservoirs in the United States and its territories. The numbers are approximate.

Year	Number of stations	Type of operation			Number of samples a
		Chemical	Sediment	Temperature	
1946	455	---	---	---	C11,087 S30,780
1947	637	---	---	---	C17,500 S80,000
1948	666	---	141	---	C17,500 S80,000
1949	859	288	149	---	C37,500 S71,000
1950	843	---	---	---	------
1951	1,064	360	187	---	C50,000 S125,000
1952	1,161	---	---	---	------
1953	820	---	114	300	
1954	835	---	---	---	------
1955	920	450	158	390	------
1956	1,000	---	200	400	b65,000
1957	1,060	---	217	---	c60,000
1958	1,090	---	220	d600	------
1959	1,100	---	---	---	------

a C, chemical; S, sediment.
b About 8,500 from wells and springs.
c About 7,500 from wells and springs.
d Includes 90 continuous recorders.

Total obligations topped the 1 million dollar mark for the first time in 1951 and reached over the 2 million dollar mark in 1958. The highest rate of growth during the period was in the Federal program.

The number of operating stations doubled in the 5-year period 1946 to 1951, then hovered around the 1,000 mark until the close of the period, 1959.

Annual Federal and State program funds available, 1950-59
[In thousands of dollars]

Year	Total	Federal	Federal-State	Others
1950	976	164	387	425
1951	1,301	310	438	553
1952	1,368	460	432	476
1953	1,462	510	416	456
1954	1,401	576	480	344
1955	1,430	548	508	375
1956	1,616	550	626	441
1957	1,903	690	719	495
1958	2,345	924	861	559
1959	2,401	935	978	489

Source: Memorandum from Administrative Office, WRD, April 2, 1964.

Prior to 1947 the Branch's participation in basic or applied research was severely restricted because of the limitation of funds for this important activity. H. A. Swenson writes (personal communication) "In most instances cooperative funds could not be diverted from operations programs, and Division Federal money for support of research was scarce and hotly contested. In 1947 fiscal year, a modest sum of $18,500 of Federal funds was specifically earmarked for water-quality research. On 1959, Federal funds for this purpose had increased to $373,000 - about 15 percent of total funds from all sources." Research funds by years is shown on the next page.

Funds for water-quality research, 1947-59

Fiscal year	Federal funds for research (thousand dollars)	Percent of total funds, all sources
1947	18.5	5.8
1948	27.5	5.0
1949	26.0	3.6
1950	32.0	3.2
1951	45.5	3.6
1952	52.5	3.9
1953	70.0	4.8
1954	97.0	6.8
1955	116.5	8.1
1956	14.6	8.7
1957	262.0	13.6
1958	285.0	12.1
1959	373.0	14.6

Cooperative investigations of chemical quality of surface waters were in progress in 1947 in Pennsylvania, Virginia, Georgia, North Carolina, South Carolina, Florida, Arkansas, Texas, Oklahoma, Ohio, Iowa, and New Mexico. Additionally, ground water studies were in progress in these and other states.

LABORATORY AND FIELD FACILITIES AND METHODS

Two field laboratories were established in 1947, one in Salt Lake City, Utah and the other at Philadelphia, Pa. The laboratory at Salt Lake City was a regional laboratory designed to serve both Federal and State interests in a large area in the west. The Philadelphia laboratory was set up on a limited scale to handle a portion of the State cooperative program in Pennsylvania.

Continuing concern was expressed over the economic loss to farmlands resulting from uncontrolled erosion. In order to determine the rate at which lands are being eroded and the rate at which reservoirs are being filled, the sediment burden of the streams must be accurately measured with reference both to the total discharge of sediment and to the distribution of sediment particles of different sizes. Progress was made in this direction during 1947. The Survey was actively engaged in an increasing but as yet limited program for measuring sediment in streams. In 1947, the Survey operated laboratories for analyzing sediment at

Albuquerque, N.Mex.; Lincoln, Nebr.; Worland, Wyo.; Norton, Kans.; Dickinson, N. Dak.; and Philadelphia, Pa.

A substantial increase in the extent and scope of sediment-measuring activities occurred in 1948 when more than 80,000 sediment samples were obtained from streams in the Colorado, Rio Grande, Missouri, Washita (Okla.), Schuylkill (Pa.), and Brandywine (Del.) River basins. About one-half of the measurements were of surface waters in the Missouri River basin. During the year, additional sediment laboratory facilities were located at Stillwater, Okla., and Schuylkill Haven, Pa.

Cooperative investigations of chemical quality of surface waters were begun in 1948 with the State of Colorado and in 1949 with Georgia and Delaware.

Throughout the period factual data was furnished concerning the adequacy of the water supply for municipal or agricultural uses or with respect to corrosiveness or scale-forming properties of waters essential to the development of Federal projects and the protection of Federally owned equipment or plants. Water samples were analyzed and the results interpreted, or advice about water problems were furnished to the following agencies: Bureau of Reclamation, Bureau of Mines, Fish and Wildlife Service, Department of the Navy, Veterans Administration, Public Housing Administration, and Federal Works Agency. The Survey laboratories also made regular analyses for the Department of Army investigations of scale and corrosion problems which involved threshold treatment of water supplies at Army posts. For example, during 1948, 2,100 analyses were made at the request of these agencies of which 450 were analyses of samples obtained at Army ground and air installations in the United States and at offshore installations.

The Washington, D.C. laboratory moved to the Old Post office Building, 12th and Pennsylvania Ave., N.W. on June 25, 1951. The ornate building, an imposing 54-year-old landmark in downtown Washington, has housed the laboratory for the past 25 years.

D. E. Weaver, chemist-in-charge reports in the WRD Bulletin (May 10, 1951, p. 49), "This is the third principal location of the Washington laboratory which first began operations on F Street in 1906 (Jointly with Geologic Division). In 1919, the laboratory was moved to Room G241C in the present General Services Building (then the Interior

Building). In 1931, additional laboratory space was set up in room 2239 of the same building."

About the time of the laboratory's relocation, advances in instrumentation were announced. For many years gravimetric methods were the only ones by which sodium and potassium could be determined with satisfactory results. These methods were in some instances tedious and time-consuming and required considerable care on the part of the chemist to give reliable results. No titrimetric or colorimetric method satisfactory for use in routine water analysis had been developed. However, since World War II several flame spectrophotometers had been marketed, and R. A. Krieger reported (WRD Bulletin, Feb. 1951, p. 2) "--at least two of them can be used for the quantitative determination of several elements, including sodium and potassium, by low temperature emission spectroscopy. A Beckman Model DU spectrophotometer with flame attachment is now being used by the Washington laboratory for the routine determination of sodium and potassium in water."

Concurrently (1951), the Columbus laboratory was studying the adaptability of the Perkin-Elmer flame photometer (Model 52-4) for the routine determination of sodium and potassium.

Krieger further reported the Beckman flame photometer produced the best results when set for a range of 0 to 10 ppm of sodium or potassium with dilution of some samples when necessary to bring them within this range. An analyst familiar with the use of the instrument could analyze 10 water samples for sodium and potassium in about 4 to 5 hours, about half the time required previously.

Simultaneously, L. L. Thatcher, in charge of methods development research unit in the D.C. laboratory reported (WRD Bulletin, Feb. 1951, p. 3) that "The determination of lithium by the flame photometer appears to be a simple determination even in highly concentrated waters. The sensitivity is good enough to allow determination of lithium encountered in water to 0.1 ppm."

Unquestionably, the adaptation of the flame photometer to routine analysis of certain elements in water heralded a new age in water chemistry and was the forerunner of major equipment development in years after the early 1950's.

Other methods were being tried elsewhere. R. H. Langford at the Lincoln laboratory reported (WRD Bulletin, Aug. 1951, p. 53) "It has been shown for natural waters found in the Missouri River basin, the direct versenate filtration of total hardness and calcium and the calculation of magnesium give results (a) comparable with those obtained by permanganimetric and colorimetric methods and (b) within the accepted limits of accuracy for routine water analysis."

Considerable discussion evolved among analysts in view of the rapid influx of new, relatively untried methods. A change in viewpoint was suggested. In the past, most procedures came from standard methods of rock analysis adapted to analysis in dilute solution. Investigation of a "checking" nature was about all that was required. The situation was different. The newer methods - versene determinations, many colorimetric determinations, flame photometry - were being used for the first time in water analysis and extensive checking would be required as was done previously in other fields.

Thatcher suggested that "All this demands a more critical fundamental approach by the investigator. Ultimate accuracy limits under standard laboratory conditions should be the goal, rather than simply a check to see if our 1 to 2 percent accuracy requirements are met. In some cases, preparation of a synthetic water of known concentration probably provides a better standard than even the most carefully analyzed sample."

These probing discussions eventually led to the convening of a Division-wide symposium on water analysis methods, Philadelphia, 1966. Equally important, they led to the development of a national water analysis standard reference service in the Denver laboratory supervised by Marvin Skougstad, which became an integral part of the QW Branch program beginning in 1962.

A major development as an aid in "tightening up" procedures used in the laboratories came in January 1950 with the release, in preliminary form, "Methods of Water Analysis." Stated objective by S. K. Love, Chief, QW Branch, "---is to set forth analytical methods used by the Geological Survey in making water analyses for the purpose of maintaining uniform analytical procedures in the Water Resources laboratories throughout the United States."

This first edition included 30 determinations with long-tested and standard, mainly gravimetric, procedures. It included none of the soon-to-emerge flame photometer and atomic absorption techniques. Work began immediately to update the 1950 edition, and the stage was set for a formidable series of individual procedures and manuals in the 1960's and 70's as technology advanced rapidly and called for a simpler form for release and updating of new approved procedures.

CONFERENCES

Two Quality Water Branch-side conferences were held during the period in Lincoln, Nebr., 1950, and Denver, Colo., April 25-29, 1955. In addition, sedimentation conference convened in Albuquerque Jan. 16-19, 1952 and a symposium on water-analyses methods was held in Philadelphia, Pa., October 11-13, 1966.

At the Denver Conference, S. K. Love discussed changes in the Branch activities: "When I reported for work with the Geological Survey in the late 1920's, the Quality of Water Branch consisted of one office and one laboratory, both located in Washington. Total personnel was about six, and total funds for Branch activities was about $20,000 per year.

"During the past 15 years---we have had our share of growing pains."

W. W. Hastings reported: "Quality-of-water activities have expanded greatly during the last decade, primarily through increased programs for collection of quality and sediment records---. At present, quality-of-water programs involving appreciably cooperative funds are underway in only 16 States.--- During the 1954 fiscal year total cooperative funds amounted to almost $500,000 or 34 percent of all funds expended for quality-of-water investigations."

Each conference included papers and discussions on operation and management of the laboratories. Noteworthy in the Philadelphia session was an in-depth discussion on new advances in technology. The Ocala laboratory reported on 14 months of satisfactory utilization of the atomic absorption spectrophotometer (P.E. Model 303) with digital concentration readout attachment for routine determination of calcium, magnesium, sodium, potassium, and strontium. Some minor elements - lithium, copper, manganese, zinc, lead, nickel, and barium - also were determined.

Concurrently, the Denver Methods Development Unit had extended the sensitivity of AA techniques beyond routine determinations by extraction-concentration techniques as a sensitive measure for determining lead, cobalt, and nickel in fresh waters. Results were in good agreement with spectrographic analysis and detection of as little as 1 microgram per liter (μg/L) of the element - at least one order of magnitude, lower than wet chemical procedures.

Two USGS Systems were described for continuous monitoring and digitally recording water-quality parameters in surface waters. The automated system, designed and adopted by the Survey, monitors temperature, conductivity, dissolved oxygen, oxidation-reduction potential, pH, and other common water quality parameters. One type is a modular system which uses potentiometric sensors for continuous stream side monitoring. The other type of system uses resistance-type sensors for in-place monitoring in remote locations where only battery power is available.

At the October 1966 conference at Philadelphia as well as at the Water Resources Division Conference on Nitrogen Chemistry held a year earlier in Menlo Park, attention was directed to possible research on the effects of land use on the balance of nutrients in streams and lakes. One conclusion was that present data (1965-66) did not indicate distribution of the nitrogen species and that one way to overcome this deficiency was to measure the components at the sampling site. These values would establish the relationship at time of collection for comparison against laboratory values obtained later. From these comparisons one could apprise the effectiveness of field practices in preserving or fixing nitrogen and phosphorous. A case was being made for more extensive use of mobile laboratories and on-the-spot analysis for nutrient determinations.

TRAINING

New Division program thrusts in the 1950's conveyed the need for broad technical training in hydrology to supplement that given new employees in the District office. Love, Hastings, and other members of the staff gave much effort to this task.

The first Quality of Water Branch Technical Training School convened at Charlottesville, Va., May 21-26, 1956 with 29 students and faculty in attendance. Coursework was directed primarily toward professional employees with one to four years service. However, the school also provided training for experienced personnel with limited opportunity for exposure to broad problems of chemical quality and sedimentation investigations and their relationship to development and conservation of water resources.

Participants enthusiastically endorsed the value of the training which was repeated at Albuquerque, N.Mex., the following year, 1957. A third school was held for 30 students in Raleigh N.C., June 2-14, 1958. The agenda now included updating personnel on techniques in ground, surface, chemical-quality and sedimentation hydrology. Participating students were from the Quality of Water Branch, Surface Water Branch, Ground Water Branch, General Hydrology Branch, and one man from State of Virginia cooperator's office. (Facing photo, First QW Training School, Charlottesville, Va., May 21-26, 1956.)

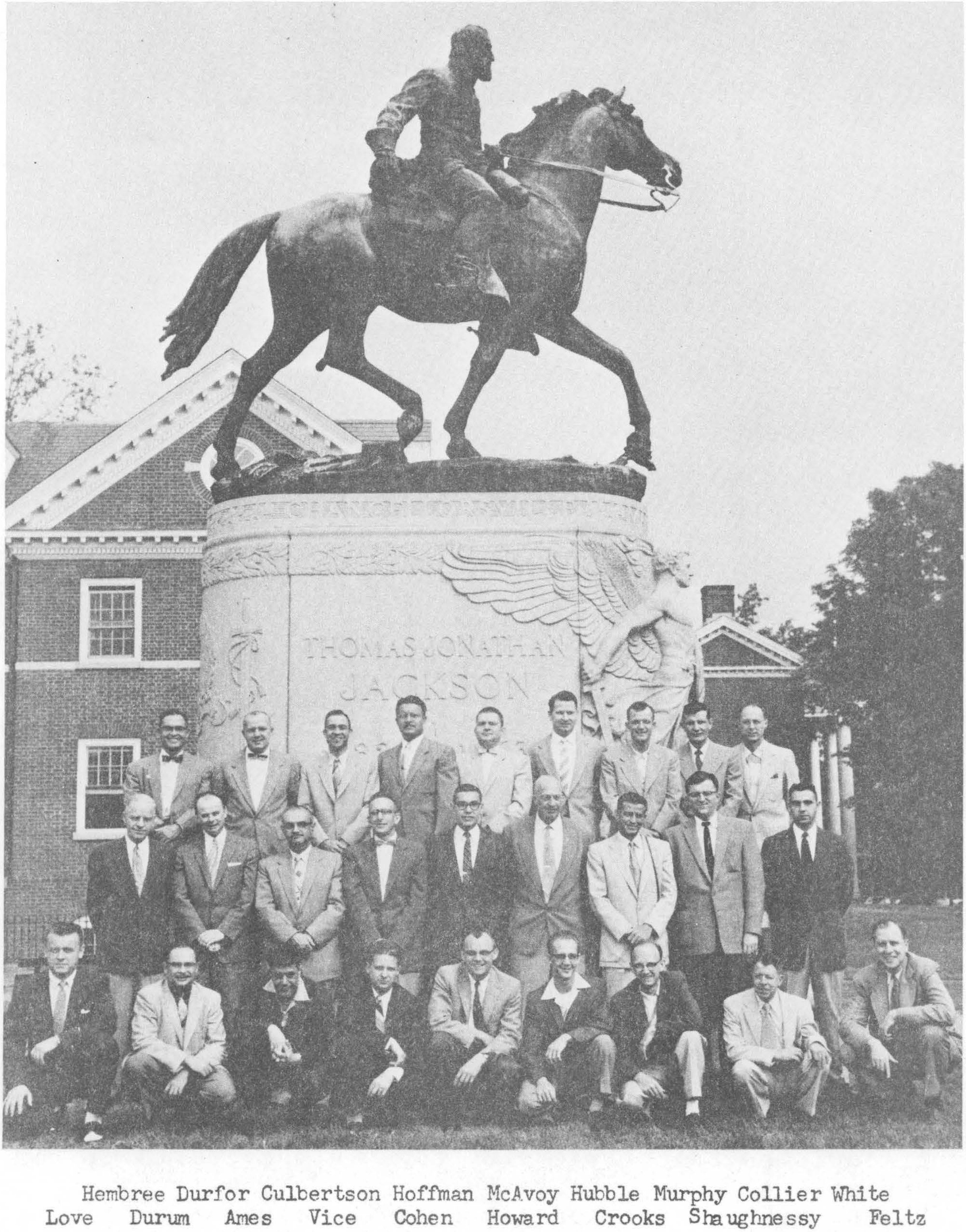
FEDERAL PROGRAM ACTIVITIES

The storehouse of water quality information continued to grow in 1951 when the chemical quality of nearly 50,000 samples of water were determined in the 13 water quality laboratories. Included in the 360 sampling stations were 33 locations established as Federal network stations on western streams to follow trends in mineral content to insure continued successful operation of existing irrigation projects.

Data concerning the larger municipal water supplies throughout the country were being assembled in 1951 and analyses were made by all laboratories to culminate in an overall report on the chemical characteristics of the public water supplies of the United States (WSP; 1299 and 1300, E. W. Lohr and S. K. Love).

The Division published reports summarizing and evaluating all available water resources data on municipal and industrial supply, pollution control, and flood protection for five large industrial centers and investigations were in progress for six other areas. Data about the chemical characteristics of the larger municipal water supplies throughout the country were being assembled. Reports on these large areas were completed during the years.

Nationwide concern on problems of pollution control and abatement continued, and the Division exchanged data on these characteristics of water with public health agencies which collect information primarily on bacteriological



Hembree Durfor Culbertson Hoffman McAvoy Hubble Murphy Collier White
Love Durum Ames Vice Cohen Howard Crooks Shaughnessy Feltz
Kapustka Barker Salotto Thatcher Hem Scarbro Drake Lamar Hastings

FIRST QUALITY OF WATER BRANCH TECHNICAL TRAINING

SCHOOL, CHARLOTTESVILLE, VA., MAY 21-26, 1956 pollution. Joint interpretations were made, such as those published in the pollution survey of the Ohio part of Lake Erie.

In 1953, the Division published a series of nine preliminary reports containing data pertaining to public water supplies of more than 1,200 larger cities of the United States. The reports filled a significant need in the field of water supply engineering by updating the information contained in Water-Supply Paper 658, "The industrial utility of public water supplies in the United States, 1932."

A program to determine and interpret the radioactivity of natural waters was begun. Where background radioactivity values for natural waters and rock formations are determined, changes that might occur through contamination by fissionable material can be observed. Such studies may also lead to the discovery of sources of fissionable material.

Laboratory facilities at Denver, Colo. for determining radioactive substances and trace elements in water samples were nearly completed in 1953. Preliminary work in determining background radioactivity revealed the need to facilitate collection of data in the field. Some study was made of procedures for the collections and preservation of samples containing minute traces of radioactive substances.

Assistance to the Atomic Energy Commission on problems of water supply and waste disposal at established sites, and the selection of new sites for installation, was continued.

In 1953 the Division reported, "Increasing recognition is being given by State, Federal, and private agencies to the impairment of the quality of natural waters by industrial wastes, mine drainage, irrigation return flows and other sources of pollution."

The Division broadened the scope of its studies of chemical quality so mineral pollutants occurring in natural waters could be properly evaluated. In many parts of the country it was found essential to include analyses for trace metals and other minor constituents in solution. Although occurring in minute quantities they have a bearing upon the utilization of the particular supply for certain purposes.

Increasing attention was given to the duration and frequency of periods of low flow in streams because the release of waste is often dependent upon the volume of water available for dilution. Adequate control of pollution in many streams requires a high degree of treatment or temporary storage of wastes during low-flow.

Missouri River basin departmental program: The Missouri River basin Program which was placed in operation in the fall of 1945 required an intensive study of sediment in the entire basin, a less intensive study of chemical quality, and a main office and laboratory was established at Lincoln, Nebr., March 6, 1946. The Quality-of-Water Branch's activities in the basin grew rapidly under the leadership of P. C. Benedict, and required additional sediment laboratories at Worland, Wyo., March 1946-1957 with T. F. Hanly, Area Engineer; at Dickinson, N. Dak., June 1946-1952, with B. C. Colby in charge followed by R. B. Vice, E. J. Tripp, and J. M. Stow; at Rapid City, S. Dak., 1952-54, J. M. Stow in charge, followed by A. R. Gustafson and at Norton, Kans., April 1947-1957, with D. M. Culbertson, Area Engineer.

Benedict had spent a large part of the period 1941 to 1945 in the Iowa District as the Survey's representative on the Federal Interagency research on sediment sampling equipment. He was transferred September 21, 1945 from the Surface Water Branch to the Quality of Water Branch and placed in charge of the Branch's activities in the Missouri River basin. The main scope of activities was with the sediment discharge of streams related to reservoirs proposed for construction by the Bureau of Reclamation, and studies of chemical quality of surface and ground water to meet requirements of other Federal agencies in the basin. Special research work also was conducted on sediment transport in the Niobrara and Middle Loup River basins, Nebraska.

The initial program consisted of determining daily sediment discharge at 25 gaging stations and miscellaneous measurements elsewhere. Chemical-quality observations were made daily at 4 gaging stations, and monthly at 38 flood-flow observations locations.

By June 30, 1947 the requested basic-data program had expanded to include 44 daily and 7 periodic sediment stations. Chemical quality observations were made at 13 daily and 61 periodic stations. In collaboration with the Ground Water Branch analyses of ground-water samples and discussions were prepared for inclusion in those reports.

The following amounts from the Missouri River basin funds were allotted to the Division:

1946	$98,000
1947	$115,450

As the young staff expanded and gained additional experience, Benedict broadened the program to interpret and assimilate the growing volume of basic data information. The combined talents of the geologist, engineer, chemist, and soil scientist, together with other discipline training as necessary were used effectively in areal studies and team reports. Among these more comprehensive, interdiscipline studies were those for the Powder River basin in Wyoming and Montana (Hembree and Colby, 1952) and the Wind River basin in Wyoming (Colby, Hembree and Rainwater, 1956).

Although hydrologic unit studies were not unique to the Survey program, the Missouri River basin activities allowed a more thorough field and research effort to relate surface water resources and their environment than had been possible in most studies elsewhere. Initially, other Federal agencies in the basin program were slow, even reluctant, to accept the Survey philosophy of broad, professional study. The length of time required to complete the field, laboratory, phases and interpretive report study no doubt was one factor as other Federal project planners faced very short deadlines. However, as the preliminary and published studies became available they were to prove a valuable source and compendium to project planners. And the Survey learned to improve the timeliness and distribution of reports.

The results of water quality investigations and research for the Missouri River basin program are found in more than 75 Geological Survey publications and 10 technical journals. One major result of the research was the development and application of a turbulence flume to measure total sediment load in sandbed streams (Total sediment measured in turbulence flume, by Benedict, Albertson, and Matejka: Trans. ASCE, 1955). This breakthrough made it possible to properly design storage reservoirs and diversion works in the Loup River, Nebr., and elsewhere in the sandhills country.

Relations between total suspended-sediment discharge and bedload discharge, and between measured discharge and unmeasured discharge could be studied. The modified Einstein method (Colby and Hembree, 1955) and direct velocity relationships (Colby, 1957) were devised to aid in determination of the coarse sediment discharge.

Serving with Benedict for most of the Missouri Basin Program years H. A. Swenson headed the chemical quality staff section and R. B. Vice, the sedimentation staff section. Bruce R. Colby was responsible for special sedimentation reports. He prepared numerous reports on sediment in streams and provided effective technical engineering and statistical interpretation to studies and reports.

As the Survey representative on the Federal Inter-agency Sedimentation Project at St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, Minn., Bryon C. Colby and the project staff carried out the development, testing, and calibration of sediment-sampling instruments, the preparation of 14 numbered technical reports and about 20 lettered reports.

As Project Chief on the Federal, Interagency Project, Colby's paper on "Scour and Fill in Sand Bed Streams" (PP 462-D) was helpful in developing an understanding of dune bed movement and hence eliminated the "probing procedure" for determining the total cross-sectional area following a flood runoff event.

Salt Lake City was selected as the site of the first regional laboratory because the program had increased in the upper Colorado River basin in Utah, and Colorado, and Idaho, and to a limited extent, the Pacific Northwest. Mr. Howard established the laboratory at Fort Douglas in a building of a former Army Post which was acquired by the Public Buildings Administration. R. T. Kiser was sent from Albuquerque in January 1947 to set up the laboratory.

Federal program in 1955: The Federal program funds are used to finance investigations which are of Federal interest or which are of concern to a group of States or to a major river-basin area covering several States. Special research projects, joint projects such as water utilization and radioactivity studies, and the preparation of reports are financed from these funds. The following are principal studies in progress.

The deposition of sediment in the Middle Rio Grande Valley has raised the valley flow to such an extent that the whole economy of the valley is seriously threatened. Intensive studies of the sediment transported by the Rio Grande and its major tributaries has been in progress since 1947 to provide reliable data as a basis for planning remedial measures. Investigations of sediment discharge of streams in the Colorado River basin have been under way since 1925 to provide basic data for the sound planning of Federal projects in that basin. The data are also needed in meeting the requirements of the Upper Colorado River Compact. Sediment-transport studies are conducted in the Pecos River basin to meet the requirements of the Pecos River Compact Commission. The sediment index station program has been developed through the Federal Inter-Agency River Basin committee (now the Federal Inter-Agency Committee on Water Resources) involving the collection of sediment discharge records over long periods at more than 200 sampling sites scattered throughout the United States in order to provide nationwide information on sediment production. This network is very limited in scope at the present time, with only 6 stations supported under this program in 1955. Sediment studies in Alaska are justified by the large amounts of high-abrasive sediment from glacier-fed streams which influence the design of dams and power plants, and the development of water supplies. The program includes the periodic collection of sediment samples from many streams in the territory and the operation of 7 continuing sediment-load stations.

Sediment studies with restricted scope and duration are conducted under areal investigations. The programs include a reconnaissance sediment study in the New York-New England area to determine the concentration level in streams, and a sediment-transport investigation on the Mississippi River at St. Louis, Mo., in collaboration with the Corps of Engineers, to provide comprehensive data on the sediment load of this important stream.

Sedimentation research projects were undertaken in 1955 under the Federal program. The development and testing of methods and equipment used in measurement of sediment loads in streams were continued at the St. Anthony Falls laboratory in collaboration with the Corps of Engineers and the University of Minnesota. Studies of sediment transportation as bedload at the turbulence flume on the Middle Loup River and under natural conditions in the Niobrara River were continued in 1955. Development of standards for programs and operations were begun in a limited way in 1955, together with associated preliminary studies concerned with the analysis and evaluation of various procedures for collection of sediment load data which were directed to more effective field operations.

The collection and analysis of data on the chemical quality of streams in the Colorado River basin have been under way since 1925. The data are prerequisite for the utilization of the waters for all uses and for meeting the requirements of the Compact Commission. Chemical quality investigations are also under way in the Pecos River basin to meet the requirements of the Pecos River Compact Commission. Chemical quality studies in the Columbia River basin and in Alaska are directed to obtaining data on the variations in composition of river waters for the proper development and utilization of streams in those areas. The base observation network on western streams is operated to determine changes in quality over long periods as a result of return flows from irrigation projects. This program was developed through the Federal Inter-Agency River Basin Committee.

Chemical quality studies of ground or surface waters are also conducted within specific areas or are of limited scope and duration. Studies of the inland saline water resources were initiated on a limited basis during 1954, in an effort to determine the availability of water of inferior quality which might be rendered potable by treatment process as developed through the Department's Saline Water Conversion Program. A statewide reconnaissance study of the saline waters of North Dakota is currently under way. Studies of the chemical composition of ground-water supplies are under way in the Metropolitan area of Washington. Likewise quality-of-water work in connection with artificial recharge is also in progress. Reconnaissance studies of the chemical characteristics of streams in the New York-New England area have been under way since 1953.

Studies of the radioactivity of water resources were continued in 1955 to determine background radioactivity of natural waters and to relate occurrence of such activity to hydrologic and geologic factors (a Joint project with Ground Water Branch). Collection and evaluation of chemical-quality data in several major metropolitan areas are carried on as a part of the Division's studies with respect to utilization and development of water resources in important industrial areas.

Research studies are also conducted under the Federal program, with the primary emphasis in 1955 being directed to improved laboratory methods for determination of dissolved constituents, geochemical studies of the occurrence of mineral constituents in natural surface and ground water and their relation to their geological environment and the analysis and evaluation of chemical quality records as to their adequateness and applicability for water-quality studies of the origin, movement and character of mineral constituents in surface waters.

FEDERAL-STATE COOPERATIVE PROGRAM

The following chemical quality and sedimentation studies were in progress in the Districts in cooperation with the several States.

Arkansas: The program is directed primarily toward evaluation of the chemical quality of the surface and ground-water resources throughout the State for all uses but with special attention to development of industrial water supplies. Special intensive studies are conducted in the Ouachita River basin where there is a serious pollution problem due to oil field brines. Studies of the chemical quality of ground water are included in the Statewide investigations.

California: The cooperative program consists of statewide studies of the chemical quality of surface and ground waters, with special reference to inorganic pollutants in streams and analyses of various wastes. Special intensive studies in the Central Valley with respect to industrial and municipal wastes are included. Seawater intrusion into streams and ground water are also being investigated, particularly in the Manhattan Beach area.

Delaware: The study involves the operation of a sediment-discharge station on the lower Brandywine Creek to measure changes in sediment yield in the basin as remedial measures to control erosion are undertaken.

Florida: Development of knowledge of chemical quality of the ground and surface water resources of the State is the primary objective of the cooperative program. Intensive chemical-quality studies are under way in the vicinity of the city of Pensacola and along the Suwanee and Withlacoochee Rivers. The degree of salt-water intrusion in the vicinity of Miami and Miami Beach is being followed through a systematic continuing program.

Kentucky: The cooperative studies consist of collection, compilation and evaluation of chemical quality of surface and ground-water resources of the State for their full utilization for all purposes. A statewide sedimentation program is also under way, with primary emphasis on collection of sediment-load data on major streams. Special geochemical studies were initiated in 1954. The study and analysis of brines is included in the program.

Louisiana: The cooperative program involves chemical-quality and sediment-load studies in a few scattered river basins throughout the State. Chemical quality of ground waters of the State is included. These programs are integrated with the overall water resources studies on a Statewide basis in the proper and economical development and utilization of the surface- and ground-water resources.

Michigan: The cooperative program currently consists of the collection, compilation and evaluation of chemical-quality data as related to the ground-water resources of the State.

Minnesota: The studies involve the evaluation of chemical quality of the ground- and surface-water resources of northwest Minnesota as to their suitability for domestic, municipal and industrial uses.

New Mexico: The program is directed toward evaluating the suitability of ground- and surface-water resources of the State for industrial, agricultural and municipal purposes. Chemical-quality and sediment stations are maintained as part of the Pecos River Compact Commission activities. Intensive studies of highly saline waters entering the middle Pecos River also are conducted.

New York: The chemical characteristics of ground- and surface-water resources are studied in a limited way under a cooperative program to evaluate the industrial utility of the State's water resources. The studies are confined to several small drainage basins, with intensive sampling throughout several seasons.

North Carolina: Cooperative chemical-quality studies are under way on a statewide basis to provide knowledge as to the chemical characteristics of the ground- and surface-water resources of the State with primary emphasis on industrial planning. Salinity intrusion studies are conducted in the Tar and Neuse River basins.

Ohio: The statewide cooperative water-resources studies include the determination and evaluation of chemical quality of surface and ground waters, transportation of fluvial sediments and the measurement of water temperature. Special intensive chemical quality and sediment studies are conducted in the Little Miami River basin in connection with a watershed improvement program. In addition, intensive chemical quality studies on the Ohio River are in progress with special emphasis on evaluating the inorganic pollution load due to industrial and other wastes that reach the river.

Oklahoma: As an integral part of the over-all water-resources studies conducted by the Water Resources Division, data on the chemical characteristics of surface- and ground-water supplies of the State are collected and analyzed with respect to their utilization for industrial, agricultural and municipal purposes. Special intensive studies are being conducted along the North Canadian River and Salt Fork Arkansas River where there are serious pollution problems.

Pennsylvania: The chemical-quality studies are confined almost exclusively to the collection and evaluation of chemical and sanitary quality data of the lower Delaware River to establish present conditions of pollution and salt-water intrusion and to establish character of water as a part of study of recharge to aquifers supplying ground water to municipalities and industries in the Philadelphia-Camden area. A cooperative program with respect to sediment yield and run-off on selected small watersheds was initiated in 1953. This is a long-range program to evaluate watershed improvement as related to the hydrology of the basin.

South Carolina: In connection with the appraisal of the surface- and ground-water resources of the State, limited chemical-quality studies are undertaken in several river basins to provide information as to the suitability of supplies for all uses.

Texas: The chemical characteristics of ground- and surface-water resources of Texas are an important consideration of the full utilization by industries, agriculture and municipalities of the water resources of the State, as many are of extremely unfavorable quality. Salt-load studies which are of interest to the Pecos River Compact Commission are conducted along the Pecos River. Studies of saline waters along certain streams and in ground water resources are receiving special attention because of possible contamination of fresh water sources, or because of need for maximum utilization of all water due to limited supplies in the area.

Utah: There are no statewide chemical quality investigations. Special localized studies are under way in several basins to ascertain adequacy of supplies for irrigation or municipal uses and the effect to transbasin diversion on quality on the waters for downstream users.

Virginia: As a part of the over-all water resources program, chemical-quality studies of the surface and ground waters are undertaken to determine the potential utility of the supplies for all purposes. Also, cooperative sedimentation studies are in progress, principally on major streams of the State.

Washington: The small cooperative program consists of sediment studies on the Green River in connection with a flood control and water-supply project near Palmer.

Wisconsin: This cooperative program consists of sedimentation studies in Black Earth Creek, Mount Vernon Creek and Yellowstone River basins in connection with hydrologic studies of a watershed improvement area.

PROGRAMS FINANCED BY OTHER FEDERAL AGENCIES

The following studies were being carried on by funds supplied by other Federal agencies in 1955.

Department of National Defense: The suitability of water supplies at continental and off shore facilities is the concern of this Department. These relate primarily to investigations of scale and corrosion problems involving threshold treatment of water supplies at defense installations as well as potability of the waters. Water samples are examined, and analytical results, interpretation of analyses, or advice about water problems are furnished to the Departments of the Army, Navy, and Air Force.

Salinity intrusion studies are conducted in South Carolina on the Combahee River for the Department of the Navy with reference to the effect of salt water on river water as a source of industrial water supply.

Corps of Engineers: Sediment load studies in connection with specific project developments are conducted in the Delaware River basin, Pennsylvania; Salinas River basin, California; and Roanoke River basin, Virginia.

Chemical-quality studies at project reservoirs with respect to the utilization of waters for industrial, municipal or other uses are under way in the Red River of the North basin, Canadian River basin in New Mexico, and Brazos River basin, in Texas.

At the request of the Department of the Army, a pollution study is under way in the vicinity of the Rocky Mountain Arsenal near Denver Colo., to determine nature and distribution of the contamination in relation to the wastes disposed by the arsenal in so-called "evaporation" ponds.

Atomic Energy Commission: Assistance was provided the Atomic Energy Commission on quality problems relating to water supply and waste disposal at the Knolls Atomic Power Laboratory, N.Y., at Los Alamos, N. Mex., and proposed power reactor on the lower Potomac River in Virginia.

Department of Agriculture: Soil Conservation Service - Evaluation studies as to sediment yield on small watershed in connection with Pilot watershed treatment programs are in progress in Kentucky, West Virginia, and Pennsylvania. Also sediment transportation studies and factors affecting trap efficiency of flood detention reservoirs are under way in North Carolina, West Virginia, Nebraska, Oklahoma, and Texas.

TECHNICAL ADVANCES IN PROGRAMS IN THE LATE 1950'S

The Branch and Division, in 1957, proceeded to augment Division policy by establishing Branch and Inter-Branch research projects coordinated by the Branch Research Chief, in Washington. Some of this work is described in the previous section and under Special Studies and Reports p. 230.

P. C. Benedict was the Chief of Research, May 1958 to July 1962, succeeded by F. Clarke, September 1962 to December 1963 and W. H. Durum, December 1963 to June 1967.

In October 1958 (QW Branch Memorandum No. 59.14) following QW Branch reorganization, in 1957, the Branch Chief restated Division policy to insure technical advancement in the Division's field of competence and "greater use of our reports by engineers, scientists, and the general public."

The programs of the Branch, regardless of financial support, may be divided into two principal lines of effort; (1) research in hydrologic principles and techniques, and (2) appraisal.

Research activities of the Branch have been broadened both in scope and in number. "In 1958 approximately 15 percent of Branch funds were applied to research. Projects currently in progress include studies in geochemistry, radioactivity, and fluvial sediments.

"Appraisal studies constitute the major part of the Branch programs. These programs are composed of (1) a network of stations for the collection of basic data, (2) areal investigations in which interpretive studies are made in selected areas for selected periods, and (3) point studies at specific sites. Until recently, except for the Missouri River basin and to a lesser extent in certain other basins, the programs of the Quality of Water Branch were confined largely to the collection of basic data. Within the past few years, greater effort has been devoted to areal studies and analytical and interpretive work.

"The Branch programs of the future should place greater emphasis on interpretation and research. This does not mean that basic records are to be given a low order of priority. Rather it means that basic data should be collected in accordance with a carefully worked-out plan. We have this as the principal objective of our network evaluation project now nearing completion. Similarly, the composition of areal project investiagations is also under study. We must strive to give balance and proper emphasis in all programs to basic data, interpretation, and research that will yield a product most useful in solving water problems. Likewise, we must combine data gathering with improved understanding of basic processes through an energetic and progressive research program."

SPECIAL STUDIES AND INVESTIGATIONS

Water quality: In 1956, in addition to the nationwide data program, more detailed chemical quality investigations were made and they continued in the basins of the Colorado, Missouri, Pecos, Yadkin-Pee Dee, and Columbia Rivers; in New York and the New England States, and in Alaska. Also a sampling network was maintained on 75 western streams to determine trends in mineral content that would affect successful and continued operation of western irrigation projects.

Important advances were made in 1957 and 1958 in the programming of quality of water studies on streams through the development of criteria for station network operation to satisfy minimum national needs.

In 1958, the Survey began a study of major worldwide contributions of dissolved solids being carried from land surfaces to the oceans.

The Survey also began a study of the significance and potential use of tritium as a tracer and age determinant in water investigations. Studies of the distribution and concentration of radioactive waste in streams by fluvial sediment were begun in 1959. The same year at the request of the Federal Housing Authority a modest start was made in measurement of synthetic detergents as related to the quality of ground-water supplies in the United States.

Investigations were made in cooperation with State and municipal agencies in 16 States, and special chemical-quality studies were made for the Department of Defense, Atomic Energy Commission, Bureau of Reclamation, Veterans' Administration, Federal Housing Authority, and Public Health Service.

Cooperation extended to about 20 State and municipal agencies by 1959.

The first comprehensive study of the water resources of the Colorado River basin was made by E. C. La Rue (1916). The introduction to the report was written by Nathan C. Grover, Chief Hydraulic Engineer, Water Resources Division. Iorns, et al (1965) state that much of what Grover said about the Colorado River basin "is as timely today (1957) as it was in 1916."

"...The region traversed by the Colorado and its tributaries is for many reasons of intense interest to the people of the United States. Here was the home of the forgotten people of which there is no record except the hieroglyphics on the rocks, the ruins of their irrigation systems, and the cliff dwellings by which they are most widely known; here were the Spanish missions whose history extends back nearly to the days of Balboa and Cortez; here is the Grand Canyon, whose sublimity was first fully disclosed by Major Powell and his associates, who navigated it from end to end in 1869 and 1872; here are the greatest known natural bridges, so remote and inaccessible ... here is the mighty river and its tributaries ..."

In their final report, "Water Resources of the Upper Colorado River Basin-Technical Report, Iorns et al (1965)", the authors state that much of the water supply of the Colorado River is already being used. Additional water developments are planned to meet the evergrowing demands of the region. The U.S. Geological Survey prepared the report on the surface-water resources of the Upper Colorado River basin as part of an appraisal of the water resources of the entire Colorado River basin. The surface-water resources of the region are described and the effects of environmental factors on these resources are explained on the basis of available data and water uses existing in 1957. The report does not contain forecasts of changes in water quantity and quality which may take place as a result of water utilization projects constructed after 1957.

The area encompassed by the report is the drainage basin of the Colorado River above "Lees Ferry," Ariz. "Lees Ferry" is an arbitrary point dividing the Upper Colorado River basin and the Colorado River basin and is defined by the Colorado River Compact as "a point in the main stem of the Colorado River one mile below the mouth of the Paria River."

The amount of which enters the basin annually as precipitation is 92,739,000 acre-feet. Only a small part of this (2,257,500 acre-ft) is consumed by humans or is diverted out of the basin. The rest leaves the basin through outflow (12,733,100 acre-ft) or is lost by evaporation and plant transpiration.

The amount and chemical quality of the streamflow vary with time and place owing to both natural and human causes. To give a common base for comparing streamflow the authors used an average that would have occurred if the level of upstream existing in 1957 had existed throughout water years 1914-57.

Water quantity and quality are changed as the water is diverted for domestic, industrial, and agricultural uses. Domestic and industrial uses add 33,600 tons of dissolved solids annually to the streamflow; irrigation adds 3,446,700 tons.

About 44 percent of the water and 48 percent of the dissolved solids at "Lees Ferry," Ariz. (combined water and dissolved solids of Colorado and Paria Rivers at Lees Ferry) come from the Grand Division (26,500 sq mi), about 37 percent of the water and 33 percent of the dissolved solids come from the Green Division (44,700 sq mi) and about 19 percent of the water and 19 percent of the dissolved solids come from the San Juan Division (38,300 sq mi).

The weighted-average concentration of dissolved solids in the Colorado River at "Lee Ferry," Ariz. (12,733,100 acre-ft) is 501 ppm (parts per million) for water years 1914-57 adjusted to 1957 conditions.

Ninety-two storage reservoirs, each having capacities greater than 1,000 acre-feet, had been constructed in the basin by 1957. The combined capacity of the reservoirs, which were constructed to utilize more of the water supply, is about 1,635,000 acre-feet. Of the total capacity, about 738,000 acre-feet is primarily used to provide water for irrigation, domestic, and industrial uses within the Upper Colorado River basin. The rest of the stored water is primarily for export, or is used to supplement the water supply in the basin at times when transmountain diversions reduce the flow of the streams to the point that prior rights are affected.

An average of about 468,400 acre-feet was being exported annually in 42 transmountain canals and tunnels as of 1957.

Of the combined sediment discharge of the Colorado and Paria Rivers (103,955,000 tons), about 20,495,000 tons (20 percent) comes from the Colorado River basin above Green River, about 27,875,000 tons (27 percent) comes from the Green River basin, and about 55,585,000 tons (53 percent) comes from the remainder of the Upper Colorado River basin below the mouth of the Green River. Of the amount from the basin below the Green River about 39,840,000 tons, or 38 percent of the combined suspended sediment of the Colorado and Paria Rivers, comes from the San Juan River basin.

Comprehensive observations of total sediment load and hydraulic characteristics of 6 cross sections in the so-called "Casa Colorado reach" of the middle Rio Grande were completed in May 1958. The discharge was slightly over 10,000 cfs, the highest experienced from snowmelt runoff in the Rio Grande in several years.

By memorandum to Branch Area Chiefs, September 25, 1958, S. K. Love, in a followup to the Chief Hydraulic Engineer's request of September 10, 1958, called for the identification and establishment of a few benchmark stations, "reasonably free from man-induced influences, that will define natural trends in sedimentation and chemical quality."

Several meetings were held during the last quarter of 1957 by personnel of the Geologic and Water Resources Divisions in Washington concerning the direction of a research study for occurrence of strontium in waters throughout the country. This resulted in a study in collaboration with AEC. with J. D. Hem as project leader and C. A. Horr, principal assistant. In a preliminary survey of analytical methods for determination of strontium in water, M. W. Skougstad reported that the flame photometric procedure was being used to determine strontium at low concentrations, i.e., 0 to 50 ppm.

During the spring months of 1958 the Division was involved in an intensive study of the effects of strip mining in the Beaver Creek Watershed project in McCreary County, Ky. Field parties were measuring the quantity and rate of movement of erosional material from the spoil bank and down the stream. A botanical study was begun to measure the effects of strip mining on trees and other vegetation on and around the spoil bank and along the stream. Growth was compared with unaffected areas. The geomorphology of the basin was studied and water samples from augered-observation wells in the spoil bank were analyzed periodically to determine the effect of strip mining on the quality of ground water. Results of the study were published in an open file report, "Influences of strip mining on the hydrologic environment of parts of Beaver Creek basin Kentucky 1955-59," C. R. Collier and others, May 1962.

A cooperative study was underway of the quality of water conditions in the Salt Creek basin, Tex. Brines from oil fields scattered through the watershed and dating as far back as 1918 caused serious pollution. Direct discharge of the brines into the tributaries, overflow the disposal pits, and numerous seepages from improperly closed wells increased the salinity of the watershed through the years.

Monthly salinity surveys were made to determine stratification and quality variations at Lake Texoma, Okla., in 1958. An odd situation at this lake, an impoundment fed by two major rivers, the Red and the Washita, is that mineral stratification is prevalent throughout the Washita arm and mineral concentrations are consistent in all depths in the Red River area.

Fluvial sediment: During the period 1955 to 1959 comprehensive investigations of waterborne sediments were continued in the Missouri, Middle Rio Grande, and Colorado River basins. These studies provided information about the sources of sediment, rates of discharge, and other pertinent factors in these areas to aid extensive Federal programs of water development.

It is noteworthy that the results of sediment investigations in the Wind River basin were published in Water Supply Papper 1373 (Colby and Hembree).

The program of the U.S. Soil Conservation Service was assisted by studies of sediment yields and the trapping efficiency of reservoirs on small watersheds in North Carolina, West Virginia, Kentucky, Georgia, Nebraska, Oklahoma, and Texas.

Special sediment studies were made for the Bureau of Reclamation in the Rio Grande and Colorado River Basins and in the watershed of Medicine Creek, Nebraska.

Investigations of sedimentation were continued in cooperation with Iowa, Wisconsin, Kentucky, Ohio, Pennsylvania, and Virginia. These included intensive studies of several small watersheds in Pennsylvania and Wisconsin to measure and explain changes in runoff and discharge of sediment induced by conservation practices.

By 1959 sedimentation studies had broadened to include the relationship of sediment transport to roughness and shape of stream channels; bedload discharge of sediment; development of automatic equipment for measuring sediment discharge of streams; and improved techniques and standards for analyzing and interpreting sediment data and records.

The fluvial sediment experimental studies were done collaboratively with the Department of Civil Engineering, Colorado State University, Fort Collins, Colo. Equipment development studies were conducted jointly with the Federal Inter-Agency Committee on Sedimentation, centered at the St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, Minn.

Through arrangements made by Chief Hydrologist Luna B. Leopold, informal discussions on various phases of sediment transport were held during the period. This arrangement made it possible for Dr. R. H. Bagnold, Civil Engineer, England, and other scientists to offer constructive suggestions for improving the scope of the Division's research program. Active in these discussions were Thomas Maddock, Jr., R. W. Carter, M. G. Wolman, P. C. Benedict, R. B. Vice, H. P. Guy, B. C. Colby, D. B. Simons, E. V. Richardson, D. W. Hubbell, C. H. Hembree, L. M. Brush, and D. M. Culbertson. In a meeting of these participants Feb. 5-11, 1958, topical discussion ranged widely from the relation between transport rate and streambed stress to a general discussion of grain velocity, fall velocity, drag coefficient and size-analysis plots.

Dr. Bagnold suggested that empirical relationships do not explain phenomena until they are integrated with the laws of physics. His flume experiments with small and large grain sediments and their application to U.S. river aggradation-degradation studies, i.e., change in concentration with change in slope, was a sure bet to stimulate lively discussion among sedimentologists during the period.

Reports: Reports on the chemical quality of natural waters, issued during 1956 and having special interest, included those on the Colorado River basin for the period 1925-40; the quality of surface waters for irrigation in the Western United States in 1952; the chemical characteristics of surface waters in the Devils Lake basin, N. Dak.; and the quality of surface waters in the Wind River basin, Wyo. Reports describing chemical characteristics of waters in South Carolina, Texas, New York, Kentucky, North Carolina, and Oklahoma were prepared in cooperation with those States. Studies of public water supplies in the larger cities of Alaska, Hawaii, and Puerto Rico were continued.

The following year, 1957, reports on studies of particular interest included those on water quality in the Fort Belvoir, Va., area 1954-55, and a report on a study of the salinity of water in the Delaware River estuary.

Hem's detailed reference report, Study and interpretation of the chemical characteristics of natural water, (WSP 1473, 1959), has been widely used in technical studies studies and as a classroom reference. Three reprintings of the publication by 1977 attests to its continuing value.

Reports describing the chemical characteristics of surface waters of Virginia, Arkansas, Texas, New York, and South Carolina were prepared in cooperation with those States.

Studies were begun on the uranium and radium content of ground water in several areas of the West and reports were released during 1958 for the Llano Estacado, Texas and New Mexico.

Radiochemical studies evolved with tritium monitoring of water resources during U.S. and other nuclear tests in the 1950's. Earlier work by Beetem, and others, was a study of the movement of pollutants in the Mohawk River by using radioactive tracers. Another study was the possible concentration of radioactive waste in bed material and suspended sediment, a potential problem in waste disposal.

Radiochemical studies had proceeded sufficiently by 1955 to allow firming up Branch objectives in this field. One phase of the work is to determine the nationwide distribution and concentration of natural activities in water resources. This will define background levels so that pollution may be more easily evaluated, provide data which may help define mechanisms for the mineralization of water, indicate areas warranting more detailed study of hydrology, and may prove a useful tool in geochemical prospecting.

Another phase is to determine the effects of pollution of both ground and surface water in order to evaluate the feasibility of various means of waste disposal for atomic power plants. A third phase is the study of the use of both natural and artificial activities as tracers for investigating the movement of ground water and the diffusion of dissolved solids in ground and surface water.

For many years the Division had searched for new methods for tracing of "tagging" water through the hydrologic cycle.

Fluorescein dyes and other easily detectable chemicals, such as sodium chloride, provided tools useful in some investigations but of limited use in others. Radioactive isotopes were found superior to nonradioactive isotopes as water tracers for many investigations because relatively small amounts are easily detected and a more accurate indication of hydrologic parameters could be obtained.

A new tracer, tritiated water, emerged in 1954 when Dr. Willard Libby reported that the isotope tritium is universally present in measurable quantity in all waters of the earth from rainfall in the last 50 years. (Kaufman S., and Libby, W. F., 1954, The natural distribution of tritium: Phys. Rev., v. 93, p. 1337). In waters older than 50 years the tritium content is generally too small to be measured.

Tritium is a radioactive isotope of hydrogen which is created in nature by cosmic ray (neutron) bombardment of air molecules at the edge of the stratosphere. $(n + N^{14} \rightarrow t + C^{12})$. The tritium oxidizes to form a water molecule, HTO, chich is identical to the ordinary water molecule H_2O, in all properties except mass (20 against 18). This newly formed tritiated water is incorporated into high-altitude clouds and eventually falls as precipitation. Because tritiated and ordinary water molecules are nearly identical in their chemical and physical properties the two molecules move thru the hydrologic cycle in essentially identical patterns. Thus tritium is a useful label to follow movement of water in the hydrologic cycle.

Tritium concentrations are generally measured in tritium units (TU) where one tritium unit is defined as equal to one tritium atom in 10^{18} protium atoms and is approximately equal to 3.2 picocuries per liter.

Dr. Libby's group at the University of Chicago established that the average concentrations of natural tritium in rainfall of the United States is 7 tritium units and the range is 2 to 10 TU.

Shortly after tritium was found in natural water, tritium levels in the northern hemisphere were raised drastically by tritium from a new source, the thermonuclear bomb. This produced values of several hundred tritium units in rain at Chicago in 1954 and immediately produced hydrologic applications.

Cosmic-ray tritium is the basis for age measurements or "water dating". For example, the radioactive half life of tritium is 12.25 years and the prebomb level in rain was 7 tritium units. Ground water that has not been contaminated by bomb rainout and which has tritium of 3.5 units must have been underground during one half life of tritium and is 12 years old.

Bomb tritium, on the other hand, was especially useful in problems which involved the shorter term turnover of water - periods of a few months or years, in which the movement of the bomb tritium pulse could be detected and followed.

In 1958, L. L. Thatcher was assigned to Libby's laboratory at the University of Chicago where he acquired the rudiments of tritium methodology and modified the analytical operations to a practical procedure for use in hydrology.

To document tritium impact on surface and ground water, the U.S. Geological Survey and the U.S. Weather Bureau established in the spring of 1958 a network of 12 stations for collecting and testing rainwater over the continental United States, Alaska, and Puerto Rico. Monitoring of tritium was continued until 1961 at the three Survey locations-- Washington, D. C., Lincoln, Nebr., and Menlo Park, Calif. (Thatcher and Hoffman, 1963. Jour. of Geophys. Res., v. 68, no. 20).

In September 1961, with the resumption of weapon testing by the Soviet Union, the observation network was expanded to include nine stations, by January 1963 to 15 stations, under the direction of G. L. Stewart.

The Survey detected the fallout peaks from the 1958 (USA) and 1961 (USSR) tests and confirmed that fallout from stratospheric tritium peaked in the late spring and early summer months.

In general it was found that tritium rainout radioactivity levels were higher toward the interior of the continent and tended to fall off in the coastal areas because the diluting effect oceanic moisture which is low in tritium. From the 2-10 TU concentrations before 1952, concentrations increased with accelerated thermonuclear tests. The large thermonuclear tests in late 1962 and the nuclear test ban treaty that followed soon thereafter resulted in 1963 being the year for the greatest tritium rainout. The highest peak concentrations occurred in 1963 for all stations except Albuquerque N. M., where peak concentrations occurred in 1964. Tritium amount then declined each year.

Samples were collected in standard 8-inch U. S. Weather Bureau rain gages. In most cases the samples represent bi-weekly composites; however, some samples from Boston and San Juan where composited over a longer period of time. The usual procedure was to collect all the precipitation falling in the rain gage during the two-week period. At the close of the two-week period, with the exception of periods in which no precipitation occurred, about 200 ml of sample was poured into polyethylene containers, labeled with pertinent information, and sent to the tritium laboratory in Washington, D. C., for analysis. Stations collecting composites for a longer period of time poured all of the precipitation from each rain into a large bottle from which a representative composite sample was taken for tritium analysis. Generally, the amount of precipitation was measured in the rain gage at the end of the two-week period.

Specific analytical procedures used to measure tritium radioactivity, except for a few refinements, are outlined by Hoffman and Stewart (1966). High activity samples (generally greater than 500 TU) were counted directly, using a liquid scintillation spectrometer and/or a gas counting system employing Geiger-Muller or proportional detectors.

Before counting by one of the two counting methods, low activity samples were enriched in tritium activitiy by employing electrolytic procedures.

Other noteworthy reports included "Chemical character of public water supplies in Alaska, Hawaii, and Puerto Rico; "Chemistry of iron in natural waters;" "Study and interpretation of water analyses;" "Hydrologic and tracer studies in Mohawk River at Knolls Atomic Power Laboratory;" "Saline water resources of North Dakota;" and "Quality and quantity of surface waters of Alaska through September 1950."

Among the reports prepared in 1959 were those on the chemical quality of surface waters of South Dakota with special reference to selenium, boron, and fluoride; a survey of analytical methods applicable to the determinations of strontium in natural waters; and distribution of uranium and radium in ground waters of the United States.

THE YEARS 1960 TO 1973

GENERAL

Changing needs in data acquisitions: National concern about environmental quality literally exploded in the 1960's and was expressed in Federal legislation such as the Water Pollution Control Act Amendments of 1972 (Public Law 92-500), the Safe Drinking Water Act (Public Law 93-523), and the Toxic Substances Control Act.

Some features of the Water Quality Act of 1965 and its impact on Interior-related activities are considered in a later section.

For many years the water-quality work of the Geological Survey in many parts of the country consisted almost exclusively of the determination of inorganic chemical parameters. These data-collection activities have been essential to the orderly development of water-use projects. Evaluating the suitability of surface water for impoundment for municipal, industrial or irrigation use; determining the source and magnitude of saline pollution, both natural and man-made; measuring the effects of impoundments on water quality; inventorying the chemical quality of water in wells as part of a ground water study are some of the vital needs that have been met by the Survey's long-term water-quality program.

Increasing responsibilities for gathering meaningful water-quality data to meet the changing needs of water-management and pollution-control agencies has resulted in the Survey extending its capabilities to include routine determinations of pesticides, nutrients, bacteria and aquatic biota, minor elements, and others.

The enactment of the Water Quality Act of 1965 (79 Stat. 905) brought increasing national attention to man-induced water-quality problems such as the proliferation in water resources of "exotic" substances including pesticides and organics, trace elements, nutrients, and biochemical substances. Highly sophisticated instruments for routine determinations in the laboratory were necessary to replace older laborious methods. And, the Water Resources Division was continuously improving systems for in situ field monitoring and digitally recording water-quality parameters.

Personnel items: S. K. Love retired as Chief, Quality of Water Branch April 1968 after 39 years of distinguished Federal service--nearly 20 years as QW Branch Chief. His principal staff personnel in Washington during all or parts of the period 1960-1968 included W. W. Hastings, E. W. Lohr, W. F. White, Jr., R. B. Vice, P. C. Benedict, H. A. Swenson, F. H. Rainwater, W. H. Durum, G. A. Billingsley, S. G. Heidel, R. L. McAvoy, H. R. Feltz, J. J. Musser, J. F. Blakey, J. K. Culbertson, D. K. Leifeste, and J. E. Biesecker.

Mrs. Martha Keith was principal secretary to the Branch during the period and for many years prior to 1960.

Mr. Love was succeeded in June of 1968 by W. H. Durum who had transferred to the Washington staff from the Lincoln office in July 1951 following assignments in water-quality field investigations in the Missouri basin. Prior to that he was an industrial chemist with E. I. duPont Co.

Several major and recurring questions needed to be considered and resolved, if possible, by the Quality of Water Branch staff.

Although District operations provided local leadership for stimulating programs and responding to local needs in water quality, national leadership was essential to focus attention on broad national interests and priorities in programs. How could this best be accomplished to develop a well-rounded program to serve public interests efficiently?

The disclosure in 1970 of excessive levels of mercury in fish in the Great Lakes system and elsewhere prompted several concerns among environmental specialists in Washington. One concern common to several Federal scientific agencies was that water-quality data-gathering activities were too traditional and not flexible enough to accommodate growing demands for new information particularly in the field of environmental quality. Were potentially hazardous substances going undetected and improperly evaluated in our water resources?

As a member of the Federal Committee on Pesticides, Durum was approached by knowledgeable scientists in the Federal sector such as Dr. John Buckley, Office of Scientific Information with the inquiry, "We know that GS, EPA, and others have an extensive water resources information gathering program for U.S. rivers. But what assurance is there that a catastrophic event such as an accidental or deliberate spill of an unknown toxic substance will be detected before reaching the intake of a metropolitan water supply?" Response to this concern was that no absolute safeguards existed. However, numerous hydrologic factors such as time or travel, dilution factor, chemical reactions and interactions with sediment, together with existing monitoring, detection, and sampling systems provided a high probability that the event would be detected in a few hours to a few days. New, unknown compounds posed a specific problem of uncertain dimensions to any water quality fact-finding organization.

Corollary to this was another major question: What technical design of a water quality observational network will best serve the expanding requirements for data in the public sector? This continued to be a basic concern of the Division faced with budgetary constraints and competing costs for data-gathering activities.

Another continuing problem dealt with the question, What system of laboratory facilities can best serve the Division's requirements? Capital costs of equipment for essential upgrading of laboratories had elevated beyond their justification for small Federal-State cooperative programs. Federal "seeding" funds had been used where warranted, however, obsolescence and depreciation of laboratory automated equipment was rapid, and recurring replacement was uncertain. Additionally, more stringent requirements for timely water quality information was needed to assist enforcement agencies in routine activities. Prior to this, weekly, monthly, or even annual transmittal of Survey information was adequate for many public works planners and designers. Now the request for "real" time data could be daily, weekly or more frequent.

Concurrently, the Division district operations of Philadelphia, Albany, Tacoma, and elsewhere were giving attention to a link between field and laboratory teletyped and computerized transmission of data to cooperators and a central data bank.

To provide technical assistance for these urgent Branch problems Durum called on experienced field operations and research personnel representing each regional office including H. R. Feltz (Atlantic Coast Region); R. A. Krieger (Mid-Continent Region); F. C. Ames (Rocky Mt. Region); P. C. Benedict, Branch Area Chief (1963-65) D. M. Culbertson, 1965- (Pacific Coast Region); and M. W. Skougstad (Analytical Methods Research). The Water Quality Advisory

Group served the Branch and Division Headquarters staff productively for the next four years.

Several additions were made to the Branch headquarters staff from 1968 to 1970. J. K. Culbertson transferred from the Rio Grande sedimentation studies to headquarters as sedimentation specialist. R. J. Pickering transferred from the Columbus, Ohio office to Washington headquarters as Assistant Branch Chief. Together with J. J. Musser, D. K. Leifeste, and J. E. Biesecker the small staff guided water-quality activities for the next four years.

Biesecker was transferred to Branch headquarters from the Harrisburg office in June 1968 with responsibility for developing and strengthening technical aspects of basic data programs for biochemical and biological techniques as well as for environmental quality studies generally in the operational program. He also was active in planning a laboratory system commensurate with the potential growth of water quality requirements of the Division.

As the staff continued to evolve basic ideas in the network design, other field ad hoc groups were developed to improve technical laboratory and field manuals, a part of the developing Division's. Techniques of Water Resources Investigations (TWRI) series.

Eugene Brown was assigned to the Denver office for full-time preparation and review of authored chapters on methods manuals for chemical and dissolved gases, organics, pesticides, radioactivity, minor elements, etc. M. W. Skougstad and other specialists in research and operation programs prepared the documents and provided guidelines in their specialty for use by Washington headquarters.

J. K. Culbertson transferred to the QW Branch headquarters staff as sedimentation specialist, November 1969. Culbertson had more than 20 years experience in District operational sediment activities, including the past 5 years on a research study of the mechanics of flow and sediment transport at the Rio Grande conveyance channel near Bernardo, N. Mex.

Mr. Durum retired in May 1972 and was succeeded by R. J. Pickering. Previous to his assignment in Washington, Pickering was in water-quality investigations in the Ohio River basin and at Oak Ridge, Tenn.

Dr. Luna B. Leopold, WRD Chief Hydrologist (1957 to 1967) and his successor E. L. Hendricks developed a keen introspect of water quality activities. Leopold shored up lagging research so essential to an understanding of the principles of basic science of water quality more nearly comparable with that of other hydrologic fields. Both Leopold and Hendricks participated in, and gave counsel to, field investigations and problems in water quality and strengthened Division program support in this area.

The Honorable Stuart Udall, Secretary of the Interior (1964-68) maintained a lively personal interest in water resources and water-quality activities of the Survey. On more than one occasion he referred to the Survey as his "technical arm" of the Department, and he and members of his staff called on the Division for information and technical advice about the highly visible Potomac River and Rock Creek.

On one occasion the Secretary invited Messers, Langbein, and Durum to a luncheon discussion with a small group of Department planners. "The Potomac River and Rock Creek are paper tigers." he said. "We must clean up these historical streams in the Nation's capital as an example for the rest of the country. Rock Creek looks like a chocolate malted whenever it rains. How long will it take to do this job?"

"At least 10 years" was the reply." "Too long," said the Secretary, a political pragmatist, "I won't be around then."

About an hour after the pleasant and simple fare luncheon in the Secretary's private dining room, a sealed envelope was delivered to Durum's desk by mail messenger. Inside was the notation: "1 luncheon--$0.76."

Federal legislation and agreements relating to Survey's water-quality activities: *Water Quality Act of 1965*--Following the enactment of the Water Quality Act of 1965 (79 Stat. 905), and interdepartmental agreement concerning consultation between Departments of Health, Education, and Welfare and the Interior was developed, September 2, 1966. Terms of the agreement were based upon the following general concept:

> "4(a) The Department of Interior is responsible for administering the Federal Water Pollution Act as amended; certain functions relating to water pollution control under Section 702(a) of the Housing and Urban Development Act of 1965, Section 212 of the Appalachian Regional Development Act of 1965, and Section 106 of the Public Works and Economic Development Act of 1965, and Executive Order 11288," Prevention, Control, and Abatement of Water Pollution by Federal Activities."

The stated purpose of the Federal Water Pollution Control Act is "to enhance the quality and value of the Nation's water resources and to establish a national policy for the prevention, control, and abatement of water pollution." The responsibilities of the Department of the Interior under the above legislation and Executive Order, involve the prevention and control of water pollution in consequence of the benefits resulting to the public health and welfare, giving due regard to the improvements which are necessary to conserve the Nation's waters for public water supplies, propagation of fish and aquatic life and wildlife, recreational purposes, and agricultural, industrial, and other legitimate uses. To meet these responsibilities the Department of the Interior, through the Federal Water Pollution Control Administration, conducts programs to identify and measure the extent of pollution and its effects on water uses and to assure the treatment and control of waterborne wastes."

Following the definition of the functions of the two Departments in water pollution as related to public health the Agreement stated:

> "8. The Public Health Service and the Federal Water Pollution Control Administration will exchange on a regular basis relevant health-related water quality data and research results. Particular attention will be given to prompt exchange of significant new findings which would affect the program responsibilities of either agency."

Moore-Pecora Agreement, 1968--In response to the directive from Department of the Interior, Under Secretary Black, February 1, 1968, the Moore-Pecora Agreement dated July 18, 1968, defined the working relationship between Interior's FWPCA (Joe G. Moore, Commissioner) and USGS (W. T. Pecora, Director).

It summarized agreements regarding responsibliities and work relations between the two agencies relative to water-data activities directed by Bureau of the Budget Circular No. A-67, "Coordination of Federal activities in the acquisition of certain water data." Under "Scope of Operations" the memorandum stated, "FWPCA is responsible for studying and controlling pollution of the Nation's water resources, which involves a wide range of water-data collection, research, and regulating activities related to pollution processes and problems. USGS collects data and conducts research to explain the occurrence, movement, and quality characteristics of the Nation's water resources, but has no water management responsibility."

The agreement called for a water-data system to be designed on the basis of user need, and the retention of a full range of analytical capabilities and laboratory facilities essential to continuing data programs of both agencies. It specified that "Data collected by FWPCA and USGS must be reliable, interchangeable for all practicable purposes, and should be equally acceptable to the courts of law. To insure this, the two agencies plan to coordinate their analytical quality-control programs."

Another key item in the Agreement is that "All water quality data which meet analytical quality requirements of either agency will be stored and processed in a mutually acceptable data handling system." (This is currently being accomplished through use of the STORET System.)

On December 2, 1970 the FWQA (formerly FWPCA) was removed from Interior and officially became the Water Quality Office (WQO) of the Environmental Protection Agency (EPA). Following this reorganization several memorandums of agreement or understanding were prepared during the 1972-73 period; however, none replaced the Moore-Pecora Agreement until 1975.

The unavoidable overlap resulting from FWPCA (subsequently EPA) responsibilities for environmental protection and Interior's responsibilities for resources resulted in a sometimes difficult working relationship between the two agencies.

Some offices seemed to operate on the premise that the Federal Water Pollution Control Act (PL 92-500) preempted assigned responsibilities of the USGS in regard to water quality, ignoring the historic role of the Survey and the water-data acquisition directives to Interior in OMB Circular A-67.

The USGS-WRD was particularly effective in the early work with FWPCA and EPA in implementing EPA's National Water Quality Surveillance System (NWQSS) by means of a data collection program financed through transfer funds from FWPCA and EPA in the amount of about one-half million dollars annually.

USGS - Quality of Water Branch and EPA's technical representatives worked effectively in the early stages of mutual and acceptable methods and procedures for NWQSS. This became a headstart for OWDC's Interagency "Recommended Methods" effort and high level of participation on 10 technical working groups.

OWDC, together with the technical branches of WRD helped EPA develop the guidelines to States for water-quality monitoring under Section 106 of the Federal Water Pollution Control Act (PL 92-500).

STATISTICAL SUMMARY OF PROGRAM

During the period 1960 to 1974 the following water quality stations were maintained by the Survey in cooperation with other agencies for the collection of basic data on the chemical, biological, microbiological and physical characteristics of streams, lakes, and reservoirs in the United States and its territories.

Year	Total	Chemical	Sediment	Temperature
1960	1,120	-----	-----	-----
1961	1,150	-----	-----	-----
1962	1,236	-----	-----	-----
1963	1,367	942	307	1,133
1964	1,497	1,003	431	1,133
1965	1,674	1,116	477	1,360
1966	1,958	1,353	502	1,623
1967	2,102	1,483	561	1,661
1968	2,458	1,782	672	2,132
1969	3,578	2,935	705	3,011
1970	4,195	3,474	772	3,648
1971	4,344	3,546	873	3,586
1972	4,964	4,191	842	4,057
1973	5,036	4,252	844	4,107
1974	5,060	-----	-----	-----
1975	5,800	-----	-----	-----

Table 2 and figure 3 in Part 1., show the annual program growth in water quality stations, and in total funds from all sources from 1960 to 1974. The number of operating stations is seen to increase rapidly from about 1965 and nearly 2-fold between 1967 and 1970 (2,102 to 4,195 stations). This marked expansion in and other Federal legislation in general, that brought added responsibilities to Survey's Water Resources Division data programs at both Federal and State levels.

In table 2 it can be seen that the total program funds doubled in the 5-year period 1960-65 from about $2.7 to $5.4 million and increased steadily to $8.8 million by the close of the period in 1973.

Table 3 shows figures for the annual sediment program for several years. These are included in the total water quality program funds, in table.

Table 2.--The annual Federal and State program funds available (in thousands of dollars)

Year	Total	Federal	Federal-State	Others
1960	2,716	995	1,211	510
1961	3,307	1,280	1,375	652
1962	3,609	1,089	1,609	911
1963	4,410	1,662	1,759	989
1964	-----	-----	-----	-----
1965	-----	-----	-----	-----
1966	-----	-----	-----	-----
1967	-----	-----	-----	-----
1968	-----	-----	-----	-----
1969	-----	-----	-----	-----
1970	7,064	559	4,879	1,626
1971	-----	-----	-----	-----
1972	-----	-----	-----	-----
1973	*8,000	1,300	4,800	1,900

* Collection of basic records only.

Source: Memorandum form Adminstrative Office, WRD, April 2, 1964; Memorandum from Chief, Planning Section (W.S. Daniels), January 28, 1974.

Table 3.--Annual Federal and State program funds available for stream-sediment program
(In thousands of dollars)

Year	Total	Federal	Federal-State	Others
1957	800	300	150	350
1958	1,050	400	200	450
1959	1,050	450	250	350
1960	1,100	500	250	350
1961	1,150	500	300	350
1966	1,700	500	650	550
1967	1,700	450	700	550

Source: Program analysis file, J. C. Stephens, April 7, 1967. Rounded to nearest $50,000.

The following ranges of budget estimates for the majority of the laboratories are considered a reasonable guideline:

1940-50	$25,000 to $ 50,000
1951-65	$50,000 to $ 75,000
1965-73	$75,000 to $300,000

A few of the smaller facilities reported an operating budget of about $30,000 through 1973, and four operated in the genreal range of $200,000 to $670,000 in the 1970's. Generally the budget increased two-to-six-fold during the lifetime of most laboratories, and two larger facilities reported and increase of nearly 20-fold during the period of operation (fig. 2, Part 1).

During the 1950's the total water quality program obligations ranged between 10 and 11 percent of the total Water Resources Division program funds from all sources. This shifted upward in the 1960's ranging from 12 to 14 percent, and by 1970 the water quality program had risen 14 to 15 percent of the Division's total funds, and this upward trend continued through 1973.

Thus, over a 3-decade period as the WRD total program expanded one observes a small but progressively larger share of the total Division program funds is composed of water quality activities.

LABORATORY AND FIELD FACILITIES AND METHODS

The last group of full-time laboratory facilities included Yuma, Ariz. (1961); Tuscaloosa, Ala. (1962); Tacoma, Wash. (1964); and Honolulu, Hawaii (1967). This brought the Water Resources Division total to 22 laboratories. All 22 District facilities were discontinued as full-scale laboratories in the 1973-74 period and converted to District service units when the Central Laboratory began full time operation at Denver, Colo; Atlanta, Ga; and temporarily at Albany, N.Y. Specific information about each of the 22 facilities is given in Part 1 of this report.

Laboratory operations were to undergo radical change during the period beginning about 1960. The reason lies in one principal advance - instrumentation. Earlier, laboratories - time consuming gavimetric procedures were superseded by rapid, more accurate instrumental methods in which the analysts' bias was largely eliminated. These new instrumental techniques reduce costs by streamlining the work. For example, the determination of potassium using the mixed chloride and chlorplatinic acid method required up to 3 to 5 days for a "set" of 10 samples. Reruns were frequently necessary. Using the modern flame photometric method adopted in QW laboratories by 1950, an analyst could now complete as many as 50 or 60 potassium measurements in a day. Possibly the first modern major advances occurred about 1960 when the QW Branch began testing the atomic absorption spectrophotometer at the Denver Methods Development Unit under Marvin Skougstad.

About 1964, the Denver laboratory began determining routinely by atomic absorption spectrophotometric (Perkin-Elmer Model 303) the elements sodium, potassium, calcium, and magnesium, and also several minor elements--strontium, lithium, manganese, copper and zinc in natural waters. These elements were directly in the aqueous phase and only in the potassium, calcium, magnesium, and strontium determinations are other reagents added to eliminate either chemical, ionization, or matrix interferences. In the determination of other minor elements such as lead, cobalt, and nickel, the concentrations that normally occur in fresh waters are lower than can be detected by atomic absorption directly. Concentration by chelation and extraction allowed detection of as little as 1 microgram per liter (μg/L) of the element.

At a 1966 Symposium on Water Analyses Methods in Philadelphia, R. L. McAvoy reported that the Baton Rouge laboratory had a Beckman Atomic Absorption Spectrophotometer with a linear strip-chart recorder and scale expander. "At present," he said, "we have the analytical capability to determine (by A.A.) iron, calcium, magnesium manganese, copper, lead, sodium, potassium, nickel, strontium, zinc, and lithium."

Since 1961, the Texas district had conducted more than 75 separate water-quality surveys in eight man-made reservoirs. H. B. Mendieta reported (1966), "The need to pinpoint our depth sampling with the series of instrument readings prompted the development of the pump sampler. The Texas district has been using a custom-built sampler in its lake studies since June, 1965. The pump sampler has been built to measure dissolved oxygen, pH, conductivity, and temperature parameters."

During the early 60's the Branch was hard at work with systems for monitoring and digitally recording water-quality parameters. At the Philadelphia Symposium (1966) George Smoot and James Blakey were ready to report that the digital recording of water-quality parameters is a link in the automated data collection and processing system of the USGS. The monitoring and digital recording systems adopted by the Survey, while punching all measurements on a standard paper tape, provide a choice of compatible components to construct a system to meet specific physical problems and data needs. Smoot said, "As many as 10 parameters can be recorded by an instrument, with the only limiting criterion being that measurements are expressed as electrical signals."

During the early months of 1969 the Methods Development Unit, Denver, tested two automated laboratory systems, the "Auto Analyzer" and "Titralyzer." The Auto Analyzer was widely used in industry and hospitals for routine chemical analysis using standard procedures, and the unit was endorsed for high volume productions in Division laboratories.

To supplement the "Auto Analyzer" and atomic absorption spectrophotometer procedures, the "Titralyzer" was endorsed for determination of alkalinity, chloride, and sulfate.

As a step toward achieving automated techniques, the Division concurred with these endorsements and approved their use in Districts where programs and funds are sufficient to warrant purchase of the equipment (QW Branch Technical Memorandums 69.06, May 1, 1969 and 69.08, June 30, 1969).

The proven performance but relatively high cost of automated equipment led to decisions on preparing a pilot study for an automated laboratory.

During the early years of the Washington, D.C. laboratory, 1919-28, total annual production averaged about 480 adjusted complete analyses annually. The addition of the second facility, Austin, in 1937, and the increase in the number of analysts in the two laboratories (total about 20) increased production to an estimated 2400 complete analyses by 1940.

About ten years later, in 1946, total analyses performed in six facilities rose to 7,800 adjusted complete analyses. By 1960 total output had increased four-fold to more than 30,000 complete analyses and by 1970 when 22 facilities were operating, the national total was estimated to be about 50,000 complete analyses (fig. 2, Part 1).

The significant increases in production for the 3-decade period 1940-70 clearly indicate that as instrumentation techniques improved several-fold the production efficiency of analytical procedures, so also the demand for water-quality information increased dramatically and led to decisions on consolidation into the Central Laboratory System in the early 70's.

During the late 1960's and early 1970's the Branch was responsible for the preparation of several chapters of book 5, "Laboratory Analysis" in the series "Techniques of Water-Resources Investigations of the U.S. Geological Survey" (TWRI). Published during the period were chapter A1, "Methods for collection and analysis of water samples for dissolved minerals and gases;" chapter A2, "Determination of minor elements in water by emission spectroscopy;" chapter A3, "Methods for analysis of organic substances in water;" chapter C1, "Laboratory theory and methods for sediment analysis; and chapter A4, "Methods for the collection of aquatic biological and microbiological samples."

Water Resources Division Memorandum No. 71.72 dated November 24, 1970 outlined Division policy regarding the use of analytical methods by Division laboratories and established procedures for recommending new or improved methods for Division use. The official Geological Survey methods for analysis of water samples for inorganic minerals and gases are described in book 5, chapter A1 TWRI. Field offices were directed (QW Branch Technical Memorandum No. 71.04, January 13, 1971) to use only these procedures for analysis of substances covered except where prior approval had been obtained from the Denver Methods Development Unit and Chief, Quality of Water Branch.

Development of water-quality monitors: The first recording of multiparameter water-quality characteristics occurred in 1959 - 1960 when a water quality monitor was installed in the Delaware River estuary, at Philadelphia. The Pennsylvania District tested and made innovative improvements to monitoring equipment for the next several years in cooperation with the city of Philadelphia and equipment manufacturers. In November 1962 a water-quality monitor was installed on the Cuyahoga River at Center Street in Cleveland in cooperation with the Ohio Department of Health. The Ohio District water-quality network in the late 1960's and early 1970's consisted of 42 stations of which 33 were 4-parameter stations (conductance, temperature, pH, and dissolved oxygen). This large monitoring program was operated and maintained by 4 men. Initially, many problems were encountered with the water-quality digital monitors as received from the manufacturers. Some appeared to be related to deficiencies in the specifications provided to the manufacturers, but many electronic problems were due to poor quality control by the manufacturers. The Pennsylvania and Ohio Districts experience, including many hours tracing down and correcting deficiencies, were helpful to George Smoot, Washington Headquarters, and to the manufacturers in designing and constructing future units.

By 1968 the Ohio District had developed a progressive digital monitoring program with State cooperators and was calling for better quality control on future monitors and improved service on tape translations in Washington in order to avoid wasting manpower and to provide cooperators with rapid essential data on water quality.

About 40 automatic monitors were installed in the field by 1968. Most of these were undergoing field tests, and they required much maintenance and calibration, and records were often erratic or the instruments failed to function properly for long periods.

But the potential for the automated instruments was never in doubt at Branch headquarters, and despite a ragged start, the age of on-site automation had begun.

In the State of Washington, two water-quality programs utilize the RM25 automatic water-quality monitor produced by Schneider Instruments of Cincinnati, Ohio. Four of the monitors were installed in the Duwamish River, at Seattle, and two were installed in the Grays Harbor area. A central digital recording and control system is also a part of the monitoring system on the Duwamish River. The data are considered reliable. (temperature, conductivity, dissolved oxygen, pH, solar-radiation intensity, and telemetry system.) The dissolved oxygen sensor requires more maintenance and calibration checks than specifications indicate, and probably has caused the most amount of trouble. With that exception, the parametric systems have operated within the tolerances specified by the manufacturer. Data have been lost mainly because of equipment failures (N. F. Leibbrand, et. al., 1966).

On June 8, 1966 (QW Branch Technical Memorandum No. 66.01) Distric offices were informed of a simplified computer program for the computation of suspended-sediment discharge and available through the Washington office. This program is designed to compute values of sediment discharge from values of daily mean sediment concentration and daily mean stream discharge. Also, the program has the capability for computing subdivided days. M. D. Edwards, project chief, also was making available other water-quality computer programs for use on a limited and experimental basis.

The following week the Washington headquarters (QW Branch Technical Memorandum No. 66.02) released preliminary instructions for the processing of multivariable water quality data recorded on a single sixteen-channel tape. These instructions were to be used in the processing of all water-quality monitoring data being recorded by the Fisher-Porter digital recorder.

The Lincoln office and some others made good use of early automatic data processing (ADP) methods available in the 1960's through a combination of local and national ADP facilities. Laboratory observations were transferred to cards for input to a local computer. The program computed the constituent concentrations and, for "complete" analyses, checked the ionic balance. Output was in the form of digital printout and punch cards. The latter were transmitted directly to Washington and entered in the Survey computer system. Data printouts from Washington were carefully checked against original analyses and corrections noted.

Central Laboratory System: In April 1970 a Water Resources Division Task Group prepared guidelines for centralizing water quality laboratories, considered alternatives, and provided detailed studies including transportation and laboratory-operation models for various workloads. On the basis of the Task Group analysis and recommendations and the support of the Regional Staffs, on August 7, 1970 the Chief Hydrologist proposed that the Division proceed immediately with the central laboratory concept. He proposed that a facility be established at Salt Lake City as a "pilot operation" to gain experience and to test the program.

The Chief Hydrologist concluded that the Division should move toward central water-quality laboratories as an established objective. "The outlook," he said, "on water quality activity combined with the availability of new high-volume analytical instrumentation prescribes with an almost certainty that the central laboratory concept must be adopted if we are to operate effectively and efficiently."

The test facility at Salt Lake City supervised by R. L. McAvoy was in production November 1, 1970, and continued until March 31, 1972 when results were evaluated and the pilot study declared a success.

Committed to the central laboratories concept the Division, in February 1973, proceeded to implement the proposal as rapidly as funding and manpower would allow. Two large-scale, highly automated laboratories at Denver, Colo., and Atlanta, Ga., were immediate goals. A third location was to be designated later. Two criteria were used for reference: (1) Each large-scale laboratory would be complete, offering laboratory services in a wide range of water quality and sedimentation analysis as required in the current workload, and (2) development of line-production procedures for currently non-automated analytical methods would be given high priroity in methods research efforts.

The Central Laboratory is the heart of the WRD national water-quality system consisting of three units with district and interrelated functions. The first unit is the streamside or well-head mobile or field unit with portable equipment that performs rapid field analyses of critical-time measurements such as pH, conductance, coliform, dissolved oxygen, and temperature. It preserves and prepares samples prior to shipping. The second unit is the District water quality service unit, of which there are nearly 50, that prepares reagents and solutions, calibrates field equipment, and performs simple routine analyses and while-you-wait services.

The third unit consists of the three Central Laboratories at Denver, Colo., Atlanta, Ga., and tentatively at Albany, N.Y. They perform production-line analysis of conventional inorganic, organic, nutrients, trace elements, radioactivity, pesticides and biological substances using automatic equipment with digital readout attachments. Facilities for coding and telecommunicating data allow processing into the Water Resources data computer and storage system.

The Central Laboratories are not a special case in the management chain, and Regional Hydrologists have the same management responsibilities for the laboratories as for other activities in the Regions. The Assistant Chief Hydrologist for Research and Technical Coordination is responsible for coordinating activities needed to support the Central Laboratories, such as scheduling and pricing, data processing, and promulgating technical standards and measures for assuring quality control. He is assisted by a National Analytical Services Coordinator at Reston, Va., headquarters under the general supervision of the Chief, Quality of Water Branch.

J. S. Cragwall, Jr., then Assistant Chief for Operations and later to become Chief Hydrologist took a special interest in the Central Laboratory concept from its inception. He viewed the activity as an example of the Federal decision-making process, studied the historical development of the Division's facilities, provided input to the Task Group analysis, and was a strong proponent of the test facility at Salt Lake City.

NEW PROGRAM THRUSTS

Federal Water Pollution Control Administration (FWPCA): WRD Memorandum No. 69.14 and the memorandum of agreement that accompanied it, dealt with the Federal Water Pollution Control Administration - U.S. Geological Survey relations in water-data activities. Numerous discussions were held at District and Regional levels to determine specific needs and how they might be met. One such meeting called by John J. Malloy, District Chief, Columbus, Ohio, February 11, 1969 included representatives of FWPCA, USGS, and Miami Conservancy District (MCD). The meeting, an early key one in continuing negotiations, dealt with means for providing meaningful data to adequately serve the need of MCD in water quality management, FWPCA in enforcement responsibilities, and useful water resources quality information for the general public - a unique responsibility of USGS. The MCD was concerned that data produced by the different laboratories would not be identical; and hence, open to doubt as to precision and accuracy, to the effect on water management, to fair and equitable assessment of charges, and to pollution control.

A summary of tentative decisions and conclusions were made on definitions, methods of analysis, and composition of programs based on best available knowledge of the state of the art in water quality. This and other meetings provided the stimulus for technical improvements in operating programs.

During the period 1968 to 1970 Branch personnel met frequently with representatives of EPA at management level in Washington and technical level at Taft Research Center, Cinncincinnati, Ohio. New ground rules had to be established to provide EPA with stringent water-quality data essential to requirements of State and Federal water quality enforcement legislation. For example, standard water analyst methods (including the Survey's methods) dealt separately with the dissolved phase, (i.e., capable of passing through a 0.45 µ (micron) filter) and the suspended or solid phase (particles larger than 0.45 µ. EPA technicians interpreted Federal legislation on water-quality criteria as a measure of the whole water sample (i.e., dissolved and suspended).

After lengthy discussions inside and outside of both agencies, continuing memoranda, and extraordinary patience by participants, these differences were settled amicably. Data in computer storage would be coded to identify treatment and analysis of the sample.

A small cooperative program with EPA with the assignment to the Survey of sampling and analytical schedules for stations in the EPA surface water-quality program was approved 1970; amounting to approximately $100,000.

For several months the Denver Methods Development Unit and National Headquarters worked closely with FWPCA's Analytical Quality Control Laboratory staff in Cincinnati, and with the Pollution Surveillance Branch in Washington, D.C., toward improving standard procedures for inclusion in the 1970 joint FWPCA-USGS surveillance program. The objective was two-fold: (1) To provide uniform data for FWPCA's regulatory and pollution surveillance mission and for State responsibilities for enforcement of water-quality standards and management needs, and (2) to allow orderly progress in USGS responsibility for standardizing data under Bureau of Budget Circular A-67. These discussions progressed sufficiently to give guidelines for laboratory analytical requirements during current negotiations. FWPCA provided national headquarters with a listing of parameters and procedures, many identical to USGS analytical procedures, for which the two agencies agreed to begin the program.

Guidelines for surveillance program with FWPCA--On May 29, 1969 (Quality of Water Branch Technical Memorandum No. 69.07) the Division outlined current guidelines for sampling, analysis, and reporting water-quality data to be used in the 1970 fiscal year Federal Water Pollution Control Agency (FWPCA) surveillance program with USGS. The guidelines were to become effective on July 1, 1969, for conducting water-quality investigations for FWPCA, as well as for other agencies. Included was a list of parameters and specific analytical procedures mutually agreed upon by the USGS staff and representatives of FWPCA at Cincinnati.

The document represented a major achievement in a coordinated effort with FWPCA and in an up-to-date of the parameters included in USGS programs and designated by FWPCA in the first year of a transfer program.

Technical review of water-quality activities: In addition to sampling and sample-treatment procedures and specific methods of analysis for parameters, reporting units, and STORET (Computer) parameter codes the chemical constituents are reported in three categories: (1) Dissolved, (2) suspended, and (3) total (dissolved-plus-suspended).

Dissolved material is that which goes through a 0.45-micron micropore membrane filter. Determinations of dissolved constitutents are made on aliquots of a filtrate. Alternatively, determinations may be made on aliquots of an unfiltered sample if it is known that the presence of suspended material has no effect on the determination.

Suspended material is that which is retained by a 0.45 micron micropore membrane filter. Determinations of suspended constituents are made either by analyzing portions of the material collected on the filter disk or, more commonly, by difference, based on determination of (1) dissolved and (2) total (dissolved-plus-suspended) concentrations of the constituent.

Total (dissolved-plus-suspended) material is the total amount present in the whole sample, regardless of its physical or chemical form. The specified treatment and analytical procedure defines the material reported by the analysis.

To be completely explicit, the method of treatment and analysis should also be reported. However, when a widely recognized and accepted method is used, mention of the procedure may be omitted, e.g., organic nitrogen.

By September, 1969 some followup visits were made by experienced analysts to determine that instructions were being followed by field personnel in regard to required sample volume, preservatives, acceptable equipment, and field procedures.

Remedial measures were taken to correct any situation where deficiencies existed or instructions were not being followed.

In June 1968 the Branch staff prepared documents aimed at strengthening certain features of the quality-of-water activities within the framework of Division objectives and goals, and to cope with emergent problems in environmental quality. Plans were outlined (WRD Memorandums No. 69.32, and WRD Memorandum No. 69.33, September 6, 1968) and initiated in the fall of 1968 for the technical review of water-quality activities at the District level. Reviews were conducted by technical specialists from the Branch and/or Regional staffs, with assistance from other senior personnel as needed.

The major topics covered included the District's design of water-quality program, operation of basic data collection system, quality control, interpretive studies, and technical training, among others. A report was prepared by the reviewers and the Regional Hydrologist initiated follow-up actions as needed.

Reviews were planned to visit all District offices within a period of 3 years beginning in May 1969. Subsequent reviews demonstrated the value of this approach.

The rationale for the review and the measure of intensity for improved quality control can be summarized as follows (WRD Memorandum 69.32).

"The ways in which the water-quality discipline is involved in hydrologic studies have increased in number and complexity in recent years. The current national emphasis on such subjects as pollution surveillance and control, and the establishment of water-quality standards requires development of new techniques and capabilities in the Division's data-collection program. Besides new requirements, there is a continuing need for better and more uniform evaluations in the chemical quality, sedimentation, and temperature aspects of the programs.

"Aside from those functions concerned strictly with analysis of samples after they have been received in the laboratory, and some aspects of our sedimentation studies, few formal guidelines have been established to control water-quality investigations. In most instances, the needs in the individual districts have been the principal controlling factors. However, there are several aspects of water quality which are emerging and assuming increased importance for which modification of present techniques are necessary. As a part of the technical reviews, attention will be given to these changing needs and the extent to which we must be prepared to meet them. For example, the increased need for evaluating unstable constituents and properties of river water, such as dissolved oxygen, pH, or BOD, and content of microorganisms requires on-site sensing and increased use of mobile laboratories and portable instruments.

"Since 1960, uniformity in the output of chemical-analysis laboratories has been aided by adopting a standard methods manual, Water-Supply Paper No. 1454, by the circulation of standard samples among the laboratories for analysis, and by examination of the output at various levels within the district offices for conformance to accuracy standards. Also, new and improved techniques and instruments have been provided by our methods development unit in Denver. The technical review will include consideration of methods used by the district to assure uniform precision and accuracy in laboratory and/or field site determinations.

"Sediment programs in general have been designed to determine the effects of sediment transport on the design of water resource developments, to aid in understanding processes of erosion, transportation, and deposition of sediment, and to answer specific questions relating to the effects of man's activities, including the magnitude of such factors as storage, diversion, urbanization, or highway construction. Uniformity in the sediment programs has been aided by research and development of instrumentation, sampling methods, and other procedures carried out by the Interagency Laboratory at St. Anthony Falls, Minn.

"Review of sediment programs will be directed particularly toward the investigational methods employed and the adequacy of the sediment program to meet current needs."

New techniques in comprehensive water quality investigations: In September 1968, Branch Headquarters summarized (QW Branch Technical Memorandum No. 68.02) new techniques that should be considered in comprehensive water-quality investigations. For water-quality evaluations more emphasis is being given to parameters such as BOD, coliform, fecal coliform, macroinvertebrates. Of the 36 districts active in the water-quality phase of the Benchmark Program, 33 are obtaining coliform data by the standard membrane filter technique. Twenty-eight districts obtain BOD analysis at USGS laboratories and eight districts rely on city or State health department laboratories. Several districts have incorporated biological evaluation of macroinvertebrates as a water-quality technique in cooperative programs. Present plans are to have a Division advisory group to guide developments in biological techniques and a chapter on biological methods is in preparation for the technical manual series.

As part of a major effort to maintain and improve quality control for data, the Harrisburg, Pa., district office evaluated field dissolved oxygen methods using the most recent DO meters compared against standard tests (K. D. Williams, QW Branch Technical Memorandum No. 69.04, March 1969, Field measurement of dissolved oxygen). Compared against the Winkler method and dropping mercury method, under a wide variety of field conditions the study showed the membrane methods as giving the best overall performance.

Additionally, each region has named a representative to the FWPCA training course "Current practices in water microbiology," held in Cincinnati twice during the year.

With increasing emphasis on biological and microbiological data for State and National water-quality programs, an Advisory Committee on Biology and Microbiology was established to make recommendations on technical matters relating to research and operations of the QW program. Committee members included K. V. Slack, Chairman, J. E. Biesecker, P. E. Greeson, M. C. Kolipinski, R. G. Lipscomb, and QW Branch Chief. At the first meeting in Fort Wayne, Ind., June 24-26, 1969 the Committee immediately began compiling acceptable procedures to assure National uniformity and quality control of biological and microbiological data from Survey laboratories and field service units. The first step was to fulfill interim requirements for the pending USGS-FWPCA monitoring program. Selected interim procedures for biological and microbiological investigations were transmitted to district offices in the last half of 1969 (QW Branch Technical Memorandums No. 70.01, July 30, 1969, No. 70.03, October 3, 1969).

The Federal Committee on Pest Control was established in 1964 by joint agreement among the Secretaries of Defense, the Interior, Agriculture, and Health, Education and Welfare to coordinate all Federal efforts to control pests and to study the effects of pesticides. Subcommittees were established to give special attention to research, pesticide monitoring of the environment, public information, review of Federal pest-control programs, and safety in pesticide marketing and disposal. A representative of the quality of water staff in Washington actively participated in the Committee work, allowing good coordination and study of specific problem areas applicable to water resources (A study of Federally financed research on pests, pesticides, and pest control, 1968, Federal Committee on Pest Control, 22 p. G.P.O.).

Guidelines for sampling and analysis--Early in 1971 the Branch staff in consultation with Division research hydrologists and others was reviewing the state of knowledge of water-quality constituents associated with suspended solids, for the purpose of establishing guidelines for sampling and analysis of those constituents. Some of the philosophy upon which quidelines were based is summarized in the following paragraphs (QW Branch Technical Memorandum 71.05, March 18, 1971).

> "It is well known that certain water-quality constituents, especially some of the minor elements and organic compounds, are transported in streams either sorbed on or attached to suspended solids in large part. For such constituents, the traditional analysis of a "clear-water" sample only may present an erroneous picture of the concentration or load in the stream. This danger has been taken into account in our current procedures for analysis of water-suspended solids mixtures for "total" phosphorus, nitrogen, mercury, and pesticides. Similar procedures are required for the remainder of such constituents.
>
> "Our objectives in sampling constituents associated with suspended solids should be: (1) To define the content of the constituent in both the dissolved and suspended phases; (2) to assess the relative significance of the two phases in the water sampled; and ultimately, (3) to define the source, behavior, and fate of each constituent. Objective 3 will be met largely through District and Division research projects, but an important contribution can be made by carefully collected basic data. In all circumstances, samples for the constituents under discussion should include the suspended phase. Whether it is necessary to sample all size fractions of suspended solids for all constituents of interest will be one of the questions considered in establishing sampling guidelines. Appropriate methods of extraction from the sampled solids will be considered also.
>
> "At the present time, programming for water-quality constituents known to be significantly associated with suspended solids should be done with the following principles in mind:
>
> (1) Sampling should include the suspended phase as well as the dissolved phase.

(2) An assessment of the relative loads of the constituent transported by each of the phases is usually desirable. For this purpose, the concentration of the solids in the water-solids mixture is needed in addition to the concentrations of the constituent of interest in each phase of the mixture.

(3) Some knowledge of the content of the constituent in bed sediments should be obtained. Solids in the streambed at low flows contribute substantially to suspended solids at high flows. Furthermore, bed sediments can act as either a source or a sink for a number of constituents, thus exerting control on constituent concentrations in the water even when immobile.

"Consideration of the above principles, along with the expected use of the data, will provide a firm basis for preliminary planning of data-collection activities related to constituents associated with suspended solids."

National Stream Quality Accounting Network (NASQAN): On November 19, 1971 the Branch submitted a detailed plan for implementing the National Stream Quality Accounting Network (NASQAN) during fiscal year 1973. The plan evoked after lengthy discussions and coordination with the Office of Water Data Coordination (OWDC) and other participants over a period of several years.

The network is based on the river-basin accounting units designated by the Office of Water Data Coordination in consultation with the Water Resources Council (WRC). It is designed to provide a measure of the quality of the water moving from one accounting unit ot another, in terms of physical, chemical, and biological aspects of water quality. This has been done by the selection of one or more stations in each accounting unit at which the bulk of the outflow from that unit can be sampled.

Both accounting and broad-scale monitoring objectives have been incorporated in the network design. Loads of major inorganic chemical constituents, dissolved solids, and heat leaving each accounting unit will be calculated from records of temperature, specific conductance, and streamflow, and analyses of samples taken periodically for major inorganic and organic constituents. Nutrients, algal growth potential, bacterial content, and other biological parameters will be measured periodically to provide information on ranges and variability of these parameters. The ability of the stream to support biological life will be assessed by periodic observations of the aquatic plants and animals living in the stream. This information, obtained for each accounting unit throughout the country, will provide a balanced base of stream-quality data nationwide. Detection of stream-quality trends, or changes with time, is an important objective of network operation.

Loads of suspended sediment, and concentration ranges and variability of the other constituents, will provide water-quality data on a less detailed basis than that obtained from the basic operation schedule. Sampling sites for these additional parameters can be regarded as constituting subnetworks of the National Stream Quality Accounting Network.

Funds have been requested for a first-stage implementation of the network during FY 1973. This degree of implementation would bring network stations at the downstream end of the 12 noncoastal WRC regions to a full basic operational status. In addition, network stations for selected interior accounting units and for selected coastal streams will also be brought to full basic operational status. These latter stations have been selected on the basis of known Federal-State needs and interest reported by WRD district offices to OWDC and the Quality of Water Branch. Funding for the 50 stations selected for implementation has been estimated on the assumption that activities presently financed by other agencies will continue, and that new funds will be required only for parameters not adequately measured at the site. Data needed for network records will be requested from the collecting agency and stored with data collected by the Geological Survey for periodic summarization and interpretation. It is planned that the network of 525 locations will be fully implemented within a 3-year period.

During 1970 many inquiries were received by the Survey regarding the occurrence of mercury in water resources. Although public interest centered on learning more about the widespread natural and manmade sources of mercury the implication in many inquiries were: Are there other potentially dangerous chemical elements present in water resources? In view of the growing national concern there was an acute need to place facts on record as soon as they accumulated.

In October 1970, the Survey completed a survey of minor elements in water which showed, as one would expect, that low levels of arsenic, lead, cadmium, and other heavy metals are widely distributed in surface waters of the United States. Circular 643 provided a baseline of minor-element data for dry weather flows of streams that are sources of municipal and industrial water for the Nation's metropolitan areas.

Mercury was found in only 7 percent of the 720 samples analyzed. In none did the concentration exceed the proposed Public Health Service upper limit for dissolved mercury in drinking water, which is 5 micrograms per liter.

There was some evidence that the concentration levels are related to man's activities in certain instances. There appeared to be no widespread occurrence of these metals in water in amounts exceeding current drinking water standards. Where data for arsenic, lead, and cadmium indicated a few potential problem areas, follow-up investigations were made in Alabama, Arkansas, Missouri, North Carolina, and Pennsylvania.

River quality assessment: During the late 1960's the Division was responding steadily to a public concern with water quality conditions across the Nation. The Division reprogrammed certain 1972 funds and requested increased funding for FY 1973, for a series of pilot river-quality assessments of selected river basins in the United States.

The principal product of each assessment will be an atlas-type report designed to provide the non-technical resource manager and the informed layman with an overall picture of river quality throughout the basin. The river-basin accounting units designated by the Office of Water Data Coordination seem to be logical units for basin assessment, and will suit possible long-range plans for national coverage.

River basin studies have been made numerous times in the past and so are not new. What is hoped for in the pilot river-quality assessments, however, is a product somewhat different than has been produced in the past--a product dedicated to those aspects of the rivers that are of most interest and concern to the general public. Therefore, these studies will give consideration not only to the physical and chemical properties of the water as they relate to water use, but also to the condition of the streams as reflected by their biota and by their attractiveness and recreational appeal. The report, which is to be largely graphic, will describe what the principal streams are now like, what natural factors influence their quality, what activities of man tend to degrade the streams, and what trends can be identified to suggest improvement or degradation in the future.

The Potomac River basin has been selected for a prototype study to be made as soon as possible, with a report scheduled for completion by June 30, 1972. The objective of this prototype study is to develop guidelines that might be followed for other basin appraisals.

Four additional river-basin assessments are scheduled for completion during FY 1973. The specific basins to be studied will be selected in the very near future. These basin assessments will build on the experience obtained in the Potomac River study, and will in turn provide additional experience for use in improving the design of future assessments.

In general, the expectation is that the basin assessments will involve intensive collection of data several times during a single year, in what might be called "basin surveys," so as to determine current river quality, and the use of these data, together with data obtained in earlier years or from other programs, to detect evidence of trends in selected river-quality parameters. The following list contains a number of indices that have been proposed for use in describing river quality for the Potomac basin study.

A. Physical and chemical indices

    1. Dissolved oxygen, biochemical oxygen demand, specific conductance, pH, turbidity, color, hardness, sodium adsorption ratio, pesticides, trace elements

    2. Nutrients: Macronutrients - carbon, nitrogen, phoshorus, micronutrients, trace elements

    3. Sediments: Suspended sediments, bed material

    4. Temperature and thermal loads

    5. Radioactivity

B. Biological indices

1. Bacterial populations

2. Plant populations: Phytoplankton, higher aquatics

3. Animal populations: Zooplankton, micro and macro invertebrates, vertebrates

4. Qualitative inventory of biota

5. Quantitative inventory of biota

C. Recreational/aesthetic indices

1. Assets: Vistas, scenery and vegetation, bank attractiveness, channel attractiveness, velocity and sound, desirable chemical and biological quality

2. Liabilities: Trash and litter, shoreline degradation, channel degradation, sludge deposits, degraded chemical and biological quality

Some of the above indices, for example, temperature, dissolved oxygen, and pH, characteristically exhibit diurnal variations. Such indices will be measured or sampled over a period of at least 48 hours so that the magnitude of the variations can be determined. Continuous monitoring by portable recording instruments will provide the best information on diurnal variations.

The list above is not complete. Each accounting unit, or basin, has its own unique mix of water-quality characteristics and problems; therefore, the quality indices used and the characteristics emphasized will be somewhat different for each study. Nevertheless, the general objectives of all four basin assessments are the same, and the products will be similar.

Following disclosure of mercury pollution in the Detroit River (Chemical and Engineering, May 11, 1970) the Division received many inquiries concerning the occurrence of mercury in the nation's water resources. Data on the general occurrence of mercury in U.S. waters was sparse. Although mercury was reported routinely using spectrographic techniques, sensitivity is poor, and other analytical procedures were not available.

The Methods Development Unit, Denver, Colo., adapted a method using a silver wire cell and atomic absorption spectrophotometer. The lower detection limit is 0.1 µg/L. Additionally, L. L. Thatcher, Radioisotopes Unit, WRD, Denver was developing procedures for "fingerprinting" waters by neutron activation analysis using the TRIGA Reactor in Building 15 at the Denver Federal Center. Both units requested water samples from one or two streams in suspected areas of mercury occurrence in each District.

Thirty-one States responded for a total of 73 samples. Range in concentration was less than 0.1 to 17 µg/L (parts per billion) including 2 greater than 5.9 µg/L, the U.S. Public Health Service tentative proposed standard or upper limit in drinking water (QW Memorandums No. 70.12, May 19, 1970, No. 71.01, July 15, 1970).

The silver wire procedure which measured only dissolved mercury was replaced by the flameless atomic absorption procedure for total mercury, modified and made available by FWPCA.

The Survey released in December 1970, Professional Paper 713, entitled "Mercury in the environment," a compilation of mercury in rocks, soils, plants, and the atmosphere.

<u>Lower Colorado River - Salton Sea Area Study</u>: Foreseeing the time when the increasing demands for Colorado River water might cause the total demand to exceed the available supply, the Geological Survey was prompted in 1960 to undertake a regional approach to a comprehensive study of the water resources of the Lower Colorado River - Salton Sea area. The project started July 1, 1960, with headquarters in Yuma, Ariz., was similar to the earlier investigation of the Upper Colorado River.

C. C. McDonald, Project Chief, and O. J. Loetz (1976) in a summary of the lower Colorado River project and of the resulting findings conclude that "Unless the ever-increasing demands on Colorado River water are curtailed the demands will exceed the dependable supply before the end of the 20th century. The net supply of Colorado River water below Davis Dam for normal runoff conditions is estimated at 10.2 million acre-feet for 1975 and 8.4 million acre-feet for the year 2030. For dry conditions, the corresponding supplies are 8.2 and 6.4 million acre-feet, respectively. The present basic allotment to Arizona, California, and Mexico is 8.7 million acre-feet per year, to which is added conveyance and storage losses of 900,000 acre-feet per year making the total 9.6 million acre-feet of water per year. The supply probably will be adequate during periods of near-normal runoff until about 1980."

Burdge Irelan summarizes the water quality studies (U.S.G.S. Prof. Paper 486E, Salinity of surface water in the lower Colorado River-Salton Sea area, 1971) thusly: "The chemical-quality record for the Colorado River at Grand Canyon indicates that the 40-year weighted-average of dissolved solids concentrations, is about 600 mg/L. The long-time average at Lees Ferry, has been moderately less. Recent storage and diversion projects above Lees Ferry have apparently caused small increases in annual weighted-average mineral concentrations, but these increases have been less than the differences between 10-year weighted averages.

Once Lake Mead was formed, dissolved-solids concentrations in Colorado River water between Hoover and Imperial Dams have generally ranged between 600 and 900 mg/L, with calcium sulfate always the dominant salt. Concentrations below Hoover Dam have been higher, on the average than those at Grand Canyon mainly as a result of evaporation from the surface of Lake Mead and solution from its bed. The higher concentrations, however, have been partially offset by precipitation of calcium carbonate in the lake. Solution of minerals from the bed of the lake, although still considerable, appears to be substantially less than during the years after its formation."

Dissolved-solids concentration of the river water increases with distance downstream and with time. For 1951-55 the dissolved solids concentration below Hoover Dam average 658 mg/L and at Imperial Dam, 706 mg/L. For 1961-65 the concentration was 714 and 824 mg/L respectively.

A marked increase in the annual diversion of the Colorado River aqueduct during 1961-65 further lessened the quality of water available in the main stream for dilution of somewhat saline return flows from irrigated areas downstream from Parker Dam. Development of new lands for irrigation, especially in Parker Valley, increased the quantity of dissolved salts in return flow to the river, thereby also contributing to the increasing salinity of the river below Parker Valley. The authors demonstrated the increasing difference between the dissolved solids concentration below Hoover Dam and Imperial Dam for 5-year periods listed in the following table:

Sampling Site	Sum of dissolved solids (mg/L) by waters years		
	1941-45	1951-55	1961-65
Colorado River below Hoover Dam	703	658	714
Colorado River at Imperial Dam	726	706	824
Difference	23	48	110

SELECTED DISTRICT WATER-QUALITY ACTIVITIES

Florida: In the 1960's some Districts encouraged by State cooperators and Washington headquarters rapidly shifted their programs to attain greater areal coverage, and to augment information for different seasonal flow conditions, i.e, high and low flow. The term "synoptic view" of water quality developed from these programs.

For example, in 1966 the Florida District, Clyde Conover, District Chief, initiated a statewide annual water-quality sampling program of surface waters in Florida in cooperation with the Bureau of Geology, Florida Department of Natural Resources and other State and local agencies. The program emphasized physical and major inorganic parameters during May (normal low flow conditions) at approximately 500 sites. In 1970, a major change was made in the program to provide more information on trace metals, organics, and nutrients at low and high streamflow conditions.

By a letter, dated August 5, 1970 to Dr. R. O. Vernon, Florida Department of Natural Resources, Conover discussed the synoptic survey of physical, biological, organic, and inorganic parameters (including trace elements) at approximately 100 sites in Florida during May (normal low flow conditions) and September (normal high flow conditions). He wrote, "The above program is designed to hopefully aid in answering questions relating to assimilative capacity of streams, organic loading, oxygen demand, nutrient-eutrophication problems, toxicity, etc."

By a letter dated, October 2, 1970, Conover, at the request of Dr. Vernon, furnished information on 66 determinations of mercury (Hg) in Florida waters in the current survey. Of 66 determinations of mercury at 57 surface-water sampling sites in Florida, "Approximately 70 percent of the analyses showed less than 1.0 µg/L (parts per billion) and approximately 90 percent of the analyses showed less than 5.0 µg/L, which is the tentative proposed standard for mercury concentrations in drinking-water supplies. The data reported--represent concentrations of the dissolved inorganic species of mercury. The field collections and methods utilized do not include evaluation of organic complexes or other species not in solution. As mercuric ions are strongly adsorbed by clay particles and may also tend to form soluble organic complexes they may be transported in hydrologic systems other than in true solutions. As part of the nationwide survey by the U.S. Geological Survey of potential toxic elements we will evaluate total mercury (including both organic and inorganic forms) as well as dissolved inorganic mercury."

Concurrently the Florida district was involved in the study of hydrologic conditions relating to the cause of rapid decline in Lake Okeechobee's water quality. The final report of Survey's two-year study, "Appraisal of chemical and biological conditions of Lake Okeechobee, Florida 1969-70," which was concluded in the summer of 1971 affirmed that the lake is eutrophic.

The Florida district was active in Survey's nationwide program to evaluate the effects of underground waste disposal on the Nation's subsurface environment. D. A. Goolsby (1971) reported on the hydrogeochemical effects of injecting wastes into a limestone aquifer near Pensacola, Fla., and M. I. Kaufman (1973) gave a summary of data and present status of subsurface waste injection in Florida. Kaufman concludes, "Prediction of movement, chemical interactions, and ultimate fate of injected waste is difficult or not possible at present, but observation wells are being monitored for hydraulic and geochemical effects."

North Carolina: In March, 1968, the North Carolina District under Ralph Heath was proceeding with plans for a revamped water quality basic data program. As a first step, the Raleigh staff was assessing the historical data as necessary part of this plan.

Here as well as in other Districts one problem was to maintain a basic data program so that action agencies would have at least a minimal current source of data to continually assess against developing State water-quality standards. Meanwhile there would be opportunity to develop further criteria for a design based on assessment of historical records and national design criteria.

One anticipated problem was that historical records were likely to be rich in inorganic analysis with virtually no Geologic Survey information on the biodegradable or non-conservative constituents. National data programs emerging under Survey purview would require capabilities for inclusion in the Survey operational programs. Some tradeoffs for sharing Federal and State capabilities in the field and laboratory were encouraged to allow technological growth in environmental studies.

One consideration was a simple mobile unit for field observational programs to supplement the fixed laboratory schedule and to provide field capability for streamside measurements. Such units were being tested in Survey's field programs in Virginia, Pennsylvania and other Districts to extend capabilities for field determination of dissolved oxygen, pH, temperature, turbidity, conductivity, parts of the phosphorus and nitrogen (nutrient) cycle, biochemical oxygen demand, and coliform.

Historical data were now being collated on punch cards and, with computer techniques available, one approach considered was that full advantage should be taken to extract predictive approaches from the past record for use in design studies.

Pennsylvania: Water quality activities, starting from a reconnaissance of the Delaware estuary in 1949, grew into a diversified program after 1960 under N. H. Beamer, District Chief (1966-). In cooperation with the State Department of Forests and Waters and the City of Philadelphia the program dealt with environmental problems--acid mine drainage, thermal pollution, and eutrophication in lakes and reservoirs. By 1970 program direction included a good balance between sediment and chemical activities including biology, limnology, soil science and engineering.

Innovative improvements were made to field instruments such as automatic sediment samplers and electronic chemical monitors of which there were eleven operating in the Delaware River basin, in 1970.

The district laboratory served the States of Pennsylvania, New Jersey, Maryland, Delaware, and West Virginia. Analyses included most inorganic constituents in water, soil and plant materials, sediment concentration and particle-size distribution, and aquatic biological substances. Statewide sediment studies based on physiographic province and consideration of land use were the most extensive Division sediment activities in the eastern states.

Analytical data now are transferred to punch cards in Philadelphia and sent to Washington for processing and publication. Special transmittal and releases for cooperators approach "real-time" data handling.

Two successful interdisciplinary studies during the 1960's included the Schuylkill River and Lehigh County.

In 1972, the Philadelphia Urbanization Study had two main objectives: (1) the precipitation runoff process, and (2) the water-quality runoff relationship including the storm water runoff in closed sewer conduits.

A remote sensing study with an Earth Resources Technology Satellite (ERTS) experiment is carried out in cooperation with the Delaware River Basin Commission. Field installation of NASA designed radio telemetry was begun in 1972.

As with many district programs, priorities are heavily influenced by cooperators, sensitive and responsive to public needs.

Louisiana: Water-quality activities had a modest beginning with three technical employees and a laboratory of Baton Rouge in the years 1957-60 under the leadership of S. F. Kapustka, District Chemist and his successor R. C. McAvoy (1964-66). Data collection programs were emphasized by R. R. Meyer, District Chief (1966-71) and his successor, A. N. Cameron (1971 to present) in cooperation with the Louisiana Department of Public Works, the Corps of Engineers, and other State and Federal agencies. The Corps of Engineers activities are largely concerned with problems of salt-water intrusion in streams and lakes of the Gulf area.

With the acquisition of new young professionals in the late 1960's, the District developed diversity in technical content of programs for study of sediment, geochemistry, stream biology and other stream-quality data collection.

Tight technical control of water quality data was maintained as the water-quality network program evolved including 12 NASQAN sites, and the stream sampling was reduced to a monthly frequency.

A sediment laboratory was established in 1973, and field water-quality measurements were augmented by three well-equipped mobile laboratories following reduced operations of the chemical laboratory.

In recent years the District has maintained successfully 14 water-quality monitors, including several 4-parameter units. Several measured parameters are transmitted to the ERTS Satellite. One monitor station is located on the Mississippi River at New Orleans.

The project, quality of the ground water in the Red River alluvium, is funded by the Corps of Engineers. The Corps plans to construct a system of navigation locks along the Red River, and the objective of the study is to obtain baseline information in order to predict what changes will take place in alluvium wells as a result of the lock construction.

Studies of quality of water in lower Mississippi River were stimulated by EPA's detection of chlorinated hydrocarbons in the vicinity of New Orleans. Technical Report No. 5 (D. E. Evertt, 1971), prepared in cooperation with the Louisiana Department of Public Works, is a summary of historical hydrologic data observations. Recent time of travel studies, Mississippi River from Baton Rouge to Pointe A La Hache, La., (A. J. Calandro, WR Technical Report No. 99) provides information on how pollutant spills in this portion of the river would move horizontally and vertically.

Data from the District and Central laboratory are placed into the National Water Data Storage and Retrieval System (WATSTORE) and checked bimonthly for correctness. The data-oriented District has developed an efficient system for producing its basic data publication and traditionally has been first in the nation to publish combined Parts I and II data report. Other general basic data reports include, "Chemical quality of surface waters of Louisiana, 1959-63 (H. C. Duncan, 1967), and Chemical, biological, and physical data for the major lakes and reservoirs in Louisiana (W. J. Shampine, 1971)."

Colorado: The Colorado District under the leadership of E. A. Moulder 1967 to 1971 and his successor J. E. Biesecker in 1971 developed a program aggressively seeking solution of diverse and complex hydrologic problems of current interest. A staff was assembled of young capable professionals offering diversity of new talent that worked conjunctively with more experienced personnel to effectively plan and manage activities. By the end of 1973 the total district program was about $1.7 million; 67 percent is for cooperative programs, 17 percent from other Federal agencies (OFA) and 16 percent is direct Federal funding. Active and responsive cooperators increased in number from 16 to 30 between 1971 and 1973.

Project activities range in scope from areal-reconnaissance investigations to research-level activities. There were seven active projects in 1968 and 25 in 1974.

Statewide basic-data programs are based on a rather unique hydrologic situation for Colorado. Four different Water Resource Council regions are involved in the State's surface water quantity and quality--the Missouri River basin (Part 6) and Arkansas-White-Red River basins (Part 7) drain toward the east, the Rio Grande basin (Part 8) drains to the south, and the upper Colorado River basin (Part 9) drains to the west.

A new water-quality monitor network is in its planning phases. The cooperator, Colorado Water Quality Control Commission has requested the Survey (WRD) to assist in the design and operation of a statewide network to fulfill requirements for PL 92-500 and revised stream standards. Eventual operation of 27 telemeter sites and five channel (temperature, specific conductance, dissolved oxygen, pH, and turbidity) automatic monitors is planned.

The Federal CBR surface water quality activities include 2 Benchmark and 2 NASQAN sites in a detailed list of stations and the sediment program is expanding in terms of CBR, project studies, and current work performed in cooperation with the State Department of Highways.

The District has a program with National Park Service to locate supplies of potable water of selected places in national parks.

A statewide water quality reconnaissance of streams affected by coal and metal mining with emphasis on selected physical indicators of quality temperature and specific conductance, pH, trace metal concentrations, and selected aquatic determinations. Problem stream reaches have been delineated and this information was utilized by the State in their revised stream standards. An estimated 450 miles of Colorado streams are adversely affected by mine drainage.

Joint cooperating agencies with WRD on a project in Jefferson County are the Colorado Geological Survey and the Jefferson County Planning Commission. The primary purpose of this study is to determine the carrying capacity of the alluvial aquifers and to estimate water supply and pollution degradation problems in this area of intensive development and population growth. Poor infiltration of waste effluents from septic tanks in the thin soil cover and highly permeable and fractured copper strata has resulted in nitrate problems in much of the area.

In southwest Colorado, areas have been identified where selenium concentrations are abnormally high in domestic and livestock-supply wells.

In cooperation with the Denver Board of Water Commissioners energy budgets and selected water-quality characteristics are being determined for a series of water-supply reservoirs serving the Denver metropolitan area.

Since the turn of the century, the mineral potential of the Piceance basin has been explored in some detail, and several reports have served to document preliminary geo-hydrologic information. Two oil shale leases (one in the Piceance Creek basin, the other in the Yellow Creek basin) were let by the Department of Interior in early 1974. The richest oil shale is in the mahogany ledge section. Preliminary developmental plans by the companies for the first lease call for operation of an open pit-mine to a maximum depth of 1,000 feet. A project study, began in September 1971, is concerned with potential problems involved in pending oil-shale development: (1) deficient water supply for processing the shale, (2) location and detrimental water quality (sediment, chemical) influences of displaced overburdens, and (3) changes in the ground water flow system caused by mine de-watering. Summary report, U.S.G.S. Professional Paper 908, 1974, was identified by the Director in USGS Contributions in the Decade.

Waste-fluids from the Denver Arsenal plant were discharged into unlined ponds starting in about 1943. In about 1955 some crops in neighboring areas were damaged as a result of irrigation withdrawn from wells in the near-surface aquifer. Subsequently, many of the disposal ponds were lined and waste fluids were disposed of in a deep well. Beginning about 1958 observed spatial variations in chloride have been evaluated. In 1972, the District has used the project as a test case for the mass transport model. Using chloride as a contaminant the question being considered is whether in 1940 with a transport model one might have been able to predict the direction and rate of movement of seepage from the disposal ponds.

Texas: T. (Trigg) Twichell, District Chief (1965 to 1971) molded a strong water-quality data program in Texas that included many diversified projects in the water quality discipline plus many projects which involve an interdisciplinary approach. A colorful and popular figure in Texas, "Trigg" took great personal interest in the District's water-quality facilities and capabilities, timely and high quality control of data and data publications, and carefully maintained records on all aspects of the program. He maintained a lively communication with Regional and Washington technical personnel for assistance in new developments and problem areas in water quality.

Under his leadership and that of his successor I. D. Yost in 1971 the quality-of-water program expanded from about $100,000 in 1960, $523,000 in 1969 to a range of $750,000 to $1 million annually in the period 1970-74. About 35 personnel are assigned to water-quality studies.

The District laboratory operated at Austin from 1941 to 1974 under recent leadership of C. H. Hembree (1961-65) and L. S. Hughes (1965-74) when it was converted to a field laboratory.

The 1970 network of quality of water stations in the State included a variety of data collection activities. A multi-parameter automatic monitor operated on the Sabine River in cooperation with the Sabine River Authority of Texas, and 19 conductivity monitors were in operation, including 10 units to measure brine loads in the Red River basin--part of the Survey's program with the Corps of Engineers. Data collected in the Red River basin will be used by the Corps of Engineers in their efforts to reduce the amount of natural and man-made brine presently reaching Lake Texoma. In cooperation with the Texas Water

Development Board, the Survey operated four conductivity monitors in the upper Brazos River basin and two units in the upper Colorado River basin to determine salt contributions from these areas.

The Survey's 1970 program includes 108 daily chemical-quality stations in Texas. Data collected at these stations include daily temperature and specific conductance and sufficient inorganic chemical analyses to define concentrations and loads of common ions. Many of these stations were in cooperation with Texas Water Development Board or with local agencies. In addition to the daily chemical stations, 10 daily sediment stations were being operated. Sediment data include concentrations, loads, and particle-size determinations. The 1970 program also included 126 sites where periodic chemical-quality data are collected.

A recent addition to Survey water-quality programs is the periodic determination of biochemical oxygen demand, nutrients (nitrogen and phosphorus), and dissolved oxygen. These data are currently being obtained 6 to 12 times per year at 87 sites. Most of the support for this program is included in the cooperative agreement with the Texas Water Development Board, who use the data in their planning activities.

Another significant part of the continuing network in Texas is the collection of pesticide data. The Survey's Federal program consists of 20 stations in western United States that are a part of the Pesticide Monitoring Network established by the Federal Committee on Pest Control. Samples collected monthly at the 20 stations are analyzed in the Survey's pesticide laboratory in Austin. Three Texas stations--in the Brazos River, Colorado River, and Rio Grande basins--are part of the Federal Pesticide Program.

In addition to the continuing network of data collection sites, the Survey's program includes studies of the quality of water of Texas bays and estuaries, the quality of urban runoff in Houston and San Antonio, and quality of water is an important part of a study of the Edwards Underground Aquifer in the San Antonio area.

The bays and estuaries study, begun in October 1967, is in cooperation with the Texas Water Development Board. The Board is developing models for the flow systems. Data collected include temperature, pH, dissolved constituents, concentration of nutrients (phosphate and nitrogen compounds), minor elements, pesticides, water velocities and distribution of nutrients; current patterns, directions and rates of movement; and the physical and organic water quality in areal distribution and time variation.

Quality of water investigations were added to active urban studies in Houston and San Antonio in 1969. In addition to continuing studies of flood frequency and magnitude, the present programs include collection of inorganic chemical quality, nutrient, biochemical oxygen demand, pesticide, and sediment data. Data collection sites are located so as to provide data for comparing contributions of urban pollutants from developed, developing, and undeveloped drainage areas.

The study of quality of ground water in San Antonio area is to provide data on the effects of urban development on the recharge area of the Edwards Aquifer and to aid management agencies in locating critical areas. This investigation is part of the continuing cooperative program with the Edwards Underground Water District.

Alaska: The earliest known records of the chemical and physical composition of water in Alaska were obtained by the U.S. Geological Survey in 1913. Daily measurements of turbidity were made on samples collected from the Copper River in 1913. Quality of water samples were taken on the Seward Peninsula in 1914, and in the Yukon River basin in 1915.

The water quality program remained dormant for the following 32 years. In 1948, a continuing chemical quality program was started by the Survey. Several miscellaneous samples were collected and analyzed that year and regular sampling stations were established in 1949. By the end of 1950, eight chemical quality stations were in operation and water temperature records were being collected at five of these stations. By 1953 suspended sediment was measured at 14 river sites including four daily stations.

In 1961, additional water quality data were obtained for pollution studies including special chemical, physical, radioactive, and microbiological analyses.

Leadership in the water quality activities and related laboratory functions included G. W. Whetstone (1948-52), F. B. Walling (1953-61), R. G. Shupp (1962-65), C. G. Angelo (1966-69), B. Irelan (1969-72). A laboratory was operated at Palmer, 1948-65 and at Anchorage, 1966-73 for analytical work in support of federally funded programs to provide base line water quality information on Alaska waters and an analysis of State and Federal water supply installations.

During the past few years under leadership of Harry Hulsing, District Chief, 1967 to 1977, water quality has been undertaken in cooperation with the State and local governments, both cities and boroughs. Fisheries enhancement, and planning and environmental impact analysis have exacted additional water quality information.

Throughout this history, many State and local agencies had a strong and continuing interest in the quality of water including pollution control. The State Departments of Fish and Game, and Health and Welfare have been particularly influential in this field. Since its establishment in 1965, the Federal Water Quality Administration (FWQA), later Environmental Protection Agency (EPA) has assumed an active role, particularly in the field of pollution control and research. Federal legislation required the State to prepare water quality standards for their interstate streams, rivers, lakes, and coastal waters. The Alaska standards were approved by the Secretary of the Interior in February 1968 and hence became Federal standards as well.

The water quality program prior to 1965 was limited mainly to the collection of chemical quality and sediment transport data on a rather frequent basis at relatively few sites in east-central Alaska; essentially no interpretive studies directed toward solution of specific water quality problems were undertaken.

Following discovery of oil at Prudhoe Bay on Alaska's North Slope in March 1968, comprehensive plans for data collection along the prospective transportation corridor Prudhoe Bay to Valdez were developed. These included combined GS-FWPCA trips for collection of chemical, biological, and microbiological data.

And, the District was attuned to the rapid need for water-quality information on the effects of oil development and related activities on water supplies and the aquatic environment.

By 1970 the District program planning effort was to identify water-quality problems and to assure some chemical quality and sediment data for virtually every stream in the State for which streamflow records are obtained. An interdisciplinary approach was evident in planning hydrologic investigations underway at Anchorage, Juneau, Kenai, and Kodiak.

Included in the 1970 sediment program for the Corps of Engineers were daily sediment sampling stations at Faribanks, Eagle, and in the Knik River basin and periodic stations between Nome and Fort Yukon from west to east and Seward to Rampart from south to north. Other areal studies included continuing technical assistance to the U.S. Air Force to solve or alleviate chemical quality and water availability problems at various sites throughout Alaska, the investigation of scour at bridges, and hydrologic studies on Amchitka Island (Atomic Energy Commission).

California: The California District has one of the largest cooperative water resources programs in the nation but prior to 1971 the water quality project and data-collection activities comprised a relatively small part of the total program. Although the number and scope of projects that involve sedimentation held fairly constant or even increased over the last several years, those involving chemical quality decreased. This was attributed mainly to a well financed and competent State data-collection program. However, a number of well designed projects, especially sediment projects concerned with transport and deposition, were among the most comprehensive in the country. The projects involving contributions of sand from coastal streams are notable examples.

From its inception with the establishment of a laboratory at Davis, Calif., (1950-52) then at Sacramento (1952-71), the cooperative program in the 1950's and 1960's was directed to define, in a general way, the water quality of California's resources. Under the district leadership of R. S. Lord, 1965-72 suceeded by L. R. Petersen, 1972-__ the water quality program was financed by project funds disbursed by the various district offices of the California Department of Water Resources. Almost all records were of local interest, and were obtained on a periodic or monthly basis with daily sampling maintained at 15 sites.

Beginning about 1970, the program evolved from a service-type to a project activity, strongly oriented toward problems in aquatic biology.

In 1971 the Menlo Park subdistrict was responsible for the operation of some 30 sediment stations which extended mainly along the coast from the Oregon border to near San Luis Obispo. The stations provided useful data on sediment yield for a variety of hydrologic, geologic, topographic, and cultural environments. Chemical-biological quality of water data were obtained at 10 stations. About 10 projects involving water quality were directed to current water problems in the subdistrict, notably the hydrology of Bollinas Lagoon., turbidity in Mad River, mercury in Dry Creek, and channel geometry downstream from a proposed water supply reservoir on Zayante Creek.

In the Garden Grove subdistrict, two multiparameter on-site sensing monitors were operating well with a low percent of lost records.

In the late 1950's and early 1960's the State of California began a series of studies of the Sacramento River. Recognizing the possibility of quality changes as well as a need to reassess the river environment and by using modern techniques, the California Department of Water Resources and the California District (WRD) entered into a cooperative study with a letter of understanding dated November 19, 1971. The overall purpose of the cooperative study was to assess the quality of water in several mutually agreed upon rivers in California. The Sacramento was chosen as one of the rivers to be studied.

The scope of the study, begun April 1972, is to evaluate the present water quality of the Sacamento River including water temperature, suspended sediment, water chemistry, selected plant nutrients, phytoplankton, periphyton, and benthic invertebrates. Five sampling stations from above Red Bluff, Calif., to below Knights Landing, Calif., have been sampled on a near-monthly basis.

Lake Siskiyou is located on the Sacramento River above Shasta Reservoir. Although relatively new, the lake showed early signs of enrichment in several of its major arms. A limnology study was begun in July 1971, to determine which tributaries are contributing the largest plant nutrient concentrations.

In November 1972 a project was started in Long Valley, Calif., to determine sources and distribution of arsenic in streams tributary to Lake Crowley. The scope of the study is to collate existing arsenic data for the area, and to obtain additional data where high arsenic concentrations are suspected.

The purpose of a limnology study of Lopez Reservoir is to document the magnitude of algal blooms and to determine algal nutrient sources. Started in July 1972, the study was limited to the near-weekly collection of water samples for algal cell counts, and the seasonal collection of samples for chemical (especially nitrogen and phosphorus) analysis.

Copper sulfate is commonly applied in sections of the California Aqueduct to destroy algae. A study was begun in August 1972 to evaluate the residual effects such as distribution and biological uptake of copper sulfate in a section of the aqueduct near San Luis Reservoir. In a reconnaissance study of circulation in the reservoir, selected chemical-quality variables and temperature are being measured periodically.

A statewide stream quality assessment study was started in July 1971 to analyze ecologically-important chemical constituents from selected major streams of California. A secondary purpose is to analyze historical chemical data to establish time trend changes.

In the Bay Area Storm Runoff Study which began October 1971 the water quality of six urban areas was measured for two winter periods. The purpose was to relate concentration changes of various chemical constituents to urban development and stream discharge.

A second urban study in Santa Clara County was started July 1972. Changes in streamflow, sedimentation, and chemical quality were documented for Calabazas Creek.

In July 1971 the District proposed an ambitious monitoring program for the major rivers and reservoirs of California, Initially seven river mainstems, the Klamath, Eel, Russian, Sacramento, San Joaquin, Salinas, and Santa Ana Rivers were to be included. The objectives of the program will be to review and bring together past water-quality data obtained for the waters, begin collection of data not obtained in the past but which are of current ecological and pollutional significance, and prepare interpretive reports on each mainstem drainage studied.

Washington: Cooperative projects that involve water quality considerations in Washington are supported largely under agreements with the municipality of Metropolitan Seattle, the Washington State Department of Ecology, the State Department of Fisheries, and several Indian Tribes of the State. Federally supported programs (IHD, Irrigation

Network, and Benchmark Programs) constitute only a small part of the total water-quality program. Limited water-quality work has been supported mainly by the Forest Service, Department of State, and Bureau of Reclamation. Sediment transport studies supported by the Corps of Engineers were discontinued in 1971.

Major water-quality problems in Washington are those associated with pollution, mainly from industrial waste disposal and runoff from urban areas. Lack of water-resources data for adequate planning and development of resources on Indian lands has been recognized and the District under leadership of L. B. Laird (1964-74) and J. E. McCall (1974- __) now places a high priority on projects involving these lands. For much of the Indian land, few or no water-quality data are available and thus there is an especially important need for baseline data on that land which represents a substantial part of the area of the State. Recent negotiations with several Indian tribes have resulted in substantial water-quality oriented projects directed mainly toward problems associated with aqua-culture, recreation, mining, and logging.

In 1971-72 the quality of surface water data-collection program consists of 44 stations throughout the State. Cooperatively funded by the Department of Ecology, this program is designed to provide baseline data as well as pollution control information responsive to water-quality problems in the State.

This data network seems to mesh with data programs in adjacent States and Canada, and supplemented by the 30-station network completely operated by the Department of Ecology provides at least minimal data needed for water quality standards surveillance.

Field measurements of dissolved oxygen, coliform, turbidity, pH, color, and specific conductance are made monthly at each site by personnel of the State Department of Ecology. Water samples are delivered to the District office for shipment to the Salt Lake City Laboratory for determination of trace metal and common mineral content. Nutrient analysis are performed in the District field service unit which provides project support and also includes facilities for biological assessments, sediment concentration, and particle-size analysis.

The availability of an IBM 028 keypunch and a computer terminal in the District office facilitates the handling, storage, and retrieval of water-quality data. Results of analyses performed in the District, mainly for nutrients, biological parameters, and sediment concentration and particle-size distribution are transferred directly to punch cards and placed into WRD computer storage through the local terminal.

A large complex project, "The Influence of Industrial and Municipal Waste on Estuarine and Off-Shore Water Quality," was begun in 1964. A model is being developed for predicting the effects of some 150 million gallons per day of effluent from the Renton Treatment Plant on water quality in the estuary and Puget Sound. Five multiparameter monitors are used as a tool in predicting dissolved oxygen in the saltwater wedge of the estuary.

Statewide ground-water quality is a continuing project which is designed to provide planning data and to define problem areas by describing the quality of water in the various aquifers across the State.

Flushing of reservoir sediment deposits through the Similkameen-Okanogan River systems is a brief, intensive study, begun in 1971, to estimate the effects of removal of Enloe Dam on downstream channels.

The study, water resources of the Lummi Indian Reservation for developing aqua-culture, involves potential problems associated with pesticides, trace metals, and pollution from paper plants and agriculture. No unusually high concentrations of trace metals or pesticides were encountered in 1971, the first year of study.

Lakes of Washington is a continuing project to describe in terms of the present trophic level the potential for accelerated eutrophication of lakes. Twenty to twenty-five lakes are selected each year for a one-year study. A rating scheme using indices as flushing time, bottom slope, intensity of shoreline development nutrient variability, etc., is being developed to rate eutrophication potential.

The broad objectives of a project Program Evaluation, begun in 1972, is to determine if the right kinds of data are being obtained at appropriate places to meet the basic data needs of the State.

Water Resources of the Colvillo Indian Reservation is concerned with providing the necessary data to allow adequate development of the mining, logging, and recreational potential of this virtually undeveloped tract of about 2,000 square miles in northeast Washington.

The wide range in background experience and diversity in academic training of the staff including chemists, aquatic biologists, engineers, geologists, and mathematicians provides a healthy distribution of disciplines in the District.

SPECIAL STUDIES AND REPORTS

During the early 1970's the Water Resources Division expanded water quality research and special studies to relate to problems encountered in operating programs as rapidly as funds and personnel allowed. The following is a summary of principal published studies.

Laboratory methods: Major improvements were reported in spectrographic techniques for determining common minor elements in water. Haffty (1960) developed a residue method using a direct current arc, and Silvey reported a combined chemical and spectrographic method in which selected chelating reagents are used to recover as little as 0.005 mg of several metal ions.

Methods for determining the extent of calcium carbonate saturation in ground water were described by Back (1961) and Hem (1960a, 1961).

Significant new developments in techniques for study of solution equilibria included equipment for field measurement of redox potential in ground water utilized by Back and Barnes (1962).

Increasing concern with the spreading of potentially hazardous levels of constituents in water systems along with recent legislation has placed more stringent requirements on laboratory analytical measurement techniques. Atomic absorption spectrophotometric methods have become routine in water analysis laboratories for the determination of many major and minor constituents. Of particular usefulness is the capability of the technique to determine microgram per liter concentrations of such metals as cadmium, chromium, copper and lead in surface water or ground water (U.S. Geological Survey, 1972).

Automated colorimetric procedures using an integrated system such as the Technicon auto analyzer have made possible the routine handling of large numbers of samples with an analytical precision exceeding that obtainable with manual methods. Automated procedures have been developed for a number of important constituents, including chloride, chemical oxygen demand, gerrous and ferric iron, iodide, ammonia nitrogen, nitrate, nitrite, phosphate, silica, and others (McAvoy, 1973).

Analytical techniques required to identify and to quantify organic solutes has advanced from the measurement of total organic levels to highly sophisticated systems for determining specific organic compounds at low levels. Goerlitz and Brown (1972) have produced a methods manual for analysis of organic substances in water and is the standard for these measurements in Water Resources Division laboratories.

Trace elements and nutrients: The content of strontium in natural waters of the United States was determined by Skougstad and Horr (1960) and relatively large amounts were found in waters of Champaign County, Ohio, by Feulner and Hubble (1960).

Hem (1960c) reported that the amount of iron in natural water is directly related to pH, Eh, and dissolved oxygen in the absence of complexing and excessive amounts of certain anions.

Thatcher (1962) concludes from studies of continental United States begun in 1958 that tritium in rainfall was maximum in the north-central part of the country and minimum in coastal areas.

Jones (1962), in a study of the distribution of radionuclides in ground water, used tritium to trace chemically contaminated waste to distances of 6,000 feet.

Relationship of chemical composition of stream water to the nature of rocks exposed in the drainage basin have been studied by Davis (1961) in the California coast ranges, Hembree and Rainwater (1961) in the Wind River Range of Wyoming, Miller (1961) in the granitic terrane of the Sierra Nevada in California, and Barnes (1962) in composition of Birch Creek, Calif.

The occurrence of minor elements in water of major rivers of the world has been studied by Durum et al., (1960) and Durum and Haffty (1961).

Greatly increased public awareness of potential environmental problems with trace metals followed the disclosure in 1970 of excessive levels of mercury in fish in the Great Lakes system and in other places where industrial wastes had been released to surface waters for several years. Many of the data obtained in surveys conducted by USGS and other Federal agencies to define the occurrence and distribution of mercury in water were subsequently summarized (Jenne, 1972). A compilation of translations of non-English language articles on mercury concentrations and geochemistry was made available (Jenne and Sanders, 1973).

The concentrations of dissolved mercury, arsenic, cadmium, chromium, colbalt, lead, and zinc in single samples taken at 720 sites on rivers and lakes were compiled by Durum et al (1971). This led to continuing programs in some states with the results published in the annual reports on surface-water quality.

During the early 70's studies showed that equilibrium solubilities may be significant controls for lead (Hem and Durum, 1973), cadmium and zinc (Hem, 1972b), as well as aluminum and iron (Jones et al., 1974) in some surface waters. But the general importance of solubility controls of trace element concentrations in natural waters remains uncertain.

Papers dealing with the analytical chemistry of trace elements and nutrients in water were summarized by Fishman and Erdman (1971, 1973).

Organic solutes: A procedure for fractionation of naturally occuring organic complexing material by electrophoresis was described by Leenheer and Malcolm (1973b). Using several chromatographic separation techniques, Wershaw and Pinckney (1973 a,b) fractionated humic acids and studied association and dissociation of the fractions at various pH values.

Crump-Wiesner et al. (1973) published a study on the distribution of synthetic chlorinated compounds, called polychlorinated biphenyls (PCB), in waters of 19 States in the Unites States, Interaction of organic pesticides with natural organic solutes such as humic acids was the subject of review articles by Wershaw and Goldberg (1972). Effects of subsurface injection of industrial wastes into ground water were described in a paper by Leenheer and Malcolm (1973d). The movement and composition of a primarily organic waste were evaluated in this study by using a network of observation wells spaced irregularly and drilled to several depths. Slack et al. (1973) have prepared a manual documenting techniques and methods for collection and analysis of aquatic biological and microbiological samples.

Specific forms of ions and rates of reaction: As more emphasis is placed on quantitative models and chemical reactions in water chemistry, studies have progressed to determine how the total concentration of an element is divided among the various species that may be present. Hem (1972a) used graphical and mathematical approaches for calculating the distribution at equilibrium of aluminum fluoride and hydroxide complexes. Hem concludes that for most natural systems a direct measurement of a specific form using ion specific electrodes may be more reliable than calculated values. Back and Hanshaw (1971) calculated the entropy production in the system through solution of limestone and by hydraulic head changes. Kharaka and Barnes (1973) and Truesdell and Jones (1973, 1974) have developed and documented computer programs for calculating the equilibrium distribution of inorganic aqueous species of major and selected minor elements in natural waters at saturation with various minerals, using measurements or estimates of temperature, pH, and redox potential. The chemical equilibrium model has been applied by Clarke and Jones (1972) to the analysis of corrosion and salinization in North Sahara wells and by Pearson et al. (1972) to silica solubility in the Arkansas Hot Springs. Estimates of dissolved aluminum (Al) and iron (Fe) calculated from solubility data on Kaolinite and amorphous $Fe(CH)_3$ compared favorably with measurements on streamflow samples treated to avoid particulate contamination (Jones et al., 1974).

Water quality modeling: Bennett (1971) described and demonstrated the convolution technique for solving DO-BOD balance differential equations with time-varying variable inputs. Bennett and Rathbun (1972) made an extensive review and evaluation of alternative methods for estimating reaeration coefficients in streamflow systems. Yotsukura and Cobb (1972) developed a model for solving the two dimentional transport equation for conservative solute distribution in a straight natural river when both solute and river discharge rates are steady.

Jobson and Yotsukura (1973) developed a linearization method of surface heat exchange based upon the ambient natural temperature rather than the equilibrium temperature. These models have been applied to several natural streams where thermal loading rates have varied diurnally. Yotsukura and Kilpatrick (1973) summarized a method for predicting concentration distributions of a continuous waste discharge into a river or an estuary based on observations of short-term test tracers.

Steele and Gilroy (1972) demonstrated that coefficients of a single harmonic function are adequate to depict the annual seasonal cycle of stream temperatures. An attempt to regionalize streamflow chemical quality characteristics from selected basin parameters was demonstrated for streams in Texas by Steele and Jennings (1972). Specific conductance has been shown to be an adequate indicator measure of major inorganic chemical composition in streamflow, an indication of the utility of a solute concentration specific conductance regression model (Steele and Matalas, 1971; Steele, 1973).

In the area of modeling of ground water quality processes, solution techniques for equations have been documented (Pinder, 1973), and some applications to the field have been reported (Bredehoeft and Pinder, 1973; Konikow and Bredehoeft, 1974). Lerman and Jones (1973) developed a diffusion model and applied it to Lake Abert, Oregon. The results agreed well with salinity-depth relations measured in cores and indicated that nearly half the dissolved solids of the lake in 1963-74 was provided by diffusion from bottom sediment pore space during the preceding 25 years.

Evaluation of long-term trends: From a Federal perspective as well as of regional, State and local concern had been expressed (1) regarding the long-term impacts of large investments in waste water treatment facilities, and (2) whether the levels of investments and technology are in fact keeping up with demands.

Selected available historical records are, however, amenable to statistical analysis. Steele and Gilroy (1971) developed a technique for assessing long-term changes in streamflow salinity and made case studies representing a diversity of hydrologic conditions and of basin land use across the United States. Steele, et al. (1974) reported on a subsequent nationwide assessment of temporal changes in available long-term records at 88 stations designated in the

U.S. Geological Survey's National Stream Quality Accounting Network. In this analysis, significant changes were noted at about 18 percent of the stations having data on stream temperature characteristics and in dissolved solids concentrations, the latter being adjusted for effects of annual flow changes.

Anderson and Faust (1973) summarized earlier reported studies and analyzed extensive long-term data available for the Passaic River and tributaries in New Jersey. Apparent increases in dissolved solids in the Passaic River basin may be due solely to concurrent decreases in streamflow, but increases in several other variables (DO, BOD, nitrate, ammonia, and bacteria) not so highly correlated with concurrent stream discharges suggest significant increasing pollutions loads in the river system.

During fiscal years 1973 to 1976 nearly one-half of the new offerings of State and local agencies in the Water Resources Division cooperative program involved studies with water quality aspects, largely in response to new environmental responsibilities mandated by recent Federal laws. Specifically these are the Federal Water Pollution Control Act amendments of 1972 (Public Law 92-500) and related research and monitoring activities. The bulk of them have been coordinated through the Environmental Protection Agency and the Department of Interior's Office of Water Resources Research and have stimulated many of the recent technological advances in several aspects of water quality.

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