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A History of the Water Resources Division

U.S. Geological Survey: Volume VII, 1966–79

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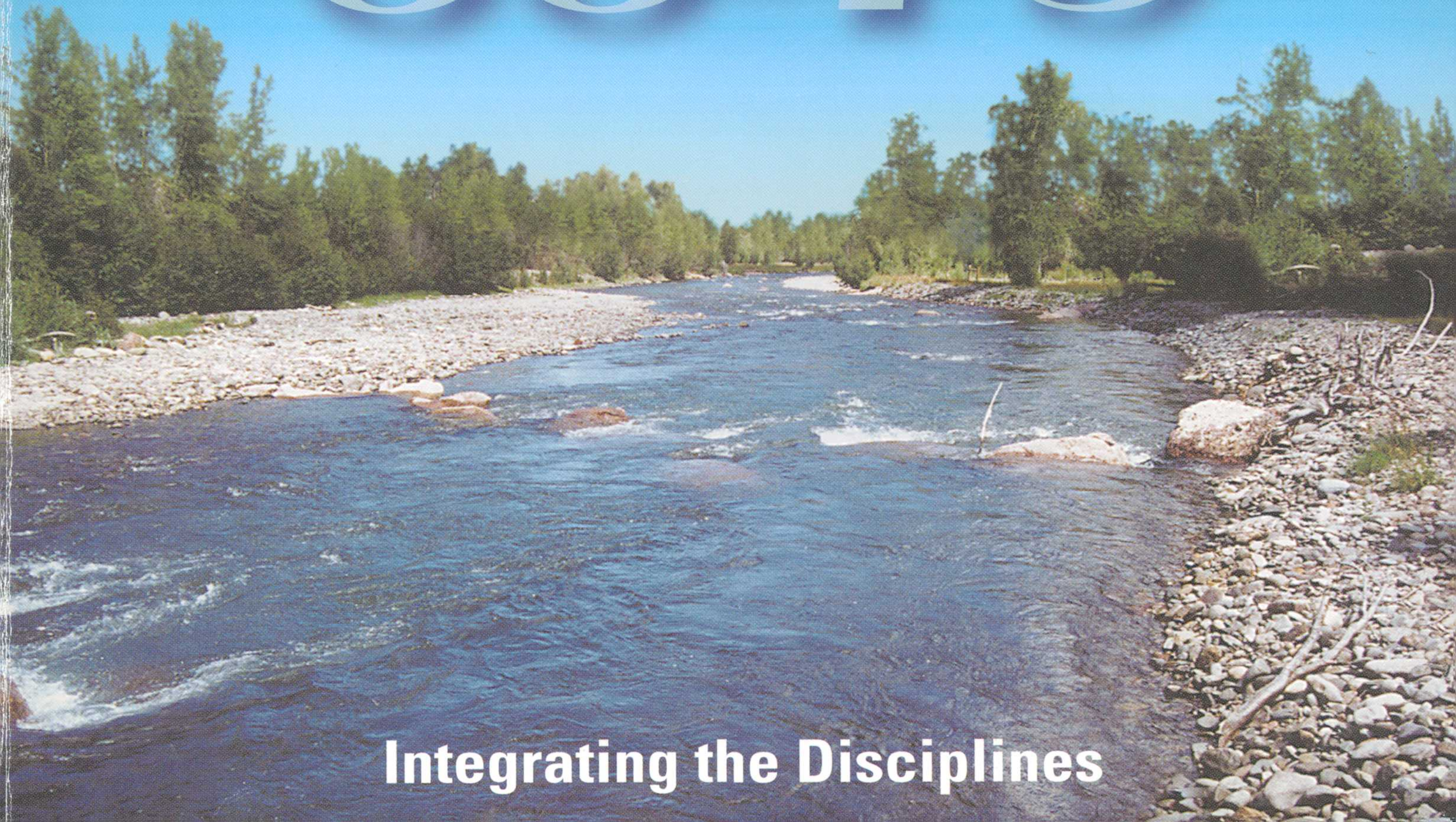

Integrating the Disciplines

Earlier volumes (unpublished), Robert Follansbee, author:

Volume I: 1866 to June 30, 1919;
Volume II: July 1, 1919, to June 30, 1928;
Volume III: July 1, 1928, to June 30, 1939; and
Volume IV: July 1, 1939, to June 30, 1947.

Volume V: July 1, 1947, to April 30, 1957, by George E. Ferguson and others

Volume VI: May 1, 1957, to June 30, 1966, by Hugh H. Hudson, Joseph S. Cragwall, Jr., and others

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A HISTORY OF THE WATER RESOURCES DIVISION

U.S. GEOLOGICAL SURVEY: VOLUME VII, 1966–79

Integrating the Disciplines

By James E. Biesecker, James F. Blakey, Herman R. Feltz, John R. George, *and* others

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PREFACE

This volume is the seventh in the series of reports on the history of the water-resources activities of the U.S. Geological Survey. The first four volumes were written by Robert Follansbee, and each is entitled "A History of the Water Resources Branch of the United States Geological Survey." The periods of Follansbee's reports are as follows:

Volume I: from 1866 through June 30, 1919

Volume II: from July 1, 1919, through June 30, 1928

Volume III: from July 1, 1928, through June 30, 1939

Volume IV: from July 1, 1939, through June 30, 1947

Later volumes are entitled "A History of the Water Resources Division, U.S. Geological Survey."

Volume V: from July 1, 1947, through April 30, 1957, by George E. Ferguson

Volume VI: from May 1, 1957, through June 30, 1966, by Hugh H. Hudson and Joseph S. Cragwall, Jr., and others

During his address to the 1975 District Chiefs' meeting, Chief Hydrologist Joseph S. Cragwall, Jr., stated: "When we met again in 1970 in Gatlinburg [Tenn.] at the District Chief's meeting, we were already in an improved operational mode to better serve the multidisciplinary hydrological needs of the environmental age which, incidentally, had descended upon us with great suddenness and as a much broader and forceful national environmental-quality policy than was signaled from the earlier national effort on water-pollution control and abatement. You will recall that Chief Hydrologist Hendricks stressed at Gatlinburg the need to expand Division horizons to include greater diversity in program content, to broaden our investigations into heretofore neglected segments of the water-impacted physical environment, and to extrapolate our hydrologic interpretations for greater usefulness to the decisionmaking institutions and processes. But in all of this he stressed the need for us to stoutly maintain our third-party, objective, fact-finding role. He saw the Division as an **interpreter of the environment**—not as its protector."

All career employees of WRD made a significant contribution to the success of the Division program. Space available in this document, unfortunately, does not permit us to recognize all individuals.

This volume is based, in part, on a draft History of the Water Resources Division, 1966–79, prepared by GLH, Incorporated, Falls Church, Virginia.

Major assistance was provided by Alberto Condes, Bruce Gilbert, and Judy Claussen, WRD employees. Bob Beall and John Kammerer, WRD retirees, also provided exemplary support.

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A HISTORY OF THE WATER RESOURCES DIVISION, U.S. GEOLOGICAL SURVEY: VOLUME VII, 1966–79

By James E. Biesecker, James F. Blakey, Herman R. Feltz, John R. George, and others

CHAPTER I – INTRODUCTION AND OVERVIEW—INTEGRATING THE DISCIPLINES

The mission of the Water Resources Division (WRD) of the U.S. Geological Survey (USGS) is to provide the hydrologic information and understanding needed for the optimum use and management of the Nation's water resources for the overall benefit of the people of the United States. This is accomplished, in large part, through cooperation with other Federal, State, and local agencies, by:

1. Collecting, on a systematic basis, data needed for the continuing determination and evaluation of the quantity, quality, and use of the Nation's water resources.
2. Conducting analytical and interpretive water-resource appraisals describing the occurrence, the availability, and the physical, chemical, and biological characteristics of surface water and ground water.
3. Conducting supportive basic and problem-oriented research in hydraulics, hydrology, and related fields of science to improve the scientific basis for investigations and measurement techniques and to understand hydrologic systems sufficiently well to quantitatively predict their response to stress, either natural or manmade.
4. Disseminating the water data and the results of these investigations and research through reports, maps, computerized information services, and other forms of public releases, .
5. Coordinating the activities of Federal agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and ground water.
6. Providing scientific and technical assistance in hydrologic fields to other Federal, State, and local agencies.

The Water Resources Division investigates the occurrence, quantity, quality, distribution, and movement of surface and underground water that constitute the Nation's water resources. Its activities include the systematic collection, analysis, and interpretation of data relating to the evaluation of national water resources and investigation of water demand for industrial, domestic, and agricultural purposes; research and development to improve the scientific basis of investigations and techniques; and reporting the results of these investigations through publications or other forms of public release. The Division provides scientific and technical assistance in appropriate fields to other Federal agencies.

The water-data collection, resource investigation, and research activities are carried out in areas where the Federal interest is paramount. These include bodies of water in the public domain, river basins, and aquifers that cross State boundaries and other areas of interstate or international concern. Activities include operation of surface- and ground-water quantity and quality measurement stations throughout the Nation, the Survey's Central Laboratories System, hydrologic research and analytical studies, and a variety of supporting services.

Chapter II discusses the program conducted by WRD personnel during this period. Program growth was very significant, and new areas of investigation included:

National stream quality accounting (NASQAN)
Water-data coordination activities
Mapping of flood-prone areas
Hydrologic studies in areas rich in energy resources
Water use
Regional aquifer-system analysis (RASA)

Chapter III discusses the organization.

Chapter IV is a discussion of hydrology and professional development.

Appendix—Significant legislation and list of pertinent WRD memorandums.

REFLECTIONS ON THE WATER RESOURCES DIVISION, 1966–79

By O. Milton Hackett

I was on the senior staff of the Water Resources Division for 19 years, under four Chief Hydrologists: Luna Leopold, Roy Hendricks, Joe Cragwall—and for a few months, Phil Cohen. From December 1968 until I retired in January 1980, I served as Associate Chief Hydrologist. My service in that position spanned much of Roy Hendricks' administration and all of Joe Cragwall's—the period that is the subject of this history. Here are my recollections of some of the highlights of those years.

At the onset of this period, the Water Resources Division was in the process of accommodating to numerous significant changes underway as a consequence of actions by Luna Leopold, Hendricks' predecessor as Chief Hydrologist, and his Associate Chief (Ray Nace through most of 1962, and Roy Hendricks thereafter). Principal among these changes was, after some experimentation, a major reorganization of the Division, which centralized Division-level control over virtually all activities and wiped out the old Branch lines of authority. The reorganization was revolutionary—by way of illustration, akin, at a small scale, to the unifying of the armed forces, which has not been accomplished even yet. Less dramatic, but also significant, was an emphasis on the Division's role as the Nation's leader in scientific hydrology at the expense, or so it appeared in the eyes of some, of downgrading the Division's traditional role as the collector of the Nation's basic water data. These changes had much merit but were accompanied by some immediate and trying side effects. Within the field force, morale was depressed by the fears accompanying reorganization, which broke old patterns of allegiance and threatened established career paths. Externally, leaders of some cooperating State agencies, many of which depended on the Water Resources Division for the data needed for water-resources management, were alarmed at the thought of a deemphasis of the basic-data program. Some of the Federal agencies, dependent on the Survey's basic data in support of their missions or having their own interests in hydrology, similarly were alarmed and also were disturbed at the perceived move by the Water Resources Division to dominate the field of hydrology. This last concern had been exacerbated by Bureau of the Budget's Circular A–67, issued in 1964, which appeared to give the Geological Survey control over Federal water-data activities.

More or less concurrently in the mid-1960's, several legislative and executive actions at the Federal level also impacted the Hendricks-Cragwall years. Responsibility for water-resources research was assigned, under the Water Resources Research Act of 1964, to a newly created Office of Water Resources Research (OWRR) in the Department of the Interior, and responsibility for water-resources planning, under the Water Resources Planning Act of 1965, was assigned to a newly created Water Resources Council (WRC). The research assignment not only dashed Leopold's dream of an Institute of Hydrology in the Water Resources Division but also meant that the Division's research program must henceforth be justified by demonstrating support of the basic-data mission or other specifically authorized programs. The Water Resources Council was given the responsibility for a periodic assessment of the Nation's water-resources situation—a responsibility that might well have been lodged with the Geological Survey. (Interestingly, some time after the period covered by this history, OWRR and WRC were disestablished, and some of their duties were reassigned to the Water Resources Division.) Another action of concern to WRD was the creation of the Federal Water Pollution Control Administration (FWPCA), under the Water Quality Act of 1965, and its placement in the Department of the Interior. This heated up an old turf battle that had existed between the Public Health Service and the Geological Survey over the responsibility for collecting water-quality data. Later, the FWPCA would itself be incorporated into a new independent super agency, the U.S. Environmental Protection Agency (USEPA), created by Executive Order in 1970.

But even more than the specific actions noted above, the rapidly changing tenor of the times was to influence the direction of WRD programs during the Hendricks-Cragwall years. The Nation was entering the space age, the computer age, the information age, and the environmental age. Environmental concerns were to greatly increase the audience and broaden the demands for water data—water-quality data in particular. Computer and space age technologies were to make possible the delivery of information, some processed in new and more usable forms, and within a much-reduced timeframe, to meet the expanded needs of both old and new clientele. Computer technology also was to make possible the modeling of hydrologic systems and processes at a stage of sophistication possible hitherto only in dreams. During this period, the goal of much of the research program was to bring the new technologies to bear on improving the Division's ability to carry out its mission. Support for this goal somewhat mitigated the negative consequence of a reversal in the national mood, which in the earlier "sputnik" years had been so receptive to the building of research programs.

William T. (Bill) Pecora became Director of the U.S. Geological Survey in 1965. He was a knowledgeable, aggressive, and dynamic leader—a perfect leader for rapidly changing times.

In early 1966, when Luna Leopold, the incumbent Chief Hydrologist, returned to his research position, Pecora chose E.L. (Roy) Hendricks, then Associate Chief Hydrologist and already instrumental in conducting much of the Division's business, as the new Chief Hydrologist, and Frank Clarke, then leader of the research program, as his Associate Chief. They immediately went to work toward rebuilding the morale in the Division and dealing with the concerns of client State and Federal agencies. Reorganization was pressed to completion.

At the Headquarters level, most key personnel remained in place. Elwood Leeson was Assistant Chief for Administration and Technical Services, later retitled Operations. In early 1967, George Whetstone became the first Assistant Chief for Reports and Data Processing, later retitled Scientific Publications and Data Management (SP&DM). Also in 1967, Roy Oltman was recalled from OWRR to serve as Assistant Chief for Research and Technical Coordination (R&TC)—Joe Upson continued as his Deputy for Research, Melvin Williams, Ken Love, and C.L. McGuinness continued as the Branch Chiefs. Frank Barrick was Administrative Officer, and Ruth Malone was Secretary to the Chief Hydrologist. O. Milton (Milt) Hackett was Chief of the Office of Water Data Coordination. George C. Taylor was Chief of the Office of International Activities. A group of Division Staff Scientists included Walter Langbein, Ray Nace, and others.

Also at Headquarters, several new positions and staff units were created to meet the needs stemming from the changes in the national scene described earlier. Harold Thomas, widely respected as a visionary in the field of hydrology, was brought into Headquarters to spearhead a new planning effort. Bob Baltzer, from the research group, was assigned temporarily to appraise the Division's potential use of the computer. Charles (Chuck) Robinove—to be followed in later years by Morris Deutsch and Daniel G. Anderson—working under the Assistant Chief Hydrologist, R&TC, headed an Office of Remote Sensing, created to represent the Division in a new program, led at the Director's level, for data acquisition by remote sensing: the Earth Resources Observation System (EROS). "Systems analysis" was just being touted as the powerful new methodology for program development and evaluation, and with the encouragement of senior staff scientist, Walter Langbein, a Systems Laboratory Group was established under the leadership of Nick Matalas.

At the field level, the four Regional Hydrologists, responsible for field operations and research within their areas of jurisdiction, were: George Ferguson, at Arlington, Atlantic Coast (later, Northeastern) Region; Warren Hastings, at Menlo Park, Pacific Coast Region; Harry Wilson, at St. Louis, Midcontinent Region; and Keith Jackson, who soon was replaced by Thad McLaughlin, at Denver, Rocky Mountain Region. Research activities and technical support were centered for the most part at the Regional centers in Arlington, Denver, and Menlo Park. Newly established field units included a national training center at Denver under the direction of Ivan Johnson and a remote sensing unit at Phoenix under the direction of Herb Skibitzke. This unit, a brainchild of Skibitzke's, was to conduct research and provide field support for the acquisition of hydrologic data from aircraft. A hydrologic (analog) modeling unit, established earlier in Phoenix at the initiative of Bob Bennett and Skibitzke, remained at Phoenix under the direction of Gene Patten. Later, this unit would be relocated to the Northeastern Region. Other principal field units included Mark Meier's snow and ice project and William (Bill) Campbell's sea-ice project, both in Tacoma, Washington.

These early years saw a new peak in the Nation's interest in water resources. This was marked by the International Hydrological Decade (IHD), which had been launched in 1965, and by the International Conference on Water for Peace. The Division was involved heavily in both. The IHD was a brainchild of WRD scientists Ray Nace and Walter Langbein, and they continued to influence its activities throughout the decade. Leo Heindl, from the Division staff, was loaned to the National Academy of Sciences to serve as executive secretary to the National Committee for the IHD, and José DaCosta, also from the Division, served with UNESCO in Paris on the international staff for the IHD. The International Conference for Water for Peace, held in Washington in May 1967, was sponsored and heavily promoted by the administration of President Lyndon Johnson. It attracted a large national and international audience, including official representatives from most of the nations of the world. Along with other Federal agencies, the Water Resources Division provided staff support for planning and carrying out this event.

These early years also were formative for the implementation of the Bureau of the Budget's (BOB) Circular A–67, which assigned to the Department of the Interior the task of coordinating Federal water-data activities and related tasks—to design a National Water Data Network and to establish a catalog of information on water-data activities. For these tasks, an Office of Water Data Coordination (OWDC) had been created in the Water Resources Division in January 1965. The staffing of the OWDC, under Hackett, was completed and two advisory committees established: one for the Federal sector and another for the non-Federal sector. Subsequently, the Director himself became deeply involved with the deliberations of the Advisory Committee for Public Use, the so-called "non-Federal advisory committee," which greatly influenced program direction of the Water Resources Division in subsequent years.

George C. Taylor continued to lead the Division's international activities.

In December 1967, Frank Clarke was reassigned to the position of Assistant Director for Engineering, replacing Bob Lyddan, a long-time ally and supporter of WRD, who returned to his parent Division, the Topographic Division, as Chief Topographic Engineer. Later, when Bill Pecora left the Directorship to become Under Secretary of the Department of the Interior, Clarke accompanied him to become his Deputy Under Secretary. In both positions, Clarke continued to give the Division invaluable support, especially on matters relating to coordination with FWPCA and its successor, the USEPA, and with the National Oceanic and Atmospheric Administration (NOAA). He also was active in looking at a proposed merger of USGS and NOAA.

Milt Hackett succeeded Clarke as Associate Chief Hydrologist in January 1968, and other changes in key personnel also took place in 1968. Hal Langford succeeded Hackett as Chief, OWDC. Harold Thomas returned to his field position in Menlo Park, and Harry Wilson replaced him as Planning Officer. Elwood Leeson transferred to St. Louis to take Wilson's former job as Regional Hydrologist for the Midcontinent Region. Joseph S. (Joe) Cragwall was recalled from the planning staff of the Department to take Leeson's former position as Assistant Chief for Administration and Technical Services (later Assistant Chief for Operations). Walton Durum replaced Ken Love (retired) as Chief, Quality of Water Branch. Sometime earlier (1967), Rolland Carter had replaced Melvin Williams (retired) as Chief, Surface Water Branch. Robert Schneider was Chief of the Office of Radiohydrology, under the Assistant Chief, R&TC.

At about this same time, an administrative study showed that the grade structure of senior Headquarters staff had failed to keep up with the new responsibilities attending the reorganization. This, in turn, was squeezing the grade structure of the rest of the Division. Subsequently, during the next few years and with the aid of Ed Grant, the Survey's Assistant Director for Administration, and the Department's personnel staff, most of these grade inequities were corrected. Beginning with the position of Chief, OWDC, the key positions at grade 15 were all regraded to 16, including the positions of the Assistant Chiefs, the Deputy for Research, and the Branch Chiefs. Concurrently, to emphasize the technical nature of their positions, the Assistant Chiefs were retitled Assistant Chief Hydrologists. Regrading as appropriate elsewhere in the Division was to follow.

Real program growth during the remaining Hendricks years was slow but steady. The cost of the Vietnam war was being reflected in the economy, and most new initiatives by the Division got little or no support in the Federal budget. These initiatives included proposals for funding in such topical areas as urban hydrology, coastal hydrology, estuaries, remote-sensing methods, data for small watersheds, ground-water recharge, lake studies, hydrologic environmental impact, water use, and subsurface storage of wastes. Funding in real dollars for the Federal-State Cooperative (Coop) Program increased gradually, but funding for the core research program and the support from other Federal agencies (OFA) kept about abreast of inflation. Funding for the International Hydrological Decade, minimal at best, was dropped.

Reprogramming and some new funding, mostly occasioned by legislative interest in local or regional problems, enabled a few new initiatives to be undertaken and some, first undertaken earlier in the Hendricks years, to be continued. Notable among these were a series of regional ground-water appraisals and a flood-plain mapping program. Some work in most of the topical areas mentioned above was carried out in the Federal-State Coop Program or with OFA support. Of special note was a sizable interdivision (WRD and Geologic Division) effort for the Atomic Energy Commission concerning the Nevada Test Site, which was carried out for WRD from Regional Headquarters at Denver under Bill Hale, and later Sam West. Proposals for estuarine and coastal studies, prepared under the direction of Joseph E. Upson, got no funding in the budget; but some studies, as for Tampa Bay, Fla., and Port Royal, S.C., were carried out in the Coop Program. Federally funded field projects of note included a study of artificial recharge focusing on the high plains of Texas, led by Richmond Brown; a ground-water investigation of the Delmarva peninsula, led by Elliott Cushing; and studies of structure and stratigraphy as controls on ground-water occurrence and movement in the Atlantic coastal plain, led by Phil Brown, and in the gulf basin, led by Paul Jones.

The demand for Division support of Departmental and Survey-level initiatives was growing. These included environmental impact studies, such as those required for the proposed Arctic pipeline and for the Florida Everglades; energy studies, including the potential for geothermal energy—studies coordinated for WRD by Alfred Clebsch at Menlo Park; and studies of waste disposal—nuclear wastes in particular. These required a draw on staff from both field and research programs, a draw that was viewed by the research staff in particular as a mixed blessing. On the one hand, it provided much-needed financial support and provided exposure to real-world problems. On the other hand, it diverted research staff from their principal objectives. Overall, however, it provided an opportunity for the Division to demonstrate its relevance to the some of the emerging problems facing the Nation.

The period of tight budgets and personnel ceilings occasioned by the Vietnam war was to last through the Hendricks-Cragwall years and beyond. In the Water Resources Division, the problem of managing for growth gave way to the problem of managing to do more with less. In the ensuing years, this would be accomplished by a sharpening of priorities and modifications of programs accordingly and by turning to the tools of the computer age. Use of the digital computer to store, process, and analyze data was to become commonplace, and use of the computer printout for data and information output, vis-à-vis the traditional book publication, was to provide economies in time and money. Also, the digital computer was to provide a greatly improved tool for the modeling of hydrologic systems.

There were a few adjustments in organization. The headquarters of the Midcontinent Region (to be retitled the Southeastern Region) was moved from St. Louis to Atlanta to conform with Department of the Interior's plans for creating Regional centers at Department level, and this move was accompanied by some reconfiguration of Regional boundaries. District water-quality laboratories were abolished and central laboratories established in Atlanta, with Don Leifeste as Chief, and in Denver, with Russ McAvoy as Chief. Later, in 1975, Art Beetem moved from Denver to Quality of Water Branch Headquarters to coordinate the laboratory activities. The abolishing of the field laboratories was the source of some pain among the water-quality contingent, as the field laboratories traditionally had been the focus for the Division's water-quality activities. A new field center for research and instrumentation development, the Gulf Coast Hydroscience Center, with Stanley Sauer as Chief, was established at the National Space Technology Laboratories near Bay St. Louis, Miss.

Of interest historically is the genesis of the Gulf Coast Hydroscience Center. At the close of the decade of the 1960's, the Water Resources Division was seeking a home for its streamflow instrumentation testing facility, then lodged with the Bureau of Standards, which was about to relocate. Coincidentally, Director Pecora was seeking a home in Sioux Falls, S. Dak., for his pet project, the Earth Resources Observation System (EROS), and NASA was seeking tenants for its testing facility near Bay St. Louis, Miss., because of cutbacks there. With the support of Senator Stennis of Mississippi, a quid pro quo arrangement was worked out—Pecora got his EROS center at Sioux Falls, S. Dak., and NASA and Senator Stennis got a WRD research center and instrumentation testing and development center at Bay St. Louis. In WRD, the catalyst and principal supporter of the move was Rolland Carter, Chief of the Surface Water Branch. The move was not popular among members of the research staff who had to relocate—they regarded the Bay St. Louis area as somewhat of a tropical Siberia.

Also in the works at this time was planning for the new U.S. Geological Survey center at Reston, Va. Representing WRD on a bureau-level team for this effort was Frank Trainer.

A national meeting of the Water Resources Division, held at Gatlinburg, Tenn., in the spring of 1970, marked approximately the midpoint of Hendricks' tenure as Chief Hydrologist.

In the middle of May 1971, Bill Pecora moved to the staff of the Department of the Interior as Under Secretary. While the search for a new Director was underway, William (Rad) Radlinski, the Associate Director, served as Acting Director, Hendricks served as Acting Associate Director, and Hackett served as Acting Chief Hydrologist. These assignments lasted until early December when Vincent McKelvey, formerly the Chief Geologist, became the new Director of the U.S. Geological Survey. Hendricks was retained as Chief Hydrologist by McKelvey. As would be expected, it took some time to build up the mutual confidence and rapport that had existed with Pecora. Nevertheless, after a short period of adjustment, the relationship was on a sound basis.

The new Director had a great interest in shaping Geological Survey efforts to address real-world problems and also in promoting multidisciplinary approaches to these problems. For this, he created an umbrella management staff at the Director's level, under the acronym LIA (Office of Land Information and Analysis), which drew together units performing multidisciplinary activities and formed some new ones. These units included the environmental review staff, geography, EROS, and Resources and Land Information (RALI) program—a new program aimed at identifying and translating the Survey's resource information for land-use planners and managers. All required personnel from the operating Divisions. Hendricks' response was to send some of the Division's best and brightest to help staff the new units, even at some expense to the Division's own operations. Among the RALI activities of note in which WRD was heavily involved were a set of urban-area pilot studies. These included studies of areas at Pittsburgh, San Francisco Bay, the Front Range in Colorado, the Connecticut Valley, Puget Sound, and Phoenix-Tucson. The Division also provided personnel for marine and coastal studies at Woods Hole, Mass.

Interest in the subsurface storage of wastes was increasing. An early consequence of this interest was a symposium on underground waste management and environmental applications—with WRD playing a lead role—jointly sponsored with the American Association of Petroleum Geologists and held in Houston in December 1971. McKelvey himself was highly interested in promoting the concept of subsurface space as a resource in itself (not only for the storage of liquids and gases but also for storage of wastes and waste heat), and WRD subsequently explored these uses.

By this time, the personnel ceiling was beginning to restrict program growth, particularly in work for other Federal agencies. Among the early victims was the Division's program with the Agency for International Development, whose staffing requirement could no longer be fully met. Otherwise on the international scene, interest in the International Hydrological Decade had begun to fade, but competition for leadership of hydrologic activities at the international level between UNESCO and WMO (World Meteorological Organization) was intensifying. In this power struggle, UNESCO, because of its close association with the Water Resources Division in IHD activities, looked to the Water Resources Division for support, while WMO looked to the Weather Service of NOAA for support. Hendricks, who had served as hydrologic advisor to Robert White of NOAA, the principal U.S. Representative to WMO, and as principal U.S. delegate to UNESCO on the IHD, took no side, in spite of pressures by Nace and other advisors within and outside WRD. He wisely foresaw that substantive financial support of hydrologic activities in either agency was unlikely, making the power struggle relatively meaningless. Besides, the operational hydrology programs of WMO needed WRD's involvement and technical expertise as much as did the IHD.

Hendricks' last year as Chief Hydrologist, 1973, was tumultuous. Earlier directives to reduce Federal employment had led to pressures to reduce staff, and so as to avoid reductions in force, retirements of senior people in the retirement zone were solicited, with a consequent surge at about this time in the exit of senior staff. The energy crisis burst upon the Nation, and new pressures for energy-related programs were a short step behind. Significant among new activities launched in the last part of Hendricks' tenure was a pilot assessment of the Willamette River Basin, and one of his last initiatives—in June—was to direct the Systems Analysis Group to study the feasibility of using satellite relay stations in the National Water Data Network. In September, the Geological Survey moved its headquarters to its new building in Reston, Va., and Joe Cragwall moved to the Director's Office as Assistant Director for programs. In December 1973, Roy Hendricks retired.

For the first 3 months of 1974, Hackett served as Acting Chief Hydrologist. The new Chief, Joe Cragwall, took over in April, returning from the Director's staff. He was broadly experienced, having served the Division in the field in the old Surface Water Branch, as Chief of one of the pilot Districts (Tennessee) selected for testing reorganization along Division lines, and as Assistant Chief Hydrologist for Operations. Also, he had served in the Department's Office of Program Analysis.

The transition went smoothly. The key staff on board with Hendricks were retained. These included at Headquarters: Hackett, Associate Chief Hydrologist; E.A. (Ted) Moulder, Assistant Chief Hydrologist for Research and Technical Coordination, with John Bredehoeft as his Deputy for Research, and Harry Barnes, Gerald Meyer, and Ranard J. (Jack) Pickering as the Branch Chiefs; Walter Hofmann, Assistant Chief Hydrologist for Operations; George Whetstone, Assistant Chief Hydrologist for Scientific Publications and Data Management; and Hal Langford, Chief, Office of Water Data Coordination. Ruth Malone, Personal Assistant to the Chief Hydrologist, remained in that position, and George Taylor continued as Chief, Office of International Activities. Charles Herbert was Administrative Officer, and Francis Sessums was Program Officer. In the field, the Regional Hydrologists were Joe Callahan, Northeastern Region, at Reston; Rolland Carter, Southeastern Region, at Atlanta; Alfred (Al) Clebsch, Central Region, at Denver; and Elwood Leeson, Western Region, at Menlo Park.

As in the later Hendricks years, the dominant management problem was how to do more with less (relatively). Especially bothersome was the continuing cap on permanent positions. This led to an increased use of part-time employees. Also, it led Cragwall to promote the increased use of direct expenditures in the Coop Program and to consider "reverse flow" in this program (use of Federal matching funds for work by the cooperating agency), and it led him to promote experiments with grants and contracts at field level. Irksome to management during this time was the policy of the Office of Personnel Management (OPM) and the Department to require extensive recruiting outside the agencies for vacancies in senior positions. This, plus the requirement for cumbersome promotion boards, including members from outside the Division, greatly lengthened the process of filling vacancies. For example, after the tragic, sudden death of Walter Hofmann, Assistant Chief Hydrologist for Operations, in June 1975, his position remained vacant until May 1976, when he was succeeded by Tom Buchanan.

In the early Cragwall years, program growth was mostly related to the energy crisis. New funds supported new programs in coal hydrology and oil-shale hydrology based in Colorado, Utah, and Wyoming. Notable among new field projects was a major study of the Madison Formation, in the northern Great Plains, as a source of water supply for energy-related development. This project was under the direction of Elliott Cushing, from Denver.

By now, the trend in public concern for the environment was becoming increasingly evident, and the shift of the WRD program from primary concern with water quantity to water quality, which began in the Hendricks years, gained momentum. The interest of the non-Federal Advisory Committee, created as a consequence of BOB Circular A–67, greatly stimulated this shift. Following in the path of the Willamette River study, other pilot quality-assessment studies were undertaken, notably for the Chattahoochee, Yampa, Apalachicola, Schuylkill, and Potomac Rivers. These would blaze the trail for a national program of river-basin studies in the post-Cragwall years. Funding was also forthcoming for the buildup of NASQAN—the quality-of-water segment of the National Water Data Network. Also, the shift to the central laboratories was completed.

The beginning of 1974 saw the end of the International Hydrological Decade. The Decade, always underfinanced, did not fulfill the expectations of its founders, but nevertheless it awakened a common interest in hydrology among the participant nations. As a consequence, they, in concert with UNESCO, established a continuing International Hydrological Program (IHP). For the United States, the State Department, in December 1974, designated the U.S. Geological Survey as leader. Subsequently, the Survey established a U.S. International Committee for the IHP, with the Chief Hydrologist as Chairman. Leo Heindl returned from the National Academy of Sciences (NAS) to the Water Resources Division to serve as Executive Secretary and occupied this position until his death in 1978, after which James (Digger) Jones took over temporarily. Although the IHP proved useful as a sounding board for international activities, the Geological Survey was unable to secure the funding for a really viable program during the rest of the time of this history. As in the past, WRD continued to be active in hydrological affairs of both WMO and UNESCO.

In December 1974, George Taylor retired, to be succeeded as Chief, Office of International Activities, by James Jones. Taylor had compiled an impressive record, and it could be said, as of the British empire, that during his years the sun never set on WRD activities. Jones faced the growing problem of the personnel ceilings, which would increasingly constrain the international program for the rest of the Cragwall period.

By 1975, the cataloging of national water data and activities, carried out by OWDC pursuant to the provisions of BOB Circular A–67, had matured sufficiently to merit recognition as a specific Division activity. Accordingly, the National Water Data Exchange (NAWDEX) was launched as a unit under the Assistant Chief Hydrologist for Scientific Publications and Data Management (SP&DM). Already developed and also under the Assistant Chief Hydrologist, SP&DM, was the National Water Data Storage and Retrieval System (WATSTORE). These activities would help fulfill the promise of the computer age in making data and information on water resources available within a short timeframe anywhere in the Nation.

The third national conference of WRD since reorganization was held at Albuquerque, N. Mex., in October 1975. The conference was enormously successful. Highlighted were a review of progress since the last national conference, at Gatlinburg in 1970, and a set of recommendations that were to serve as guidelines for action during the rest of the Cragwall period.

Initiatives during the next few years included renewed attempts to gain support for a water-use data program and steps toward the development of a real-time data system. Support for a federally funded water-use data program was not forthcoming, but funding for a start was made available within the Federal-State Coop Program. After some study and experimentation by way of a Satellite Data Relay Project, transmission of data by satellite was deemed feasible and work was begun to create an operating system.

In 1977, the several activities related to instrumentation were reorganized. These were placed in a newly established Hydrologic Instrumentation Facility (HIF) at the Gulf Coast Hydroscience Center under the direction of Russ Wagner. Responsibility for coordinating the programs of the HIF and the Satellite Data Relay Project were assigned to Richard (Dick) Paulson, under the Assistant Chief Hydrologist for Operations. Also, in the summer of 1977, Herb Skibitzke retired. This terminated his remote-sensing project for which, regretfully, through the life of the project, the Division had been unable to raise adequate funding.

In the late-middle 1970's, most of the Nation was in the grip of a severe and extended drought. This stimulated an interest by the Congress in the development of ground-water resources. In response, and using the study of the Madison Formation as a prototype, the Chief Hydrologist proposed a new program of regional aquifer-system analysis (RASA), to be carried out over a period of several years. For fiscal year 1978, 5 million dollars was appropriated to begin this program. Responsibility was centered in the Ground Water Branch, with Gordon Bennett as program coordinator. The promise of this program was shown in the next decade as the RASA studies were completed.

The late 1970's also saw renewed interest in nuclear-waste studies, and a bureau-level program was initiated for this purpose, with WRD as the lead Division. George DeBuchananne, under the Chief Hydrologist for R&TC, headed a rejuvenated Office of Radiohydrology to coordinate this program.

Vince McKelvey stepped down as Director of the USGS at the end of 1977. He was replaced in early 1978 by William T. (Bill) Menard, from Scripps Oceanographic Institute in California. Menard was only the second Director chosen from outside Survey ranks (the other was William Wrather). Menard was a bright, innovative man, with impeccable credentials as a scientist and some firm notions as to the role of the Survey and changes to be made. But as an outsider, he faced an unusually difficult task. Many of the Survey employees viewed the replacement of the popular McKelvey by an outsider as a first step toward politicization of the position of Director, and their lack of enthusiasm, especially in the Geologic Division, hampered Bill Menard throughout his tenure.

March 1979 was a memorable month. On March 2–3, the Centennial of the United States Geological Survey was celebrated at the National Center in Reston, Va. March 9 marked the retirement of W.A. (Rad) Radlinski as Associate Director, and effective March 12, Joe Cragwall was appointed as Associate Director. Milt Hackett again served as Acting Chief Hydrologist until Philip Cohen was appointed as the new Chief Hydrologist in August 1979.

Key personnel at Headquarters at the end of Cragwall's term as Chief Hydrologist were O.M. Hackett, Associate Chief Hydrologist; Leslie B. Laird, Assistant Chief Hydrologist for Research and Technical Coordination, with John Bredehoeft as Deputy for Research, and Gerald Meyer, Jack Pickering, and Harry Barnes as the Branch Chiefs; Thomas Buchanan, Assistant Chief Hydrologist for Operations; Philip Cohen, Assistant Chief Hydrologist for Scientific Publications and Data Management; and Hal Langford, Chief, Office of Water Data Coordination. Francis Sessums was Program Officer. Charles Herbert was Administrative Officer. Helen St. John was Personal Assistant to the Chief Hydrologist. James Jones was Chief, Office of International Hydrology (formerly Office of International Activities). In the field, the Regional Hydrologists were: James E. Biesecker, Northeastern Region; Robert J. Dingman, Southeastern Region; Alfred Clebsch, Central Region; and W.H. Robinson, Western Region.

Both Hendricks and Cragwall had enjoyed the support of a seasoned group of senior advisors. These included, at various times: Walter Langbein, Luna Leopold, Thomas Maddock, Jr., Harold Thomas, Arthur Piper, Ray Nace, C.V. Theis, Carl Kindsvater, V.T. Stringfield, George Davis, Nick Matalas, and Isabel Picken. Special assistants for a time on Roy Hendricks' staff, dealing mostly with personnel matters, were James W. Geurin and Delmar W. Berry.

Organization—the key units and their missions—was remarkably stable during the Hendricks-Cragwall period, but roles of some units had to be bent to cope with the many proliferating and unforeseen urgencies of the day. For example, the increasing demand for staff attention to Division, Bureau, and Department projects and questions diverted the Branches from needed attention to their primary mission—oversight of the technical progress and health of the Division in its three subdisciplines. And in the Hendricks years, the concern of the Division for the quality of its reports absorbed much of the effort of Joe Upson, Deputy for Research, leaving him little time for leadership of research, his primary mission.

Throughout the period, the field and research efforts supported each other. Federal-State cooperation, supplemented by support from other Federal agencies, was the backbone for the Division's overall effort. The Coop Program provided most of the Division's output of data and information, provided early warning of emerging national problems, and served as a testing ground for new techniques and technology. The Research program kept the Division at the cutting edge of scientific hydrology and provided the field operations with the latest in techniques and technology.

The Cragwall-Hendricks period, spanning 13-plus years, is memorable in many ways. Hendricks successfully restored the morale of the Division and its credibility in the eyes of cooperating State agencies and other Federal agencies, and he kept it abreast of the rapidly changing times. Building on the Leopold-Hendricks legacy, Cragwall brought the Division through what might be considered its golden days. Old hurts from the reorganization of the 1960's were gone or forgotten, and multidisciplinary efforts could be directed as needed. The Division advanced far toward turning the corner in regard to using the tools of the computer and space ages, and it successfully tuned its program to meet the needs of a new day and a changing and enlarged audience. Coordination of Federal water-data activities under OMB (formerly BOB) Circular A–67 was well in hand except for occasional problems between the Survey and the USEPA. The stage was set in good form for the next act.

A brief overview of the careers of the two Chief Hydrologists during the period of this history is presented.

E.L. "ROY" HENDRICKS

Roy Hendricks was born October 8, 1909, in St. Augustine, Fla. He was a child of some adversity, which likely imparted to him a notable strength of character. Both parents, who were deaf, died while he was young; and he was raised by his grandparents on a farm in northern Florida. After receiving a B.S. degree in Civil Engineering from the University of Florida in 1931, Hendricks worked for a few months for the Florida road department and then taught high school mathematics until 1935 when he was employed by the Water Resources Division. Thus, he began a 38-year career with the U.S. Geological Survey.

Roy's first assignment with WRD was to the Ocala Field Office of the Surface Water Branch, where he gained experience in basic surface-water techniques and completed an analysis of the flow characteristics of the Kissimmee River Basin. Field projects in Georgia and Louisiana followed. In 1942, Hendricks did hydrologic research in southwest Georgia in cooperation with the U.S. Public Health Service and Emory University. This study was an attempt to relate the hydrology of lime-sink ponds to the incidence of malaria. Hendricks was among the first to use statistical analyses extensively in processing hydrologic data. Because this was before widespread use of computers, the analyses were painstakingly performed by Hendricks and his staff on personal calculators. In 1948, Hendricks was assigned to Baton Rouge, La., and was responsible for a study of the water available in the low-gradient streams for irrigation of rice in southwest Louisiana. He demonstrated proficiency as a hydrologist and water-problem solver. In 1952 he transferred to the Division's Technical Coordination Branch, stationed in Atlanta, to assist in fostering interbranch coordination. There, he sharpened his skills as a communicator and coordinator.

Hendricks transferred to WRD Headquarters in 1956. He served first as Chief of the Research Section for the newly formed General Hydrology Branch. Rapid promotion followed: Chief, Surface Water Branch, 1960; Associate Chief Hydrologist, 1963; and Chief Hydrologist, 1966. During this entire period, he coordinated multidisciplinary research efforts. He maintained his direct personal connection to research through his annual participation in the Mount Rainier glacier project, which studied the relationship between climatic change and glacier movement. As a key player on the WRD staff, Roy participated in reorganization of the Division, which was begun under Luna Leopold in the early sixties. As Chief Hydrologist, he inherited the task of completing the reorganization and the onerous task of reconstruction that necessarily followed. These tasks he accomplished with skill and sensitivity.

The world was changing rapidly, and Hendricks led the Division into the age of new technologies and shifting national concerns. He promoted the application of computer and space-age technologies to acquire, deliver, and improve the usefulness and timeliness of hydrologic information, and he pressed the reorientation of the field program to better meet the growing concern over water quality. Significant program initiatives undertaken included flood-plain mapping, regional ground-water studies, ground-water recharge, pilot studies of estuarine and coastal hydrology, and use of remote sensing. Organizational changes included the centralization of water-quality laboratories and the establishment of the Gulf Coast Hydroscience Center near Bay St. Louis, Miss.

Central to Hendricks' administration was his view that field and research efforts support each other, with the Federal-State Cooperative Program, supplemented with support from other Federal agencies, as the backbone of the Division's program. Hendricks was a gifted speaker and, in his position as Chief Hydrologist, ably represented the Survey at various national and international meetings.

Roy Hendricks retired from full-time service with WRD in 1973. He served as the first elected President of the WRD Retirees in 1976–77. Some years later, he and his wife, Idena, moved to a beach home at Caswell Beach, N.C. For many years he and Idena had been active lay leaders in their local Baptist churches as biblical scholars and teachers, and they remained active in their church at Caswell Beach. He also pursued his environmental interests—among them a Turtle Watch program that he organized and directed. On February 3, 1998, after lingering illness, Roy Hendricks died at his home at age 89. He successfully led the Water Resources Division through a difficult time of organizational change.

JOSEPH S. CRAGWALL, JR.

The second Chief Hydrologist during this period was Joseph S. Cragwall, Jr. His dynamic leadership came at a critical time—the Geological Survey was facing the challenge of meeting the Nation's need for earth-science information relating to the energy crisis of the early 1970's and to the rapidly growing awareness of environmental problems caused by a variety of man's developmental activities, which required new kinds of data and increasingly sophisticated interpretations. The integration of the three disciplines in the Division was well underway but still demanded considerable attention.

To many who worked for him, and also those for whom he worked, Joe Cragwall was the epitome of a Chief Hydrologist. He possessed a unique combination of outstanding leadership and management skills. Joe was widely respected and admired by WRD personnel. Because he had served as a District Chief himself, field personnel knew Joe had an intimate and firsthand knowledge of the problems encountered in dealing with cooperating State agencies and other Federal agencies. Joe's understanding and love of WRD is expressed in the following quote: "My most satisfying memories of the period were of the opportunities to work and associate with people in the U.S. Geological Survey, at Headquarters and in the field, and with the outside community of water and earth science professionals. My visits to the WRD Districts and many other field offices during the period convinced me more than ever that we all worked for the best organization in the public service, and that we, and those who served ahead of us, made it that way. Those who follow will keep it so."

Physically impressive—tall, ramrod straight—articulate in a Virginia gentlemanly way, he had a thorough knowledge of WRD's work. A colleague who had the chance to observe him firsthand as the WRD representative to the Clinch River Study Steering Committee stated that "Joe Cragwall was so thoroughly knowledgeable about WRD that his commitments to the Steering Committee were gospel to both the committee and to the WRD team members he represented." This statement demonstrates one of Joe's leadership traits that was tremendously important to the Division—the very positive effect his sincere, strong, and articulate style had on the outstanding morale of the Division during his leadership.

He was also admired and respected by those folks in Headquarters who had the opportunity to work with him on a day-to-day basis while he was Chief Hydrologist. In addition to having the ideal field assignments necessary to develop an understanding of WRD, its people and programs, Joe had assignments in the Survey and Department of the Interior (DOI) that equipped him with a broad-based knowledge of the forces that influenced the Division at all levels.

Joe possessed an uncanny ability to make people want to work very hard while simultaneously enjoying themselves. He was also able to instill professional pride in personnel throughout the entire Division. He and his loving wife, Jane, paid particular attention to the family feeling that existed in the Division during his time as Chief Hydrologist by hosting many parties, large and small, in such a gracious way as to convey a feeling that WRD was one big, happy family.

Joseph S. Cragwall, Jr., was born and raised in Virginia and still has a keen understanding and love for his home State. He received a B.S.C.E. degree in 1940 from the University of Virginia where he was a member of the Engineering Honorary Fraternity, Tau Beta Pi. He began his WRD career in the Marion, Va., office as a Hydraulic Engineer and streamgager and learned the skills of a surface-water hydrologist. During his early career he served in the Virginia, Louisiana, and Tennessee Districts and in the Floods Section of the Surface Water Branch. Joe met the girl he would marry, Jane Elizabeth Anderson, in high school. Joe and Jane were married in 1941 and they had a wonderful marriage and partnership for 50 years, until Jane's death in 1991. They have one daughter, Linda Cragwall Kubistek who, with her family, currently resides near Joe in Charlottesville.

Joe Cragwall served in Tennessee as District Engineer from 1958 to 1962 and District Chief from 1963 to 1966. Joe was so highly regarded as a manager of technical water-resources programs that the Tennessee District was selected as one of the three pilot Districts to test the integrated Division concept. His skillful leadership of Tennessee was a key factor in the successful test of the reorganized Division. In 1966, Cragwall was assigned to the Deputy Undersecretary's Office in the Department of the Interior (DOI) as the Staff Assistant for Planning, Programming and Budgeting of Water and Energy Programs. This Departmental assignment served him well in future years because it gave him a firsthand knowledge of DOI operations.

He was appointed Assistant Chief Hydrologist, Administration and Technical Services in 1968—this position was renamed Assistant Chief Hydrologist for Operations in 1971. Blessed with a keen mind and an intellectual's understanding of water-resources programming, he was also admired for his personnel management skills. He was the first USGS representative to attend the Federal Executive Institute (FEI), in 1969. Joe was a strong proponent of the FEI management training and encouraged WRD senior staff to attend this program. As Assistant Chief Hydrologist he was actively involved in building a management information system for the Division and working on coordination issues between Headquarters and the field. He served as Assistant Chief for 5 years and then in 1973 was appointed the Assistant Director for Programs, reporting to the Director.

In 1974, he was selected as Chief Hydrologist. Cragwall served in this position for 5 years. In the early Cragwall years, program growth was mostly related to the energy crisis. The infamous oil crisis of 1974 got everyone's attention when the price of gasoline tripled in a few months and all too often meant waiting in line for quite some time to "fill up." WRD was called upon to assist in most energy-source areas: coal hydrology studies, all facets of radiohydrology in support of nuclear-energy development and disposal of nuclear waste, water resources required for, and the environmental impact of, developing oil shale resources in Colorado, and supplying water-resources information for the design and construction of the Trans-Alaska pipeline were all hydrologic activities critical to the Nation. Notable among other field projects was a major study of the Madison Formation, in the northern Great Plains, as a source of water supply for energy-related development. During the later years of Cragwall's administration, the trend in public concern for the environment was becoming increasingly evident, and the WRD program in water quality gained momentum. A series of water-quality assessment studies, with the first being in the Willamette River Basin, blazed the way for a vigorous and increasing WRD effort in the field of water quality.

Cragwall stated that during his tenure as Chief Hydrologist, two notable programs were initiated—the National Water-Use Data Program and the Regional Aquifer-System Analysis (RASA) Program. In the mid-1970's, most of the Nation was in the grip of a severe and extended drought. This stimulated Congressional interest in the development of ground-water resources. While in the Program Office at DOI, Joe pressed for USGS funding to prepare a series of river-basin, ground-water summaries. In 1977, during an extensive and record-breaking drought, WRD submitted a well-prepared proposal that, with Departmental support in the budget justification process, resulted in a multi-year, multi-million-dollar program of regional aquifer-system analysis (RASA). The National Water-Use program provided the first nationwide quantification of the weakest link—the demand side—of the hydrologic equation. WRD had assembled available water-use data at 5-year intervals since 1950, but the information was somewhat limited in scope. The Water Resources Council pressed for the design of a continuing data-collection system structured to the river-basin framework. It fell to WRD to build upon its existing program, with increased Federal-State cooperative funding to build a systematic water-use program.

In addition to his duties of leading WRD, Joe was very active in professional activities outside of the organization; for example, he served as the Hydrologic Advisor to the U.S. Permanent Representative to the World Meteorological Organization from 1974 to 1980, was Chairman of the U.S. National Committee on Scientific Hydrology from 1975 to 1979, and was Chairman of the Water Policy Task Force of the National Society of Professional Engineers from 1982 to 1983. To all of these he brought a superb understanding of water resources and keen management skills.

In 1979, until his retirement in February 1980, Cragwall was the Associate Director of the Survey. After retirement, Cragwall remained active in the field of hydrology in work with the State of Virginia and was the co-author of Volume VI of the WRD History. As a gubernatorial appointee, he served on the Virginia State Water Control Board from 1982 to 1986. Throughout his career he was active in the American Society of Civil Engineers, the National Society of Professional Engineers, the American Water Resources Association, and many other professional organizations. He received the Department of the Interior's highest award, the Distinguished Service Award, in 1973. Joe also has been listed in American Men and Women in Science, Who's Who in Engineering, and Who's Who in America. After retirement, Joe and Jane moved to Charlottesville, Va., where he is still very active in his retirement community and is close to his beloved University of Virginia. Jane also remained very active in community matters until her death. Joe maintains interest in his life-long avocations of woodworking, golf, and gardening, and he still is an active golfer at age 81, as this edition of WRD History goes to press.

CHAPTER II – THE PROGRAM OF THE WATER RESOURCES DIVISION

INTRODUCTION

This chapter is a discussion of the program changes that occurred from 1966 through 1979. During the period, existing programs grew and 12 new programs or program functions were added to the Division. In his presentation on the State of Water Resources Division in Albuquerque in 1975, Joe Cragwall identified Office of Water Data Coordination, National Stream Quality Accounting Network, National Water Data Exchange, and Flood Mapping as major additions between 1970 and 1975. The program funds increased by 74 percent.

Growth from 1975 to 1979 was equally significant, increasing by about 60 percent with new programs in the Coop Program, water use, energy, and Regional Aquifer-System Analysis. The individual programs are discussed below.

Program planning, formulation, and management at all levels of the Division during this period were based on program elements of water records, analytical and interpretive studies, and research. Sources of program funding were the traditional budget elements of the Federal program, the Federal-State Cooperative Program, and funding provided by other Federal agencies. Table 1 shows the funding for Fiscal Years (FY)1966–79. Division leadership emphasized program management, and responsibility for achieving WRD goals and objectives was delegated to Regional and District managers. Many new initiatives were underway during the period.

MAJOR COMPONENTS

THE FEDERAL-STATE COOPERATIVE PROGRAM

Reliable supplies of suitable quality water are necessary to the health and well-being of America's people, cities, and businesses. Numerous Federal, State, regional, and local agencies share keen interests in appraising the Nation's water resources and seeking solutions to water-related problems. Because of their varying missions and areas of responsibility, these many agencies hold diverse perceptions of approaches, needs, and priorities. The U.S. Geological Survey's (USGS) Federal-State Cooperative (Coop) Program accommodates this diversity through joint planning and funding (50:50 matching) of systematic

Table 1. Appropriated, Coop, and OFA funding for the Water Resources Division (dollars in millions)

Fiscal year	Appropriated funds			Reimbursable funds		Total
	Federal program	Federal-State Coop Program	Subtotal appropriation	State-side Coop (includes unmatched)	OFA (includes miscellaneous non-Federal)	
1966	10.8	11.8	22.7	12.5	7.9	43.0
1967	11.7	13.0	24.7	13.9	8.9	47.4
1968	11.9	14.6	26.5	15.5	9.0	51.0
1969	12.5	15.2	27.7	16.2	9.6	53.5
1970	14.2	17.3	31.5	17.3	10.8	59.6
1971	15.6	19.2	34.8	19.5	12.0	66.3
1972	17.7	20.0	37.7	21.3	12.6	71.6
1973	19.3	21.2	40.5	22.7	15.2	78.4
1974	20.5	25.3	45.8	25.8	17.1	88.7
1975	26.8	27.0	53.8	28.6	19.5	101.9
1976	30.3	26.9	57.2	29.7	25.6	112.5
1977	34.5	34.0	68.5	34.8	28.2	131.5
1978	45.8	35.0	80.8	36.5	31.1	148.4
1979	60.5	38.3	98.8	40.1	31.4	170.3

studies of water quantity, quality, and use on a national basis. The Coop Program has contributed to water-resources knowledge for 80 years. Program priorities are developed in response to mutual Federal, regional, State, and local requirements. Thus, the USGS and cooperating agencies work together in a continuing process that leads to adjustments in the program each year.

The Federal-State Coop Program, a partnership between the USGS and State and local agencies, provides information that forms the foundation for many of the Nation's water-resources management and planning activities. In addition, the information may function as an early warning of emerging water problems. The fundamental characteristic of the program is that local and State agencies provide at least one-half the funds, but the USGS does most of the work.

From its earliest days, the Coop Program fostered the development of procedures for streamflow gaging, concepts of surface-water and ground-water flow, and analytical techniques for investigations of water quality. More than 700 cooperating agencies have participated in the program. These cooperators include State, county, and municipal agencies, as well as interstate compact organizations, conservation districts, water-supply districts, sanitary districts, drainage districts, flood-control districts, and similar organizations.

A comprehensive and forward-looking program of hydrologic data collection and investigations is needed to provide the information necessary for the wise development and use of the Nation's water resources. The jointly planned and funded Cooperative Program provides assurance that the information needed to meet national and local needs will be produced and shared. Because rivers and aquifers cross jurisdictional lines, studies and data collected in one county or one State have great value in adjacent counties or States. The USGS can respond to major floods with personnel from all over the Nation. This versatile response capability would not be possible if State agencies had to act alone in flood emergencies. Having the USGS do the work results in consistent application of techniques of data collection and archiving, with the information stored in common data bases, readily available to all. The knowledge gained in the studies is published and added to the growing body of information about the hydrology of a region or area.

The benefits of the Coop Program are demonstrated by the extent to which other agencies apply the information produced. For example, the National Weather Service uses streamflow and water-level information from some 3,000 USGS-operated gaging stations for their flood-forecasting systems.

In 1979, the USGS operated about 17,000 streamflow-gaging stations and 12,000 surface-water-quality sites, measured water levels in 30,000 wells, and collected and analyzed samples for water quality. The Federal-State Coop Program funded 50 percent of the streamflow-gaging stations and ground-water sites and 30 percent of the surface-water-quality sites.

Since the early 1970's, there has been an increase in the number of investigations that have emphasized water-quality issues such as aquifer contamination, river quality, storm-runoff quality, and the effects of acid rain, mining, and agricultural chemicals and practices on the hydrologic system.

ARTIFICIAL RECHARGE

To reduce evaporation, it is possible to store water underground instead of in surface reservoirs. This method, "artificial recharge," had been undertaken with varying degrees of success. In 1968, the feasibility of recharging declining ground-water supplies of the Southern High Plains of Texas and New Mexico was investigated. In this area, ground-water levels had been dropping for many years. To support the economy of the 35,000-square-mile area, about 2.5 trillion gallons of water had to be imported each year. Because surface-reservoir sites were inadequate to store so much water between growing seasons and evaporation losses from surface reservoirs were so high, it was desirable to store as much as one-half of this imported water underground. If successful and economical methods were found to inject this amount of water in the ground, it meant that underground storage could be an important technique for water development and management.

A report was completed on the various mensuration techniques of the parameters related to design of pits for artificial recharge on Long Island, N.Y. This included recharge of ground water using highly treated sewage in spreading basins. Instrumentation was emplaced in a manhole in the center of the basin to study the long-term water quality and clogging effects of such recharge. This instrumentation facilitated a study of the movement of viruses into the aquifer during recharge.

In FY1972, WRD began an inventory and evaluation of the nature and magnitude of the effects of current disposal practices on ground water. Regional appraisals of the waste-injection aspects were made of the deep limestone aquifer in the Florida Peninsula, the buried Triassic rocks in the Atlantic Coastal Plain, the sandstone in the Wilcox Group in the Gulf Coastal Plain, and the Paleozoic rocks used for injection in the Ohio River Basin. Documented examples of the movement of pollutants in freshwater aquifers in Barstow, Calif., Denver, Colo., and Long Island, N.Y., were analyzed to determine the rate that pollutants were dispersed or otherwise diluted in moving through the subsurface. Studies were begun on the chemical reactions of organic substances in ground water, the capacity of geologic membranes to absorb and filter minerals from waste solutions, and techniques to measure the existing stress in a potential injection horizon to enable the prediction of whether the pressure increase will initiate earthquakes. A national symposium on waste-management technology was co-sponsored in which industrial representatives, well designers, ground-water consultants, and Federal and State officials met to exchange knowledge on the current state of the art in subsurface waste disposal.

COAL HYDROLOGY

Coal hydrology studies involved the concurrent determination of available water supplies and baseline water-quality data reflecting pre-mining or current mining and reclamation conditions. The information was used to assess future impacts caused by additional mining and by new conversion industries. WRD studies, aimed at answering basic questions about water availability and related effects of coal mining, ranged from collection of basic data on water quantity and quality through laboratory investigations of gases and organisms in water to analyses of regional aquifer systems, such as the Madison aquifer. The coal hydrology program consisted of three elements—mining-water supply and quality; coal slurry-line demands and impacts; and water-supply impacts of waste management in conversion processes. In FY 1975, WRD concentrated on defining the hydrology of areas underlain by coal.

Passage of the Surface Mining Control and Reclamation Act of 1977 (SMCRA) set national policy regarding the control of the surface effects of coal mining on the environment. The potential for adverse effects on water resources and the need to assess and mitigate these potential impacts received considerable attention in the act. One section, Section 507(b)(11), required the "appropriate Federal or State agency" to "provide hydrologic information on the general area" to the mining permit applicant. The Congress authorized new funds to WRD to begin acquiring the necessary information.

To meet this responsibility, WRD first analyzed the existing water-data networks in coal regions of the Nation by using the requirements of SMCRA to assess network adequacy. The following general areas of deficiency were identified: (1) the lack of data on smaller drainage areas, (2) the need for additional water-quality information, and (3) the need for sediment data.

In 1978, WRD-funded activities ranged from collecting hydrologic data from contractors to the regional analysis of the Madison aquifer. WRD funding represented only slightly more than one-half the financial outlay for coal and other energy-related studies. WRD activities in coal hydrology were funded by the USEPA, the Bureau of Land Management (BLM), and 31 States in the Federal-State Cooperative Program in addition to direct appropriations. The WRD program attempted to obtain answers through coordinated efforts of Federal, State, and local agencies. Efforts centered on Western coal and oil-shale areas with other investigations in progress in the Appalachians, the Midwest, and the West.

In FY 1979, WRD began to conduct additional water-quality and sediment data collection at existing continuous-record surface-water stations. These stations provided background data on natural variability and the effects of changes other than mining on the stream system. New trend and reference sites were selected, and gages were installed as dictated by changing needs and analysis of the data collected.

FLOOD-PRONE AREA MAPPING

In the early 1970's, WRD produced a variety of products related to flood-plain mapping. The Federal Insurance Administration (FIA) of Housing and Urban Development (HUD) by legislation was requested to identify all flood-prone areas in the United States. The FIA asked the USGS to delineate flood boundaries on topographic quadrangles. The initial number was all 33,000 quadrangles, but the FIA agreed, after meetings with the Secretary of the Interior and the Director of the USGS, to delineate only the important flood plains identified by WRD.

With strong endorsement from the Department and the Bureau, the Division began a program, with George Edelen as the Headquarters contact, to provide flood-prone area maps to HUD and to several States. Flood plains were outlined on more than 4,000 quadrangle maps in the first 2 years. The Topographic Division and other Federal agencies provided some support as the effort grew and the pressure increased to complete the job.

The flood-prone area maps were well received by individuals, private organizations, and Federal, State, and local government agencies. The maps proved to be particularly useful in planning evacuations of areas likely to be flooded. By the end of FY 1979, 13,048 maps and 895 pamphlets had been published. Each WRD District participated in the process. About 250 maps, prepared by the Soil Conservation Service, were printed and distributed by the USGS. Updated frequency curves and physical and climatic characteristics of the contributing drainage areas were defined for 12,000 gaged sites. These data were used to define relations for estimating flood magnitude and frequency at any ungaged, natural flood site where estimates were needed for planning, designing, or regulating.

GEOTHERMAL INVESTIGATIONS

In 1977, WRD had 19 ongoing research projects and several supporting activities as part of the Survey's Geothermal Energy Investigations Program. These projects supplemented the studies of the Geologic Division, and as Cragwall explained, the Geologic Division served as the Survey's lead in this area. Some financial support was provided by the Energy Research and Development Administration. The projects covered the following studies of mass and energy transport in geothermal systems; numerical modeling studies; land subsidence research in geothermal areas; geochemical studies; and areal and regional hydrologic studies.

Significant accomplishments and findings included:

- Testing of a high-temperature acoustic televiewer to a depth of 3,050 meters and a temperature of 200 degrees Celsius in a borehole and of a high-temperature acoustic velocity probe in a laboratory; developing this equipment was important to improve understanding of fractured rock geothermal reservoirs.
- Determination of rock-water chemical interactions for selected constituents in about 100 springs and geysers in liquid-dominated geothermal systems in the Western United States. The findings indicated that hot spring waters generally are in equilibrium with the solids which they contact.
- Modification of a numerical model that described the movement of steam in a vapor-dominated geothermal system to include the effects of heat conduction in the overburden, the weight of the steam column, and the effects of condensation when production was terminated.
- Detailed chemical analyses of about 100 formation water samples from 15 oil and gas fields in coastal Texas and Louisiana that showed that the salinity of water in the geopressured zone ranged from about 20,000 to more than 150,000 mg/L dissolved solids; samples from many gas wells yielded low salinities that were not representative of the true salinity of formation water because they were diluted by the condensed water vapor produced with natural gas; and the concentrations of hydrogen sulfide, silica, and mercury were low in geopressured waters and the concentrations of toxic components (boron, ammonia) were moderately high.

NATIONAL STREAM QUALITY ACCOUNTING NETWORK (NASQAN)

In the late 1960's and early 1970's, a number of incidents alerted the American public to the declining quality of many of the Nation's large rivers. The Cuyahoga River, flowing into Lake Erie at Cleveland, Ohio, actually caught fire as a result of pollution from petroleum products floating on its surface. The "Nation's River," the Potomac, was closed to swimming and fishing as a result of gross pollution in its waters as they flowed through Washington, D.C., the Nation's capital. In the West, the storied Colorado River was essentially "used up" before it could escape into Mexico, making it questionable whether the United States could meet either quantity or quality requirements of its treaty obligations concerning the river water passed on to its neighbor. In fact, the United States was eventually forced to build and operate an expensive desalination plant at Yuma, Ariz., in order to meet those obligations. Rachel Carson had recently alerted the Nation to new environmental concerns about pesticides through her book "Silent Spring." There was a broad awareness of the need to monitor environmental conditions nationwide, especially the condition of our large rivers.

The Federal Bureau of the Budget recognized this need in writing Circular A–67, which called on the USGS not only to coordinate water-data collection throughout the Nation, but to design and operate a "National Water-Data Network." As part of this effort to define a national network, the Office of Water Data Coordination, using both its own staff and detailees from USGS Field Offices, designed a National Stream Quality Accounting Network (NASQAN) to monitor streamflow and water quality on large rivers throughout the Nation. Design of the network used the recently defined hydrologic accounting units and called for measurement, on a continuing basis, of a wide variety (55) of physical, chemical, and biological water-quality characteristics. The primary objectives of the network were:

1. To account for the quantity and quality of water moving within and from the United States,
2. To depict areal variability,
3. To detect changes in stream quality, and
4. To lay the groundwork for future assessments of changes in stream quality.

Where possible, existing measurement sites for streamflow or water quality were incorporated into the network, and data collected by other Federal, State, and local agencies were used where they conformed to the operational design. Station locations were picked to monitor the quantity and quality of water as it left each accounting unit. Samples were collected on a consistent schedule nationwide, and all samples collected by USGS personnel were analyzed in the Survey's Central Laboratories System using specified methods.

Rivers integrate the landscape through which they flow. Water quality measured at any one point in a river reflects a complex combination of natural processes and human activities that occur upstream. By measuring the amount of chemicals and sediment that flows past stations on the Nation's largest rivers, NASQAN provides the data needed to:

- Characterize large subbasins of these rivers,
- Determine regional source areas for these materials, and
- Assess the effects of human influences on observed concentrations and amounts of these materials.

Because these large rivers typically coincide with State and international boundaries, monitoring these rivers primarily is a Federal responsibility. NASQAN stations are sampled frequently enough to characterize variations in chemical and sediment concentrations that occur during a year, particularly the variation that occurs between low and high flows, during different seasons of a year, and during different hydrologic regimes—such as periods when snowmelt dominates river discharge.

NASQAN was different from other water-quality monitoring studies in several important ways:

- The network was designed around a system of subdivided river basins, so the collected water data could be related to conditions within a known area upstream and compared with that from adjacent or nearby areas.
- Stations were operated uniformly; therefore, results obtained could be compared directly because the same methods were used to collect and analyze the samples from all stations in the network.
- Stations were committed to long-term objectives, so the length of record at all stations, the frequency of sampling, and the sampling locations would remain uniform for a long time. The uniformity allowed for valid comparisons among stations and provided an opportunity to look for long-term changes.

The need for a network that could be used to detect changes in stream quality had been well documented by prominent hydrologists and by the President's Council on Environmental Quality. A vast amount of data was available for tens of thousands of locations throughout the Nation, but what was lacking was national consistency—measurement of the same water-quality characteristics at the same frequency at the same places over an extended period of time. The implementation and operation of NASQAN was intended to produce a set of systematically collected baseline water-quality data that would be available for nationwide studies involving transport of and changes in chemical and biological characteristics of surface waters. Although NASQAN was intended to provide data needed to assess regional trends in order to evaluate the effectiveness of programs to control water quality, it was realized that the broad-scale information collected was not likely to be detailed enough to assess the effectiveness of pollution-control measures on a local basis. For this, finer scale studies would be required. Nevertheless, in 1973, NASQAN was designated by the Council on Environmental Quality as the Nation's primary network for uniform water-quality assessment.

A river-quality accounting network to provide broad-scale accounting data was a primary component of a Departmental "thrust" document on river-quality monitoring that was prepared in March 1972. Other components included periodic synoptic assessments of water quality in each hydrologic accounting unit using NASQAN stations to bridge the time gap between assessments, expansion of agency research in topics related to river-quality monitoring, and an inter-Bureau analytical quality control program for measurement of physical, chemical, biological, and esthetic characteristics of river quality. Although only NASQAN was implemented as recommended, the document provided support for the Survey's successful River Quality Assessment Program and can be viewed as a step toward larger scale assessment such as those in the National Water-Quality Assessment (NAWQA) Program of the 1980's and 1990's. The Chairman of the committee that prepared the thrust document was Ranard (Jack) Pickering, who in April 1972 was named Chief of the Quality of Water Branch, the organizational unit given the responsibility for making NASQAN a reality.

NATIONAL WATER DATA EXCHANGE (NAWDEX)

As the Nation's resources developed, water played an increasingly important role—both as a resource to be developed and as a resource to be protected. The proper development and protection of our water resources, however, depends on adequate data on the quantity and quality of our water. Vast amounts of data have been collected by hundreds of agencies, and much more information is being collected.

Before the advent of the World Wide Web, and associated easy access to data obtained by agencies, finding and obtaining water-resources information was difficult. Even though an enormous amount of information was being collected, the potential user faced a bewildering problem in trying to determine if the specific information needed had been collected or where it might be available. To help solve these problems of matching user needs to available data, NAWDEX—the NAtional Water Data EXchange—was established.

NAWDEX consisted of a national confederation of water-oriented organizations working together to improve access to water data. Its primary objective was to assist users of water data in the identification, location, and acquisition of needed data. The USGS accepted the lead responsibility for implementing NAWDEX, and work began on this effort in January 1973. The program was formally established and made operational in January 1976. Melvin D. "Doug" Edwards was the first Chief of NAWDEX.

The Program Office was located administratively with the Water Resources Division of the USGS and provided data-exchange policy and guidelines to all participants in the NAWDEX Program. The office maintained close working relationships with the USGS Office of Water Data Coordination in updating the "Catalog of Information on Water Data" and in obtaining advice and counsel from the (Federal) Interagency Advisory Committee on Water Data and the (non-Federal) Advisory Committee on Water Data for Public Use. The Program Office also established working relationships with U.S. organizations that maintained water-related data banks and with foreign organizations that maintained water-data information systems.

Membership in NAWDEX was voluntary and open to any water-oriented organization that wished to participate. Membership included organizations from the Federal, State, interstate, local governmental, academic, and private sectors of the water-data community. No dues or fees were associated with becoming a member. Members were required, however, to sign a memorandum of understanding with the Program Office defining a member's general commitment to take an active role in NAWDEX activities, to provide information on its data holdings for indexing purposes, and to provide data from its holdings upon request. NAWDEX was operational through the end of this reporting period.

NUCLEAR HYDROLOGY

One of the most serious issues related to the development of the nuclear industry has been disposal of radioactive wastes. The wastes are classified as high level if they result from the reprocessing of reactor levels and low level if they are from any other source. Many nuclear wastes may remain a threat to the environment for some time.

In 1977, WRD, in cooperation with the Energy Research and Development Administration, began an effort to characterize several potential regions for the disposal of high-level waste. Studies were initiated in areas of bedded salt in New Mexico, Utah, New York, and Michigan; at salt domes in Louisiana and Texas; and in shales in Colorado, Nevada, and North and South Dakota. Also, WRD initiated a study of specific sites in granitic rocks of southern Nevada in 1977.

Simultaneously, WRD began to investigate existing low-level waste-disposal sites to determine the amount and direction of movement of radionuclides under actual field conditions. The radionuclides moved by ground-water transport, erosional processes, or as gaseous emissions. Geologic materials collected at field sites were evaluated to assess their effectiveness in retaining radionuclides by sorption and ion exchange. Studies at the low-level waste sites were designed to gather information and develop geohydrologic criteria for more suitable location of future burial sites. Ground-water tracer studies were in progress in the Amargosa Desert of Nevada to develop a method to determine local ground-water movement. Results of the studies would be used to develop hydrogeologic criteria for locating future low-level radioactive-waste burial sites and to design the hydrologic monitoring systems for such sites.

Theoretical and laboratory studies were underway to:

- Detect and identify radionuclides by borehole geophysical techniques
- Use digital modeling techniques to predict ground-water flow and quality
- Evaluate geochemical kinetics of radionuclides
- Predict the movement of radionuclides in the unsaturated zone
- Predict the behavior of transuranic elements in the geologic environment
- Predict the transfer of heat in aquifers
- Improve the use of tracers in studying ground-water movement.

OIL-SHALE HYDROLOGY

The largest known oil resource in the world is in the oil-shale deposits of the Green River Formation in Colorado, Wyoming, and Utah. The known deposits include about 600 billion barrels of oil in deposits at least 10 feet thick and averaging more than 15 gallons per ton. These deposits represent a potential energy resource that could supply the Nation's oil demand for many decades. The potential of oil shale to alleviate the Nation's dependence on foreign oil supplies has stimulated industrial and governmental interest in developing oil-shale technology. In 1971, the Department of the Interior announced plans to permit development of a small part of the oil-shale resources on public lands in Colorado, Wyoming, and Utah.

The oil-shale hydrology program was initiated to provide data on the surface- and ground-water hydrology needed to predict the amount and quality of ground water present in the oil shale and how it affects underground mining, surface mining, and in-situ oil-extraction processes; to predict the effects on ground and surface water of the disposal of spent shale; and to provide baseline data to evaluate the long-term impacts of oil-shale development on water quantity and quality. The program measured and modeled, as appropriate, the parameters of different water-bearing formations (aquifers), the connection between aquifers, the occurrence of fresh and saline ground water, and the relation between different ground-water zones and surface water.

The WRD began a study of a 25,000-square-mile area in Colorado, Utah, and Wyoming, which included four Federal prototype leases and several developments on private lands. Basic hydrogeologic data on aquifer properties and the relation of surface water to ground water were obtained by core drilling and aquifer testing and were used to develop predictive models of the hydrologic system to simulate the effects of mining. Hydrologic issues associated with these techniques included locating adequate water supplies for personnel, dewatering during development and production, disposing of what may be highly saline water pumped for dewatering, and assessing the long-term effects of the retorted shale on the region's water supply after development.

In 1974, the WRD prepared a report, in cooperation with the Colorado Department of Natural Resources, which concluded that development of oil-shale deposits in the 900-square-mile Piceance basin in northwestern Colorado will have significant effects on the hydrology of the region. A digital computer simulated the possible effects on the hydrologic system of precipitation changes that were due to the introduction of atmospheric pollutants from oil-shale development or cloud seeding and mine dewatering. The model results showed that for the hypothetical dewatering method simulated, one proposed mine could produce enough water to meet the demands of oil-shale processing and disposal over a 30-year period and a second hypothetical mine would not produce enough water. In 1975, new projects included a study of organic wastes percolating from spent oil-shale and coal-mine wastes and a study of the function of microbes in decreasing or increasing the solubility of minerals in oil shale and coal-mine wastes.

By FY 1979, WRD oil-shale studies continued to focus on Colorado because two active Federal prototype oil-shale leases were in northwestern Colorado. Both sites were evaluated by using modified in-situ techniques, which involved driving a shaft through the zone to be developed, mining about 15 to 25 percent of the shale, fracturing the surrounding shale to refill the area mined, and through combustion controlled from the surface, retorting the shale in place. One major unknown being studied was the potential for collapse into the retorted depositions some time after development. The part the ground-water system played was to be evaluated.

REGIONAL AQUIFER-SYSTEM ANALYSIS (RASA)

The drought of 1976–77 in the United States caught the attention of the U.S. Congress. When conferring with officials of the Department of the Interior, current information on river flows revealed the status of the Nation's rivers. No comparable system was available for describing the stress of droughts on the Nation's ground water. Accordingly, the USGS was asked, in a proposal, to develop a program for evaluating and describing the nature and use of the Nation's ground-water systems.

To supply such information for water-resources management, the U.S. Geological Survey in 1977 instituted the Regional Aquifer-System Analysis (RASA) Program to study the Nation's ground-water systems on a regional scale. A regional aquifer system, as the term is used here, is of two general types: aquifers that are of regional extent, such as aquifer systems in the Northern Great Plains, and small aquifers that share so many characteristics that they can be studied together, such as aquifer systems in the Southwestern Alluvial Basins or glacial valley aquifers in the Northeast.

Purpose and Approaches of the RASA Program

- The objective of each study was to define the regional hydrology and to establish a framework—geologic, hydraulic, and geochemical—for detailed local investigations.
- While each investigation was designed to fit the particular problems of the study area, every project used computer models, or simulations, to analyze the hydrologic systems and to provide predictive capabilities with logic systems and to provide predictive capabilities with which the effects of future development could be estimated and evaluated.
- Information also was to be assembled on the quality of water throughout each aquifer system by bringing together all existing information and by collecting such field data as were required to fill the gaps.

RESEARCH

In the mid-1960's, the step-by-step reorganization of the Water Resources Division brought about important changes in the administrative support of those people engaged in the Division's federally funded research program. In the late 1950's, that program had begun under the aegis of a Research Section in each of the three principal operating Branches, namely, Ground Water, Quality of Water, and Surface Water. By 1966, those Research Sections had been abolished, the position of Regional Research Hydrologist had been established on the staff of each Regional Hydrologist, and all research personnel now were assigned to the particular Regional Office that had jurisdiction over the area in which they were headquartered. Thus, the Regional Research Hydrologist became the mentor for all WRD researchers in his region.

Implicit in the mentor role was the need to serve as a focal point or clearinghouse for all administrative support actions including research project planning, budget development and approval, monitoring expenditure rates throughout the fiscal year, recommendations for pay raises and promotions, and recommendations for awards.

Beginning in FY 1975, the concept of a cadre of Research Advisors was introduced. In each research discipline, a Research Advisor was designated to become, in effect, the new mentor for the research project leaders active nationwide in that discipline. Justification for this administrative step was strongly rooted in the urge to enhance and maximize the prospects for the most expeditious technical advancement of the research.

Throughout most of this historical period, the Division Headquarters included the Office of the Assistant Division Chief for Technical Coordination and Research. Although the Regional Research Hydrologist was organizationally a part of the Regional Hydrologist's staff, he nevertheless worked closely with the cited Division Office in the overall planning and implementation of the Division's national program of research.

Synoptic statements on significant advances in the research work were published annually in the USGS Professional Paper series. Each such paper bore the title "Geological Survey Research 19__." Research project leaders' names were included in the index at the back of each paper, thereby affording a ready key to locating the summary of progress on any given project.

Major categories of research included:

- Geochemistry
- Ground-Water Physics
- Sediment
- Surface-Water Physics
- Ecology
- Surface-Water Hydrology
- Geohydrology
- Socioeconomics
- Aeration Capacity of Streams
- Hydrobiologic Investigations

Hendricks and Cragwall continued the policy established by Luna Leopold whereby 10 percent of the funds for certain program areas (for example, ground water, estuaries, coastal zone management, urban hydrology, coal hydrology, and lakes and reservoirs) would be set aside for research efforts. Program monies in effect were tied to research activities.

WRD Memorandum 75.15, August 15, 1974, discussed the WRD Research Program. Research in WRD primarily was applied research. The purpose of the research program was to develop methods and techniques to facilitate and improve operational activities. The strength of the WRD program was its nationwide scope and the variety of real problems confronted. Some of the field programs provided ideal opportunities to test new research. By 1976, the research program was funded at a level of approximately $13 million.

Researchers were expected to spend up to one-third of their time consulting with Districts in their area of expertise and/or instructing in the Division's training program. Bredehoeft, as Deputy Associate Chief Hydrologist for Research, and Cragwall, as Chief Hydrologist, both worked to improve communications between the researchers and other hydrologists. They promoted the concept of each researcher spending a portion of his or her time in the field each year.

Research was considered vital to the WRD program. It was supported to provide advances to the science of hydrology; new and improved methodologies; and the expertise for help, consultation, and training to the operating program.

Public Law 88–379, July 17, 1964, the Water Resources Research Act, empowered the Secretary of the Interior to dispense certain sums to designated land grant colleges and other educational institutions, private foundations, firms, individuals, and Federal, State, and local government agencies for the purpose of conducting water-research projects. The Office of Water Resources Research was set up to administer the Act within the Office of the Secretary, and each State was provided a fixed annual sum in order to set up and maintain a water-resources research institute at a land grant college.

At the time the Office of Water Resources Research was established, many felt that it should be managed by WRD in association with WRD's research program rather than through the Office of the Secretary in the Department of the Interior. Others felt, however, that this activity would change the nature of the mission of WRD even though it would have added additional research capability to the Division. Hendricks had mixed feelings on the subject. Some persons were concerned that, because of the funds associated with the endeavor, it would tend to become a highly visible and political activity and would not be in consort with the WRD position as one of interpreting the environment.

WRD adopted a policy to attempt to guide the research institutes away from the water-resource evaluations of the type which were recognized as the particular province of the USGS, from projects in which no substantial research benefits were to be gained, and from other types of work which the Survey and other existing agencies already had underway.

RIVER QUALITY ASSESSMENTS

The American public identified the enhancement and protection of river quality as an important national goal. As a consequence, considerable investment was made to improve the quality of the Nation's rivers. It was important that alternative plans for river-quality management be scientifically assessed in terms of the ability to produce environmental benefits.

In 1971, the Non-Federal Advisory Committee on Water Data for Public Use formally recommended that the USGS conduct an interdisciplinary river-quality study. The recommended objectives were (1) to define a practical framework for conducting comprehensive river-quality assessments; (2) to determine the kinds and amounts of data required to adequately assess various types of river-quality problems; (3) to develop and document methods for assessing planning alternatives in terms of potential impacts on river quality; and (4) to apply the framework, data, and methods to assess the critical river-quality problems of a major river basin.

The USGS responded to the Committee's recommendation in January of 1973 by starting a prototype river-quality assessment study in the Willamette River Basin in Oregon. Specific topical subjects included practical approaches to mathematical modeling, analysis of river hydrology, analysis of earth resources, river-quality relations, and development of data-collection programs for assessing specific problems.

URBAN HYDROLOGY

Prior to 1968, the principal involvement of the Survey in the field of urban hydrology was related to the flood potential of urban storm runoff. Efforts pursued were almost entirely within District programs. With impetus from the Federal Water Pollution Control Act (Public Law 92–500, Section 208) of 1972, significant concern was directed to the problem of water-quality degradation resulting from urban runoff.

The rapidly increasing population in the Nation's urban areas impacted the water resources. Many cities were experiencing water-quality problems and urban flooding. The WRD began an urban hydrology program in FY1969 to identify and evaluate the hydrologic parameters that were significant in the urban environment and to design a corresponding data network for collecting information in various urban areas. The WRD collected rainfall, runoff, and water-quality data at 20 key metropolitan areas throughout the United States.

WATER DATA COORDINATION (OWDC)

In response to the mandate presented in Bureau of Budget Circular A–67, the Office of Water Data Coordination, led by Milt Hackett and Hal Langford, moved ahead with development of several new program efforts. During this period, many WRD personnel were involved in the following actions to enhance coordination of water data:

- Development of the first Catalog of Information on Water Data
- Permanent establishment of two advisory committees—the Advisory Committee on Water Data for Public Use and the Interagency Advisory Committee on Water Data
- Preparation, jointly with the Water Resources Council, of the first river basin hydrologic unit maps for the entire United States
- Formal agreement between the U.S. Geological Survey and the Federal Water Pollution Control Administration that divided responsibility for Federal water-quality monitoring and provided a philosophic basis for future coordination
- Activation of National Stream Quality Accounting Network (NASQAN), National Water-Use Data Program, National Water-Data Exchange (NAWDEX), and River Quality Assessment Program
- Publication of "Index to Catalog of Information on Water Data"
- Annual preparation of Regional and Federal Plans for Activities in each of the 21 Federal Regions
- Publication of the multiagency "National Handbook of Recommended Methods for Water Data Acquisition"
- Implementation of WATSTORE, which made available to the public more than 150 million streamflow, water-quality, and ground-water measurements collected from more than 100,000 sites across the United States

WATER USE

The U.S. Geological Survey began compiling estimates of water use every 5 years in 1950. These estimates were derived from many sources and had a wide range of accuracy. Therefore, they fell short of providing a national data base that was both current and reliable. In 1977, the Congress of the United States recognized the need for uniform information on water use and directed the U.S. Geological Survey to establish a National Water-Use Information Program to complement the Survey's data on the availability and quality of the Nation's water resources.

The National Water-Use Information Program was designed as a cooperative program between the States and the Federal Government. The goals of the program were: to collect and compile water-use data; to develop and refine computerized water-use data systems at both the State and national levels; to devise new methods and techniques to improve the collection and analysis of water-use information; and to disseminate this information to those involved in establishing water-resources policy and to those managing the resources. The first Program Manager for Water Use was Frederick Ruggles.

CHAPTER III – THE WRD ORGANIZATION

By James Biesecker

From 1964 to 1966, significant organizational changes in WRD were implemented. It took approximately a decade to implement these changes fully at all levels of the organization; therefore, the period 1966 to 1979 was both a stressful and an exciting one for WRD personnel. The reorganization placed greater emphasis on hydrology as a new disciplinary science, combining the previously separate scientific disciplines into an integrated Division-wide program. The Division mandated conversion of qualified personnel from other disciplines to the Hydrologist series.

WRD ORGANIZATIONAL STRUCTURE—1967–71

A chart of the reorganized Water Resources Division as of April 1967 is shown in figure 1. Regional boundaries and offices in WRD are shown in figure 2. The Headquarters Office of the Division in Washington, D.C., was composed of the Office of the Chief Hydrologist, the Office of Water Data Coordination, Staff Advisors, and the Offices of the Assistant Chief Hydrologists for Administration and Technical Services, Reports and Data Processing, and Research and Technical Coordination. The composition and functions of these Offices were:

- The Office of the Chief Hydrologist was composed of the Chief Hydrologist and Associate Chief Hydrologist. These officials were responsible for exercising the authority delegated by the Director for the execution of programs, planning and evaluation of programs, and the scheduling and production of reports and publications.

- The Office of Water Data Coordination was responsible for performing the coordination functions assigned to the Department of the Interior by Bureau of the Budget Circular Number A–67, dated August 28, 1964. This included the coordination of national network and special water-data acquisition activities and the maintenance of a central catalog of water information for use by Federal agencies and other interested parties.

- Staff Advisors assisted the Chief Hydrologist in setting the overall policy direction of the Division's programs and the management policy related to these programs. Specific functional assignments included national program goals and program emphasis to reach the goals, operations research and systems design, personnel policy, and administrative matters. The group, which included Division Staff Scientists, had the capability to deal with many technical problems concerning programs and the management of these programs.

- The Office of Assistant Chief Hydrologist for Administration and Technical Services assisted the Division Chief's Office in the establishment of policy on budgetary, accounting, personnel, program status, and technical service activities. This office provided administrative and technical services to operational offices in support of their individual programs and Division objectives. The Assistant Chief served as line officer for Division field operations. The following sections made up this Office:

  –The Manpower Section assisted in the planning, organizing, and administering of programs to carry out the Division's policy regarding recruiting, training, career development, and processing of promotions, transfers, and reassignments regarding professional and technical personnel.

  –The Administrative Section provided centralized services for the Division in budget and finance, personnel actions, property and procurement, records management, and other fields of administrative services.

  –The Fiscal Management Unit provided centralized document services for the Division, Regional, and Field Offices in budget, finance, planning, and allocation of funds.

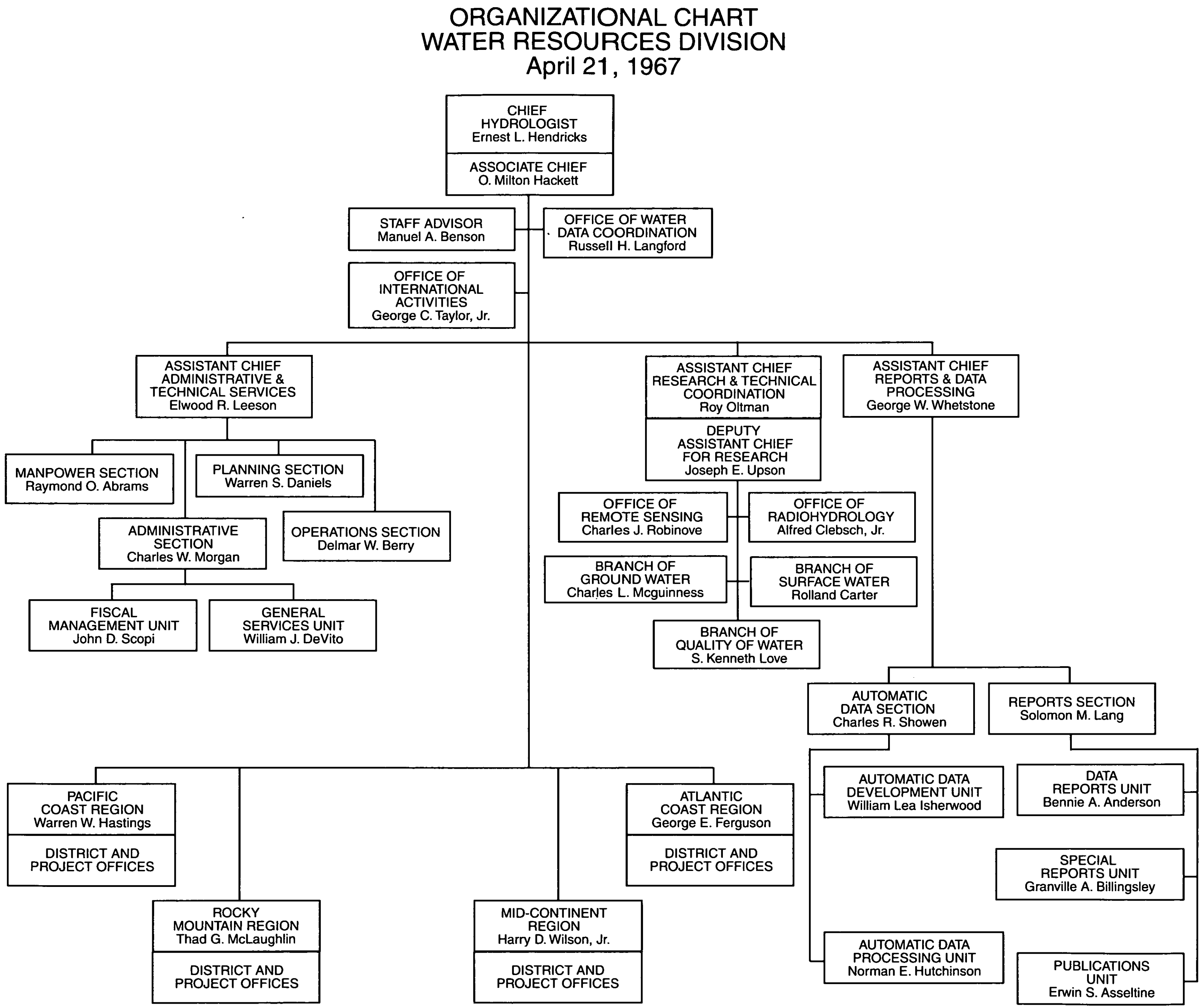

Figure 1. Organizational chart of the reorganized Water Resources Division, 1967.

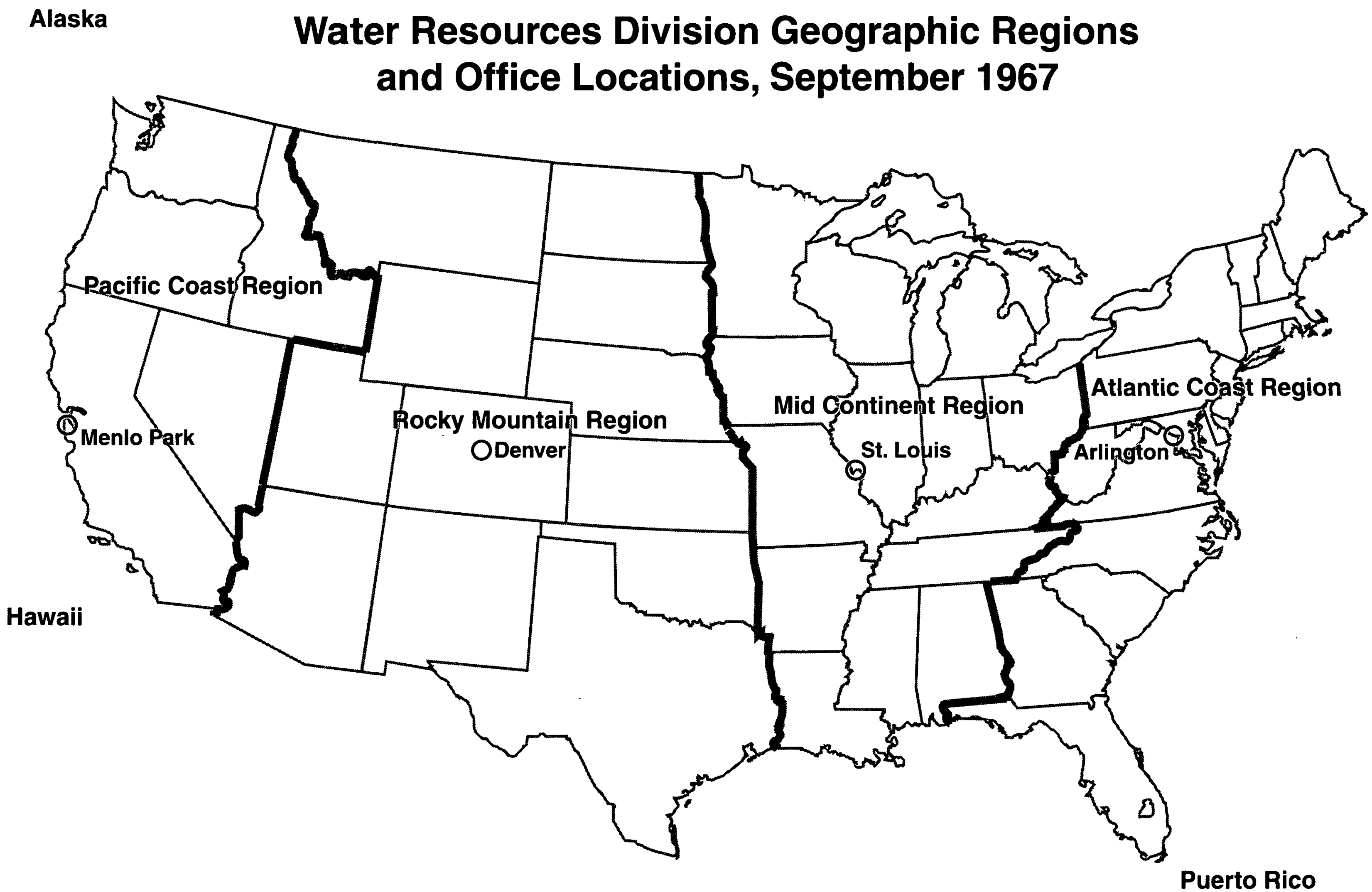

Figure 2. Water Resources Division Geographic Regions and Office Locations, September 1967.

–The General Services Unit provided centralized services for the Division, Regional, and Field Offices for personnel action processing and records, space utilization, property records, issuance of procurement documents, central files, storage and disposal of records, distribution of mail, and so forth.

–The Planning Section maintained records of program information, including project descriptions, program summaries, work plans, and project status reports; developed detailed program analyses and reports on program content and financing, cost reduction, and manpower conservation; prepared research project notices for transmittal to the Science Information Exchange; prepared annual budget justification materials; monitored Congressional legislative activities related to water; and maintained liaison with other Federal agencies for program planning.

–The Operations Section provided Regional, Field, and Project Offices with information, assistance, and guidance on operational matters related to program execution that required liaison or coordination with Washington Headquarters, other units in the Survey, and other Federal agencies. This included reviewing specifications and contracts for well drilling and field equipment; providing information and advice on safety matters; and reviewing operational programs to recommend measures to improve effectiveness.

- The Office of Assistant Chief Hydrologist for Reports and Data Processing assisted the Division Chief's Office and served as Division line officer in the development of programs relating to the production of reports; the processing of data; and the storage, retrieval, and dissemination of water information. The following organizations were part of this Office:

- The Office of Water Information provided water information on request to units of the Survey, the Department of the Interior, other Federal agencies, and the general public.

- The Automatic Data Section was the focal point for all automatic data processing (ADP) activities within the Division, including the development of practical applications of ADP techniques to the Division's activities and day-to-day operation of these activities.

–The Automatic Data Development Unit developed practical techniques and computer programs to carry out new ADP systems and necessary changes and improvements in present ADP systems and furnished consultant services on ADP methodology to other Division units.

–The Automatic Data Processing Unit provided ADP services, training, and consultation for all elements of the Division, maintained the Division's "Data Storage and Retrieval System," and provided technical guidance to field ADP centers.

- The Reports Section developed the reports to meet the objectives of the Division's overall program, including the development of policy and standards for preparation, review, processing, and publication of reports.

–The Data Reports Unit reviewed, processed, and prepared for publication basic (standardized) hydrologic data, including noninterpretive analyses and various summaries of data. This unit coordinated and scheduled annual surface-water supply, ground-water level, and water-quality reports; prepared basic-data reports such as water-level reports and statistics on monthly, seasonal, and annual pumpage; and prepared regional maps showing water in storage, ground-water quality, and physical characteristics of aquifer systems. The unit provided guidance to Field Units on the preparation of basic-data reports and processing of records.

–The Special Reports Unit prepared or coordinated the preparation of reports, such as the monthly Water Resources Review, Water Resources Bulletin, water-use circulars, annual bibliography of hydrology, annual series on selected techniques in water-resource investigations, information leaflets, reports on specific hydrologic events, and special series reports such as annual summaries of hydrologic events, flood frequency reports, flood-inundation maps, and so forth.

–The Publications Unit processed and maintained control over reports submitted for the Director's approval, advised WRD personnel on preparation standards for illustrations and reports, and recommended methods to increase the usefulness of reports and efficiency and speed of processing. The unit prepared and maintained Publication Guides and developed standards for preparation and printing of illustrations, including handling of base-map materials.

- The Office of Assistant Chief Hydrologist for Research and Technical Coordination assisted the Division Chief's Office in the development of national programs of research and water investigations and provided technical guidance to the Division's operating programs. This Assistant Chief was responsible for research in hydraulics, hydrology, instrumentation, and in the chemical and physical properties of water and served as Division line officer in the development of competence in all technical disciplines. The Deputy Assistant Chief for Research assessed the Division's program in light of needs for research in water-resource subjects, evaluated proposed research projects and programs, and recommended appropriate research efforts; assisted in devising methods for publicizing research findings and for assuring prompt availability of research products to field operations; and promoted seminars to effect proper exchange of information and dissemination of research findings. The following units were under this Assistant Chief:

  –The Office of Radiohydrology provided technical guidance and coordination of hydrologic investigations related to occurrence of natural and artificial radioactive materials in the environment; promoted hydrologic research; and provided specialized consulting service on hydrologic and geologic aspects of the use, development, and control of nuclear energy facilities for the Survey and other agencies.

  –The Office of Remote Sensing encouraged and promoted hydrologic applications of remote sensing methods, provided consultation on current and proposed projects with regard to the use of remote sensing methods, and provided liaison with the hydrologic community regarding remote sensing methods.

  –The Branch of Ground Water provided Headquarters leadership in development of ground-water technology, maintained a system of technical standards and quality control to assure the technical excellence of field programs and personnel with respect to ground water, translated research findings to field needs, conceived and developed techniques of application of the ground-water discipline, designed and sponsored special training in basic and sophisticated elements of ground-water hydrology and practice, and served as consultant to the Chief Hydrologist on matters pertaining to ground water.

  –The Branch of Quality of Water provided Headquarters leadership in the development of technology dealing with chemical, physical, and biological properties of water, with dissolved and suspended matter, and with interrelations of these water-quality properties and characteristics with hydrologic, geologic, geochemical, biological, and ecological environments; maintained a system of technical standards and quality control to assure technical excellence of programs and personnel regarding quality of water; translated research findings to field needs; designed and sponsored special training in basic and sophisticated elements of quality of water disciplines; and served as consultant to the Chief Hydrologist on matters pertaining to water quality.

  –The Branch of Surface Water provided Headquarters leadership in the development of surface-water technology, maintained a system of technical standards and quality control to ensure technical excellence of programs and personnel with respect to surface water, translated research findings to field needs, designed and sponsored special training in basic and sophisticated elements of the surface-water discipline, and served as consultant to the Chief Hydrologist on matters pertaining to the surface-water field.

INTEGRATING THE DISCIPLINES

The organizational structure implemented during 1964–66 has remained largely unchanged since that time. Much of the background of this reorganization is contained in the WRD histories, Volumes V and VI. An overview of the early efforts is presented in this section.

Task forces and staff committees in WRD worked to plan the reorganization and its implementation. The formal proposal to reorganize the Division was submitted in September 1964 to the Director of the Survey. Approval was received in December 1964. Many changes were to be made, but they would be implemented slowly. On December 21, 1964, an Interior press release by Secretary Morris Udall announced the reorganization plan for the Division and presented the rationale for it as follows:

> The immense growth of this country had strained the Nation's water resources to the point that a community or industry seeking new or enlarged sources of water must consider a number of sources and the quantity and quality of the water from each source. This change brought increasing inquiries to the Geological Survey's many field offices for answers to questions involving surface water, ground water, and water quality—engineering, geologic, and chemical information—all related to one another, and yet all traditionally separate. The reorganization of the Survey's Water Resources Division was designed to provide more effective and complete answers by blending previously fragmented individual skills of engineers, geologists, and chemists.

All Branch activities and offices at the District level were integrated into single Division-level Districts. This major change followed the pilot efforts that began in 1964 in Nevada, Tennessee, and Puerto Rico. On February 15, 1965, the title of "District Chief" was adopted for the person in charge of all WRD activities in each State, and the title of "Area Hydrologist" was selected for the former position of "Division Hydrologist."

On April 1, 1965, E.L. Hendricks, then Associate Chief Hydrologist, provided Division, Branch, and other key officials with an initial draft of the functional statement for the Branches. In July 1965, Hendricks and F.E. Clarke, then Chief, General Hydrology Branch, analyzed and recommended supervisory patterns of research and Area staff positions to assign the majority of research personnel to an Area Hydrologist. By January 1, 1966, 27 of the 47 Districts were consolidated into Division Districts under the leadership of the District Chiefs. The remaining Districts were integrated during 1966 and 1967.

Although the reorganization was in progress at Area and District levels, it was not until Hendricks became Chief Hydrologist in June 1966 that it was implemented at WRD Headquarters. Developing new organization structures, defining roles, and reassigning personnel were done in a careful, iterative process. There was extensive study of alternate proposals involving different opinions about the roles of the Branches and concern about maintenance of scientific, technical disciplines, competence, and oversight in an emerging and growing multidiscipline program context. Branch officers particularly were concerned about their ability to maintain technical leadership and quality control with no line authority over project management.

Harry D. Wilson, Area Hydrologist, played a major role in the process while detailed to Headquarters during 1965 and 1966. He served as a moderator, facilitator, and consultant to Division and Branch officers in the Headquarters organization and drafted a Headquarters reorganization plan. A three-pronged staff arrangement, each headed by an Assistant Chief Hydrologist, was proposed: one for reports and data processing, one for administration and technical services, and one for research and technical coordination. The research and technical coordination unit included the reconstituted Ground Water, Quality of Water, and Surface Water Branches. These proposals were presented in an internal report to Hendricks, the Acting Chief Hydrologist in May 1966.

Hendricks announced the WRD Headquarters organization changes by WRD Memorandum number 67.18 on August 16, 1966. The reorganization involved an apportionment of the line responsibilities of the Chief Hydrologist's office among three Assistant Chiefs and a change in designation of the geographic subdivisions from "Area" to Region." Area Hydrologists were to be addressed as Regional Hydrologists. The Assistant Chief Hydrologists had responsibility for administrating key units located in Washington but also served as line officers to the field by virtue of delegation from the Chief Hydrologist.

The status of Branches in Headquarters was changed from line to staff, and the operational responsibilities of each Branch in Headquarters were abolished and replaced by an operations unit serving the entire Division.

In WRD Memorandum 67.101, May 10, 1967, Hendricks promulgated further guidelines for the new structure. Section Chiefs and Unit Chiefs were given authority and responsibility for day-to-day decisions pertaining to their functions. Former operational responsibilities of the Branches now were Division functions. Technical Branches were to concentrate on strengthening competence in the organization in particular disciplines. Functions relating to research, formerly carried out in the General Hydrology Branch, were transferred to the Assistant Chief for Research and Technical Coordination.

The basic concept of the organization was single-line communication from the Chief Hydrologist, or delegated members of the staff, to the Regional Hydrologists. Under this concept, the Regional Hydrologists were responsible for the administration of all WRD offices and projects based in the Region. Responsibility for communication with the Regional Hydrologists was delegated to the Assistant Chief Hydrologists, according to the type of work involved. This single line communication between Headquarters and the Regions involved all elements of the Division's work—policy statements, directives, and work requests. Technical information exchange on any subject remained unrestricted among the individuals involved.

The purpose of this major reorganization was to further integrate the scientific disciplines in WRD and to ensure that the responsibility for performing the function was delegated to the lowest level possible. At the District level, there was one point of contact for WRD initiatives in the State. The structure was adapted to ensure an integrated approach to the scientific challenges facing the Division.

Reflections on the WRD Reorganization, Based on Interviews with WRD Leaders

Hendricks noted that in the former structure there were problems because of the competition between Branches for funding from State agencies in the Cooperative Program. This created tension; there was little, if any, coordination between WRD's Ground Water, Surface Water, and Quality of Water units. The State agencies had to work with three different organizations in WRD. Hendricks said this was "unbearable from a management point of view." However, the real impetus for the reorganization was emphasis on the environment. WRD leaders knew that environmental issues could not be addressed through a separate discipline approach in WRD. These issues required an integrated systems approach. Based on the organizational structure at the time, WRD was not prepared to deal with any of the upcoming questions on the environment. To meet the challenges, a different organizational structure was needed under one management in which an integrated approach could be used to address environmental issues.

G.W. Whetstone, Assistant Chief Hydrologist, SP&DM, said that in many States, there was a severe imbalance between the WRD Ground Water, Surface Water, and Quality of Water programs. Quality of Water programs particularly were limited in scope. The establishment of Water Resources Councils did not provide the coordination needed. He added that WRD was not prepared for environmental challenges unless it changed its structure in the field; even the Area Hydrologists did not have the authority to correct imbalances because they lacked line authority and could provide only advice and oversight.

Hendricks explained that the pilot programs in the Tennessee, Puerto Rico, and Utah Districts allowed staff throughout WRD to become accustomed to the idea and to see that the integrated structure was feasible. Whetstone added that many persons were scared of the change, and the pilot program allowed them time to adjust to it. The actual implementation occurred over several years while persons were selected throughout WRD as District Chiefs. Hendricks noted the difficulty in personnel selection and said that if there was an outstanding person already in a District, it was easy to elevate this individual to the Chief position. A problem arose when there were three persons in a State representing the three areas, and none of these persons had the skills considered essential for the job. Then, someone had to be sent in to the District. Such moves were very traumatic. Another problem, as F.T. Schaefer, Assistant Regional Hydrologist, Northeastern Region, explained, occurred when there were three outstanding persons at the Branch level in a District, and only one of them could be selected for the Chief position. Thad McLaughlin, Regional Hydrologist, Central Region, explained that there were many personnel and morale problems. Some persons were assigned to jobs for which they were not necessarily the best qualified. The reorganization led to rivalry among some District Chiefs. Some Branch Chiefs were transferred to Regional Offices if they were not selected as a District Chief. J.T. Callahan, Regional Hydrologist, Northeastern Region, noted the need to meet with staff members in the three Branches in the Districts to explain the concept, to assuage fears and concerns, and to minimize the friction among staff in the former Branches.

However, Hendricks said that he felt they got through the radical change well and were successful in the implementation process. McLaughlin stated that over time, new teams developed as a result of the reorganized structure. By the time of the 1970 District Chief conference, the reorganization was totally implemented. Ferguson noted that in other organizations, such a radical change has taken as long as a generation to implement, but in WRD, it was accomplished more smoothly because of the concept of teamwork which permeated the organization.

Biesecker stated that the reorganization represented the greatest institutional change ever for the Division. He saw this change as a "stroke of genius." He said that because the Branches competed for the same cooperators' dollars, there was a tendency to publicly criticize colleagues in the quest for additional funds. The competition among the Ground Water, Surface Water, and Quality of Water Branches was not a healthy one. He personally welcomed the reorganization as he had seen competition where there should have been collaboration and integration on hydrologic problems. He said that today in WRD, personnel do not even think in terms of separate disciplines.

Revisions to Regional Boundaries—1971

Throughout the Federal Government, there was an initiative to standardize regional boundaries across Government. During June 1971 to September 1972, WRD management decided to change the WRD regions to conform to the standard Federal boundaries and to reach consistency within the Survey. Cragwall was responsible for this effort in WRD. This decision led to several major changes. A new regional Headquarters was established in Atlanta, Ga., for the Southeastern Region; the St. Louis Regional Office was closed, and changes were made in the geographical jurisdiction of the other three regions: Northeastern, Central, and Western.

On July 20, 1972, new organizational boundaries for the Division were announced with an effective date of September 3, 1972. These were reflected in changes to the Department of the Interior Departmental Manual, Part 120, Geological Survey. Four regions were established: Northeastern, Southeastern, Central, and Western.

1. Northeastern Region, Arlington, Virginia: States of Connecticut, Delaware, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, Wisconsin, and the District of Columbia.
2. Southeastern Region, Atlanta, Georgia: States of Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, the Commonwealth of Puerto Rico, and the Virgin Islands.
3. Central Region, Denver, Colorado: States of Arkansas, Colorado, Iowa, Kansas, Louisiana, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming.
4. Western Region, Menlo Park, California: States of Alaska, Arizona, California, Hawaii, Idaho, Nevada, Oregon, and Washington, and Guam, Samoa, and other Pacific Islands.

In a Department of the Interior news release dated September 25, 1972, Hendricks announced that: "Our newly structured regions are part of the Department of the Interior's move to adopt a system of regional boundaries which coincide with the 10 administrative districts recently developed in President Nixon's Federal Assistance Review Program. The program is designed to make the Federal Government more responsive to the needs of State and local governments, and, as newly organized, each of our four regions will completely include several of those administrative districts and have common boundaries with them. Each of these new regions—Northeastern, Southeastern, Central, and Western—will have a Regional Hydrologist who will provide policy guidance and coordination over water resources activities within the area and provide liaison with all other Federal, State, and local agencies."

WRD ORGANIZATIONAL STRUCTURE—1971–79

Reporting to the Chief Hydrologist were three Assistant Chiefs responsible for Operations, Scientific Publications and Data Management, and Research and Technical Coordination. In 1971, the Reports and Data Processing Unit was renamed the Scientific Publications and Data Management Unit to emphasize the expanding role of computer processing of data. The Administrative and Technical Services Unit was renamed Operations, to more clearly define the diverse functions. Also reporting to the Chief Hydrologist was the Office of International Hydrology, Office of Water Data Coordination, and a Program Officer. The four Regional Offices remained as the Northeastern Region, Southeastern Region, Central Region, and Western Region. National Water Quality Laboratories were located in Atlanta and Denver. The Gulf Coast Hydroscience Center was located in Bay St. Louis, Miss., and the National Training Center was located in Denver. Numerous personnel changes had taken place during the period at every position. Figure 3 presents the organizational chart for WRD in 1979. Regional boundaries and offices in WRD are shown in figure 4.

HEADQUARTERS OPERATIONS

by Thomas J. Buchanan

Listed below are people who filled major positions in Operations during 1966–79.

Assistant Chief Hydrologist for Operations
- Elwood R. Leeson, 1966–67
- Joseph S. Cragwall, Jr. 1968–73
- Walter Hofmann, 1974–75
- Thomas J. Buchanan, 1976–79

Deputy Assistant Chief Hydrologist for Operations
- Bruce K. Gilbert, 1977–79

Manpower Section, Chief
- Raymond O. Abrams, 1966–79

Planning Section, Chief
- Warren S. Daniels, 1966–75
- George E. Williams, 1976–79

Operations Section, Chief
- Delmar W. Berry, 1967–70
- Mearle M. Miller, 1971–73
- David E. Click, 1974–77
- Alberto Condes de la Torre, 1978–79

Instrumentation Group, Chief
- Richard Paulson, 1978–79

From 1966 through 1970 this unit was called Administration and Technical Services. During this period the Assistant Chief Hydrologist for Operations had five major goals. They included enhancement and protection of the Federal-State Cooperative Program, the reorientation of the Federal Data Program, the reorganization of the Instrumentation Program, the implementation of the revised Career-Development Program nationwide, and improvement in administrative matters such as contracting, financial management, and management information systems.

The Federal-State Cooperative Program was under serious attack by budget analysts in the Department and Congressional staffers. There was a major communication gap in making the budget people understand the value of the Cooperative Program to the States. It was realized there was no documentation on the Cooperative Program except for the annual budget justifications. Tom Buchanan and Bruce Gilbert prepared a series of reports and journal articles documenting the history and successes of the Cooperative Program. Finally reports were available that the budget analysts could understand, and they began to see the nationwide value of the program. This resulted in successful efforts to obtain additional funding for the Cooperative Program to meet the shortfall of Federal matching funds—until then, State offerings far exceeded the availability of Federal matching funds.

The Federal Data Program did not have much appeal to the budget examiners, and for many years the program remained level. Inflation was eating into the program and Dave Click had to work with the Districts to identify the most critical data-collection activities that needed to be continued. The level funding resulted in the discontinuation of many important data-collection sites. Finally, in the 1970's, some budget increases took the pressure off this program and the diligent effort and communication associated with this activity paid off.

At the start of this period, the Instrumentation Program was spread between the Administrative Division and the Water Resources Division. The Administrative Division did all of the supply, warehousing, and shipping of instruments to the field. Within WRD, the office of Research and Technical Coordination conducted instrumentation research, and the remaining functions were performed by Operations. WRD made a big push to bring all instrumentation activities to WRD. A Memorandum of Agreement was signed with the Administrative Division that relocated the machine shop and shipping and receiving activities to WRD. Ted Moulder and Tom Buchanan agreed, with the concurrence of Joe Cragwall, that the entire Instrumentation activity should be housed in Operations. Tom and Bruce Gilbert set about to develop a major addition to one of the buildings WRD occupied at Bay St. Louis, Miss. The onsite contractor at Bay St. Louis engaged an architect and a final design was approved.

WATER RESOURCES DIVISION ORGANIZATIONAL CHART, 1979

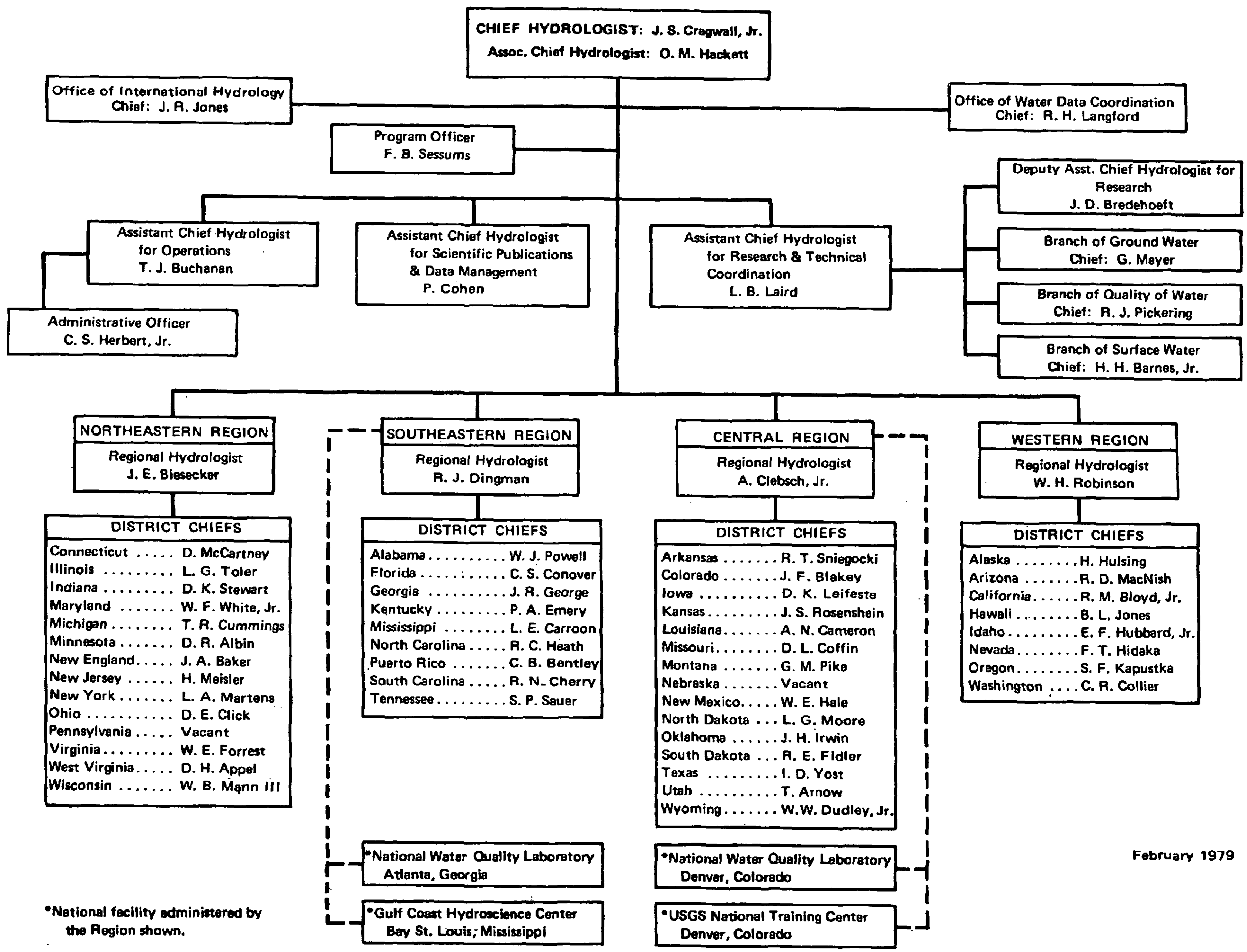

Figure 3. Water Resources Division Organizational Chart, 1979

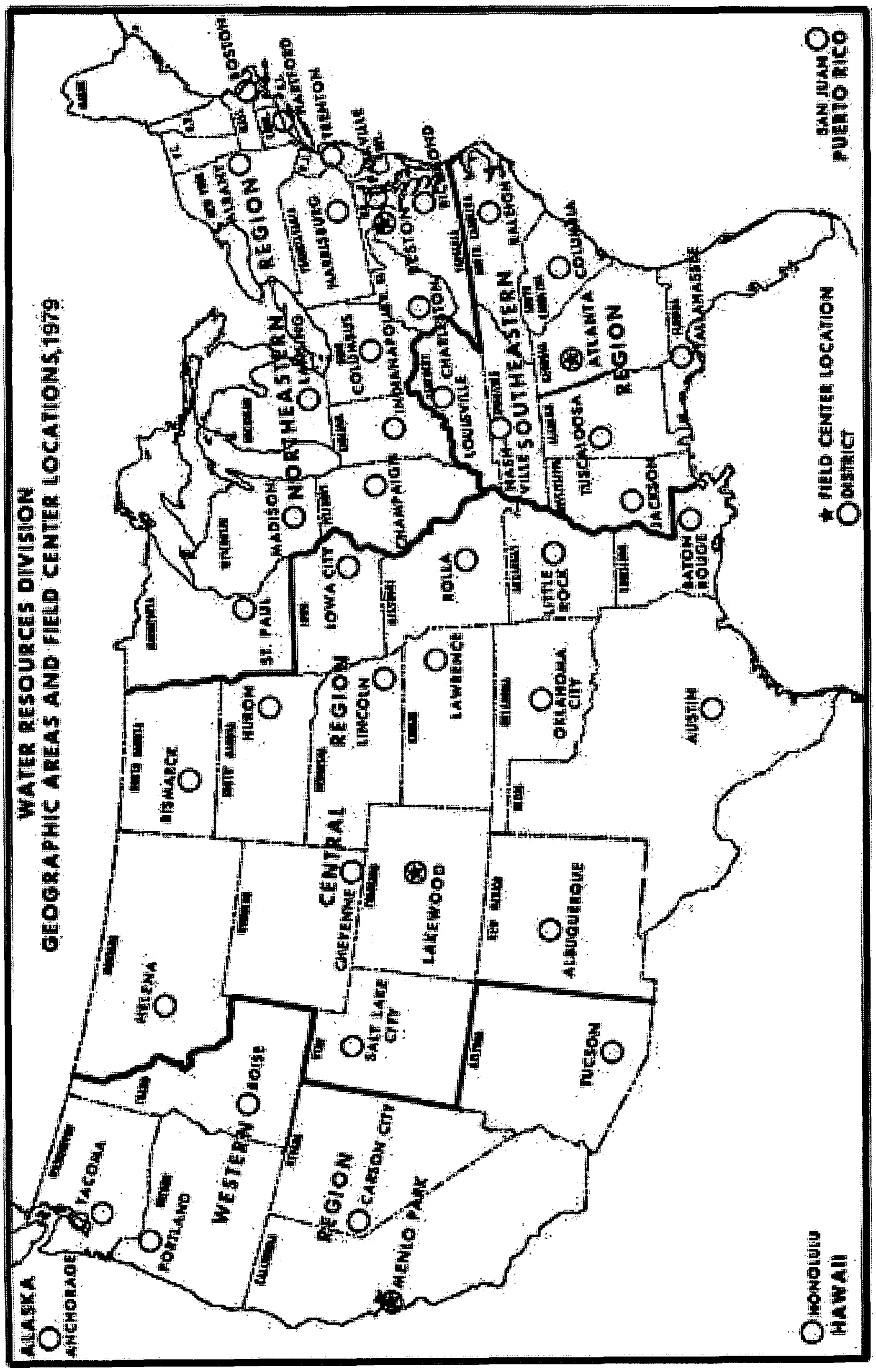

Figure 4. Regional boundaries and offices in WRD, 1979.

Construction of the addition was completed as this period of history ended, and the move of the instrumentation unit to Bay St. Louis was begun.

The career development forms were revised to provide more detailed information about each employee to provide the Division with more comprehensive human resources information. The new forms also provided each employee the opportunity in working with their supervisor to develop a training plan, which many employees did, and most of those followed through on the plan. Ray Abrams was given the responsibility to implement the updating and completion of a career development plan by all WRD employees. Ray followed through on this program, and within a year very complete information was available.

One of the major problems WRD was facing was the development of contracts. Most WRD field offices had very little experience with contracting, and the contracting officers were having a difficult time with WRD. Al Condes was brought to Headquarters as the WRD contracting specialist. He worked directly with WRD offices and the contracting officers in the Administrative Division and in short order had the contracting logjam broken. WRD offices also were having a difficult time obtaining real-time financial management data. A plan was developed to define what information was needed at local levels, and implementation of the plan during this period made it easier for WRD project managers to obtain meaningful financial management data.

Research and Technical Coordination, 1966–79

by Leslie B. Laird

Listed below are people who filled major positions in Research and Technical Coordination (R&TC) during 1966–79.

Assistant Chief Hydrologist—Research and Technical Coordination
- Roy Oltman, 1966–71
- Warren W. Hastings, 1971–73
- Edward A. Moulder, 1973–77
- Leslie B. Laird, 1978–79

Deputy Assistant Chief—Research and Technical Coordination
- Joseph E. Upson, II, 1966–73
- John D. Bredehoeft, 1974–79

Chief, Branch of Ground Water
- Joseph T. Callahan, 1966
- Charles Lee McGuinness, 1966–71
- Joseph T. Callahan, 1971–72
- Gerald Meyer, 1973–79

Chief, Branch of Quality of Water
- S. Kenneth Love, 1966–68
- Walton H. Durum, 1968–72
- Ranard J. Pickering, 1972–79

Chief, Branch of Surface Water
- Melvin R. Williams, 1966–68
- Rolland W. Carter, 1968–72
- Walter Hofmann, 1972–73
- Harry H. Barnes, Jr., 1973—79

Chief, Systems Analysis Group
- Nicholas C. Matalas, 1968–76
- Ivan C. James, 1976–79

Chief Office of Radiohydrology
- Alfred Clebsch, Jr., 1966–67
- Robert Schneider, 1968–71
- George DeBuchananne, 1971–79

The Systems Analysis Group originally reported directly to the Chief Hydrologist. This was changed in 1976 and the Group was placed under the Assistant Chief Hydrologist, Research and Technical Coordination.

Comments by Les Laird

When I assumed the position of Assistant Chief Hydrologist, Research and Technical Coordination in 1978, Joe Cragwall, Chief Hydrologist, asked me to address three things in particular: (1) Improve fiscal management of the National Research Program (NRP); (2) improve the working relationships between the Technical Branches and the Districts; and (3) improve the relationship between the Branches and the National Research Program. During 1978–79, the following were some of the actions instituted to move toward meeting Cragwall's requests.

A system of budget review for each research project was put in place. The Regional Research Hydrologist first reviewed the project budgets. Subsequently, the four Regional Research Hydrologists together with the Assistant Chief Hydrologist, R&TC, and the Deputy Assistant Chief Hydrologist for Research met and adjusted budgets (and personnel ceilings) to meet projected funding for the NRP as well as projected research goals. Year-end requests for support from Division "surplus" funds still were allowed, but this funding was not necessary to balance NRP funding as it had been in past years. The Regional Research Hydrologists were given more oversight responsibility for individual project spending. The Research Project Chiefs also responded to the budget reviews by doing better fiscal planning.

During this period, the Technical Branches were directed to review technical activities in each District on a 3-year rotation—that is, one-third of the Districts every year. District technical reviews had been carried out in previous years but at varying frequencies. Quality and Surface Water Branches scheduled them every 3 to 5 years and the Ground Water Branch from 3 years to never. The 3-year approach used personnel from the Branch and Regional Offices for reviews and occasionally from other District Offices. These reviews were not necessarily a "procedural audit" but were an opportunity to upgrade the technical quality of ongoing and proposed studies. Contacts with knowledgeable personnel in the NRP and other Districts often were recommended.

The NRP–Branch relationships were something of a "stickler." The Surface Water Branch had an excellent relationship with surface-water research personnel—with frequent contacts. The Ground Water Branch—NRP relationships were so-so, usually cordial but not too frequent outside of research personnel located in the Reston Headquarters building. But Quality of Water Branch people viewed their brethren in the NRP with "suspicion" and vice versa. Researchers thought the Branch too conservative and that it "should be pushing the cutting edge of water-quality technology," while the Branch thought some of the researchers were too quick to promote "untested" concepts and were suspicious of some of their methodology. Attempts to promote joint technical sessions and exchanges of viewpoints failed until the early 1980's when some small successes were achieved in improving this relationship.

The WRD's NRP continuously developed from 1966 to 1979. A number of people guided this growth, but one individual, John Bredehoeft, deserves a great deal of credit for enhancing the scope, depth, and quality of the program. He pushed for research projects in geochemistry, climatology, stream biology, limnology, and numerous other areas—far beyond what the Division had been addressing in water-resources investigations in its first 50 years. In 1960, Tom Nolan, Director of the USGS, stated that the WRD should not hire any biologists—we should not be working in that area. Bredehoeft pushed the Division and developed an NRP that received national and international recognition for its scope and quality.

Ground Water Branch

By Gerald Meyer

Branch functions—Though the Ground Water (GW) Branch continued as a significant technical component of the Water Resources Division functions during 1966–79, its line management responsibilities had declined progressively throughout the early and mid-1960's as one consequence of the major Division reorganization. Pages 60–80 of the preceding volume (Volume VI) of the WRD History series, covering the period of 1957–66, document the extensive GW Branch organization instituted in the post-World War II years to pursue the broad line mission of the Branch. The many Section and other operating units within the Branch structure in that era—research, operations, planning, personnel, and training; hydrologic, geophysics, and modeling laboratories; equipment center; foreign hydrology unit; reports review and publications—reflect the breadth of Branch operation just prior to the period covered in this volume.

The historical enabling line authority under which the Branch had pursued that broad suite of technical responsibilities, however, gave way to a Headquarters staff role for the Branch in the 1960's, coincident with similar organizational revisions of its two sister technical branches—Surface Water and Quality of Water. Principal purposes and functions of the Branch during 1966–79 (and continuing into succeeding decades as well) were to exercise National Headquarters leadership in the development of expertise in ground-water hydrology and its applications to investigations of the Water Resources Division. The GW Branch provided policy advisory guidance to the Chief Hydrologist at National Headquarters and technical information and consultation to Regional and District staffs throughout the Nation regarding subsurface-water resources, including investigation, assessment, development, regulation, geochemistry, and management aspects. Training oversight and quality control to assure technical excellence of personnel and products with respect to the ground-water discipline, firmly established fundamental responsibilities of the Ground Water Branch throughout its existence, remained so during the period of this volume and subsequently.

Branch Staff—Responsibility for most Division ground-water operations were reallocated to the Regional Headquarters Offices, with continuing exercise of technical oversight by the Branch. Thus, the GW staff was reduced accordingly to a comparatively moderate number of experienced geologists and supporting personnel sufficient to meet staff-level responsibilities.

Branch staffing ranged from a low of six members in 1966 to a maximum of 12 during several years of the middle to later years of the period.

Personnel—Branch of Ground Water, 1966–79
- Callahan, Joseph T. (–78, 1972–73)
- Meyer, Gerald (–)
- Kohout, Francis A. (1967–75)
- McGuinness, Charles Lee (1967–75)
- Ferris, John G. (1969–)
- Wood, Leonard A. (1969–)
- Rollo, James R. (1969–73)
- Winograd, Isaac J. (1972–75)
- Appel, Charles A. (1973–)
- Weeks, Edwin P. (1973–)
- Baker, Claud H., Jr. (1974–75)
- Maddock, Thomas, III (1976–77)
- Patten, Eugene P. (1976–)
- Bennett, Gordon D. (1977–)
- Sammel, Edward A. (1977–78)
- Konikow, Leonard F. (1979–)

The three Chiefs of the GW Branch during the 13-year period were all highly experienced ground-water hydrogeologists who graduated from Division field programs to the National Headquarters staff. Charles L. McGuinness was appointed to the position of GW Branch Chief in 1966. McGuinness served until 1972 when poor health dictated that he relinquish the post. Joseph T. Callahan was Branch Chief during 1972. Gerald Meyer followed as GW Branch Chief from 1973 through the remainder of the decade and into the next one.

Secret weapons of these Branch Chiefs were the able scientists on the staff who exerted strong influence on the quality and substance of Branch activities. They included, for various period of service, Gordon D. Bennett, John G. Ferris, Francis A. Kohout, Leonard F. Konikow, Thomas Maddock, III, Eugene P. Patten, Jr., Edward A. Sammel, Isaac J. Winograd, and Leonard A Wood. Leopold A. Heindl, though administratively attached to the Branch, was on special assignments, in particular, to the National Academy of Sciences, throughout much of his tenure with the Branch.

Historically, ground-water personnel throughout the Division were a close-knit community bound together by mutual compelling dedication to the ground-water discipline. That strong scientific alliance continued into and throughout the period of this volume, though perhaps diluted somewhat by the increased emphasis on interdisciplinary hydrology inherent in the reorganization. That nationwide scientific bond could be viewed as still another secret weapon of the Branch, Thus, fortunately, the wisdom and counsel of several hundred ground-water hydrologists throughout the Division organization continued to be readily accessible irrespective of geographic location or organization lines. The Branch relied especially on a cadre of outstanding scientists residing elsewhere in the organization. A short list of these "Branch mentors," with apologies to many others who surely warrant citation, includes Robert R. Bennett, John D. Bredehoeft, Russell H. Brown, Alfred Clebsch, Hilton H. Cooper, Edward Moulder, O.M. Hackett, Stanley W. Lohman, Joseph F. Polland, Robert W. Stallman, and Charles V. Theis.

Projects—Though without line authority, the Branch nevertheless was endowed with responsibility for design, staffing, technical oversight, and quality control of a number of major regional or research studies initiated at National Headquarters. Principal among these were:

Summary Appraisals of the Nation's Ground-Water Resources—In its final report (1973) the National Water Commission recommended that the Geological Survey investigate the principal aquifer systems of the Nation, giving priority to those threatened with declining water supplies and deteriorating water quality. The Division responded immediately with a proposal for a 5-year nationwide program of rapid appraisals designed by GW Branch staff personnel. Polling its District, Regional, and Headquarters resources, the Division completed a series of Professional Papers entitled "Summary Appraisals of the Nation's Ground Water Resources" covering 21 regions of the United States and addressing ground-water supplies, quality, and availability and the role of the resource in integrated water management and land-use planning. The program was completed in 1979.

Madison Limestone—Water needs and water-quality concerns associated with expanded coal production in the Northern Great Plains attracted attention to the principal untapped source of ground water in the region, the Madison Limestone. In support of the national energy program, an intensive study of the extensive Madison Limestone aquifer system was designed and initiated by Branch personnel.

Regional Aquifer-System Analysis (RASA)—In an April 1977 report appraising Federal water-resources projects, President Jimmy Carter recommended major policy reforms in the Nation's water conservation practices. Spurred by that report and drought conditions in much of the Nation, a program of regional aquifer-system analyses was started. Major aquifer systems of the United States were identified. A rigorous assimilation of understanding of the Nation's ground-water resources was presented in a usable format.

Lubbock Artificial Recharge Project—The Division initiated research in the High Plains region in 1968 in response to a request by the Bureau of Reclamation to determine the potential for recharge of imported surface water to the Ogallala aquifer, in order to arrest declining water levels. Under the leadership of Richmond F. Brown, the analysis of the amount of water that could be stored underground was explored. Similar studies were conducted on Long Island, N.Y.

Computer simulation—Volume VI of this series documents the origination of analog modeling. During this period, under the innovative leadership of John Bredehoeft and George Pincer, digital simulation of ground-water systems largely replaced analog modeling. This powerful analytical tool became widespread in many important Division projects.

Quality of Water Branch

by Ranard J. (Jack) Pickering

The period 1966–79 was one of many changes, both in the function of the Quality of Water Branch and in the concept of water itself. Expertise in the Branch staff expanded to include aquatic biologists and data-handling experts in addition to the chemists, geologists, and sediment transport experts already there. The changes presented challenges to the three men who served as Branch Chiefs during the period:

S. Kenneth (Ken) Love, a chemist by training, had field experience in the Colorado River Basin and in Idaho. He served the last 2 of his 22 years as Branch Chief from 1966 to 1968.

Walton H. (Walt) Durum, also a chemist by training but with research experience in the chemical manufacturing industry (including the Manhattan Project), obtained his field experience out of the Lincoln, Nebr., office. He served as Branch Chief from 1968 to 1972.

Ranard J. (Jack) Pickering was trained as a geochemist and worked in mineral exploration before joining the Water Resources Division. Field experience was obtained working on the Clinch River project and in the Columbus, Ohio, office. He served as Branch Chief from 1972 through the end of the period in 1979.

Besides its normal responsibility for the technical quality of the work done by WRD Field Offices, carried out through office reviews, consultation, and training, the Branch coordinated several major projects out of Headquarters. One of these projects was creation of the Central Laboratories System. Rachel Carson's publication of "Silent Spring" in the early 1960's had a profound and lasting effect on the public's expectation of what the environment should be like, including the hydrologic part of it. With the establishment of the Environmental Protection Agency in 1970, the concept of "water quality" was greatly expanded from major constituents affecting potability and agricultural use to include a host of minor constituents and physical properties that determined the biological health of the water. Control of analytical quality and acquisition of expensive new equipment required a large, multi-laboratory system coordinated through Headquarters. Such a system was set up by the Branch, working through the Regional Offices, over a period of several years beginning in 1970. Eventually, three large laboratories produced a daily average of 7,000 determinations that were transmitted by computer to the submitting offices and to data storage. Branch staff members involved in that effort included James Biesecker, Donald Leifeste, and Art Beetem.

The burst of new water-quality parameters, as well as implementation of WRD's WATSTORE data storage and retrieval system, required close coordination with other agencies. The Branch was responsible for making sure parameter identifiers, definitions, and reporting units were the same in WATSTORE and in USEPA's STORET data system. The Branch staff member most involved in that activity was James Schornick.

Coordination of several nationwide water-quality data networks was another Branch activity during this period. One of these was the National Stream Quality Accounting Network (NASQAN). The network was designed by the Office of Water Data Coordination to account for the quantity and quality of water as it flowed from one hydrologic accounting unit to the next, and eventually to the sea. NASQAN was implemented under Branch funding in steps during the period 1973 through 1979. The full network eventually included 525 streamflow and water-quality measurement sites. A series of reports was produced. Branch staff members participating in this activity included Timothy Steele, Rich Hawkinson, John Ficke, and John Briggs. The National Hydrologic Bench-Mark Network of stations in small, largely pristine basins was coordinated by the Branch also.

Another major program coordinated by the Branch was the River Quality Assessment Program. This demonstration program grew out of a recommendation by WRD's Advisory Committee on Water Data for Public Use and was designed to demonstrate the analytical approaches needed for developing water-quality information that would provide a sound basis for assessing river-quality problems and evaluating management alternatives. By the end of 1979, assessments had been made of the Willamette River in Oregon, the Yampa River Basin in Colorado and Wyoming, and the upper Chattahoochee River Basin in Georgia. Assessments were in progress on the Potomac River Estuary near Washington, D.C., the Truckee and Carson River Basins in Nevada and California, the Schuylkill River in Pennsylvania, and the Apalachicola River in Florida. The staff member most responsible for this activity was Philip Greeson.

Other professionals serving on the Branch staff during the period 1966–79 included Raymond Vice, John Musser, Marvin Yates, James Culbertson, Jerry Stoner, Donald Goolsby, and Robert Middelburg.

Surface Water Branch

by Don Thomas

Functions of the Surface Water Branch (SWB) as stated in the 1966 WRD Directory: Provides headquarters leadership in development of surface-water technology. Provides policy-level guidance to the Chief, WRD, and technical guidance to the Regional Hydrologists and District supervisors on matters pertaining to the Nation's water resources. Maintains a systematic system of quality control to assure technical excellence of field programs and personnel with respect to surface-water technology.

Significant additional work resulted from new legislation and a decision to review the status of the streamgaging network. At the beginning of the 1966–79 period, the SWB consisted of three units: the Office of the Branch Chief, the Hydraulics Section, and the Hydrologic Section. The SW Branch Chiefs during the period all had engineering degrees, began their USGS careers as streamgagers in field offices, and worked their way upward through the ranks: Melvin R. Williams from December 1962 to October 1967 Rolland W. Carter from December 1967 to May 1972 Walter Hofmann from May 1972 to November 1973 Harry H. Barnes, Jr., from November 1973 through 1979.

In addition to the Branch Chiefs, two other individuals exerted a considerable influence on the Branch staff. Manuel A. Benson was Carter's principal assistant until he retired in 1971. H.C. "Charlie" Riggs headed the Hydrologic Studies Section.

All SWB staff members participated in the quality control, technology transfer, and consulting activities noted in the statement of Branch functions, and this work probably consumed the majority of staff time. Significant additional work was required during 1966–79 including analysis of the streamflow-gaging program and flood activities. Quality-control activities included review of all Field Office-prepared analytical reports and reviews of Field Office activities. Technology transfer had always been a primary function of the Headquarters staff of SWB, and the growing utilization of computers in hydrology greatly increased the technology transfer aspect. Numerous reports were prepared and distributed in the Surface Water Technique (SWT) series, the Techniques of Water-Resources Investigations (TWRI) series. and other types of publications. By 1968, about 270,000 station years of streamflow records had been collected, a network of over 8,500 continuous record stations were in operation, and the number of stations was continuing to increase. Questions were raised about how many gaging stations were needed and how they should be funded. To address these questions, Rolland Carter and Manuel Benson proposed a network evaluation scheme. The scheme suggested that each gage should provide data for a specific purpose, that is, for general hydrologic evaluation, for water management, or for enforcement of legal and compact requirements. During 1970–75, each District performed a network review under guidelines proposed by Carter and Benson. Overall, the network analysis resulted in a reduction of 265 continuous-flow record stations and formed a firm basis for funding and planning future station operations.

House Document 465, detailing much work needed to be done in defining flood-prone areas, was adopted in 1966. The responsibility to quickly define nationwide the approximate areas of potential flooding was assigned to WRD. The intent of Congress was to obtain a nationwide "reconnaissance level" of information quickly by having a hydrologist assess readily available information and apply his field experience in map interpretation. By the end of 1979, 13,048 maps and 895 pamphlets had been printed and distributed. The flood-prone area maps were well received by individuals, private organizations, home financing establishments and Federal, State, and local agencies.

The SWB staff was involved in a significant number of low-flow and channel geometry studies during the 1966–79 period. Branch personnel developed seminars to urge regional regression analysis of all flood data to provide a flood-estimating technique for ungaged, small stream sites and to repeat analyses at about 5-year intervals.

Personnel serving in the SW Branch, in addition to those described above, are listed below:

James F. Bailey
Conrad D. Bue
Charles W. Boning
Daniel P. Bauer
P. Hadley Carrigan, Jr.
Patrick B. Cawood
Ernest D. Cobb
Ethel W. Coffay
Dannie L. Collins
Jacob Davidian
Harold G. Golden
Ronald L. Hanson
Clayton H. Hardison
William L. Isherwood
Marshall E. Jennings
Gerald J. Knecht (WAE)
Edward J. Kennedy
Frederick A. Kilpatrick
George A. Kirkpatrick
Oscar G. Lara
Raul S. McQuivey
Kyle D. Medina
Larry A. Martens
Marshall E. Moss
Alvin F. Pendleton
William A. Somers
Stanley P. Sauer
Vernon B. Sauer
Verne R. Schneider
Arthur G. Scott
James O. Shearman
Gary D. Tasker
Wilbert O. Thomas
Donald M. Thomas
Medford T. Thomson
James F. Wilson
Kenneth L. Wahl

Three personable ladies served as secretary to the Branch Chiefs. They were Benita V. Belden, Eva R. Jennings, and R. Eileen Smith. Additional secretarial/clerical support was provided by Carol S. Cummin, Toni L. Clark, Elizabeth P. Crawford (WAE), Barbara J. Guthrie (WAE), Maria Gac (WAE), Glenn Golden, Belle C. Jacomet, Pamela J. Phillips Adams, and June Rosson.

Additional support staff included Joan Barnes Hofmann, a statistical assistant, and the following WAE engineering aides: Robert N. Lunden, John Mirabella, John C. Meacham, Philip A. Somers, Wayne R. Slaughter, and Harold E. Stull.

Systems Analysis Group

In the mid-1960's, Walter B. Langbein was instrumental in the formation of the Systems Analysis Group. Walter, at the time, was a senior scientist in WRD, editor of Water Resources Research, and a close advisor to the Chief Hydrologist. Walter saw that WRD had few capabilities in the tools of systems analysis and believed that such capabilities were essential in defining future programs. In 1966, Langbein convinced the WRD senior staff that a systems analysis group should be established in the Division. In 1968, Nick Matalas was selected as the first Chief, Systems Analysis Group. Other personnel in the group were David Moody, Ivan James, Ed Close, Carl Huzzen, Russ Cruff, and Timothy D. Steele.

Early projects of the group were very successful, and as a result, they were asked to participate in a number of important interdisciplinary projects. These included the Outer Continental Shelf Lease Management Study, a study of the Mine and Health Safety Act, the Puerto Rico water-resources planning study, water use in energy production, and others.

Scientific Publications and Data Management

by Melvin D. Edwards and James E. Biesecker

Listed below are people who filled major positions in Scientific Publications and Data Management SP&DM during 1966—79.

Assistant Chief Hydrologist for Scientific Publications and Data Management—
- George W. Whetstone, 1966–78
- Philip Cohen, 1979

Automatic Data Section—
- Charles R. Showen, 1966–79

Automatic Data Processing Unit—
- Norman E. Hutchinson, 1967–74
- Robert B. Wall, 1975–79

Reports Section—
- Solomon M. Lang, 1967–70
- Granville A. Billingsley, 1971–79

Current Conditions Group—
- George Edelen, 1971–72
- Herman D. Brice, 1973–75
- Carrol Saboe, 1976–79

National Water Data Exchange (NAWDEX)
- Melvin D. Edwards, 1978–79

This Assistant Chief Hydrologist position was designated Reports and Data Processing from 1966 to 1970. In 1971, recognizing the rapid and continuing advancement in computer technology and the importance of scientific publications in maintaining a leadership position in hydrology, the Assistant Chief Hydrologist for Scientific Publications and Data Management unit was established. This group significantly impacted the very essence of the Water Resources Division—they developed and managed software and systems to process and store the hydrologic data that are the key to WRD success. SP&DM also reviewed and processed reports that are the main product of WRD personnel.

During this period, the Automatic Data Section began the modernization and improvement of the WRD's computer processing and software systems. District personnel sent digital tapes containing gage heights and water-quality measurements to the Automatic Data Processing Unit, where the tapes were processed and stored. Pages for the Annual Data Reports were also printed under the direction of this unit—a large and important task. Their development of improved techniques for the mass storage of data on magnetic tapes and disks was an important first step in the modernization of these systems. This system proved very successful, as it allowed stewardship of the vast hydrologic data of the Division, which are indeed a national treasure. The Automatic Data Development Unit developed the software systems necessary to process, analyze, and report the Division's hydrologic data. They also designed and implemented the conversion programs and data-base management systems critical for the efficient storage and retrieval of the large volumes of current and historical data. These achievements eliminated the bulky and inefficient storage of data on punch cards and paper tapes and assisted Division scientists in making more effective use of its extensive data resources.

The Reports Section was responsible for the review and approval of all interpretive reports. They also supervised the printing of the Federal reports series. This section worked closely with Regional Reports Specialists to help ensure the quality of WRD publications. It also developed an automated process to keep track of the status of the hundreds of reports being processed at any given time. A significant achievement during this period was the preparation of a Publications Guide to assist authors of WRD reports in presenting their material in a useful format.

Recognizing the increasing demand for current hydrologic information, George Whetstone, with the encouragement and support of Joseph S. Cragwall, established the Current Conditions Group in 1971. Real-time data were very rare at the time, but these data were widely distributed by this group; in addition, summaries of drought and flood conditions also were prepared. The reports of this group were helpful to WRD key personnel on many occasions.

In 1976, the (Federal) Interagency Advisory Committee on Water Data and the (non-Federal) Advisory Committee on Water Data for Public Use of the WRD's Office of Water Data Coordination (OWDC) approved the design of a National Water Data Exchange (NAWDEX) to improve the sharing of hydrologic data. SP&DM was chartered to develop the exchange. Solomon M. Lang developed the specifications for the new program. Melvin D. Edwards implemented the program and developed a national organization of partners dedicated to indexing and sharing hydrologic data collected by various Federal, State, and private organizations. The program eventually had participants in every State. This was a remarkable achievement and an activity that was well ahead if its time. NAWDEX successfully addressed the sensitive issue of sharing data in a time when this was not the normal method of operation among agencies.

Office of Water Data Coordination

by O.M. Hackett, R. Hal Langford, and Ginger Levin

On August 28, 1964, the Bureau of the Budget (BOB) (now the Office of Management and Budget) issued Circular A–67 to coordinate certain water-data acquisition activities of Federal agencies. Included were such activities as processing, storing, and disseminating water data, as well as collecting quantitative and qualitative data on the Nation's streams, lakes, reservoirs, estuaries, and ground water. The circular included six principal charges:

1. To exercise leadership in achieving effective coordination of water-data acquisition activities.
2. To undertake continuing and systematic review of water-data requirements and activities.
3. To prepare and maintain a Federal plan for the efficient utilization of these activities.
4. To maintain a central catalog of information on water data and on Federal activities being planned and conducted to acquire water data.
5. To design and operate a national network for acquiring data on the quality and quantity of surface and ground water, including the sediment load of streams.
6. To organize the national network data and the catalog of information to facilitate maximum use.

Responsibility for implementing Circular A–67 was assigned to the Department of the Interior (DOI), which in turn delegated the task of implementation to the Geological Survey. For this purpose, the Office of Water Data Coordination (OWDC) was created in the Water Resources Division.

The OWDC was activated in January 1965, with Milton Hackett, formerly Chief of the Ground Water Branch, as its first Chief. George Whetstone, formerly Ohio District Chief, was Assistant Chief, and Helen Moore, from the Ground Water Branch, was secretary.

The first task of OWDC was staff work to establish a non-Federal advisory committee—its formal name, "The Advisory Committee on Water Data for Public Use." This Advisory Committee consisted of representatives invited from the principal national, regional, and State organizations concerned with water resources, with representation balanced geographically and by hydrologic disciplines. Early on, OWDC also established the Federal Advisory Committee on Water Data, consisting of the Federal agencies concerned with water data.

First efforts of the OWDC staff were directed toward creation of a catalog of information on water data and data-acquisition activities. In a companion effort, work was begun on developing maps dividing the country into hydrologic units. This effort would provide a base for the Catalog of Information and served as an aid for coordination and network planning.

Continuing also was the coordination activity carried out by the Federal Advisory Committee and the non-Federal Advisory Committee on Water Data for Public Use. The annual meeting of these committees served as forums to describe and discuss data needs and activities of the agencies represented and to give them the opportunity to respond to plans of the Geological Survey.

In 1968, the DOI directed the USGS to assess its efforts for coordination within the Department and to develop a plan for a DOI water-data system. Later in the year, the Federal Water Pollution Control Administration (FWPCA, then in DOI) signed an agreement dividing responsibilities for Federal water-quality monitoring and related activities between FWPCA and USGS. The agreement also provided a philosophical basis for future coordination.

During the subsequent 10 years (1969–79), the coordination activity, under the leadership of OWDC, progressed in several broad areas:

- Further development of the Catalog of Information on Water Data.

- Designation of a commonly agreed upon set of river-basin boundaries and numerical coding of basins.

- Production of a set of State base maps at a scale of 1:500,000 depicting the basins designated.

- Development of a field-coordination program utilizing the Catalog of Information and the coded river-basin maps as a basis for communicating ongoing and planned data-acquisition activities of all Federal agencies.

- Design of the National Water Data Exchange (NAWDEX) to improve access to existing water data.

- Further refinement of the National Water Data Network concepts and subsequent activation of programs by the Water Resources Division to meet identified needs for water-resources information (for example, the National Stream Quality Accounting Network [NASQAN], the National Water-Use Data Program, the National Water Data Exchange, and the River Quality Assessment program).

- Development of a program to designate standard methodologies for collecting water data and publication of a National Handbook of Recommended Methods for water-data acquisition.

In each of these activities, OWDC utilized the Federal and non-Federal Advisory Committees in a variety of ways including:

1. Serving as a sounding board for proposed activities;
2. Serving, through working groups, as a means of identifying needs and recommending programs to meet those needs; and
3. Serving as a mechanism for review and endorsement of results of coordination activities.

Development of a Catalog of Information on Water Data was a logical first step in carrying out the implementation of Circular A–67. First, it was specifically called for by the circular. Knowledge of ongoing and planned data-acquisition activities of the agencies was essential if those activities were to be coordinated and if a national network (called for by the circular) was to be designed. The catalog was to serve as a file of information about water-data activities; it was not a compilation of the collected water data. It presented for the first time a nationwide compilation of water data—where data were being acquired, and by whom. The catalog was used in coordinating ongoing and planned water-data activities, in answering requests for information on water data and current data-acquisition activities, and in designing a national water-data network.

In late 1966, OWDC was able to compile information provided by about 30 Federal agencies including WRD and FWPCA. Approximately 6,000 long-term water-quality stations and 21,000 surface-water stations were reported. In 1967, the catalog was expanded to include non-Federal agency data and information on ground-water data sites. That catalog reported 24,000 surface-water stations and 13,000 water-quality stations.

The advisory committees were instrumental in the success of the Catalog and assisted over time in expansion of areas covered by the Catalog. By 1979, the Catalog contained information about data collected at more than 50,000 locations. The information was supplied by more than 200 Federal, State, and local agencies and universities in the United States. In addition, the Canada Department of Fisheries and the Environment provided information for station activities along the international boundary.

National Water Data Network

The design concept developed for the National Water Data Network included not only data acquired through station-type activities but also data obtained through areal investigations and synoptic studies of water systems. The network design encompassed three levels of information. Level I was a base level of information for broad national and regional planning and assessment. It allowed for the development of unanticipated needs and provided a foundation for more detailed and precise activities. Level II included data for water-resources planning needs within a subregion. Three interrelated elements carried through Levels I and II—accounting, surveillance, and areal synthesis. Level III consisted of data for water-resources operation and management at the local level.

To meet the objective for accounting at Level I, the United States was divided into about 350 hydrologic units designated as accounting units. The main focus of the design effort was on two of the Level I objectives—streamflow and stream quality accounting. These objectives were met by WRD's National Stream Quality Accounting Network (NASQAN), which provided data for regional and nationwide overview of the quality of major surface waters. This information was used to account for the quantity and quality of water moving within and from the United States, to detect changes in stream quality with time, and to develop large-scale knowledge about streamflow quality throughout the United States.

Implementation of the National Water Data Network by WRD began in January 1973 with the initiation of uniform data-collection activities at stations established near the downstream end of 50 of the accounting units. By September 1977, funding for the network permitted expansion of the number of active stations to at least one in each unit of the Level I Accounting Network. Full implementation of about 525 stations, constituting the entire streamflow and stream-quality phases of the Level I Accounting Network, was completed during FY 1978.

State Hydrological Unit Maps

The maps used by OWDC in the development of the Catalog of Information were inadequate for coordination because of scale (1:1,000,000) and inaccuracies. The need for a better set of uniform maps at a larger scale and with improved accuracy was recognized. Accordingly, OWDC initiated in 1972 a project to develop such a map series using the existing USGS State base maps at a scale of 1:500,000. The result of this nationally coordinated effort, involving the non-Federal water agencies as well as Federal agencies in the review process, was a series of 47 four-color maps designated "State Hydrological Unit Maps," which presented information on political boundaries, towns, drainage, culture, and hydrological boundaries.

Development of Regional and Federal Plans

Another OWDC responsibility was the development of the regional and Federal plans for water-data acquisition by Federal agencies. Beginning in 1971, Federal agencies were requested to describe their ongoing data activities and their plans to acquire water data through the budget year. The agencies also were asked to describe any unmet data needs.

To carry out the actual task of coordinating agency activities and developing an annual Federal plan, OWDC established a continuing field coordination and planning program which was organized on the basis of the 21 major water-resources regions of the United States Water Resources Council. To direct this activity for OWDC, a position was staffed in each of the Water Resources Division's four Regional Offices. This staff member served as the OWDC field representative and as the Division's Regional Program Officer, with responsibility for developing plans for data acquisition and USGS programs that are responsive to anticipated needs for data.

Thirty Federal agencies and regional river-basin commissions named about 130 field-level officials to work with the OWDC Regional Representatives in developing regional plans for each of the 21 regions each year. This field-coordination and planning activity provided the basis for the Federal plan. These reports set forth the ongoing and planned activities and the unmet needs of participating Federal agencies for the coming year.

Recommended Methods

In 1970, OWDC organized an interagency activity to develop recommended methods for collecting water data. In 1972, OWDC published a preliminary report titled "Recommended Methods for Water Data Acquisition." Also in 1972, the Federal Advisory Committee on Water Data recommended that:

1. The recommended methods activity be continued;
2. The scope be expanded to include all phases of the hydrological cycle; and
3. New and updated methods be widely distributed.

In response to these recommendations, a Coordinating Council for Water Data Acquisition Methods, consisting of representatives from 18 Federal agencies, and a Working Group on Recommended Methods, consisting of 10 representatives from the non-Federal Advisory Committee, were established to provide guidance in developing a National Handbook. The coordinating Council, chaired by Ivan Johnson of OWDC, subsequently established 10 technical working groups, consisting of about 180 scientists representing 25 Federal agencies, to prepare the handbook's chapters on recommended methods for acquiring data. The handbook chapters were reviewed by Work Group members and more than 120 non-Federal specialists. To keep the standard-setting organizations informed, communications were maintained with the American National Standards Institute, the American Water Works Association, the American Society for Civil Engineers, the American Society for Testing and Materials, the American Society of Mechanical Engineers, the Water Pollution Control Federation, and other technical societies.

In FY 1978, the "National Handbook of Recommended Methods for Water Data Acquisition" was published. The handbook included field, laboratory, and office methods to acquire data related to the quantity and quality of water in streams, lakes, reservoirs, estuaries, underground, and the atmosphere. Methods also were in the handbook on acquiring data related to fluvial sediment, soil, water, and drainage-basin characteristics.

National Water Data Exchange (NAWDEX)

In 1968, the OWDC presented a proposal for a national system for handling water data. This proposal prescribed guidelines for the coordination of Federal activities in the acquisition of water data. Under the auspices of OWDC, a task group of the Federal Interagency Advisory Committee on Water Data was established in March 1968 to develop the recommendations for a national system. In October 1960, the prerequisites and design characteristics for the National Water Data Exchange (NAWDEX) were endorsed by both the Federal and the non-Federal Advisory Committees. The final report of the Federal Interagency Water Data Handling Work Group, "Design Characteristics for a National System to Store, Retrieve, and Disseminate Water Data," was distributed in September 1971.

NAWDEX was implemented in 1975 with the opening of two major computer files: (1) WATSTORE, an index to sites with stored data, and (2) a Daily Values file, containing water data reported on a daily basis. WRD also established a national network of local assistance centers for public access to NAWDEX. All water-oriented organizations who were users of the data files were invited to become members of NAWDEX. As of September 30, 1978, there were 22 Federal and 98 non-Federal members of NAWDEX. Member organizations of NAWDEX varied in size, function, mission, and program orientation.

The Director of the Survey commissioned the establishment of a NAWDEX Program office in May 1975, under the Assistant Chief Hydrologist for Scientific Publications and Data Management. On January 26, 1976, Melvin D. Edwards was selected as the Program Manager for NAWDEX.

By 1979, WATSTORE contained approximately 70 percent of the streamflow and water-stage data and 35 percent of the ground-water and surface-water quality data. More than 150 million streamflow, water-quality, and ground-water measurements were collected at more than 100,000 sites across the United States and were available in WATSTORE.

River Quality Assessments

In January 1973, the Advisory Committee on Water Data for Public Use requested that the Survey initiate a river-quality assessment program. The Advisory Committee felt the Nation needed to understand how to study river quality—for example, how to study an estuary. The program was designed to evaluate the accuracy of existing water-quality data and the validity of data programs, to determine future water-quality data needs and to develop appropriate methodologies to meet these needs.

National Water-Use Data System

The Federal and non-Federal Advisory Committees also recommended that the Survey establish a national water-use data system to ascertain on a continuing basis the degree of use and the status of development of the Nation's water resources. Data collection, storage, and retrieval were handled by State and local agencies, and the program was financed through cooperative funding.

During the period 1965–79, the following senior hydrologists served in management positions within OWDC:

Chief - OWDC

O. Milton Hackett 1965–68
Russell H. Langford 1968–79

Assistant Chief

George W. Whetstone 1966–67
Russell H. Langford 1967–68

G. Lawrence Bodhaine 1968–70
A. Ivan Johnson 1971–79
Chief, Information Unit
William W. Doyle 1968–69
Herbert G. Stewart, Jr. 1969–70
Rufus H. Musgrove 1970–73
John E. Wagar 1974
Chief, Program Coordination and Information Unit
John E. Wagar 1975–79
Chief, Program Analysis Unit
Herbert G. Stewart, Jr., 1970–72
Louis W. Cable 1972–75
Chief, Network Planning and Evaluation Unit
Alvin F. Pendleton, Jr. 1968–72
Paul R. Seaber 1972–76
F. Paul Kapinos 1976–79

THE FIELD

The Changing Role of the Regional Offices

by Alfred Clebsch[1]

In a contribution to the WRD history elsewhere in this volume, Thad G. McLaughlin[2] wrote, "The Water Resources Division has continuously undergone change—in organization, in objectives, in programs, and in staff,—but no changes in my memory approach the magnitude of those made during the period of this history." Although these major changes permeated the entire Division, and the most drastic changes in management structure took place at the District level, the Regional Offices were focal points for effecting the changes in field-level management, program planning and development, recruiting, training, and personnel management. Many of these changes were initiated during the Leopold years (1957–66), but they were augmented under the leadership of Hendricks and Cragwall as Chief Hydrologists; other changes were initiated and implemented under that leadership.

Redefinition of the role and responsibilities of the Branches from operational and line authority to staff support and assurance of technical quality (see WRD Memorandum 67.28,[3] which conveyed an Advance Draft of Departmental Manual Chapter 120.7.1), strengthened the line authority of Regional Hydrologists over District-level operations and research program management, which had been put into effect in December 1964 (see WRD Memorandum 65.41). This meant that Branch Area Chiefs (BAC) in each Regional Office were relegated to staff positions with advisory and support functions when their line authority was removed and redelegated to the Regional Hydrologists. In some cases, these changes led to reassignments and changes in staff position, and in other cases, the changes led to retirements by Regional officials, some of them brought about by the major and sometimes traumatic reorganization. Filling the vacancies resulted in major changes in the Regional Office management structure, such as the reassignment of E.A. Moulder, who had been BAC, Ground Water (GW) Branch, to Program Officer in the Western (then Pacific Coast) Region and subsequently to District Chief of the consolidated Colorado District, and McLaughlin's replacement of S.K. Jackson as Regional Hydrologist, Central (then Rocky Mountain) Region. Other BAC's became Assistant Regional Hydrologists (for example, T.B. Dover in Denver, formerly BAC, QA, Central Region, and R. Stanley Lord, formerly BAC, SW, WR, in Menlo Park).

The changes involving the BAC's, General Hydrology (GH) Branch, were somewhat less disruptive than those for the three operational Branches because the Regional Research Hydrologist position, which succeeded the BAC, GH, merely became the immediate supervisor of the research activities at that Regional center or elsewhere in the Region. But giving the Regional Hydrologist line authority over the research activities may have made it somewhat more difficult to conduct a "national research program." One Regional Hydrologist is reported to have referred to "my researchers" with the implication that they should not do work outside the Region. The morale of some of the researchers was adversely affected, at least temporarily, when for budgetary and manage-

[1]Review of this contribution by James F. Blakey and Hugh H. Hudson is gratefully acknowledged.

[2]Regional Hydrologist, Rocky Mountain Region and Central Region, February 1967–June 1972, and Assistant Director, Central Region, June 1972–December 1975.

[3]Water Resources Division memorandums are issued serially on a fiscal year basis and are used to promulgate policy on such topics as Organization and Management, Programs and Plans, Personnel, and others. Where cited, they have been the source of information, especially on effective dates, for this contribution. The number to the left of the decimal point indicates the fiscal year, the other number indicates the sequence of issuance.

ment reasons the group at Colorado State University was broken up and part of it reassigned to Denver and part to Bay St. Louis in Mississippi.

As the reassignment or retirement of Branch Area Chiefs played out, "discipline specialists" were selected for the staff positions, with more weight in the selection process being given to scientific and technical competence than to management skills. In the Western Region under W.W. Hastings, the Regional staff functions were structured as an analog to the Headquarters staff, and the discipline specialists were encouraged to develop close working relations with their counterparts in the Headquarters Branches. Other Regions followed somewhat the same pattern but not as strictly as Hastings had defined it.

Regional Hydrologists, as line officers of the Division, also were members of the Senior Staff, which consisted also of the Associate Chief and Assistant Division Chiefs, chaired by the Chief Hydrologist. This group met quarterly as a committee to set policy, to resolve problems common to the Regions, and to ensure that the work of the Division was carried out expeditiously.

Responsibilities for Reports

The role of the Regions in reports processing and review was formalized in WRD Memorandum 67.92, which "instituted a plan wherein the Regional Hydrologists will serve as the major focal point for receipt, logging, first-order policy review, and transmittal of all reports originating in the field, including reports from non-District projects (research, and so forth)".

In addition to the "discipline specialists," each Regional Office was staffed with a "Reports Specialist" who primarily had responsibility for carrying out this mandate, which also included ensuring the adequacy of colleague review (WRD Memorandum 68.43). Although the incumbents to these positions were selected on the basis of their experience and understanding of report preparation, editorial policies and practices, and so forth, they worked closely with other staff members and referred reports with technical problems to the discipline specialists for their resolution. This process triggered a feedback mechanism that could, in many cases, lead to better planning of projects and reports in the future.

Water Data Coordination

Regional Offices of WRD also were influenced, and to some extent modified, when BOB (later OMB) Circular A–67 delegated responsibility for Federal water-data coordination to the WRD's Office of Water Data Coordination (OWDC). New positions were established in each Region with specific responsibilities for data coordination within the Region and somewhat vague responsibility for overall program coordination. But each Region already had a Program Officer who was, on behalf of the Regional Hydrologist, taking the lead on program management and especially allocation of funds. Furthermore, the language that established the regional OWDC positions, and indeed the language of Circular A–67, implied that OWDC was somewhat independent of WRD management structure; this led, in some situations, to conflict within Regional Offices.

Events external to the reorganization and management of the Water Resources Division brought on further change in the role of the Regional Offices. In 1972, the Nixon administration formalized and standardized boundaries of Federal-agency regions; this brought about changes in WRD Regional boundaries, changes in the names of the Regions, and creation of one new Region (Southeastern) and abolishment of one (Mid-Continent). To bring WRD Regional boundaries into line with the standard Federal regional boundaries, Arizona became part of the Western Region, and Iowa, Missouri, Arkansas, and Louisiana (from the former Mid-Continent Region) were incorporated into the Central Region, whereas Minnesota, Wisconsin, Illinois, Indiana, and Ohio joined the Northeastern Region, and those south of the Ohio River, east of the Mississippi River and south of the Virginia-North Carolina line became the Southeastern Region (WRD Memorandum 72.139).

These changes had the following results: The Central Region became the largest one in terms of program dollars and total personnel, and the Southeastern Region, with headquarters established in Atlanta, initially had virtually no research component. The Western Region covered, as it had before, the largest geographical area, extending across the Pacific from Alaska in the north to American Samoa in the south and Guam in the west.

Other Program Coordination from Regional Offices

The "energy crisis" of the early 1970's resulted in increased funding for USGS resource programs related both to fossil fuels and geothermal resources. Although the resources appraisal aspects of these programs were assigned to the Geologic Division, it was recognized early on that water was either an essential ingredient, as in geothermal energy, or that development of the resource either required water or could lead to serious water problems.

In the case of geothermal investigations, the resource lies primarily in the Western United States, and the Geologic Division assigned program coordination and planning responsibility to Patrick Muffler in the Menlo Park Center. Accordingly, and to facilitate interdivisional communication, the Water Resources Division assigned responsibility for its program planning and coordination function to Alfred Clebsch, then staff hydrologist for ground water on the staff of the Regional Hydrologist, Western Region (WRD Memorandum 73.29).The WRD involvement in geothermal studies included both field investigations conducted under District management (primarily in the west) and research studies carried out under several different Regional Research Hydrologists. The latter ranged from theoretical modeling by research personnel in the Northeastern Region to appraisal of off-shore geothermal fluids beneath the Gulf of Mexico at the Bay St. Louis, Miss., facility. This assignment of nationwide coordination and planning responsibilities to a Regional staff member marked a major move of program coordination responsibilities to Regional Centers. Clebsch was succeeded in 1973 by Lee C. Dutcher (WRD Memorandum 74.147).

In 1975, the Division received a major increase in funding for investigation of water problems related to the development of fossil fuels—another response to the energy crisis. Although most of the work would be done in the Central Region, each Region appointed an Energy Studies Coordinator to oversee the planning and execution of those projects on behalf of the respective Regional Hydrologist. They were James Guerin, Northeastern Region; Malcom Hale, Southeastern Region; Hugh Hudson, Central Region; and G.L. Bodhaine, Western Region. Overall coordination was carried out by George H. Davis on behalf of the Chief Hydrologist. These individuals were responsible for making budget estimates, reviewing project proposals from District Offices, and all the other duties of a Regional Program Officer—but with a strong focus on the environmental impacts of resource development on water as well as the need for water supplies for development processes. Although the program nominally included work in coal, oil shale, nuclear energy, and underground heat storage, as a practical matter, it concentrated on increased production of coal and potential development of oil shale. In the West, these fuels were present mainly on Federal lands administered by the Bureau of Land Management; this led to close working arrangements with that agency.

Because of hiring restrictions, it was necessary to let contracts with commercial firms for data collection in support of the program. This proved to be somewhat challenging because the Division had had virtually no experience in writing specifications and other elements of a contract for the collection of hydrologic data by outside entities. Such contracts were ended after a few years.

One of the most important, and least-heralded, new programs in this period of the Division's history was the cooperative water-use data program (see WRD Memorandum 77.43). Previously, the work of the Division had been concerned almost entirely with the supply side of the water equation. The water-use data program deals with the demand side. Its initiation was important also because it envisioned that the work would be done, not by USGS personnel, but by State agency personnel with half their funding from Survey appropriations earmarked for the purpose. Regional Offices were affected because of the need to improve methodology and implement standards for data collection and to ensure that data collected in one State was comparable to and consistent with those collected in other States. In some Regions this could be done without adding additional staff; in others, an assistant to the Program Officer took on those responsibilities.

Technical Training

Although responsibility for technical training was shared among all levels of management, the establishment of the Committee for Technical Training by the Chief Hydrologist (see WRD memorandum 69.35) called for the designation of one representative from each Regional Office to serve on that committee, along with the three Branch Chiefs. Most Regional Hydrologists designated the Assistant Regional

Hydrologist. The committee usually met quarterly or semiannually to plan training programs that would enhance the technical competence of individuals throughout the Division.

In addition to the foregoing responsibilities for technical training, the Central Region had a unique role in technical training, due in large part to the vision and foresight of T.G. McLaughlin and to the energy and creativity of A.I. Johnson in setting up and operating the National Training Center, first as a Water Resources Division facility (see WRD Memorandum 69.18) and later as the USGS National Training Center. Initially the center concentrated on formalized training of new hydrologists, but its role later evolved to concentrate on teaching new investigational technologies for hydrologists, technicians, and other scientific disciplines that make up the Division's scientific investigational and data-collection work force.

Summary and Conclusion

During the 1966–79 period, the role, capability, and productivity of the Regional Offices of the WRD evolved—and changed as a result of administrative fiat and new societal demands for water information—for the better. As an intermediate echelon in the Survey's management structure, the Regions served as a fulcrum, on the one hand transmitting leadership initiatives from Division Headquarters to the field operations and on the other hand exerting leverage from the District and other field activities to keep the Division Headquarters abreast of water problems and the need for water information throughout the Nation.

NORTHEASTERN REGION

By Joseph Callahan and Herman Feltz

Regional Office

In 1966, as the remaining discipline offices in some States were being converted to consolidated activities as District Offices, the Atlantic Coast Area (which became the Atlantic Coast Region and then the Northeastern Region in 1972) was under the leadership of George E. Ferguson. The Atlantic Coast Area consisted of offices in the States of Connecticut, Delaware, Florida, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, South Carolina, Vermont, Virginia, West Virginia, the District of Columbia, the Commonwealth of Puerto Rico, and the Virgin Islands. The office of the Area Hydrologist and staff was located in a "Field Center" in Arlington, Va. In 1966, the technical staff consisted of George Ferguson, Area Hydrologist, Henry C. Barksdale, Francis T. Shaefer, Walter F. White, Wilbur T. Stuart, William Back, Dagfin J. Cederstrom, George D. DeBuchananne, Harry H. Barnes, Jr., James W. Crooks, and Joel O. Kimrey. Mary Jayne Swanson served as program analyst, and there were six members of the clerical staff, some full-time and some part-time. By 1979, only F.T. "Bill" Schaefer remained on the staff as constituted in 1966.

In 1967, the Office of the Atlantic Coast Region was reorganized to more clearly define assignments and responsibilities. Ferguson continued in his leadership role, assisted by F.T. Schaefer, Henry Barksdale, John George, Porter E. Ward, Mary Swanson, and a clerical staff of three persons. Porter Ward was chosen to be Program Officer as part of the reorganization effort to meet the needs of the Regional Office. There were six staff discipline specialists representing surface- and ground-water activities. James F. Bailey became a member of the staff specialists for surface-water activities. The Research Staff was led by William "Bill" Back. Some members were housed in Arlington, and several were scattered throughout the Atlantic Region.

The Northeastern Region Headquarters Staff remained fairly constant through 1969 except for the Research staff, which grew in number and added disciplines. Considerable change occurred in 1970 when W.D.E. Cardwell joined the staff as Reports Specialist and Bruce K. Gilbert came to assist Porter Ward in programming. Herman R. Feltz became the Water-Quality Specialist, and Franklin H. Olmsted became the Ground-Water Specialist. James W. Geurin joined the staff to handle special programs. Bruce Gilbert left the staff in 1971 for assignment in Puerto Rico; otherwise, the staff remained the same through 1972. Special Project Offices were established to conduct the South Atlantic–Gulf Regional Ground Water Study (D.J. Cederstrom) and the North Atlantic Regional Drought Study (Medford T. Thompson).

Late in 1972, the Atlantic Coast Region and the Mid-Continent Region were combined and bisected, so to speak, to form the Northeastern and Southeastern Regions. Under the realignment, the Northeastern

Region included the States of Connecticut, Delaware, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, Wisconsin, and the District of Columbia.

When created, the Northeastern Region contained about 90 percent of the heavy industries of the Nation, most of the population, and surface-water contamination of great variety. For example, some rivers in Ohio had so much waste oil and chemicals floating on their surfaces that occasionally they caught fire. Bootleg trucks hauled industrial wastes out of Chicago to the dune areas bordering Lake Michigan in Indiana and drained their lethal loads on sand roads at night, all of this before the U.S. Environmental Protection Agency had begun an effective program that later curtailed the practices. Most of the rivers of the region were badly contaminated by industrial wastes and sewage, and the condition of the Great Lakes was so poor that commercial fishing had been banned in many areas.

The Northeastern Regional Office remained in Arlington, Va., but had new leadership in June 1972 when Joseph T. Callahan replaced George Ferguson, who retired. The staff remained essentially the same. William C. Griffin transferred to Arlington from his position as District Chief in West Virginia. Gordon D. Bennett joined the staff late in 1972 as Ground-Water Specialist following the transfer of Frank Olmsted to California. Russell H. Brown became the Regional Research Hydrologist.

By August 1973, the staff was relocated to the new Survey quarters in Reston, Va. Roger G. Wolf succeeded Russ Brown as Regional Research Hydrologist, and Nancy Bley joined the staff as Administrative Assistant. Otherwise, the staff was the same through 1976. Bill Schaefer became the Delaware River Master, a position that demanded much, but which Bill enjoyed.

In April 1977, James E. Biesecker became Regional Hydrologist, replacing Joe Callahan upon his retirement. Biesecker's assignment to the Region (from his position of District Chief, Colorado) signaled a change in upper-level management because he was the youngest person ever to hold the position. He greatly increased the emphasis on strengthening technical aspects of projects and providing technical and administrative assistance to District personnel. Bennett transferred to the Ground Water Office in mid-1977 and was replaced by Ren Jen Sun a short time later. Herbert J. Freiberger joined the staff in 1978, bringing his expertise in hydraulics and experiences with water-quality projects. Roger Wolff became the Assistant Chief Hydrologist for Research, leaving the position of Regional Research Hydrologist open into 1979.

During this period, the Northeastern Regional staff also provided leadership towards administration of the Delaware River Compact—a major interstate water-resources agreement designed by the Supreme Court. In July 1977, Assistant Regional Hydrologist and Delaware River Master Francis T. Schaefer approved a Memorandum of Agreement that had been negotiated among the signatories to the amended decree of the United States Supreme Court handed down June 7, 1954. The agreement, undertaken with tacit approval of Chief Justice Warren E. Burger, provided for a temporary increase in releases of water stored in New York City reservoir in the Delaware River Basin for the purpose of enhancing environmental quality in the stream reaches downstream from the reservoirs.

The change in release patterns was managed by the River Master to ensure that the mandatory minimum flow, 1,750 ft^3/s, at the U.S. Geological Survey gaging station at Montague, N.J., would not be jeopardized and that the authorized diversions by New York City and New Jersey could be maintained. The modification of release requirements was a significant departure from the rigid application of the provisions of the decree that had been in force since 1954.

The staff were a team of personnel experienced in their respective fields. Each of the old "Branch" specializations was represented by a senior person who was qualified to work with and advise District personnel and the Regional Hydrologist on technical and administrative developments and problems. The system worked well. Regional staff, however, were required to travel often and extensively to each District and to Regional meetings. The trade-offs from the old Branch organization to the reorganized Division created a greater overhead in the Regional staffs and greater costs in administration, and more people were in travel status to ensure the specializations in the water-resources world.

Changes in the District make-up between the Northeastern and Southeastern Regions during the period of this history negated the reporting of fiscal data for all years; however, stability in alignment did allow reporting for 1973–79, as shown in the following table.

Fiscal data for Northeastern Region programs, 1973–79 (in millions of dollars)

Year	Total	Federal	Other Federal agencies	Federal-Coop
1973	$1.941	$0.072	$0.492	$1.377
1974	2.001	.076	.403	1.522
1975	2.496	.129	.373	1.994
1976	2.856	.132	.722	2.002
1977	3.022	.177	.676	2.169
1978	3.288	.232	.688	2.368
1979	3.587	.235	.531	2.821

The growth was impressive even when corrected for escalating inflation. The period is significant, too, because of technological advances and dedication to enhancing work at the District level by employing new investigative techniques. Ground-water hydrology was changing from the old descriptive studies ("Ground Water Availability in ...," and so forth) to model-based projects. This was also a time when the "model business" itself was changing from analog models built in the Analog Model Centers (first in Phoenix and then in Reston) to digital models developed in District Offices by project leaders.

The Regional Office strongly encouraged the trend toward digital modeling to help understand the ground-water-flow regime and what was happening to it during resource development. Not only did younger personnel take to changes, but older, experienced hydrologists joined in the surge to new directions, in some cases providing a way to do quantitative evaluations not possible previously. Bennett developed a popular "self-guided modeling course" (in the TWRI series) as an important effort in encouraging and teaching digital modeling.

This period was witness to the dawn of the application of the digital computer to the solution of hydrologic problems, and to store and manipulate hydrologic data. An IBM 360–370 mainframe computer had been installed in Reston, to be followed soon by a second computer as demand by technical personnel exceeded that of administrative personnel. Originally, the computer was used mostly for payroll and other administrative purposes. For paydays, the computer was used exclusively for the payroll. But as more computer programs were developed by personnel in specialties of water chemistry, ground-water pumping-test analysis, and surface-water analysis, the second computer was acquired and quickly was in operation 24 hours a day, 7 days a week. The time of the computer had arrived.

In 1974, funds became available under a Federal program to assist an economically depressed Wilkes-Barre, Pa., area. A contract made possible the processing of ground-water data for computer storage. A 1-year test proved the feasibility by processing and storing data from a few selected States. The program was extended to more States in 1975, and then to all States. Water-quality data were processed for streams and aquifers. At that time also, the decision was made to disband the analog model unit in Phoenix, Ariz., because programs were being written for the digital computer that simplified the work and outmoded the analog model for most problems. District personnel were making digital models of aquifers to solve local problems of supply and the effect of pumping on the aquifers. A whole new field had developed that would have profound effects on the field of hydrology. Callahan felt strongly that the birth of computer analysis probably was the greatest advance in ground-water hydrology since the development of the Theis equation for the analysis of pumping tests.

The Water-Quality and Surface-Water Specialists on the staff were busy within their disciplines, as was the Ground-Water Specialist. An example is the reconnaissance of water quality in the Potomac River Basin with emphasis on the presence of hydrophobic organic compounds associated with sediment. Polychlorinated biphenyl compounds (PCB's), a commonly used coolant in electrical transformers, were reported by District personnel as likely contaminating streams because of widespread use and spills. A sample collection program was organized in West Virginia, Virginia, and Maryland for a week in the dry fall months when flows would be at a seasonal low. Arrangements were made for chemical analysis at the Denver Water Quality Laboratory, and results were obtained within weeks. PCB's and DDT were present in concentrations great enough to warn State and local officials by telephone, letters, and reports. Data were reported in technical meetings within weeks. It would be more than 4 years before Staff were called to appear before a Congressional Committee investigating why, among other things, that the presence of the contaminants had not been reported to State and local authorities.

Records were produced to show the USGS had made the investigation and reported its findings to all the proper authorities in a timely fashion.

Hurricane Agnes struck in 1972 with widespread fury and demanded intense effort in coordinating activities to measure water discharge and later to make indirect measurements. There were numerous small dam failures, particularly in West Virginia, that required field work and documentation.

The discipline specialists dedicated themselves to working directly with District personnel to understand their problems and seek remediation. Particular emphasis was directed to activities in weather extremes such as floods and frozen streams, lakes, and rivers.

In the 1960's, the political parties in control in Washington began an effort that continued through following administrations to build their own agendas without affecting the total number of Federal employees by forcing existing agencies to freeze their total numbers of full-time employees. In later years, as politics refined the personnel system, any vacancy created by retirement or other cause could be filled only by part-time employees. In time, this caused serious personnel problems. Part-timers worked along side full-timers without earning annual leave or sick leave, nor were they paid for holidays. The inequities caused morale problems in District and Regional staffs as time went on. Inter-regional competition for qualified personnel was heightened and caused conflicts previously unknown in the reorganized Division.

By 1977, the review of Environmental Impact Statements required the full-time effort of more than one person of the Regional staff, as well as contributions of personnel in the Districts. Nearly every statement contained references to the probable impact of almost every proposed activity on rainfall runoff, streamflow, ground water, or water quality. In addition, the interest of the Water Resources Division had encompassed biological aspects of streams and wetlands, and biologists became members of the organization. The effects of the mandate of the USEPA were felt in every District in the Region. The personnel problems created by outside pressures had an adverse effect on Regional and District operations, but progress continued in the identification and solution of hydrologic problems, and new people were brought into the organization to carry on the work. Biesecker intensified efforts in program development, broader field activities, and production of timely reports.

DISTRICTS

ILLINOIS

by Larry G. Toler and G. Wayne Curtis

Personnel and Organization

In 1966, only the Surface Water Branch had a District Office in Illinois. William D. Mitchell was the third District Chief in the 46 years Illinois had been a separate office. Mitchell was also in charge of the Hydrologic Data Unit. John P. Monis was his assistant and was also in charge of Operations. Additional staff of nine professional, eight technical, and three administrative persons were located at the Headquarters office at 605 South Neil Street in Champaign. Five professionals and four technicians were located in a Subdistrict Office at Oak Park with Davis W. Ellis as the Engineer-in-Charge. One technician was located in Peoria. During 1966, Davis Ellis moved to Champaign to head the Hydrologic Section, and Allen W. Noehre succeeded him as Engineer-in-Charge at Oak Park. Also, one technician was moved to a new office in Mt. Vernon.

In July 1967, the District was reorganized into a WRD office. John Monis transferred to the Mid-Continent Regional Office, Theron R. Dosch transferred into the District as Mitchell's assistant, and J. David Camp transferred into the Hydrologic Data Unit. The reorganization established four Subdistrict Offices—Champaign, with Delbert E. Winget in charge; Oak Park, with Allen W. Noehre in charge; Peoria, with Herman C. Wibben in charge (succeeded by Kenneth W. Fowler in 1969); and Mt. Vernon, with Richard L. Stahl in charge. In January 1968, the Champaign office relocated to 605 North Neil Street. The 1970 organizational structure had Theron Dosch as Associate District Chief with Davis W. Ellis and Charlie R. Sieber as Assistant District Chiefs. Davis Ellis transferred to Ohio in July 1970, and David Camp replaced him as an Assistant District Chief.

In June 1971, William Mitchell succumbed to a heart attack, and in August, Ellis returned to Illinois as District Chief. The organizational structure remained stable until December 1973, when Ellis also succumbed to a heart attack. In June 1974, Lawrence A. Martens transferred from Louisiana to Illinois to replace Ellis as District Chief.

The middle to late 1970's was a period of significant change in the District in response to technical advances and to the broadening of activities brought on by reorganization to WRD District Offices. In December 1974, computer equipment was installed, and the District began to process and publish records locally. David Camp left the District in July 1974, and Don C. Perkins transferred to Illinois in November to head the Operations activities. Larry G. Toler transferred to Illinois in April 1975 as the District's first Water Quality Specialist and, in 1976, was made Chief of a newly formed Investigations and Appraisals Section. In September 1976, James B. Foster transferred into the District to head a project in nuclear hydrology at the low-level waste site at Sheffield. He also became the District's first Ground Water Specialist. Many of the new people hired during this period were trained in fields not traditional to the District such as geology, chemistry, biology, mathematics, and hydrology.

In April 1974, Robert D. Livesay transferred to the Peoria Office to replace Kenneth Fowler, who retired. Livesay left the District in August 1975, and the Peoria office was closed. In 1976, a new office was opened on the Northern Illinois University Campus in De Kalb. By 1977, all personnel in the Oak Park office had moved to De Kalb, and the Oak Park office was closed. Subdistrict Offices were then located at Champaign, De Kalb, and Mt. Vernon with Kent Ogata, Allen Noehre, and Richard Stahl in charge of the respective offices. In 1978, the Subdistrict Offices at Champaign and Mt. Vernon were redesignated as Field Headquarters.

Don Perkins transferred to Pennsylvania in November 1976, and, in May 1977, Theron Dosch transferred to Colorado. Larry Toler was named Assistant District Chief as an additional duty. In September 1978, David Grason transferred to Illinois from Connecticut and became the District Water Quality Specialist. Leroy G. Davis transferred to Illinois from Indiana in July 1977 and became Chief, Operations Section. In November 1978, Martens transferred to New York, and in February 1979, Larry Toler was appointed District Chief in Illinois.

In February 1979, Marvin G. Sherrill transferred from Wisconsin to be Chief of the Midwest Regional Aquifer study in Illinois. He was later designated Chief, Investigations and Appraisal Section. In February, Leroy Davis transferred to the Office of Surface Mining in Indiana, and Charlie Sieber received a temporary appointment as Chief, Operations Section. Dave Grason transferred to Maryland in June 1979. In September, Charlie Sieber retired, and Douglas G. Glysson transferred from California to be Assistant District Chief and Chief of the Operations Section.

The District ended the period with 29 professional personnel, 17 technical personnel, 7 administrative personnel, and 18 part-time technicians. Employees in the District during the entire period included Howard Allen, Wayne Curtis, James Dwyer, Mary Garrelts, Helen Larson, David LaFont, Allen Noehre, and Richard Stahl. Delbert Winget retired in October 1979.

Programs

Illinois was one of the last States to be reorganized into a consolidated Water Resources Division District. Prior to 1966, the Illinois District programs traditionally had been oriented toward the surface-water discipline. Hydrologic studies reflected the organizational specialties, and this trend continued into the mid-1970's. Wayne Curtis reported on Statistical Summaries of Illinois Streams (1969), and Charlie Sieber prepared a Proposed Streamflow Data Program for Illinois (1970). Flood frequencies of Illinois streams were studied from 1966 to 1972 and reported on by Jack Carns (1973). About 350 flood-hazard maps were prepared at a scale of 1:24,000 during 1967–79. Beginning in 1973, flood-inundation maps were prepared for National Flood Insurance purposes, and historical floods for northeastern Illinois were documented on 1:24,000 quadrangle maps and published as 70 hydrologic atlases during 1963–73.

Drainage areas of Illinois streams were reported by Kent Ogata (1975), and depths and frequencies of floods were reported by Byron Prugh (1976). Beginning in 1955, numerous stream drainage areas less than 10 square miles had been instrumented for obtaining flood-frequency information. In 1977, Curtis used the small-stream data to prepare separate reports on the analysis and estimating techniques and to update earlier flood-frequency estimating formulas.

A study of the dispersion characteristics of Illinois streams was begun in 1975 and was continuing in 1979. Studies of the effects of urbanization on floods also began in 1975. In 1977, a study of the time of concentration and travel coefficients for Illinois streams was begun, and a measurement program was started to check ratings of dams on the Illinois River.

The reorganization and the tendency for hydrologic curricula to be offered at many universities were prompted by the need for integrated hydrologic information. In the mid- to late 1970's, the District programs began to be oriented toward broader coverage of the different hydrologic disciplines. New personnel and new programs in the Illinois District began to reflect these broader interests.

In 1971, the District began cooperative studies with the Metropolitan Sanitary District of Greater Chicago (MSDGC) to collect hydrologic information in Fulton County, where MSDGC was storing liquefied sludge transported from their Chicago-area wastewater-treatment plants and spreading it on reclaimed strip-mined land to recondition soils. In 1974, the Bloomington-Normal Sanitary District became a cooperator in collecting streamflow and water-quality information in the twin-city area. Also in 1974, the Illinois Environmental Protection Agency (IEPA) became a cooperator in monitoring water temperatures of streams. Their historical water-quality data were reviewed and published in six volumes in 1978–79. After a joint review of water-quality data collection by all governmental agencies in Illinois, the IEPA became a major cooperator in the collection of water-quality data. Through the cooperative effort of data collection and quality control, water-quality data collected by the U.S. Geological Survey (USGS), IEPA, MSDGC, and the State Water Survey (SWS) at more than 200 stations were published in USGS annual data reports.

In the late 1970's, environmental concerns related to energy sources spawned great interest in hydrologic studies of energy sources and waste disposal. In Illinois, these concerns were focused largely on hydrologic consequences of mining coal and disposal of low-level nuclear wastes. In 1971, the U.S. Environmental Protection Agency (USEPA) funded the collection of water-quality data from streams in surface-mined areas. In 1974, Federal funds were provided for describing the hydrology of surface-mined areas in Illinois. Nuclear low-level waste site studies began in 1976 with a federally funded study of a site at Sheffield. An innovative method of study was to construct a 5-foot horizontal tunnel beneath the burial pits, 300 feet into the site, in order to monitor water movement in the unsaturated zone. Another study was begun in 1978 to evaluate the spread of radionuclides from the oldest low-level waste site in the Nation, located in the Palos Forest Preserve in northeastern Illinois.

Near the end of the period, in 1978 and 1979, cooperative studies were begun investigating shallow ground water in McHenry County, effects of mine reclamation in Fulton County, and effects of detention ponds on urban runoff. Also in 1979, a regional aquifer study in northern Illinois, Wisconsin, and Indiana was begun as one of several federally funded regional aquifer studies.

The most significant change in the hydrologic data program during the period was the increase in the number of water-quality stations. The following table indicates trends during the period.

Number and types of stations in the Hydrologic Data Program

(CSG-PR = Crest Stage Gage, Partial Record; CSG-PROF =Crest Stage Gage, Profile only; WELLS = Ground-water-level measurement station; QUAL = Site where samples taken for chemical analysis)

Year	Stream-flow (cubic feet per second)	CSG-PR (number)	CSG-PROF (number)	Stage (number)	WELLS (number)	QUAL (number)
1966	163	182	330	7	0	2
1975	174	148	251	10	3	41
1979	171	135	42	9	42	204

Cooperators

Several State, local, and Federal agencies supported the District's water-resources programs during 1966–79. At the State level, the Illinois Department of Transportation, Division of Water Resources (formerly the Illinois Department of Public Works and Buildings, Division of Waterways), was the principal cooperator with interest in surface-water data collection and surface-water-oriented investigative studies. Investigative studies included flood frequencies, depth frequencies, time of travel, and time of concentration values. The Illinois Department of Transportation, Division of Highways (also formerly a Division of the Department of Public Works and Buildings) supported the small streams program that began in 1955 and was completed in 1977. In the mid-1970's, the Illinois Environmental Protection Agency became a principal cooperator with interests in the collection and analysis of water-quality data. The Illinois Institute of Natural Resources, State Water Survey (formerly a part of the

Illinois Department of Registration and Education) contributed to the collection of surface-water data, chemical analyses of water, and determination of drainage areas and was the principal State participant in the Federal/State Water-Use program. Other State cooperators during the 1970's were the Illinois Institute for Environmental Quality; the University of Illinois at Urbana-Champaign, Board of Trustees; and the University of Illinois at Urbana-Champaign, Environmental Studies.

Twelve local agencies cooperated in hydrologic data collection and investigative studies. The Northeastern Illinois Planning Commission (formerly the Northeastern Illinois Metropolitan Area Planning Commission) cooperated in flood inundation mapping in northeastern Illinois with funds allocated by Cook, Du Page, Kane, Lake, McHenry, and Will Counties. The Metropolitan Sanitary District of Greater Chicago cooperated in the mine-reclamation studies in Fulton County. Other cooperators were the Sanitary District of Bloom Township, Fountain Head Drainage District, Forest Preserve District of Cook County, City of Springfield, Bloomington and Normal Sanitary District, the County Highway Departments for Du Page, Kane, and Lake Counties, Fulton County, East Liverpool Drainage and Levee District, and McHenry Regional Planning Commission.

Seven Federal agencies provided funds or services to USGS to collect and interpret water data. Four Districts of the U.S. Department of the Army, Corps of Engineers—Rock Island, Chicago, St. Louis, and Louisville—continued their long-standing support. In 1973, the U.S. Department of Housing and Urban Development, Flood Insurance Administration, began funding a flood-insurance study program. The USEPA provided funds for water-quality stations and for monitoring water quality in mined areas. Other Federal agencies supporting data collection or hydrologic studies included the Federal Water and Power Commission, U.S. Department of the Interior (forerunner of USEPA); Environmental Science Services Administration, Weather Bureau of the U.S. Department of Commerce; Atomic Energy Commission; and the U.S. Forest Service, Shawnee National Forest.

Funding

Funding of Illinois District programs during the period was essentially from the three sources: the Federal/State Cooperative Program (Coop), direct Federal programs, and from other Federal agencies (OFA) in support of their programs. The Cooperative Program was the principal source of funds throughout the period, as shown in the following table, although it decreased in percentage of total program from 78 percent in 1966 to 47 percent in 1979.

Illinois District funding, in thousands of dollars

Year	Coop	Federal	OFA	Total
1966	372	--	79	451
1975	572	55	250	877
1979	1,222	819	568	2,609

For most of the period, the OFA program was the second largest source of funds except for 1979. OFA funding was 15 percent of the total program in 1966, rose to 30 percent in 1974 and decreased to 22 percent in 1979. Direct Federal funding supported a few key gaging stations until the mid-1970's. Beginning in the mid-1970's, the Federal programs related to energy and the regional aquifer studies caused an increase in the Federal share to about 31 percent of the total District program in 1979.

Although the table on station operation shows a large increase in the number of water-quality stations and a near constant number of streamflow stations, the growth in investigative projects was greater than the data-collection projects in terms of total funding. From 1966 to 1979, the funding for investigative studies increased from 22 to 58 percent of the total program.

INDIANA

by J.L. Cook

In Indiana, organization as a WRD District occurred in 1965. The combined Surface Water (SW) and Ground Water (GW) offices remained at 611 North Pack Avenue, Indianapolis, until 1970, when they relocated to 1819 N. Meridian. The office remained at that site through the remainder of the period.

Organization and Personnel

Malcolm D. Hale served as District Chief until mid-1970, when he was named Program Officer for the Mid-Continent Area in St. Louis, Mo. James L.

Cook, Subdistrict Chief, Garden Grove, Calif., was selected to replace Hale and reported in February 1971. He served until mid-1977, when he was named Assistant Regional Hydrologist, Southeastern Region, Atlanta, Ga. He was succeeded in late 1977 by Dennis K. Stewart, Assistant District Chief, Oregon, who served in that position throughout the remainder of the period.

Claude M. Roberts, who had been District Geologist (GW) before the Division reorganization, served as Assistant District Chief until his retirement in 1968. At that time, the District was reorganized and Archie A. McCollam was named Assistant District Chief, Basic Data Operations, and Robert W. Maclay was named Assistant District Chief, Special Studies.

In 1970, Archie McCollam was named Associate District Chief and remained in that position throughout the remainder of the period. Philip J. Carpenter transferred from Water Resources Division Headquarters to replace McCollam as Chief of the renamed Hydrologic Surveillance Section. Carpenter transferred to the Washington District in 1974 and was succeeded by Paul J. Rohne. Rohne subsequently left the Survey, transferring to the International Boundary Commission in 1977. He was succeeded by William E. Harkness, who remained in that position through the remainder of the period.

In 1970, William G. Weist, New York District, succeeded Maclay, who had transferred to Texas. Weist remained as Chief of the Hydrologic Studies Section until 1974, when he was named a staff hydrologist. He was succeeded by William Meyer, who served in that position throughout the remainder of the period.

In 1972, William J. Shampine transferred from the Louisiana District to develop a water-quality program. As the program developed, an Environmental Quality Section was established in 1975, and Shampine was named Section Chief. He remained until 1977, when he transferred to Saudi Arabia. He was succeeded by Steven E. Ragone, who transferred from the New York District. Ragone remained through 1979.

The Field Headquarters at Fort Wayne was closed in 1969, and Robert G. Lipscomb, Project Chief, was transferred to the National Water Quality Laboratory in Atlanta.

The one-person Field Headquarters at Carlisle was closed in 1976 upon Leo W. Carrico's retirement. With the closing of the Carlisle Field Headquarters, all field operations were centered at the District Office in Indianapolis.

Mary F. Miller was the District Administrative Clerk in the Indiana District Office until her transfer to Nevada in 1968. She was succeeded by Barbara L. Gallagher, who headed the Administrative Services Section for the rest of the period.

This was a period of steady growth in the District's data programs but was also a period of explosive growth in the hydrologic studies program. Many hydrologists contributed significantly to this expansion of the investigative programs.

Cooperating Agencies

The Indiana Department of Natural Resources (DNR) was the prime State cooperator. All of the topical and modeling studies in the ground-water discipline, the interdisciplinary areal studies, the lake program, the surface-water hydraulic and hydrologic studies, and most of the stream-gaging and sediment-data programs were supported by DNR funding.

In 1971, a cooperative program, Floods from Small Drainage Areas (FFSDA), was begun with the Indiana State Highway Commission. The program funded a network of 104 crest-stage gages throughout the State. The network was designed to provide peak discharges for small drainage areas so that flood magnitudes and frequencies could be extended downward to drainages of approximately 1 square mile. The Indiana State Board of Health contributed to the overall data program. In the early 1970's, these funds were reprogrammed and used solely to support projects in the new environmental section. In the mid-1970's, the Ohio River Sanitation Commission (ORSANCO) supported an extensive water-quality sampling program of the main-stem Ohio River and its major tributaries from Pittsburgh, Pa, to Cairo, Ill. Data collection for the entire program was handled by the Indiana District.

Several utilities, municipal water works, and cities provided support for stream-gaging stations in their areas of interest. In addition, the cities of Carmel, Columbus, Elkhart, Fort Wayne, Indianapolis, Logansport, Muncie, South Bend, and Vincennes provided funds in support of extensive ground-water studies in their immediate areas.

Federal support for District operations came from the Geological Survey, the U.S. Army Corps of Engineers, the Soil Conservation Service, the Federal

Emergency Management Agency, the National Park Service, and the U.S. Environmental Protection Agency. In addition to matching funds supplied by State and local agencies, the Geological Survey provided full support for a small number of selected streamflow stations and ground-water observation wells for an in-depth analysis of the stream-gaging program and startup funding for a water-quality assessment of the upper White River. In addition, coal hydrology funding became available in fiscal years 1978–79. These funds were used to augment the surface-water, ground-water, and water-quality data programs in the coal-producing regions and to provide support for interpretive projects on the impact of mining on the water resources of those areas.

The greatest support from other Federal agencies came from the U.S. Army Corps of Engineers, which funded a portion of the streamflow and reservoir stations. Corps funding came from the Louisville, Chicago, and Detroit Districts. Soil Conservation service funding supported water-quality studies on several small watersheds. The Federal Emergency Management Agency provided funds through USGS Headquarters for outlining flood-prone areas on topographic maps as part of a nationwide Federal program for managing flood losses. Maps of urban areas with potential flood problems were excerpted from these topographic maps and published as pamphlets. In Indiana, 482 topographic maps and 39 urban-area pamphlets were completed. One of the pilot studies for this program was conducted on a tributary of the White River. The National Park Service provided funding for a comprehensive analysis of the water resources of the Indiana Dunes National Lakeshore with an emphasis on ground water.

Summary of Program

In the earlier years of the program, most of the District's efforts were devoted to the collection, processing, and publication of surface-water records. In the early 1970's, data collection was increased to accommodate expanded ground-water and water-quality programs. With reorganization, interdisciplinary studies became common, and in the 1970's, the District experienced a tremendous growth in ground-water and water-quality investigative studies to the point where they constituted most of the District's funding by the end of the period.

Surface-Water Records

Records of daily river stage and discharge remained steady throughout this period and numbered 184 sites in 1977. Records of daily water levels were collected at 78 lake and reservoir stations, with total volume of water determined for 11 of the sites.

Ground-Water Records

A basic network of observation wells was maintained throughout the period. The wells numbered 65 in 1976. Observations varied from continuous at approximately half of the sites to monthly or quarterly at the other sites. There were over 400 project wells in the program in 1976. Specific conductance and pH were measured at 186 of the wells, while a suite of inorganic constituents and total organic carbon (TOC) were measured in samples from 62 wells.

Water-Quality Records

In the late 1960's, specific conductance measurements were collected at the time of all discharge measurements at all surface-water stations in Indiana. This program was phased out and replaced by an expanded sediment-data collection program at 30 sites and water quality at 37 surface-water stations. Water-quality stations on the White River at Hazelton, Wabash River at New Harmony, and Whitewater River at Brookville were part of the National Stream Quality Accounting Network (NASQAN).

Other Data Activities

In 1972, P.B. Rohne published Open-File Report "Low Flow Characteristics of Indiana Streams." In 1974, L.G. Davis published Circular 510, "Floods in Indiana—Technical Manual for Estimating their Magnitude and Frequency." In 1975, a preliminary analysis of the Floods from Small Drainage Areas Program was published by Davis and Horner as an Open-File Report. Also in 1975, "The Drainage Areas of Indiana Streams" by R.E. Hoggatt was published as a State Report. This important contribution to the surface-water program required many person-years of effort and was many years in the making. "Statistical Summaries of Indiana Streamflow Data" was published as a Water-Resources Investigations Report by R.G. Horner in 1976.

Investigative Reports

The hydrologic studies of specific areas of Indiana, which had been initiated by F.H. Klaer and R.W. Stallman with their "Ground Water Resources of St. Joseph's County, Indiana" in 1948, terminated with "Water Resources of Delaware County" by R.E. Hoggatt, J.D. Dunn, and W.J. Steen in 1968. In this series, there were 35 bulletins published by the State of Indiana (DNR). This series was replaced by basin-wide studies of the Wabash, Maumee, Middle Wabash, and St. Joseph River Basins, published as Hydrologic Atlases 433, 493, 508, and 537, and of the upper White River Basin, which was published as Water-Supply Paper 1999–C.

In the late 1960's, as the need for quantitative analysis of ground water was recognized, electric-analog model studies of the Columbus area by F.A. Watkins and J.E. Hiesel and of the upper Wabash River by Hiesel were completed and published as Water-Supply Paper 1981 and Water-Resources Investigations Report 29–73, respectively. The analog model gave way to the digital model as the District entered into the computer age. With the acquisition of a Data 100 computer in early 1972, Indiana became the second District (New York was the first) in the Northeastern Region to be directly wired to the main-frame computer in Washington, D.C.

Due to a rapidly expanding ground-water program, a CME 75 drill rig equipped for auguring was purchased in 1973. The following year, the need for a rotary mud drill rig became apparent, and a second CME 75 was obtained. Over the remaining years of this period, thousands of wells were drilled in support of the ground-water and water-quality investigative programs of Indiana and for the District offices in Kentucky, Illinois, Michigan, and Ohio.

In 1972, a comprehensive study of seven landfills in the Indianapolis area was begun. This project, in cooperation with the city of Indianapolis, was one of the Division's early attempts at defining, both qualitatively and quantitatively, plumes emanating from hazardous waste sites. Shampine began as chief of this project, and upon his transfer, R.A. Pettyjohn completed the study.

In the mid-1970's, T.K. Greeman studied fracture traces in Jennings County, examining the relation of permeability in the limestone aquifer to the distribution and density of fracture traces and lineations mappable from aerial photography. This study helped solve water-supply problems of many small communities in the karst region of southern Indiana.

In this same period, Shampine studied the changes in concentrations of selected metals and characteristics of the buffer systems in a stream and lake adjacent to an area that was being mined. This project, in cooperation with DNR, preceded by several years the federally funded Coal Hydrology Program.

L.O. Arihood's water-quality assessment of the Indiana Dunes National Lakeshore, published as Water-Resources Investigations Report 14–75, was the precursor of long and intensive studies of the Indiana Dunes supported by the National Park Service. Modeling studies were conducted by Meyer, Shedlock, and others.

Time of travel studies had been conducted for many years; S.E. Eikenberry and L.G. Davis regionalized these data and published them as Water-Resources Investigations Report 76–9. This report was used extensively by the State Board of Health in waste-load allocations.

In 1976, R.J. Shedlock began an investigation of the movement of saline water into the Vincennes well field. This work was subsequently published as an Open-File Report.

MARYLAND-DELAWARE-DISTRICT OF COLUMBIA

by Thomas H. Yorke and Sumner G. Heidel

Organization and Management

The District was consolidated in 1965 from a Surface Water Branch office in College Park, Md., a Ground Water Branch office in Baltimore, Md., and a Water Quality Branch office in Rockville, Md. The new District office was located in Towson, Md. The District included Subdistrict Offices in College Park and Dover, Del., and a Field Office in Cumberland, Md.

In 1966, the District was under the direction of John W. Wark as District Chief and William E. Forrest as the Assistant District Chief. Edmond G. Otton, the previous District Geologist of the Ground Water Branch, was the Ground Water Specialist and provided oversight for ground-water activities. Sumner G. Heidel, an expert in sediment and water quality, was the Water Quality Specialist. He also served as advisor to the District Chief for report preparation and publication. In 1967, John Wark transferred to the California District, and Walter (Finch) White transferred to Towson from the Atlantic Coast Regional Office to become District Chief. In 1973, Bill Forrest transferred to the New York District, and Ken Taylor and Irv Kantrowitz became Assistant District Chiefs shortly thereafter. Mary Lowry was the District Clerk until 1972. Elizabeth Smith and Mildred Wojcik assumed those duties through the remainder of the 1970's.

District Program and Cooperators

The District program grew substantially between 1966 and 1979. Total funding was $439,000 in 1966; it more than doubled to $910,000 in 1972 and more than doubled again to $2,000,000 in 1979. The Federal-State Cooperative Water Resources Investigation (Coop) Program was the main source of funding for the District during this period. The Coop Program represented 85 percent of the District's total program in 1966, 76 percent in 1972, and 76 percent in 1979. The remainder of the District funding was fairly consistently divided between the USGS Federal program and other Federal agencies (OFA). In 1966, the Federal and OFA programs were 5 and 10 percent of the District funding, respectively. In 1979, they were 5 and 19 percent, respectively.

The composition of the District program continued to experience the same change that began in the early 1960's. The collection and compilation of basic streamflow, ground-water levels, and ground- and surface-water quality data represented 49 percent of the District program in 1966. These activities decreased to 31 percent in 1979. The number of daily streamflow stations operated by the District was 89 in 1966, 104 in 1972, and 100 in 1979. The water-quality program was supported primarily by the National Stream Quality Accounting Network (NASQAN) program.

As the District program grew in the 1970's, the number of cooperators also increased significantly. In 1966, there were 13 State and local cooperators and 2 cooperating Federal agencies. Between 1966 and 1979, there were 21 cooperators and 5 Federal agencies, which are listed below in alphabetical order.

Anne Arundel County
Baltimore County
Charles County
City of Baltimore
City of Salisbury
Delaware Department of Natural Resources and Environmental Control
Delaware Geological Survey
District of Columbia
Frederick County
Harford County
Howard County
Interstate Commission on the Potomac River Basin
Maryland Department of Natural Resources
Maryland Geological Survey
Maryland National Capital Park and Planning Commission
Maryland State Roads Commission
Maryland Water Resources Administration
Montgomery County
Prince Georges County
Town of Ocean City
Washington Suburban Sanitary Commission
Federal Emergency Management Agency
National Park Service
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
U.S. Soil Conservation Service (now Natural Resources Conservation Service)

District Office

The investigative staff in the late 1960's included Eliot Cushing, Irv Kantrowitz, Pat Walker, Jim Weigle, Richard Gardner, Pat Holliday, Jolly Thomas, Wayne Webb, and Larry Nutter. Much of the investigative work during this period was county ground-water studies done in cooperation with the Maryland Geological Survey. Other individuals joined the investigative staff in the 1970's. These included Alan Jackman, Stu McKenzie, and Glenn Kapple in the early 1970's, Richard Mandle and Jim Williams in 1974, and Bill Fleck in 1978.

Wayne Solley was Chief of the Hydrologic Data Section in the Baltimore area in the late 1960's and 1970's. His staff included Bernard Helinsky, John Kamosa, Richard Lucas, John Hornlein, and Jim Manning. Lillian Maclin and Mike Smigaj joined the staff between 1974 and 1976.

The District staff also included one-person Field Offices in Baltimore and Annapolis, manned by Claire Richardson and Fred Mack, respectively. They collected and compiled data from ground-water observation wells and conducted special ground-water investigations in the metropolitan areas of Washington, D.C., Baltimore, and Annapolis.

As indicated above, there was a heavy emphasis on ground-water investigations throughout the 1960's and 1970's. The District produced reports on the availability of ground water for many of the counties in Maryland and Delaware, particularly those near the more densely populated centers. Ed Otton, Fred Mack, and Claire Richardson produced much of the work done in the Baltimore–Washington corridor. Otton and others also produced atlases of the hydrogeology of 16 quadrangles in Maryland. Numerous studies were done in the coastal plain between Baltimore and Washington, D.C., and the Atlantic Ocean. The Magothy aquifer was studied intensively, and changes in the potentiometric surface of the aquifer were documented annually. Larry Nutter concentrated on the aquifers of the Piedmont and the carbonate valleys of Frederick and Washington Counties. Another area of emphasis was the deep aquifers of the Delmarva Peninsula that provide municipal water supplies for the vacation communities on the barrier islands along the Delaware and Maryland coast. Jim Weigle prepared several reports on the ground-water resources of the coastal areas of Maryland. The use of digital models increased substantially in the late 1970's, and reports were produced on the simulation of ground-water levels in the Piney Point and Magothy aquifers in Maryland by Jim Williams, Fred Mack, and Richard Mandle.

The District also conducted a number of multidiscipline studies in the 1970's. These included water-resources investigations of southern Maryland by Jim Weigle, Wayne Webb, and Dick Gardner, and the Delmarva Peninsula by Eliot Cushing, Irv Kantrowitz, and Ken Taylor, that encompassed the quantity and quality of both ground water and surface water. The Delmarva project staff coordinated well drilling and geophysical logging with the Exxon Corporation to gather lithologic data useful for defining water resources and potential oil reserves. Jolly Thomas conducted water-quality reconnaissance of streams throughout the State of Maryland. Stu McKenzie conducted a similar study of streams in Delaware. Wayne Webb conducted a reconnaissance to determine the extent of brackish waters contiguous to the Chesapeake Bay. Jolly Thomas and Sumner Heidel prepared a report in the late 1960's on the chemical and physical characteristics of municipal water supplies in Maryland. The streams affected by mine drainage in western Maryland were investigated by Pat Holiday and Stu McKenzie in the early 1970's.

Much of the surface-water investigative work of the District Office was done by Pat Walker in the 1960's and early 1970's. He produced a report on the streamflow characteristics of Maryland streams. Other work was done by Ken Taylor, Dave Carpenter, and Bob Simmons, as described in the sections on the College Park, Cumberland, and Dover Field Offices. Dave Carpenter assumed much of the streamflow-analysis work of the District in the mid- to late 1970's.

The Field Offices

College Park Subdistrict Office—The College Park office was an office in transition between 1966 and 1979. The office evolved from the District Office for the Branch of Surface Water to the College Park Subdistrict Office of the Maryland District. The staff in 1966 included Leslie W. Lenfest as the Engineer-in-Charge of the Hydrologic Data Section, Bill Davis, Wayne Solley, Earl Eiker, Dave Carpenter, Charles Laughlin, Michael McDonald, Tom Yorke, and Bonnie Pfaff. In 1966 and early 1967, Les Lenfest transferred to the Office of Hydrology of the National Weather Service, Earl Eiker transferred to the U.S. Army Corps of Engineers, Mike McDonald entered the U.S. Navy, and Wayne Solley transferred to the District Office in Towson. Ewell (Sonny) Mohler moved from the District Office and assumed the responsibilities of the Chief of the Hydrologic Data Section. Myron Lys and Denis Gillen relocated to College Park from the Massachusetts District in 1967, and they maintained much of the hydrologic data network in central and southern Maryland. Other staff hired during this period included Mike Cady, Chuck Gubisch, Lee Lenfest (Les, Jr.), and Dean Spacht. The Hydrologic Data Section in College Park was responsible for the compilation of the annual Water Resources Data report from 1966 to 1976.

The office was located in the Engineering Building of the University of Maryland throughout the 1960's. In 1970, the office relocated to a small industrial park adjacent to the College Park airport. The Goodyear blimp became a regular visitor to the airport as ABC televised Washington Redskin games and the Penn State-Maryland football games on the gridiron. In 1976, the College Park office was closed and the staff was reassigned to the District office in Parkville.

Sonny Mohler transferred to the Virginia District, and Tom Yorke accepted a detail to the U.S. Fish and Wildlife Service in Columbia, Mo.

There were two major projects conducted from College Park in the 1960's and 1970's. A rainfall-runoff project done in cooperation with the Maryland State Roads Commission was led by Dave Carpenter. The project included a network of partial-record or flood-hydrograph stations and rain gages on small watersheds. The project used the concurrent rainfall and runoff data, long-term rainfall data, and a rainfall-runoff model to extend the record of annual peak flows. The other project conducted from the College Park office was the Rock Creek-Anacostia River Urban Runoff and Sedimentation project. Bill Davis was the chief of this project until he joined the Montgomery County government in 1971. Tom Yorke was project chief from 1971 until its completion in 1976. Bill Herb joined the project staff in 1974. The project was done in cooperation with six county and regional agencies in the Washington metropolitan area and produced numerous reports on urban hydrology and the effectiveness of sediment controls during urban construction. The Subdistrict staff also conducted a sediment-trap efficiency study of Lake Frank, a Public Law 566 flood-control structure in Montgomery County.

Cumberland, Maryland, Field Office—Kenneth R. Taylor was the Engineer-in-Charge of the Cumberland office when the District was formed in 1965. Other members of the staff included Gene Auvil, Ralph Kerr, and Mary Skelly. In addition to his responsibilities as office chief, Ken Taylor coordinated a series of time-of-travel studies on the Potomac and Monocacy Rivers and the Antietam and Conococheague Creeks. When Ken moved to the District Office in 1968, Wayne Hammond took over responsibility for data operations in western Maryland. He remained in Cumberland until he transferred to the Office of the Assistant Chief Hydrologist for Operations in 1974. Bob James succeeded Wayne in Cumberland after gaining field experience in the Dover Subdistrict Office.

Dover, Delaware, Subdistrict Office—The hydrologic data program in Delaware and northeast Maryland was operated by the Subdistrict Office in Dover, Del. Philip Phannebecker was the Engineer-in-Charge from 1966 through 1979. Other members of the staff in the 1960's included Richard Johnston, Robert Simmons, Wilbert Thomas, Charles Kobb, and Marjorie Martin. Henry LaRose and Robert James joined the staff in 1971, and Art Hodges and Pat Leahy moved to the Subdistrict in 1975. The Subdistrict staff conducted numerous investigations in cooperation with the State Highway Department and the Delaware Geological Survey. Bob Simmons conducted a study of flooding in small streams, and Dick Johnston, Art Hodges, and Pat Leahy conducted ground-water studies along the Delaware and Maryland coast. Johnston and Leahy developed digital ground-water flow models of the unconfined and Piney Point aquifers, respectively, in Delaware.

Hydrologic Conditions

The District experienced the extremes of droughts and floods in the 1960's and 1970's. A widespread drought occurred in the Northeastern United States in 1965 and 1966, and there were concerns about the water supplies for New York City, Philadelphia, and Washington, D.C. The District and the Atlantic Coast Regional office in Arlington intensively studied the long-term recession characteristics of the Potomac River to estimate when demand would exceed the discharge of the river. Solley and Yorke measured the lowest recorded flow of 151 cubic feet per second on the Potomac River at Washington, D.C., on September 9, 1966. This flow was less than the normal withdrawal for the Washington metropolitan area. However, the drought was broken a few days later when the entire region received heavy rains that caused flooding throughout Maryland. The flooding in 1966 was a precursor of other floods that occurred in Maryland and Delaware in August 1967, August and September 1971, and June 1972. Hurricane Agnes in 1972 caused record floods on most of the streams and rivers in the District, including the Susquehanna River at Conowingo and the Potomac River at Washington, D.C.

MICHIGAN

by T. Ray Cummings and Robert Knutilla

Organization and Personnel

In June 1965, Water Resources Division activities in Michigan were reorganized to integrate surface-water, ground-water, and water-quality work into one administrative and technical unit. Arlington D. Ash, the Surface Water Branch District Engineer in Michigan, was appointed District Chief to guide the Division's programs in the State. Ash served as District Chief in Lansing until his retirement in 1970. Under the new organization, Subdistrict Offices were located in Escanaba and Grayling. Gordon C. Hulbert served as Chief of the Escanaba office, and Dale Pettengill served as Chief of the Grayling office. Although engaged largely in data-collection activities, both field offices provided personnel support for project work undertaken in their respective areas.

During the 1966–70 period, the Water Resources program in Michigan was composed principally of surface-water and ground-water data collection. Gerth F. Hendrickson, Assistant District Chief, supervised a small but varied program of special studies that related the State's water resources to availability, recreation, and conservation. Principal cooperators during the period included the Michigan Water Resources Commission, the Michigan Geological Survey, Department of Conservation, the U.S. Army Corps of Engineers, and more than 40 counties and other local units of government. Notable technical contributions to the District's work were made by staff members Kenneth E. Vanlier, Paul C. Bent, Robert L. Knutilla, and Floyd R. Twenter. Upon the retirement of Arlington Ash in March 1970, Gerth Hendrickson was appointed Acting District Chief.

In July 1970, T. Ray Cummings transferred from Columbia, S.C., to become Michigan District Chief. Hendrickson was named Associate District Chief. Paul Bent, Assistant District Chief, became responsible for surface-water data-collection activities, which constituted the largest segment of the District's program.

In July 1975, Dale Pettengill, Chief of the Grayling office, retired. He was replaced by Theodore Sieger, who transferred from Iowa. In November 1975, Michael G. McDonald transferred from New Jersey to assist William B. Fleck in the development of a 3-dimensional ground-water flow model of the Muskegon County waste-irrigation facility. This project was a major undertaking for the District and was the Division's first attempt at development of such a model for management use in a field environment.

Peter W. Anttila moved to the Lansing District office from Columbus, Ohio, in 1976 to supervise water quality work. After several notable accomplishments, Pete transferred to the California District in 1978. When Robert Knutilla transferred to Florida in mid-1978, Floyd R. Twenter was selected as Chief of the Hydrologic Studies Section. In November 1978, Alonzo H. Handy transferred from Reston, Va., to become Assistant District Chief.

Summary of Programs

By the late 1970's ground-water contamination by organic chemicals had become one of Michigan's most serious water-resources problems. In late 1979, at the request of the U.S. Air Force and the Michigan Department of Natural Resources, the District began a study of ground-water contamination by trichloroethylene at Wurtsmith Air Force Base. The study drew national attention and was a harbinger of much of the District's work on ground-water contamination problems in the decade that followed.

In 1971, the composition of the District program began to change. Surface-water data collection, as a percentage of total program, decreased as project activity increased. Funding sources also began to change. The Federal-State Cooperative Program became a smaller fraction of total District funding as funds for the Federal program and from other Federal Agencies increased.

Interest in water quality grew rapidly in the early 1970's as the State of Michigan used new legal authorities to address the impact of waste discharges on streams. Jon O. Nowlin supervised an expanded District effort in this regard. More detailed examinations of water quality were made as part of areal and special studies. Routine monitoring of the water quality of streams also increased.

When Gerth Hendrickson transferred to Wisconsin in 1972, he was replaced by Robert Knutilla as Assistant District Chief and Chief of the Hydrologic Studies Section. Under Knutilla's guidance, a major program of flood-plain mapping, funded by the U.S. Department of Housing and Urban Development, was undertaken and successfully completed. Following Paul Bent's retirement in 1973, John B. Miller guided data-collection activities until his appointment as Chief of the Basic Data Section in 1975.

Beginning with a study of the relation of water quality to agricultural land use in the upper St. Joseph River Basin in 1974, the District undertook a series of studies addressing the environmental impact of agriculture on water resources. Funds were made available within the Federal-State Cooperative Program by the Michigan Department of Agriculture, the Michigan Geological Survey, and various counties. Because of interest in the origin of nitrates in ground water, the relations of nitrates to land use became one of the common threads running through each study. Other studies relating hydrology to the selection of landfill sites were also begun. Results of these studies provided facts that permitted the State of Michigan to develop Statewide criteria for locating new landfills and prompted new research at Michigan State University related to contamination of ground water on agricultural lands.

Southeastern Michigan

Southeastern Michigan, an industrial area, experienced rapid growth. In the past, growth was primarily in the immediate Detroit metropolitan area. However, beginning in about 1950, the growth spread rapidly into adjacent areas. Growth patterns moved from Wayne County into St. Clair, Macomb, and Oakland Counties to the north, into Washtenaw County to the west, and into Monroe County to the south. This development resulted in new pressures on the area's water resources. Water-resource problems developed relating to obtaining adequate water supplies for both municipal and domestic use; for wastewater treatment; to maintain the esthetic, recreational, and homesite value of lakes and streams; to preserve sources of water for irrigation, cooling, and other uses; and to preserve ground-water supplies to meet water-supply needs.

In 1965, the U.S. Army Corps of Engineers initiated a comprehensive plan for the development and efficient utilization of the water resources of the region drained by streams which discharge, within the State of Michigan, into the Saint Clair River, Lake Saint Clair, the Detroit River, and Lake Erie. The Corps requested the Michigan District to assist in evaluating the water resources of the area. District personnel evaluated existing data files of the U.S. Geological Survey and undertook extensive field surveys to obtain additional information. Analyses of these data resulted in the preparation of a series of hydrologic atlases on each of the eight river basins in the study. Included is information on the physical setting, surface-water quality, streamflow characteristics, physiographic data, bedrock and glacial geology, yield of wells in bedrock and glacial drift, the quality of water, and infiltration rates. In addition to the atlases, gazetteers of hydrologic data were compiled for each basin.

In addition to the water-resources evaluation done as part of the Corps of Engineers comprehensive study, intensive studies also were completed for Oakland and Washtenaw Counties. The Oakland County study was done in cooperation with the county and the State of Michigan. The Washtenaw County study was done in cooperation with the Washtenaw County Metropolitan Planning Commission.

By 1970, the population of Oakland County was about 850,000, more than twice that of 20 years earlier, a pattern that continued. With this growth, the county recognized a need for a water-supply evaluation of surface and ground water and protection of these resources. Of special importance were the nearly 1,500 lakes and ponds in the area as a source of water supply, recreation, and esthetic value.

Washtenaw County also experienced rapid growth and required a water-resources evaluation for obtaining adequate water for municipal and domestic supplies and wastewater treatment. The Detroit water system obtained water from Lake Huron and had the potential to supply sufficient water with good quality. The study also considered how long local supplies would be adequate to meet local needs.

Robert L. Knutilla was the Project Chief for the study undertaken with the U.S. Army Corps of Engineers. He was assisted by John Nowlin, Robert Larson, William Allen, S.D. Hanson, Floyd Twenter, and T. Ray Cummings.

Floyd Twenter was Project Chief for the Oakland and Washtenaw County studies and performed most of the ground-water analyses. Knutilla coauthored each report and performed most of the surface-water analyses. John Nowlin performed most of the water-quality evaluations or assessments for the Washtenaw County study and wrote those sections of the report.

Cold-Water Rivers

Michigan is surrounded by the Great Lakes, dotted with hundreds, even thousands of inland lakes, and drained by a large network of streams. All are valuable resources and enjoyed by fishermen, canoeists, boaters, recreationalists, and the casual observer. Among the streams, the cold-water rivers in the northern part of Michigan's Southern Peninsula provide a unique recreational resource for residents and tourists. In order to make intelligent decisions for use and management of the water resources, the Michigan District, in cooperation with the Michigan Geological Survey, entered into a program in 1966 to describe the characteristics of several cold-water streams in northern Michigan and to show how they relate to recreational uses. Among these characteristics were streamflow, water quality, and the character of riverbeds and banks.

Streams were rated as to open-water reaches for fly casting, depth and variability in velocity for wading, gravel beds for spawning, objects for trout cover, bottom vegetation for food production, width and depth for boating, obstructions to boating, degree of stream-side development, frequency of dangerous high discharges, and variability in the character of riverbeds, banks, and channels for esthetic value.

A second aspect of this study was to relate trout populations to the characteristics of cold-water rivers. This study was designed to determine the relative importance of various hydrologic parameters on the populations. In 1970, a preliminary analysis of hydrologic parameters and trout populations was made for 16 stream segments in Michigan. That study was followed with an analysis of cold-water streams in Michigan and Wisconsin.

Gerth E. Hendrickson was the Project Chief, assisted by Charles J. Doonan who helped collect data on channel characteristics, water quality, and streamflow. Robert L. Knutilla assisted in data collection and performed the statistical analyses relating trout populations to hydrologic parameters and also assisted in report writing.

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MINNESOTA

by Charles R. Collier

Organization and Personnel

Prior to May 1967, the WRD offices in Minnesota were organized by individual Branches with coordination through the local council. The Ground Water District was under R.F. Brown, District Geologist and the Surface Water District under D.B. Anderson, District Engineer. The Quality of Water Branch was represented by the Lincoln, Ne., laboratory.

In May 1967, the Branches were reorganized as a WRD District. C.R. Collier transferred from Columbus, Ohio, to be District Chief. D.B. Anderson was Assistant District Chief for Operations, and R.F. Brown was the Assistant for Areal Studies until his transfer in December to the High Plains Recharge project in Texas. The Lincoln laboratory continued to provide chemical analyses for Minnesota until the establishment of the Regional laboratories.

In 1969, D.B. Anderson was Associate District Chief, T.C. Winter was in charge of the Areal Studies Section, and W.B. Mann, IV, was in charge of the Hydrologic Data Section. D.W. Ericson was Hydrologist-in-Charge of the Grand Rapids Subdistrict Office, and J.H. (Foss) Jackson was Administrative Assistant. In 1972, a three-person Field Headquarters was established in Montevideo, with C.E. Cornelius in charge.

In 1973, T.C. Winter was assigned to graduate school training and D.B. Anderson retired. Then, W.B. Mann, IV became Assistant District Chief, R.F. Norvitch was Chief of the Areal Studies Section, L.C. Guetzkow was Chief of the Flood Hydraulics Section, and R.W. Lamson was Chief of the Hydrologic Data Section. In 1975, Mann transferred to Florida and was replaced by V.J. Latkovich, who transferred from Puerto Rico.

In mid-1977, the District had a major change in leadership. Guetzkow and Lamson retired and were replaced by G.H. Carlson and E.G. Giacomini. Norvitch transferred to Idaho to be Assistant District Chief. P.G. Olcott then headed up the Areal Studies Section. Collier transferred to Tacoma to be District Chief of the Washington District. Latkovich served as Acting District Chief for Minnesota until D.R. Albin arrived to replace Collier.

Programs and Cooperators

Cooperative programs in Minnesota with State and local agencies included the Minnesota Department of Natural Resources, Division of Waters; Minnesota Department of Transportation, Division of Highways; Minnesota Pollution Control Agency; Metropolitan Council of the Twin Cities Area; Metropolitan Waste Control Commission of the Twin Cities Area; and some cities and watershed districts. Programs with other Federal agencies included the U.S. Army Corps of Engineers, Department of Housing and Urban Development, U.S. Forest Service, U.S. Environmental Protection Agency (USEPA), U.S. Fish and Wildlife Service, and the Soil Conservation Service.

The Minnesota Department of Natural Resources, Division of Waters was the major State cooperator. The program included support for much of the basic-data networks and for many areal studies.

A major effort was to provide a general assessment of the water resources of each of the 39 watershed units of the State and present it in the WRD Hydrologic Atlas series. This project continued throughout the period of this report. The northern watersheds were completed out of the Grand Rapids Office by D.W. Ericson, G.F. Lindholm, and J.O. Helgesen. The Minnesota River Basin watersheds and other southern units were done by the St. Paul Office, Areal Studies Section. Project leaders included R.D. Cotter, R.P. Novitzki, W.A. Van Voast, W.L. Broussard, D.F. Farrell, and H.W. Anderson, Jr.

In the early 1970's, the use of ground water for irrigation increased. The cooperative program with the Division of Waters was expanded to evaluate glacial outwash sand and gravel deposits as sources of supply. Surficial deposits were evaluated in the Alexandria, Park Rapids, Perham, and Appleton areas, and deep deposits were evaluated in the Brooten-Belgrade area. A statewide reconnaissance of the Sand Plains aquifers also was begun. Methods for identifying the surficial sand and gravel deposits by using Landsat imagery was explored.

A network of intermittent and daily sediment data-collection stations was begun on streams throughout the State to measure the rates of stream erosion. Arrangements were made with the Iowa District to analyze the Minnesota samples. In 1975, an interagency project to evaluate methods for stabilizing the highly erosive red-clay area in the Nemadji River Basin was started.

The Division of Highways supported a statewide network of crest-stage gages on small streams to provide peak-flow data for their bridge and culvert designs. The District also made site-specific bridge site investigations to provide the highway engineers with flood-flow data for proposed major river crossings.

The exploration and proposed mining of copper-nickel deposits in northeastern Minnesota required the definition of the pre-mining hydrologic conditions of the area. The study, led by P.G. Olcott for the U.S. Forest Service, included definition of the ground-water resources, streamflow characteristics, and water quality. The information was for the environmental impact statement being prepared by the U.S. Forest Service.

The Metropolitan Waste Control Commission was the principal cooperator for work on the lower Minnesota River and the Mississippi River in the Twin Cities area. A network of real-time water-quality stations was operated on the rivers to provide information useful to the operation of the sewage-treatment plants. Time-of-travel studies also were conducted for various low flows on the Minnesota and Mississippi Rivers in the area.

A noteworthy report on this work is WRI Report 76–94, "Graphic and Analytical Methods for Assessment of Stream-Water Quality—Mississippi River in the Minneapolis–St. Paul Metropolitan Area, Minnesota," by S.P. Larson, W.B. Mann, IV, T.D. Steele, and R.H. Susag.

A cooperative program with the Metropolitan Council of the Twin Cities Area was begun to evaluate the availability of ground water in the aquifers of the Twin Cities artisian basin. These aquifers are the source of the municipal supplies for the suburban cities of the area. The study was under the leadership of R.F. Norvitch.

At about the same time, the District was involved in the Regional Level B planning study of the Twin Cities area with several local, State, and Federal agencies. The District had the lead for the hydrology section of the study and participated in several others. A similar Level B study was made for the Upper Mississippi and Souris-Red-Rainy River regions.

For the Upper Mississippi River Basin Comprehensive Plan, C.R. Collier served as WRD representative on the Interagency Sedimentation Committee. The Committee, chaired by the Corps of Engineers, Rock Island District, provided an analysis of sedimentation rates throughout the basin and prepared that chapter of the report.

As might be expected for Minnesota, lake hydrology was a significant part of the District program. Lake studies included water-budget determinations, evaluation of computer models for simulating ground-water flow, and measuring the effect of advanced waste treatment on lake quality. These studies were in done cooperation with State agencies, Watershed Districts, and the USEPA.

Weather conditions during the winter of 1968–69, with the early cold causing deep frost followed by heavy snowfall, set the stage for severe flooding in the spring. Considerable planning and preparations were made by the agencies concerned. The Corps of Engineers detailed their dredging crew of six to eight persons to the District to assist in flood measurements. Flooding started in late March on streams in the southeast and continued into May in the extreme north. It was most severe in the Minnesota River and Red River of the North Basins. D.B. Anderson directed the District's flood activities and was senior author of a multi-District report.

The District, along with the Corps of Engineers and Soil Conservation Service, provided the State with flood-plain delineation maps required for the Federal flood-insurance program. Additional mapping was done under the Division of Waters cooperative program for the lower Minnesota River and other selected streams. This work was directed by L.C. Guetzkow. He also authored WRI Report 77–31, "Techniques for Estimating Magnitude and Frequency of Floods in Minnesota."

At the other extreme of river flows, WRI Report 77–48, "Low Flow Characteristics of Minnesota Streams," by K.L. Lindskov, documented drought conditions.

During the early 1970's, water-pollution control hearings for Lake Superior were held in Duluth. C.R. Collier served on the Interior Department committee to assess the effects of the Reserve Mining Company's taconite plant on the lake. He presented one of the committee statements at the hearing in Duluth and testified in both State and Federal court cases.

As a part of the Survey's research effort, H.O. Reeder led a study of artificial recharge of fractured carbonate rocks. The Prairie du Chien dolomite in the South St. Paul area was selected for study. The work included drilling a large-diameter injection well about 550 feet deep, drilling six observation wells, and testing several recharge techniques.

Another research program was the Sedimentation Instrumentation Unit headed by J.V. Skinner and located at the St. Anthony Falls Hydraulic Laboratory, University of Minnesota. This office, not a part of the District, was supported financially by the Survey and other Federal agencies to supply and improve sediment-sampling equipment.

Excellent relations were maintained with the Civil Engineering and Geology Departments of the University of Minnesota. Several District personnel were frequent lecturers at the various water-oriented classes.

NEW ENGLAND (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont)

CONNECTICUT

By Edward L. Burke

Personnel and Organization

John Horton was District Chief at the beginning of this reporting period until his retirement in 1970 and was succeeded by John Baker. The ground-water program of the Connecticut District was conducted from Middletown, Conn., under the direction of John Baker until he became District Chief. After John Baker left Hartford to take up new responsibilities in Boston in 1974, Fred Ruggles, Chester Thomas, and Dave McCartney became District Chiefs, successively. Larry Weiss and Mike Cervione were the last old-timers to stay on staff after Jim Stackpole and Ed Burke retired in 1975 and 1977. Mendall Thomas had been with the Hartford office since the mid-1930's under B.L. Bigwood. Mendall died in August 1988, not long after he retired from the Survey. Bigwood died in May 1978.

The 10-year period, 1960–70, saw the expansion of the Hartford office to more employees both in the field and in the office.The Connecticut District office space expanded and changed over the years from a small, crowded, two-room office to a multi-room arrangement. The early office space was in the old Hartford Post Office building near the railroad station. Alterations to the post office during the time of great expansion of the Hartford office in the 1960's kept us busy working in shifting, temporary quarters with much construction, noise, dust, and confusion. Later, more suitable quarters were occupied uptown in the new Ribicoff Federal Building at 450 Main Street.

In the mid-1970's the field and office staffs had grown to about 70 persons, integrated into surface-water, ground-water, and quality-of-water disciplines, aided by specialized staff in computers and in the drafting room. We did our own construction and maintenance of gaging structures, including stilling wells and cableways for measuring floodflows. Security of equipment at gaging stations at ground-water observation wells, and at quality-of-water sites sometimes was affected by vandalism and break-ins resulting in damage to or loss of very expensive devices. The early gage houses had wooden doors that had to be replaced by bulletproof steel to protect the recorders. Reinforced concrete was used for some gage structures and heavy sheet steel for others. Temporary stilling wells were made of 3-foot or 4-foot steel culvert pipe on which steel shelters were bolted. Many of the gage sites in the Connecticut District were located at or near highway bridges, which made for convenient access. Winter work did not require special vehicles or airplanes to get to gages. Connecticut is 100 miles long and 50 miles wide and has a dense highway system.

Program

One of the largest single projects undertaken was the measurement and gaging of tidal stages and discharges on the Connecticut River at Middletown. This work required 24- or 48-hour calibration measurements and construction of special stilling wells near Middletown. At about this same time, digital stage recorders were replacing the old-style strip charts; digital recorders were installed at all of the gage sites in Connecticut. The digital stage recorders were developed in conjunction with digital computers, which gradually took over computation and printout of streamflow records and records at ground-water observation wells.

About 1970, special water-resources studies were begun in Connecticut by the USGS in cooperation with the Connecticut Department of Environmental Protection, and had the generic title "Water Resources Inventory of Connecticut." There were 10 river basins studied for surface water, ground water, and quality of water records and characteristics. Three or four experienced employees headed up each river basin study. Six of the 10 river-basin studies were published in the period 1966–74.

One of the problems facing the field crews was storage space for vehicles, spare parts, and field equipment. Storage space for equipment in the earlier years had been rented in garages in the neighborhood; later, more suitable space was obtained in Hartford or East Hartford.

MAINE

Information was provided by retirees Gordon S. (Hap) Hayes, Richard A. Morrill, Glenn C. Prescott, Wayne B. Higgins, Gordon R. Keezer, and C. Russell Wagner, and Derrill J. Cowing, currently (2000) District Chief of Idaho.

INTRODUCTION

Although the District had been reorganized into the new Divisional format in April 1966, no significant personnel or program changes occurred until 1974. Prior to the reorganization, G.S. (Hap) Hayes had been the Surface Water District Chief since 1956, and Glenn C. Prescott had been the lone Ground Water Branch representative as part of the Boston District since 1957. Details of operation of the reorganization are included in Volume VI of the history.

Organization and Management

As noted above, Hap Hayes had been the Surface Water District Chief for more than 10 years when the WRD reorganization took place. Glenn C. Prescott had served as Assistant District Chief since April 1, 1966. Engineer Richard A. Morrill, and Technicians C. Richard Haskell, Gordon P. Keezer, and Wayne B. Higgins had been on board prior to 1966. Lura McLain served as District Clerk from 1936 to 1972.

Hap Hayes retired in May 1974, and on July 1, the Maine District Office was reclassified as a Subdistrict Office of the reorganized New England District. John Baker, located in Boston, was the District Chief. In August 1974, C. Russell Wagner transferred from Ithaca, N.Y., to the position of Subdistrict Chief, which he held until January 1979 when he transferred to take the position as Chief of the new Hydrologic Instrumentation Facility in Mississippi. Jeffrey T. Armbruster took over as Subdistrict Chief in February 1979, serving in that position until the end of this period in WRD history. During this period, there was no formal breakdown of operating sections because of the small size of the program, although specific functions were performed by designated employees.

The Maine office had always occupied space provided by the principal State cooperator, the Public Utilities Commission. In 1976, the USGS operations were moved into a specially designed office, laboratory, and storage facility which also provided indoor vehicle parking.

Personnel

From prior to 1966 until 1974, the office staff was unchanged from the six technical personnel and one clerk, as noted above. A number of summer students assisted with summer maintenance work. The first new addition to the staff was Derrill J. Cowing, who relocated from Boston in June to take on a new lake study project. Cowing also provided technical guidance on water-quality issues until he transferred to Alaska in July 1978. Robert Lippert joined the office in September 1974 as the first "new" technician in more than a decade. Patricia Clark was hired in 1976 to take on the growing administrative duties. A number of professionals were recruited to carry on the expanding program in the next few years: Gene Parker in 1975, Richard Fontaine in 1976, William H. Nichols in 1978, and Leonard R. Frost in 1978. A large number of individuals served in ongoing temporary, part-time, and Hydrologic Field Assistant positions.

Funding

The total funding for the Maine program was $106,000 in 1966. By 1977, the program had grown to $562,950.

PROGRAMS

Data Collection

Surface-water data collection has been the backbone of the Maine program. In 1966, there were 57 full-time gaging stations, which increased to 69 in 1979. A number of crest-stage gages also were operated until 1976 when the Maine Department of Transportation ceased funding. In 1966, ground-water was monitored in 13 wells in addition to water quality at five stream gages. In 1979, water-quality monitoring was conducted at 27 wells and 13 stream sites.

Ground-Water Programs

Virtually no information was available on the State's ground-water resources until Glenn Prescott arrived in the Maine in 1957. A reconnaissance investigation performed in 1958–59 indicated that supplies large enough for public supply, industrial supply, and irrigation were available in scattered sand and gravel deposits of glacial origin. For the next 2 decades, Prescott, working alone, mapped the surficial geology, basin by basin, for most of the populated areas of the State because no maps existed. Other aspects of a specific study were collection of data on wells and springs, water use, and limited chemical quality of ground water. Each interpretive report included a map of the surficial geology, an overlay pattern indicating areas most favorable for obtaining large quantities of water, information on water quality, and statistics of bedrock and surficial wells. Basic-data reports also were produced for each study area. Prescott produced 27 reports during this period, with several published after 1979. Funding for this work was provided by the Maine Public Utilities Commission until 1976 when the Androscoggin Valley Regional Planning Commission assisted, and 1978 when the Maine Bureau of Geology also contributed financial support. In addition to the work described above, Prescott answered many ground-water questions addressed not only to USGS but also to the Public Utilities Commission.

Lake Studies Program

A study of 43 Maine lakes was undertaken from 1974 to 1978 to collect baseline data and evaluate water-quality sampling frequencies and parameters to assist in the environmental management of the State's lakes.

Drainage Area Study

Statewide information on the drainage areas of the State had never been done on a systematic basis. A program was initiated in 1976 to provide this information. Areas were calculated for drainage basins greater than 25 square miles.

Section 208 Studies

The Maine Department of Environmental Protection served as coordinator of studies under the non-point runoff component of the Water Improvement Law, PL 92–500, known as section 208. The USGS formed cooperative agreements with four regional planning commissions to provide additional streamflow, water-quality, and ground-water information to consultants assembling planning commission reports. Most of this project was completed in 1975–76, although it formed the basis for some continued work in ground water and surface water.

HUD Studies

Maine was involved in doing flood-prone-area mapping as part of the HUD Flood Insurance program during the period 1975–79.

Maine State Highway Research Project

The Maine Office had a cooperative project with the Maine State Department of Transportation to develop a technique for estimating the magnitude and frequency of floods in Maine. The study included the operation of a crest-stage gage program. The program ran from 1963 to 1975, resulting in a report "A Technique for Estimating the Magnitude and Frequency of Floods in Maine" by Richard A. Morrill.

MASSACHUSETTS

by Larry Toler and Michael Frimpter

Personnel and Organization and Management

The Water Resources Division Central New England District (CNED) was formed in 1966 by combining the Branch District Surface Water and Ground Water Offices. Charles E. Knox, the former Surface Water District Chief, became the new Division District Chief, and Richard Peterson, the former Ground Water District Chief, was the Assistant District Chief. The District included the States of Massachusetts, New Hampshire, Rhode Island, and Vermont. In April 1975, Larry Toler transferred out of the CNED and William Silvey transferred in as the District Water Quality Specialist. Charles E. Knox, Chief of the Central New England District, retired in 1973. The District was reorganized to encompass Maine, Vermont, New Hampshire, Massachusetts, and Rhode Island—all the New England States except Connecticut. John Baker transferred from Connecticut to become District Chief and Patrick N. Walker transferred from the position of USGS representative to the Delaware River Master to become Assistant District Chief, of the reorganized New England District. All of the member States had Office Chiefs except Vermont and Massachusetts. In 1979, Michael Frimpter was appointed Massachusetts Office Chief.

Program and Cooperators

At the beginning of the 1966–79 period, hydrologist (Engineer) Joseph Rosenshein was Chief of the Rhode Island office. He transferred to Tampa, Fla., in 1967. Hydrologist Joseph Gonthier (Geology) then served as acting Subdistrict Chief until September 1968, when he was replaced by Hydrologist (Geology) Herbert E. Johnston, who transferred from Harrisburg, Pa. Later that year, Gonthier transferred to the Oregon District. Johnston remained Subdistrict Chief through 1979. Administrative services were provided by the District Office in Boston throughout the period. The Subdistrict office, during 1966–79, was located in the old Post Office building in downtown Providence.

The principal surface-water activities of the District were the stream-gaging program funded in all States in cooperation with the respective State and local agencies, the U.S. Army Corps of Engineers, and some Federal Collection of Basic Records (CBR) funds. A study of flood frequencies of small streams was supported by Federal funds and funds from other Federal agencies (OFA).

Ground water and surface water in Massachusetts were being evaluated, in cooperation with the Massachusetts Water Resources Commission, under a long-term program which was to include each river basin in Massachusetts with the results to be published in the Hydrologic Atlas series. Typically, the atlases consisted of two large sheets, one describing the quantitative and qualitative aspects of surface water and one describing favorable areas for ground-water exploration and the chemical constituents likely to be in the water.

The routine monitoring of highway salt in ground water had been restricted to wells near highways. Samuel Pollock had worked closely with the Research and Materials Section of Massachusetts Department of Public Works (MDPW), which had drilled single and(or) multiple depth wells at several locations at distances of 15 and 30 feet from the highway. These wells showed that high concentrations of chloride reached the water table and that the concentrations varied with the amount of salt applied to the highway and the periods of rainfall and resulting recharge to the ground water.

In 1971, the Highway Salting Project was expanded, and Larry Toler was made interim project leader. Ivan James provided expertise to design a well network for the purpose of evaluating the factors that affected the movement and concentrations of chloride in wells downgradient from highways. The network included nests of multi-depth wells at several locations extending away from the highway to a hydrologic boundary where possible. The expanded program also included instrumenting 10 small basins where specific conductance, temperature, and streamflow were measured continuously. On each visit to the stations, samples of water were collected and analyzed for chloride. Predictive equations were developed to estimate the concentrations of chloride in receiving streams. The difference between the amount of salt applied to highways and the computed salt loads of the streams provided an estimate of how much salt percolated downward in the recharge to the ground water. In 1973, Leonard Frost transferred into the CNED to become project leader of the Highway Salting Project.

From the information obtained during the Highway Salting Project prior to 1971, Larry Toler and Samuel Pollock coauthored a report that was published in the Survey's Journal of Research and described how various size fractions of materials in the unsaturated zone retained chloride above the water table. Because of the practice of salting highways for snow removal, the Federal Highway Administration financed a study through the MDPW, Research and Materials Section, to monitor chloride in wells along State highways. Small (one- or two-person) offices were maintained in Rhode Island and Vermont for the purpose of conducting ground-water studies.

In the fledgling water-quality activity, monthly samples were collected for chemical analyses at three stream sites under the Survey's Basic Record Program. One of the three sites, the Merrimack River below the Concord River at Lowell, Mass., had been designated an International Hydrologic Decade Station. Some water samples were analyzed as part of most basin studies. All water samples were analyzed in the District laboratory at Albany, N.Y.

In July 1966, Larry Toler transferred into the CNED as the first Water Quality Specialist in the District. With no water-quality program to support a specialist, he became project leader of two of the Basin studies—the Deerfield River and Hoosic River basins in northwestern Massachusetts. Frederick Gay and Bruce Hansen were project members, and both were dedicated to enhancing the water-quality activities in their respective areas of expertise in surface water and ground water. They also became involved, along with many others, in all efforts to expand the water-quality activities in the District and in shifting the District toward interdisciplinary projects and programs.

Normally, there were three or four river-basin studies being conducted concurrently. The first effort in enhancing the water-quality expertise in the District was to ensure that each of these had a systematic program of sampling, analyzing, and reporting on chemical constituents in both surface water and ground water.

Water-quality activities under the Federal program were expanded in 1967 when a sediment station was established at the International Hydrologic Network station on the Merrimack River. Also in 1967, Federal funds were provided to install and operate an automatic water-quality monitor on the Merrimack River upstream from the Concord River, at Lowell, Mass. This was one of the state-of-the-art stations at the time, where a submersible pump was mounted in the river and water was pumped through an instrument cabinet in which were mounted sensors to measure specific conductance, pH, dissolved oxygen, and temperature. Water samples were collected monthly for analysis of chemical constituents. In succeeding years, District personnel were trained in bacteriological sampling and suspended- and bottom-sediment sampling as part of programs with other Federal agencies and to meet requirements of the National Stream Quality Accounting Network.

The water-quality-monitoring station on the Merrimack River at Lowell demonstrated the feasibility of collecting information useful to the State in their water-pollution-control programs. During the years 1968 to 1973, eight stations similar to the one on the Merrimack River at Lowell were established in cooperation with the Massachusetts Water Resources Commission. The eight sites were the North Nashua River at North Village, Merrimack River at West Newbury, Blackstone River at Millville, Chicopee River at Chicopee Falls, Connecticut River at West Springfield, Westfield River at Westfield, Connecticut River at Agawam, and Hoosic River at Williamstown. Samples were collected monthly at all stations. Hydrographs of all the monitored parameters were provided monthly to the cooperator, and summaries of all measurements were published in the District's annual Hydrologic Data Reports.

While working on one of the Hydrologic Basin projects, George Morrill, III, collected information on water quality in small streams in the Ipswich and Shawsheen River Basins where residents relied on septic tanks for waste disposal. After Morrill left the Survey, Larry Toler worked with the information and coauthored a report with Morrill, published in the Survey's Journal of Research, that described some of the effects of septic-tank effluent on small-stream water quality.

Cooperative Hydrologic Studies Section

The National Seashore had been established on Cape Cod and the National Park Service was dealing with water-resources-related claims made by land owners whose land had been taken. At the request of the National Park Service, David Delaney and John Cotton evaluated a potential withdrawal site and prepared a ground-water budget for part of the National Seashore in Truro that was published in 1972. Later, in 1976, John Guswa and Clark Londquist reported on a pumping test for the National Park Service that included monitoring of saltwater upconing at a test site in Truro.

Public interest in the limits of Cape Cod's resources had been fueled by establishing the National Seashore and by rapid population growth on Cape Cod. In 1972, the citizens of Barnstable County, Cape Cod, in a public referendum, voted by over two-thirds to provide funding for up to $500,000 for ground-water studies of Cape Cod to be conducted specifically by the Water Resources Division of the USGS. Michael Frimpter launched the District's first 3-dimensional ground-water modeling effort in 1973 to describe the Cape Cod aquifer system and its interaction with seawater. The project represented a shift from resource appraisals previously published to more system- and process-oriented projects.

In 1973, Frimpter was appointed Chief of the Hydrologic Studies Section, and John Guswa was assigned Project Chief of the Cape Cod ground-water study. Denis LeBlanc, Clark Londquist, Frederick Gay, Richard Willey, William Caswell, and geology students on a work-study program from Northeastern University rounded out the project team. The large project was supported by Barnstable County, the

Massachusetts Water Resources Division, the Massachusetts Division of Water Pollution Control, cooperative matching funds from the USGS, and funds from the National Park Service. With so many cooperators and so much public interest, the project was constantly monitored, and quarterly progress meetings were attended by and reported in the local press. The study allayed fears that the Cape Cod aquifer would be pumped dry to meet the water demands for an expanding population or that it was about to be ruined by saltwater intrusion. This project, and the attention it received, heightened public awareness and generally dispelled many incorrect or incomplete beliefs and concepts.

Most important, the study focused attention on the fragility of water quality in the shallow water-table aquifer. In response, State and local water-planning and regulatory agencies realized that their initial aquifer protection policies would be inappropriate for an area where all the available land was an aquifer recharge area. Planners described the situation as being like the entire population of the Cape living on a screen suspended 5 to 20 feet above their water-supply reservoir, flushing their wastes into septic systems, applying fertilizers and pesticides to their lawns and golf courses, spilling gasoline and fuel oil from storage tanks, and dumping their garbage into pits. This image led to the USGS assisting the Cape Cod Planning and Economic Development Commission with the development of the concept of protecting zones of contribution around public supply wells. A report describing this concept was eventually published in the 208 water-quality-management plan of Cape Cod in 1978. With this approach, land uses could be controlled to limit threats to water supplies in zones of contribution while allowing polluting activities in other nonthreatening land areas. In 1979, based on this Cape Cod approach, the Massachusetts Division of Water Supply, and again with technical guidance from the USGS, evolved a more advanced approach to delineating protection zones representing four levels of water-quality threats concerning public-supply wells that is still being applied throughout the State. These efforts were prototype forerunners of the USEPA Wellhead Protection Program.

As an indirect consequence of the first USGS ground-water studies of Cape Cod, in 1977 Denis LeBlanc began an investigation of the fate of treated sewage discharged to infiltration lagoons at the Massachusetts Military Reservation on Cape Cod. The work was done in cooperation with the Massachusetts Division of Water Pollution Control, a division of the Massachusetts Department of Environmental Quality Engineering. The type of disposal used at this site was used at over 350 sites nationwide and was at that time favored for new facilities. Previous unofficial private investigations at the site did not sample water deep enough in the aquifer and had given the false impression that ground-water quality was unaffected by the disposal. In 1978 and 1979, LeBlanc mapped a well-defined plume of contaminated water extending nearly 2 miles downgradient from the source. The results were an eye-opener for public health agencies and led to even more intense investigations at the site, which eventually became a USGS Toxic Waste Ground-Water Research Site.

During the work preparing a Hydrologic Atlas for the Island of Nantucket, Project Chief Eugene Walker teamed up with the Geologic Division of the USGS to drill a stratigraphic test hole 1,686 feet deep in the center of the island. The test hole established the thickness of the island's freshwater lens at 520 feet. The hole bottomed in Triassic basalt, after penetrating about 1,500 feet of Pleistocene, Tertiary, and Cretaceous unconsolidated sediments. A report on anomalous occurrences of freshwater found at about 800 feet and brackish water between 1,200 and 1,500 feet deep in this test hole was published by F.A. Kohout and others in 1977.

Observation-Well Network

Throughout the 1966–79 period, Anthony Maevsky managed and maintained the Massachusetts observation-well network. The network was supported by CBR funds and by cooperative funding with the Massachusetts Division of Water Resources and the MDPU. The network had recently undergone a significant expansion with 30 new wells drilled in 1965 in response to a major drought in the region. New wells were gradually added to the network as the basin-by-basin resource inventory studies were completed. Some wells were destroyed or replaced new wells, but the total number gradually increased. Water-level data were published monthly in the Current Conditions report. In 1976, Maevsky published summary report of the well-site descriptions and water levels from 1936 to 1974.

Faced with an unacceptable number of septic system failures in the State, the Massachusetts Department of Environmental Quality Engineering, now the Department of Environmental Protection, entered into a cooperative study with the USGS to develop approaches for estimating high ground-water levels in 1977. With the newly available computing capability in the District and the experience and insights of Anthony Maevsky, Michael Frimpter analyzed the long-term records of the USGS network of 87 observation wells in Massachusetts and 146 short-term records of project wells on Cape Cod. Two reports, one for Cape Cod and one for all of Massachusetts, were published. The approaches for estimating high ground-water levels described in these reports rely upon the historical and current water levels at observation wells and continue to be used and have been written into health department regulations on Cape Cod.

NEW HAMPSHIRE

by Herman R. Feltz

Personnel

At the beginning of this period, New Hampshire was a Subdistrict of the Massachusetts office. Activities were conducted from Concord with Charles Hale the Engineer-in-Charge of the office. Other staff members were James Weigle, geologist; Frank Blackey, engineering technician; and Richard Kranes, physical science aid. Weigle transferred to Maryland during 1966 and was replaced by Harold Whitcomb. Kenneth McKenna (hydrotech) joined the staff in 1967. By 1969, Stephen Shore (hydro-engineering aid) was added to the staff, and the complement remained the same until July of 1972 when John Cotton, geologist, transferred to Concord from the District office in Boston. The staff was unchanged through 1976; however, increasing field work required the addition of two more hydrotechs (Michael Coakley and James King) and three more field assistants in 1977–78. In 1979, Kenneth Toppin, biologist, joined the staff to increase the size to 12 persons. Hale remained Chief of the office throughout this period.

Activities

Surface-water and water-quality activities were conducted in cooperation with the New Hampshire Water Resources Board.

In 1966, the New Hampshire Subdistrict operated 10 gaging stations in the Androscoggin River Basin, 4 stations in the Piscataqua River Basin, 29 stations in the Merrimack River Basin, and 17 stations in the Connecticut River Basin. The number and distribution of stations were relatively unchanged through 1979.

Water-quality activities during 1966–79 were very limited, consisting of a continuous record of temperature at one station and specific conductance with temperature at six others.

Ground-water activities consisted of a reconnaissance investigation of New Hampshire, the continuing program to monitor ground-water contamination by highway de-icing chemicals, maintaining an observation-well network, and working with municipal water-department officials to develop ground-water exploration programs.

RHODE ISLAND

by Herb Johnson

Introduction

In 1966, Rhode Island was a Subdistrict Office of the Water Resources Division's Central New England District. Charles Knox was District Chief until his retirement in 1973. He was succeeded by John Baker, who was previously Assistant District Chief in the Connecticut District. Baker remained Chief through the remainder of the 1966–79 period, but was killed in an automobile accident in November 1979.

Organization and Management

At the beginning of the 1966–79 period, hydrologist (Engineer) Joseph Rosenshein was Chief of the Rhode Island office. He transferred to Tampa, Fla., in 1967. Hydrologist Joseph Gonthier (geology) then served as acting Subdistrict Chief until September 1968, when he was replaced by Hydrologist (geology) Herbert E. Johnston, who transferred from Harrisburg, Pa. Later that year, Gonthier transferred to the Oregon District. Johnston remained Subdistrict Chief through 1979. Administrative services were provided by the District office in Boston throughout the period. The Subdistrict office, during 1966–79, was located in the old Post Office building in downtown Providence.

Personnel

Throughout 1966–79, the office was staffed by only two hydrologists, Johnston and David C. Dickerman, and a small support staff consisting of a clerk-typist, one or two technicians, and a number of temporary employees. During the early part of reporting period, stream-gaging services were provided by hydrologic technician Hubert "Skip" White from the Boston office. He transferred to the Providence office in 1974. A ground-water-level monitoring network was serviced monthly by hydrologic technician Eugene L. Peterman (WAE). In 1976, Hydrologic technician Joel Russell was hired to provide assistance with ground-water projects. Later in the period, Russell became a backup streamgager.

Owing to inflationary pressures, limited funding from cooperators, and hiring freezes throughout much of the 1970's, the need for additional support personnel to assist with extensive test-drilling activities, water-use data collection, drafting, data collation, and numerous other activities was met largely by hiring temporary help from local colleges and universities through the work-study program. The quality of work done by these students and their productivity were uniformly excellent. Two Comprehensive Employment Training Act employees, Paul Silva and Warren Diesl, were loaned to the USGS during 1976–77 by the Rhode Island Water Resources Board (RIWRB), a principal cooperator, to assist with ground-water projects. Also contributing technical support for brief periods during the late 1970's were several technicians on loan from the Maine office.

Five very competent and dedicated employees provided clerical services through the reporting period. They were, in order of their tenure in the position, Ruth Hawthorne, Fern Baris, Carol Devine, Maria deAbreu, and Irene Dailey.

Funding

Note: The 1957–66 WRD history section on Rhode Island shows the following funding, in thousands of dollars, for the fiscal year (FY) ending 06/30/66:

Coop: 69.3 (95 percent)
Fed: 2.3(3 percent)
OFA: 1.3 (1.8 percent)
Total: 72.9

Total funding available in September was about $78,000, and percentage distribution of funds was about the same as in FY 1966, except there were no OFA funds. Funding totals and percentages remained at about the same level until FY 1973 or FY 1974, when increases in Coop funding were needed to cope with inflation. In FY 1974, total program funding for Rhode Island was about $90,000 to $100,000. By 1979, total funding probably was about $180,000 to $210,000.

Most of the money went for salaries, overhead, and transportation; very little money was available for construction test drilling, water-quality analyses, and so forth. Extensive test drilling as part of ground-water projects was done between 1974 and 1979, but it was paid for directly by the Water Resources Board.

From July 1965 to September 1974, the Rhode Island Department of Transportation (RIDOT) cooperatively funded five gages and several peakflow gages on small drainage basins in Rhode Island. The agreement apparently was between the Massachusetts office and RIDOT and not part of the Rhode Island office budget.

Funding for the Rhode Island office ranged from about $73,000 in FY 1966 to about $180,000 in FY 1979, most of which was from the Federal-State Coop Program. Less than 5 percent of the total was from Federal and OFA programs. The principal cooperator was the RIWRB, which funded ground-water projects, most of the stream-gaging network, and an observation-well program. One stream gage was funded from 1966 to 1971 by the City of Providence, and the Rhode Island Department of Transportation provided cooperative dollars for five gaging stations between 1966 and 1974. The Federal program supported two stream gages and two observation wells for monitoring water levels throughout the reporting period.

In FY 1979, the Rhode Island Department of Environmental Management (RIDEM) became a new cooperator, funding a program of periodic water-quality sampling on major streams.

In the early 1970's, a small amount of OFA funding supported collection of water samples at several locations on Narragansett Bay by hydrologic technicians from the Rhode Island and Massachusetts offices. The effort was part of a water-quality reconnaissance project funded by the U.S. Environmental Protection Agency. Funding covered salaries of two people 2 days per month, plus cost of analyses for about six samples per month for about 2 years. USGS field personnel made bacteriological counts and measured dissolved oxygen, temperature, and specific conductance. The Rhode Island Department of Natural Resources provided boat transportation.

PRINCIPAL PROGRAMS

Hydrologic Data Collection

A statewide stream-gaging program, ongoing since 1940, continued throughout 1966–79. In 1966, 20 gaging stations were being operated. The number increased to 23 by 1974, then declined to 17 by 1979.

Seven long-term, multipurpose gaging stations established between 1939 and 1941 continued in operation throughout 1966–79 with financial support of the RIWRB. One long-term gage, in operation since 1940 on Adamsville Brook in eastern Rhode Island, was discontinued in 1978 for lack of funding.

Operation of five gages installed for the RIWRB in the early 1960's continued through 1966–79, except for one that had to be discontinued in 1975 because of property access problems. The original purpose of these gages was to obtain data for an ambitious RIWRB plan to construct surface-water reservoirs to meet future public supply needs.

From 1966 to about 1971, a gage on the Moshassuck River in Providence was operated for the City of Providence. Purpose of the gage was to provide data for operating flood-control gates on a recently completed hurricane barrier located a short distance downstream. After 1971, financial support for the station was taken over by the RIWRB.

Five gages installed on small drainage basins in 1965 as part of a cooperative project with the Rhode Island Department of Transportation continued through FY 1974, then were discontinued. The purpose of the gages was to obtain data for designing highway culverts for small drainage areas. Also funded as part of this project were peak-flow stations on 15 additional small drainage basins. All peak-flow stations were monitored from 1966 to 1974; five were monitored from 1966 to 1978.

A network of observation wells established in the late 1940's, primarily to monitor water levels in the State's principal sand and gravel aquifers, was maintained throughout 1966–79. The network consisted of 20 wells, three of which were monitored continuously with graphic recorders. The remaining wells were measured monthly by USGS personnel.

During the early 1970's (around 1972–73), hydrologic technicians from the Rhode Island and Massachusetts offices collected water samples from several (5 or 6) locations on Narragansett Bay for a reconnaissance evaluation of bay water quality conducted by the U.S. Environmental Protection Agency. Field and laboratory analyses were provided by the USGS. The Rhode Island Department of Natural Resources provided boat transportation for sampling.

The first program of periodic water-quality data collection began in November 1978, in cooperation with RIDEM. Purpose of the program was to provide data on spatial variations of dissolved inorganic and organic constituents in water at six streamflow sites. RIDEM required the data to prepare water-pollution-control plans, including the establishment of effluent limitations for point-source discharges, and to monitor long-term changes in the quality of the State's major streams. Chief of the new project was John Briggs, the District water-quality specialist. Sampling and field analyses of water quality were done monthly by technicians in the Rhode Island office; samples were sent to the Denver water-quality laboratory for analysis.

Statewide water-use data were collected in 1970 and 1975 as part of the Survey's national water-use data-collection program. These data constituted the only comprehensive water-use data available in Rhode Island.

Interpretive Studies

The principal role of the WRD in Rhode Island during 1966–79 was to assess the State's ground-water resources. The most important of these are glacial sand and gravel aquifers that underlie major stream valleys. These aquifers underlie about one-third of the State's land surface. High-capacity supply wells constructed in the aquifers derive a large fraction of their water from induced infiltration from overlying streams. The areal and vertical dimensions of all major ground-water reservoirs in Rhode Island had been mapped by the WRD prior to 1966, and quantitative assessments of the potential yields obtainable from them had begun.

Just prior to his departure from Rhode Island in 1967, Joe Rosenshein had completed a quantitative assessment of glacial aquifers in the Potowomut-Wickford area. Results of this study were published in 1968 as WSP 1775. Between 1966 and 1968, Joe Gonthier completed a similar assessment of several ground-water reservoirs in the Lower Pawcatuck River Basin. The report on this study, published as WSP 2020 in 1974, was completed with the assistance of newly arrived Herb Johnston and Glen Malmberg after Gonthier transferred to Oregon. Malmberg was then Assistant District Chief of the Central New England District.

Two additional quantitative ground-water studies were completed for the Branch River Basin and the Blackstone River area of northern Rhode Island in the early 1970's by Herb Johnston and Dave Dickerman. Results were published in WRIR's 74–18 and 74–4, respectively, in 1974. These were among the first reports published within the District as Water-Resources Investigations Reports. At that time, all typing and drafting of Rhode Island reports for publication was done in the Providence office.

Productivity in computing results of image-well-model analyses, done initially with a noisy mechanical calculator, improved markedly in 1970 with the purchase of an $800 electronic calculator. However, the new machine was not sophisticated enough to do square roots (bummer!!). Another major improvement in making tedious model analyses for the Blackstone study came about with the very welcome assistance of Alan Burns, then a mathematician in the Boston Office. Because most of the water obtained from wells in the Blackstone area was infiltration from nearby streams, Alan wrote a program that allowed a hypothetical recharge boundary to shift interactively until maximum drawdown was achieved in simulated pumping wells. It worked like a charm and allowed the authors to complete the report on schedule. (Well, nearly.)

In 1974, the U.S. Navy in Newport, R.I., on the eastern side of Narragansett Bay, was in need of additional water supplies. The Water Resources Board was planning to provide this water supply from abundant, and largely untapped, ground-water resources in the Pawcatuck River Basin on the other side of the bay. An ambitious exploratory and aquifer testing program was undertaken in five ground-water reservoirs previously evaluated by the USGS. The USGS was asked to oversee collection, collation, and publication of geohydrologic data resulting from this program. The result was publication of an extraordinary amount of detailed lithologic, aquifer-test, and water-quality data. By the end of 1979, geohydrologic data reports had been prepared for the Chipuxet River, Beaver-Pasquiset River, and lower Wood River ground-water reservoirs and had been published as Water Resources Board Information Series reports.

As part of the RIWRB test drilling program, the USGS was also asked to analyze the aquifer-test data and to use the results in numerical models of the stream/aquifer systems. The purpose of the model analyses was to give the RIWRB a better understanding of how ground-water withdrawals would affect low flows of streams and of the quantities of ground water that could be developed without causing streams to go dry. The first of five planned studies was of the Chipuxet River ground-water reservoir, done by Herb Johnston and Dave Dickerman. This study got underway in 1977 but was not completed by the end of 1979. Computer modeling assistance for the study was provided by William E. Kelly, Chairman of the University of Rhode Island Civil Engineering Department, and several of his graduate students.

Topical Studies

Excessive concentrations of manganese in well-water supplies has been one of the few natural water-quality problems associated with development of high-capacity supply wells in glacial aquifers in Rhode Island. The problem usually develops a year or more after wells have been put into production. This problem has affected supply wells serving the University of Rhode Island (URI), which is located in the Chipuxet River Basin. As part of the Chipuxet River investigation, William D. Silvey, District water-quality specialist, and Herb Johnston determined that the dissolved manganese resulted from infiltratration of water through a thick layer of organic sediment lining the bottom of a ponded area of the river. Results were published in 1977 (OFR 77–561). Simulated withdrawals from three supply wells, using a three-dimensional ground-water flow model of the URI well field developed by one of Kelly's graduate students, illustrated why one of two wells was not affected.

Other Activities

- During test drilling in the lower Wood River Basin in 1977, a plume of low-level radioactive contamination was discovered in the sand and gravel aquifer downgradient from a cold-scrap recovery plant owned by the United Nuclear Corporation. The discovery resulted in much publicity in the press and subsequently led to a USGS research study of the problem at the this site in the early 1980's. Also, at a different location in the aquifer, a plume of ground water was discovered that contained high concentrations of aldicarb, a herbicide applied to nearby potato fields. This discovery, too, resulted in much publicity in the press and prompted a wider search for this chemical in ground water by the RIDEM. Several drinking-water wells near other potato fields were found to be contaminated with aldicarb, and the State supplied emergency drinking water to many homes for several months.

- Because Rhode Island had no State Geologist and employed no hydrologists during 1966–79, the USGS-WRD office fielded and responded to numerous inquiries on earthquakes, local geologic conditions, and many ground-water and surface-water problems.

- During the latter part of the reporting period (1978?), court testimony by Herb Johnston concerning the movement of water from a landfill overlying a sand and gravel aquifer in northern Rhode Island into which hazardous wastes were being dumped resulted in subsequent closure of the site. The landfill later became a USEPA Superfund site.

- Herb Johnston served as a member of the State's review committee for projects proposed for support by the URI Water Resources Center. He also served on an ad hoc committee established by the Rhode Island Department of Environmental Management to codify hazardous-waste landfill regulations.

EPILOGUE

The cooperative WRD-RIWRB ground-water program, begun soon after the end of World War II, had by 1979 resulted in publication of reports containing extensive hydrogeologic knowledge of all of Rhode Island's major sand and gravel aquifers. For several of them, potential yields obtainable from selected schemes of wells had also been determined. This body of knowledge has provided the information needed by State officials, and others, to understand the quantitative importance of ground-water resources, the vulnerability major aquifers to contamination, and the intimate interrelationship of ground-water reservoirs and the streams that flow over them.

VERMONT

by Arthur L. Hodges

The Cooperative Program between the USGS and the State of Vermont consisted primarily of the collection of continuous and peak-flow surface-water records. As there was no permanent office in the State, these measurements were made by personnel from the Central New England District Office in Boston. A small number of ground-water-level measurements and water-quality analyses were made in the State by the New York District in Albany.

The Vermont legislature, during the 1964–65 session, authorized the establishment of a Federal-State ground-water program to be funded through the Vermont Department of Water Resources (DWR). This legislative bill also required that DWR establish a permit and completion report system for all water wells drilled in the State. Arthur L. Hodges was assigned to the program, which was to be a 3-year reconnaissance of the ground-water potential in Vermont. An office was established (one desk in the offices of DWR), and David Butterfield, a geologist and full-time DWR employee, was assigned to assist in the project.

The State was divided into 11 report areas, each including one or more rivers. Mapping was done by windshield survey, noting the location of basic geomorphic features and composition of materials in natural or manmade exposures. Any available subsurface information was incorporated to produce maps of the basins, showing areas favorable for producing large, moderate, or small quantities of water from wells.

The Federal-State ground-water program was renewed in 1968 and was directed toward refining the geohydrology of rapidly growing areas of the State. The Barre-Montpelier area and the White River Junction area were the first two population centers selected for study. Minimal Federal funding during 1968–70 precluded the test drilling needed to evaluate the deep alluvial aquifers of these areas. A grant was obtained in 1970 from the U.S. Department of Agriculture, Farmers Home Administration, specifically for the purpose of subsurface exploration in the two project areas. Reports on the results of the test drilling were prepared in 1972 as required by the terms of the grant. These reports were published by the State as "Ground Water Availability in the Barre-Montpelier Area" and "Ground Water Availability in the White River Junction Area." Final reports on the two areas were published by the State in 1976.

James W. Ashley, also a geologist and full-time State employee, was added to the Federal-State program in 1973 when work began on a ground-water-resources study of the upper Winooski River Basin. This basin to the east of Montpelier and to the north of Barre was expected to be the future suburban growth area for central Vermont.

The year 1975 saw the Vermont ground-water program moving forward with two reports ready for publication and one study ready to enter the report preparation phase. It also saw a change in leadership when Arthur Hodges was transferred to Delaware, and Richard E. Willey from the Central New England District Office in Boston was named Hydrologist-in-Charge of the Vermont office.

By the end of this reporting period, 16 ground-water reports had been published through the Cooperative Program, and three were published by Federal ground-water projects, including USGS Hydrologic Atlas HA–249.

Anecdotes from the Vermont Experience

Shortly after Arthur Hodges established the Field Office in Vermont, the Vermont Commissioner of Water Resources, Reinhold Thieme, called a meeting of Vermont well drillers so that the benefits and objectives of the new ground-water study could be explained to them. Unfortunately, the only thing on their minds was the new law requiring them to obtain permits and submit completion reports for every well they drilled. Vermont drillers are a rather free-spirited group and were not about to comply without much kicking and screaming. Also, they were totally convinced that the Federal hydrologist sitting at the head of the table was personally responsible for their misfortune.

The Commissioner introduced Hodges, but before he could stand up, a driller jumped up and said "You're the one responsible for this *#%%#* new law! It was all downhill from there as the others joined in. Just before they pulled out the lynch rope, Ed Hartly, president of the New England Water Well Association, stood up (Ed is just shy of 7 feet tall) and told the group to simmer down. He then told the drillers that the NEWWA fully backed the new permit and report requirements, and that if they thought about it they would realize that it and the new ground-water program would benefit them in the long run.

Dead silence—then some mumbling—then all the drillers got up and walked out. Hodges never did get a chance to give his presentation on the Federal-State program. In time, the drillers did open up and eventually provided the program with vast amounts of most valuable data.

The Vermont Geological Society, which is now in its 26th year, began in the office of the cooperative ground-water program in the early 1970's. Hodges and Dave Butterfield invited other geologists from State agencies to a brown-bag lunch to trade information on projects and other items of mutual interest. Word of the meetings spread to the academic community, and attendance soon outgrew Hodges' office space. Meetings were then held in available State space or at nearby colleges. Plans to formalize the group started in 1974, and in 1975 Hodges was elected first president of the new Vermont Geological Society.

NEW JERSEY

by George M. Farlekas

In New Jersey, organization as a Water-Resources Division District occurred in August 1967. Prior to 1967, water-resources investigations were conducted separately by the Ground Water (GW) and Surface Water (SW) Branches. A Quality of Water (QW) Branch field office was operational in 1966. District headquarters for all water-resources investigations in New Jersey during the period 1966–79 was located at the Federal Building on West State Street in Trenton.

Organization and Personnel

An Administrative Services Section was set up in 1967 as part of the reorganization to the Division status. Evelyn Lehman was designated as head of the Administrative Services Section. She provided the same service for each of the three Branch offices. Evelyn retired in 1978 and was replaced by Anthony Cannarsa in March 1979.

John E. McCall served as District Engineer (SW) until he was named the first District Chief in 1967. He transferred to the Washington District in 1975. Harold Meisler was named the District Chief in 1975 and served in that capacity until spring of 1979 when he became Project Chief of the Northern Atlantic Coastal Plain Regional Aquifer-System Analysis. Donald E. Vaupel became the District Chief in September 1979.

The organizational structure of the Surface Water and Ground Water Branch offices in 1966 was: **Surface Water**, District Engineer, John E. McCall; Assistant District Engineer, Thomas (Tom) J. Buchanan; Special Studies Section Chief, Alexander (Al) Lendo; and Basic Records Section Chief, Arthur (Art) A. Vickers; **Ground Water**, District Geologist, Allen Sinnott; and Assistant District Geologist, Seymour (Sy) Subitzky. Peter (Pete) J. Anderson was the Chemist-in-Charge of the **Quality of Water** Branch Field Office under the direction of Norman Beamer, District Chemist, Philadelphia.

Allen Sinnott served as the District Geologist (GW) until the District was reorganized in 1967, at which time he was reassigned to the Office of the Regional Hydrologist, working from Trenton, N.J. Peter Anderson served as the Chemist-in-Charge (QW) until the District was reorganized in 1967, at which time he became the Chief of the Water Quality and Technical Services Section of the reorganized District.

The organizational structure of the New Jersey District in 1967 consisted of a District Chief (John E. McCall), two Assistant District Chiefs (Tom Buchanan and Harold Meisler), and four sections. Buchanan served as Assistant District Chief until 1968 and was replaced by John J. Murphy in 1968. Murphy transferred out of the District in 1977. From 1975, when Meisler became District Chief, only one Assistant District Chief served to the end of the report period. Steven M. Hindall was the Assistant District Chief from 1978 to 1979. The four sections and their Chiefs in 1967 were as follows: Basic Records - Art Vickers; Water Quality and Technical Services - Pete Anderson; Areal Studies - Sy Subitzky; and Hydrologic Studies - Al Lendo.

Vickers was Chief of the Basic Records Section and the renamed (in 1974) section, Hydrologic Records Section, until 1979, when he was named Chief of the newly established Publications Unit. Anderson was the Chief of the Water Quality and Technical Services Section until 1973, at which time he worked part time while pursuing his Ph.D. He left the U.S. Geological Survey in 1973. James C. Schornick, Jr., became Acting Chief of the Water Quality and Technical Services Section in 1973 (renamed Water Quality Section) and Chief of the Section until 1978 when he transferred to the Branch of Quality of Water in Reston, Va. The Water Quality Section was abolished in 1979. Sy Subitzky was Chief of the Areal Studies Section until 1968, when he was assigned to the Office of Radiohydrology, working from Trenton. William Kam replaced Sy Subitzky as the Chief of the Areal Studies Section, which was renamed the Hydrogeologic Studies Section in 1974, and remained Chief through the period of this report. Al Lendo was Chief of the Hydrologic Studies Section until 1971, when he was assigned as a staff hydrologist in the Office of the District Chief. Everett G. Miller became Chief of the Hydrologic Studies Section in 1971 and the renamed (in 1974) Streamflow Studies Section until 1975, when he retired. In 1975, Stephen J. Stankowski became Chief of the Streamflow Studies Section until 1976, when he became ill and later (spring 1977) passed away at a young age. The Streamflow Studies Section was abolished in 1979. A Computer Applications and Graphics Unit, headed by Michael G. McDonald, was established in 1974 and abolished in 1976. The District, in late January 1979, consisted of two sections (Hydrologic Records Section and Hydrologic Studies Section), and two units: the Automatic Data Processing Unit (established in 1978) headed by Jan J. Ryan, and the Publications Unit (established in 1979) headed by Art Vickers.

The GW project activities for this period of history from 1966 through this period covered by this report were conducted by a number of individuals: Edward C. Rhodehamel, John Vecchioli, Harold E. Gill, Louis D. Carswell, James C. Rooney, William D. (Dave) Nichols, Bronius (Bruno) Nemickas, and George M. Farlekas (starting in 1968). With the exception of George M. Farlekas, all of these individuals left the New Jersey District prior to the end of the period covered by this report. Rhodehamel transferred to the Geologic Division (1970), Vecchioli transferred to Mineola, N.Y., Subdistrict Office, (1968), and Nemickas (1974) transferred to the New York District. Carswell (1972) transferred to the Pennsylvania District, while Nichols (1973) was selected for 1-year graduate studies program at Berkeley, Calif., with the U.S. Geological Survey and then transferred to the California District. Rooney took early retirement in 1977. Individuals in ground-water activities after 1966 include James E. Luzier (1972–78), Michael G. McDonald (1972–76), Arlan W. Harbaugh (1977–79), and Robert S. Poggioli (1977–79). Ground-water project support was provided by Richard L. Walker (1974–79), Richard E. Hodges (1969–74), and Frederick L. Schaefer (1976–78).

The SW project activities from 1966 to the end of the period covered by this report were provided by a few individuals. Lendo and Miller were involved with SW project activities starting in 1966. Lendo and Miller retired in 1971 and 1975, respectively. Individuals in SW project activities after 1966 include Stephen J. Stankowski (1966–76), Stanley L. Laskowski (1968–72), Robert D. Schopp (1973–79), Herbert J. Freiberger (1966–70), Anthony J. Velnich (1969–79), Brian D. Gillespie (1976–79), Thomas G. Ross (1966–69), and George M. Farlekas (1966–68).

The QW project activities from 1966 to the end of the period covered by this history included Peter W. Anderson (1966—73), Lawrence J. Mansue (1966–71), James G. Schornick, Jr. (1973–78), Owen O. Williams (1966–70), John S. Zogorski (1966–74), David K. Fishel (1976–79), and Michael C. Yurewicz (1972–78).

The SW and GW data collection and processing operations were combined in 1967 under the Basic Records Section, later renamed Hydrologic Records Section. In addition to the Chief, others in the operations included Edward W. Moshinsky, Edward A. Pustay, James Nakao, Richard S. Cole, Eugene Dorr, Richard L. Walker, Frederick L. Schaefer, John T. Fisher, and Guerino (Woody) L. Centinaro.

Because of space limitations, it is not possible to mention the many other employees through whose efforts the District functioned successfully.

COOPERATING AGENCIES

From 1966 to 1969, the New Jersey Department of Conservation and Economic Development, Division of Water Policy and Supply, was the prime State cooperator. In 1970, the name was changed to the New Jersey Department of Environmental Protection, Division of Water Resources. Most of the SW, GW, and QW project activities were supported by the New Jersey Department of Environmental Protection, Division of Water Resources, as were the SW, GW, and QW data-collection and processing operations. Other cooperators for data collection and processing were New Jersey Department of Environmental Protection, Division of Fish, Game, and Shell Fisheries; New Jersey Department of Agriculture, Soil Conservation Committee; North Jersey District Water Supply Commission; Passaic Valley Water Commission; counties of Bergen, Camden, Mercer, Morris, and Somerset; townships of Cranford and West Windsor; U.S. Army Corps of Engineers, New York and Philadelphia Districts; U.S. Environmental Protection Agency; New Jersey Water Resources Research Institute; Federal Power Commission; City of Philadelphia; and the Delaware River Basin Commission.

The New Jersey Department of Environmental Protection, Division of Water Resources, was the primary State agency on policy and regulation of water resources. It was responsible for permitting water withdrawals from ground and surface sources, regulating the development of flood plains, and supporting data-collection activities of ground and surface water, which included an extensive network of stream-gaging stations, low-flow partial-record stations, crest-stage gages, tidal-gaging stations, ground-water observation wells, ground-water-quality and surface-water-quality sampling networks, and a saltwater intrusion network for the major aquifers of the New Jersey Coastal Plain.

In addition to the data-collection efforts, the New Jersey Department of Environmental Protection, Division of Water Resources, was the primary support for ground-water, surface-water, and quality-of-water interpretive studies. Other cooperators for interpretive studies included the U.S. Army Corps of Engineers, New York and Philadelphia Districts; Delaware River Basin Commission; Delaware Valley Regional Planning Commission; New Jersey Department of Environmental Protection, Division of Fish, Game, and Shell Fisheries; Rutgers University; Federal Water Quality Administration (later the U.S. Environmental

Protection Agency, Region II); Federal Insurance Administration of the U.S. Department of Housing and Urban Development (later known as Federal Emergency Management Agency); National Park Service; and West Windsor Township.

Federal support for the District operations came from the U.S. Geological Survey, the U.S. Army Corps of Engineers; the Federal Water Quality Administration (later the U.S.Environmental Protection Agency [USEPA]), the Federal Insurance Administration of the U.S. Department of Housing and Urban Development (later the Federal Emergency Management Agency [FEMA]); National Park Service; and the U.S. Weather Bureau (later the National Weather Service). In addition to the matching money supplied by State and local agencies, the Geological Survey provided full support for selected streamflow stations and ground-water observation wells, for an in-depth analysis of the stream-gaging program, and for outlining flood-prone areas on 7.5-minute topographic maps as part of a nationwide Federal program for managing flood losses. The greatest support from other Federal agencies came from the Corps of Engineers. Not only did the Corps support selective streamflow stations, they also provided funds for several interpretive ground-water studies. FEMA provided support for mapping flood-prone areas on 7.5-minute topographic maps and preparation of flood-insurance studies for more than 15 communities in the State. The USEPA provided some support on an interpretive surface-water/water-quality study. The National Weather Service provided support in the form of service or use of their facilities.

Summary of Program

The District's program during the period was a balance between GW, SW, and a smaller effort in QW activities. The GW program was somewhat larger than the SW program, with much of the effort in areal-type studies for many of New Jersey's counties, funded mainly by the 1958 Water Supply Law. Studies related to geology and GW resources of specific areas were the principal element in the GW operations. In addition, a water-level monitoring program for network and project wells, as well as saltwater intrusion monitoring for the New Jersey Coastal Plain aquifers, were part of the GW program. During the period, well-construction information for project and network wells were incorporated into the Ground Water Site Inventory System (GWSI), a ground-water storage and retrieval system that is part of the Survey's National Water Data Storage and Retrieval System (WATSTORE).

Much of the District's SW program was devoted to the collection, processing, and publication of streamflow records. The conversion from analog to digital records was completed during the period, and the computer processing of SW records became a standard operating procedure. A number of gaging stations were equipped with devices that could be interrogated by telephone to supply real-time data. By the end of the period, all the water records collected were being stored in WATSTORE. Additional SW discipline efforts included flood studies and low-flow studies. QW (mainly surface water) projects and data-collection efforts were limited during the early part of the period but increased. Types of QW (surface water) studies included nitrification, time of travel, water temperature, and nonpoint pollution.

Surface-Water Records

Records of daily stream stage and discharge were collected at 78 stations in 1965 and at 94 stations in 1978. Crest-stage (high-flow) and low-flow partial records were obtained at 122 sites in 1965 and 83 sites in 1978. Tidal crest stages were collected at 15 sites in 1965 and 22 sites in 1978. A hydrologic benchmark station was established on McDonalds Branch in Lebanon State Forest in the early 1960's as part of a nationwide network to monitor hydrologic response to purely natural forces. The site is located in the Pine Barrens. Two map publications, "Water Resources Investigations in New Jersey, 1972 and 1977," provide information on publications, location of hydrologic-data station activities and investigations in progress, and a list of station activities. Listed for 1972 for surface-water stations, continuous records, were 95 sites with discharge and stage data and 7 sites with stage data. The number of partial-record stations listed for 1972 for peak flow, low flow, and peak and low flow were 41, 78, and 29, respectively. Listed for 1977 were 86 sites with discharge and stage data and 10 sites with stage data. The number of partial-record stations for 1977 for crest-stage, low flow, peak and low flow, and tidal crest-stage were 83, 63, 5, and 16, respectively.

Ground-Water Records

"Water Resources Investigations in New Jersey, 1972," a map publication, lists continuous records of water levels for 112 wells. The same report lists 1 well with monthly water-level measurements and 82 wells with quarterly water-level measurements. "Water Resources Investigations in New Jersey, 1977" lists the number of network observation wells as 182 wells and the number of project wells as 150 wells. The number of continuous records of water levels of network wells for 1977 is 28 wells. The number of water-level extremes (maximum-minimum) network recorder sites for 1977 is 52 wells. The number of network manual wells for 1977 is 102 wells. Project wells for 1977 included sites with continuous and extremes recorders and sites with manual measurement wells.

Water-Quality Records

"Water Resources Investigations in New Jersey, 1972" lists 52 sites where water-quality data were obtained at surface-water stations and an additional 47 sites where discharge and stage were not collected. The type of data collected and frequency of sampling were: chemical quality, continuously 22, daily 1, monthly 45, partial record 27; temperature, continuously 22, daily 4; sediment (suspended), daily 2, storms, 23; pesticides, annual 8; radiochemical, annual, 8; trace-metal ions, annual, 26. "Water Resources Investigations in New Jersey, 1977" lists 43 sites where water-quality data were obtained at surface-water sites and an additional 74 sites where discharge and stage were not collected. The 1977 map publication lists the following water-quality parameters: water temperature, specific conductance, sediment data, inorganic constituents, organic constituents, pesticides, radiochemical data, and biological data.

"Water Resources Investigations in New Jersey, 1972" lists 50 water-level network observation well sites where water-quality data were obtained and an additional 250 well sites where data were obtained and water levels were not obtained. The frequency of sampling for water-quality data was semiannual at 250 well sites and annual at 50 well sites. The District data base for water year 1977 indicated water-quality data for 217 well sites were collected. Of the 217 well sites, 211 were sites with water-quality samples for the salt-water-intrusion-monitoring network.

Other Data Activities

New Jersey has experienced flooding in many parts of the State. Urbanization has caused increases in floods, especially in the northeastern part of the State. Extent and frequency of floods, together with flood data, were reported in open-file reports and the Hydrologic Atlas series for the Delaware River in the vicinity of Belvidere, N.J. (1966–67), the Delaware River at Easton, Pa.–Phillipsbug, N.J. (1965, 1967) and the upper Millstone River Basin in the vicinity of Hightstown, N.J. (1969) by Farlekas; the Millstone River and Stony Brook in the vicinity of Princeton, N.J. (1966–67) by Bettendorf; the Beden Brook Basin in Somerset and Mercer Counties, N.J. (1969–70) by Ross; and the Crosswicks Creek from New Egypt to Bordentown, N.J. (1971 open-file report), by Freiberger and Ross. Flood-prone area maps were published as open-file reports for the Mullica River in the vicinity of Pleasant Mills, N.J. (1978), and for the Cedar Creek in the vicinity of Lanoka Harbor, N.J. (1978), by Velnich and Schopp. Documentation and analysis of specific flood events in New Jersey were reported by Stankowski in 1972 for the floods of August and September 1971 in New Jersey; by Stankowski and Velnich in 1974 for the flood of August 1973 in New Jersey; by Stankowski, Schopp, and Velnich in 1975 for the flood of July 21, 1975, in Mercer County, New Jersey; and Schopp and Velnich for the flood of November 8–10, 1977, in northeastern and central New Jersey.

Topical and Areal Studies

All three disciplines published reports centered on topical and areal studies. Topical reports related to floods included an analysis of population density as an indirect indicator of urban and suburban land-surface modifications (report by Stankowski, 1972), magnitude and frequency of floods in New Jersey with effects of urban development by Stankowski in 1974, and development of a technique for estimating depth of 100-year floods in New Jersey by Velnich and Laskowski in 1979. Other surface-water reports during the period included documentation and analysis of record low tide (December 31, 1962) on the Delaware River by Lendo in 1966; flow probability of New Jersey streams by Miller in 1966; and selected streamflow data for the Delaware River Basin by Schopp and Gillespie in 1979.

Thirty-one interpretive reports on surface water were published by the New Jersey District as USGS or State publications during the period 1966–79. Nineteen were flood-related reports with 12 flood-inundation reports, while 4 related to specific floods. Other flood-related reports included studies on population density, magnitude and frequency of urban flooding, and estimating the depth of the 100-year flood. Also included were reports on recreation coefficients, drought, record low tide, flow probability, statistical summaries of streamflow records, water resources of a specific area, and remote sensing. Authors of two or more reports/papers for the period are G.M. Farlekas, S.J. Stankowski, R.D. Schopp, A.J. Velnich (four), E.G. Miller, T.G. Ross, J.A. Bettendorf, and S.L. Laskowski.

QW reports and papers that were published not only included surface-water quality but also ground-water quality. Time-of-travel measurements on the Passaic and Pompton Rivers were reported by Horwitz and Anderson (1966). Buchanan (1968) was the author of a paper on computation of reaeration coefficients for a river system in northeastern New Jersey. Zogorski, Anderson, and Williams (1973) prepared an open-file report on velocity and depth measurements for use in determination of reaeration coefficients. Temperature was a physical parameter reported on by Williams (1968) on the reservoir effect of downstream water temperatures in the upper Delaware River Basin and by Williams (1971) on the analysis of stream-temperature variations in the upper Delaware River Basin. Temperature of natural waters in New Jersey was reported on by McDonald and McCall (1974) and included SW as well as GW temperatures. Four reports about sediment were published during the period. Anderson and McCall (1968) described the effect of urban development on sediment yield. Mansue (1972) provided information on suspended-sediment yields of the New Jersey Coastal Plain streams draining into the Delaware estuary, and Mansue and Commings (1974) provided an analysis of sediment transport by streams draining into the Delaware estuary. Mansue and Anderson (1974) reported on effects of land-use retention practices on sediment yields in the Stony Brook Basin. Drought and surface-water quality concerns were addressed in three reports: Anderson and McCall (1968) reported on effects of drought on stream quality in New Jersey; Anderson and Faust (1972) reported on impacts of drought on quality in a New Jersey water-supply system; and Anderson, Faust, and McCall (1972) reported on impacts of drought on New Jersey's water resources. The characteristics of stream quality were described in three reports. Anderson and George (1966) prepared Water-Supply Paper 1819–G on water characteristics of New Jersey streams. Anderson and Faust (1973) reported on the characteristics of water quality and streamflow for the Passaic River Basin upstream from Little Falls, N.J., and the same authors (1974) reported on the water quality and streamflow characteristics for the Raritan River Basin. Two papers on phenolic content of surface water were published in 1968 (Faust and Anderson) and in 1971 (Faust, Stutz, Aly, and Anderson). Schornick (1978) prepared a report on the nitrification in four acidic streams in southern New Jersey. Ground-water quality was presented in interpretive reports on ground water and are given below.

There were 15 interpretive reports or papers on water quality prepared by New Jersey District personnel and published as USGS or State reports or papers during the period 1966–1979. There were seven additional papers published in a non-USGS or non-State publication during the same period. Of the 22 reports/papers on water quality, issues discussed more frequently were related to sediment (4), drought (3), phenols (3), stream-quality characteristics (3), and temperature (3). Authors of two or more reports/papers for the period: P.W. Anderson (14), L.J. Mansue (3), J.E. McCall (3), J.J. Murphy (2), and O.O. Williams (2).

GW addressed topical and areal studies, drilling programs, modeling of regional aquifer units, and some ground-water-quality reports. Areal studies included information on geology and ground water, and many included information on water resources, surface-water/base-flow conditions, and ground-water quality. Some of the publications were prepared by individuals who left the New Jersey District before 1966. Many of the areal studies were limited to individual counties, while some were of drainage basins. The 11 county reports given by publication date were: 1968, Atlantic by Clark, Meisler, Rhodehamel, and Gill; Burlington by Rush; Essex by Nichols; and Monmouth by Jablonski: 1969, Gloucester by Hardt and Hilton; Ocean by H.R. Anderson and Appel; and Salem by Rosenau, Lang, Hilton, and Rooney; 1971, Cumberland by Rooney; 1976, Camden by Farlekas, Nemickas, and Gill; Passaic by Carswell and Rooney; and Union by Nemickas. The areal study of the

Rahway area by H.R. Anderson was published in 1968. The drainage basin ground-water studies included the Ramapo River Basin (1973) by Vecchioli and Miller, the Hackensack River Basin (1976) by Carswell, and the Wharton Tract and Mullica River Basin (1973) by Rhodehamel. Rhodehamel also was the author of hydrologic analysis of the New Jersey Pine Barrens (1970). Two USGS Miscellaneous Investigations Map reports were prepared from the county reports; Nichols (1968) prepared a report on the bedrock topography of eastern Morris and western Essex Counties, and Nemickas (1974) prepared a report on the bedrock topography and thickness of Pleistocene deposits in Union County and adjacent areas. Reports produced during the period as a result of drilling programs include the results of the drought-disaster test-drilling program near Morristown (1966) by Vecchioli and Nichols; the results of the second phase of the drought-disaster test-drilling program near Morristown (1967) by Vecchioli, Nichols, and Nemickas; and the test-drilling program to establish observation wells in Cumberland County (1974) by Nemickas. The latter drilling program led to a paper on the stratigraphic and hydrologic relationship of the Piney Point aquifer and the Alloway Clay Member of the Kirkwood Formation in New Jersey (1976) by Nemickas and Carswell.

Four ground-water-flow model reports were published during 1966–79. Meisler (1976) prepared the report on the computer simulation model of the Pleistocene valley-fill aquifer in southwestern Essex and southeastern Morris Counties. The framework data used in the model was, in part, collected for the drought-disaster test-drilling program. Nemickas (1976) developed the report on the geohydrology and digital-simulation model of the Wenonah-Mount Laurel aquifer in the New Jersey Coastal Plain. Nichols prepared two reports on the Englishtown Formation of the New Jersey Coastal Plain: one on the geohydrology of the Englishtown Formation (1977) and one on the digital-simulation model of the Englishtown aquifer (1977). Gill and Farlekas (1976) prepared a Hydrologic Investigations Map report on the geohydrology of the Potomac-Raritan-Magothy (PRM) aquifer system of the New Jersey Coastal Plain. Information from the report was used, in part, by Farlekas (1979) to develop the report on the geohydrology and digital-simulation model of the Farrington aquifer (part of the PRM aquifer system) of the northern part of the New Jersey Coastal Plain aquifer system. Three papers and two reports were prepared during the period that were mainly ground-water-quality efforts. Langmuir produced two USGS Professional Paper articles, one on the geochemistry of iron in coastal-plain ground water of the Camden area (1969) and the other on the Gibbs free energies for ferric oxyhydroxides in order to explain the occurrence of iron in the water of the PRM aquifer system (1969). Langmuir also is the author of a State report on iron in ground waters of the PRM aquifer system in Camden and Burlington Counties. Kam (1978) prepared an open-file report on the effect of controlled land application of sludge on ground-water quality of the surficial aquifer at sites in Ocean County. Winograd and Farlekas (1974) were authors of a paper on the problems in carbon-14 dating of water from aquifers of deltaic origin—an example from the PRM of the New Jersey Coastal Plain, prepared for the international publication "Isotope Techniques in Ground Water Hydrology 1974" by the International Atomic Energy Agency (Vienna, Austria). A paper on the occurrence and movement of ground water in the Brunswick Shale near Trenton by Vecchioli, Carswell, and Kasabach (1969) was published in the USGS Professional Paper 650–B.

There were 33 interpretive reports about ground water prepared by New Jersey District personnel and published as USGS or State publications. In addition there were two papers prepared by District personnel that were published in a non-USGS or non-State publication during the period. Of the 35 reports/papers on ground-water issues, 19 were areal studies reports. Five of the 35 reports/papers were predominantly ground-water-quality reports or papers. There were four ground-water-flow model reports. In addition, there were three test drilling reports. Authors of two or more reports/papers for the period are B. Nemickas, W.D. Nichols, L.D. Carswell, G.M. Farlekas, J. Vecchioli, H.E. Gill, D. Langmuir, H. Meisler, E.C. Rhodehamel, J.G. Rooney, H.R. Anderson, and G.S. Hilton.

NEW YORK

by Robert Dingman

General History

The cooperative cost-sharing program between the Federal Government and State and local agencies has long been one of the strongest parts of the Water Resources Division programs. The history of the WRD program in New York during the early part of the period 1966–79 graphically illustrates the vulnerability of these programs to shifts in State budgets. In 1966, the Division program in New York under District Chief Ralph Heath was a strong, well-balanced program. Ken Darmer was Ralph's assistant, and they received excellent support from a competent, experienced staff. The program in upstate New York was strongest in surface-water data collection and in surface-water hydrologic investigations. The Long Island Subdistrict Office, under the guidance of Bruce Foxworthy, was in the process of developing a strong program in ground-water hydrology.

Ralph Heath was transferred at his request in April 1967 to North Carolina to be District Chief. Gerald Parker was transferred from Florida in April 1967 to become District Chief in New York replacing Ralph Heath. Under the guidance of Parker, the program of cooperative studies in upstate New York grew rapidly during 1967 and 1968. By 1969, there had been an approximate increase of 30 percent in the District program over the 1966 level. Interpretive studies in both surface water and ground water had increased. Rufus Musgrove had replaced Kenneth Darmer as Assistant District Chief, and Darmer had moved over to take charge of the enlarged Hydrologic Studies Section. The Long Island program continued to develop under Bruce Foxworthy. Several large interpretive programs were begun on Long Island during 1967–68, including the Bay Park project, which was designed to study the feasibility of using tertiary-treated sewage to recharge the Long Island aquifers. Early in 1969, Foxworthy left Long Island to accept the position of District Chief in Seattle, Wash. Gerald Parker elected to retire at the end of February 1969, and Robert Dingman, District Chief in Kansas, was selected to replace him.

Dingman met with George Ferguson, Regional Hydrologist in Albany, N.Y., during April 1969 to meet the District staff and to be introduced to the State cooperators. The newly appointed District Chief made the customary get-acquainted talk to the staff and commented that the program was going very well and that very few changes in staff or program would be made in the near future. At the meeting with the major cooperator, a half-million-dollar cut in the cooperative offering for the State fiscal year was announced. This was the result of a reduction in the New York State budget and not because of any dissatisfaction with the cooperative program. The result was a million-dollar reduction in the District program. In 1969 dollars, this amounted to the salaries and support for approximately 30 staff members. The resulting financial problem was complicated by the 3 months offset between State and Federal fiscal years.

After careful analysis, it was determined that in order to keep the District program operational, it would be necessary to immediately place a number of the staff on details out of the District, and that by June 30, the staff would have to be reduced by 30 positions. Many of the programs and projects were either terminated or postponed. Cooperation from the Division, Region, and District offices was tremendous. The objective was to avoid a Reduction-in-Force, and that objective was met. A few of the older staff who were eligible chose to retire; several others were able to transfer to State agencies, and several chose to separate from the Survey rather than accept the transfers that were offered to them. A number of the staff did accept transfers to other District Offices or to the Division staff. Rufus Musgrove, the Assistant District Chief, performed invaluable service in coordinating the downsizing of the staff. As a part of the exodus, Rufus transferred to the Office of Water Data Coordination at the National Headquarters. In the end, the objective of a reduction of approximately 30 staff members was reached by June 30, 1969. No one was reduced in grade, and no one was separated involuntarily.

Unfortunately, many excellent, young, well-trained hydrologists and technicians that had been recruited during the previous few years were lost from the District staff as a part of the downsizing process. The process of rebuilding the program and staff began almost immediately. Cooperative programs were initiated or increased with State agencies or with local governments. The program on Long Island, under the direction of Philip Cohen as Hydrologist-in-Charge of the Subdistrict Office in Mineola, developed rapidly. An analog model of the Long Island aquifer system was completed and was very well received by the cooperators. An increased emphasis was placed on the processing of reports and the reduction of the reports backlog. The vacant Assistant District Chief position in Albany was filled by the transfer of Ed Harris into the District. This appointment also strengthened the surface-water part of the District program.

Cooperating Agencies

During the period 1966 to 1969, a large part of the surface-water data collection in upstate New York, as well as the interpretive studies in both surface and ground water, were concentrated in a program with one cooperator, the Department of Environmental Conservation. After the program reduction of 1969, the counties and cities that were the end users of much of the surface-water data were encouraged to develop their own cooperative programs with the Water Resources Division. Among the counties that entered into agreements or continued existing agreements with the WRD were: Cortland, Monroe, Nassau, Onondaga, Putnam, Rockland, Suffolk, Ulster, and Westchester Counties. Cooperative programs were also developed and expanded with many of the other State agencies, including the Department of Health, Department of Transportation, State Park and Recreation Commission, Department of Education, State Geological Survey, and the Power Authority of New York. Agreements were continued or developed with a number of towns and cities including New York City, Albany, Auburn, Rochester, Brighton, Clarkston, Fishkill, Warwick, Waterford, and Nyack. Cooperative data programs also were conducted with the Hudson River-Black River Regulating District, the Irondequoit Bay Pure Waters District, and the Oswegatchie River-Cranberry Reservoir Commission.

Federal programs were conducted with the U.S. Army Corps of Engineers, Departments of Agriculture, Housing and Urban Development, the Interior (Office of the Secretary), Transportation, the Energy Research and Development Administration, the U.S. Environmental Protection Agency, the Federal Energy Regulatory Commission, and the New England River Basins Commissions.

Organization and Personnel

The New York District was converted to a consolidated Division District in 1965. Ralph Heath was the District Chief from 1965 to 1967, Gerald Parker from 1967 to his retirement in 1969, and Robert Dingman from 1969 until his transfer in 1978 to become Regional Hydrologist for the Southeastern Region. Larry Martens was selected as District Chief in September 1978. Kenneth Darmer was Assistant District Chief from 1965 until 1967, Rufus Musgrove from 1967 to 1969, Ed Harris from 1969 to 1971, William Forest from 1972 to 1973, Walter Scott from 1974 to 1975, and William Gannon from 1975 through the end of 1979 and beyond.

The District office was located in Albany in the Post Office Building throughout the period 1966 to 1979. The Subdistrict Office on Long Island was located in Mineola and then moved to Syosset in 1978. Bruce Foxworthy was Hydrologist-in-Charge 1966 to 1969; Philip Cohen, who later became Chief Hydrologist, from 1969 to 1972, when he was transferred to the Director's Office; Edward Bradley from 1972 to 1977; and Erwin Kantrowitz from 1977 to 1979.

Subdistrict Offices, mainly for data collection, were maintained at Albany, Ithaca, and at Middletown, and a Field Headquarters was established at Potsdam to service the gaging stations in northern New York.

There were approximately 99 total staff attached to the New York District in 1966. By the beginning of 1969, the staff had grown with the increased program until there were 124 staff members. As a result of the reduction in the cooperative program with the State, the staff was reduced to 99 (including part time, WAE, and staff on extended leave without pay), the same level that it was in 1966. After 1969, the program slowly but steadily increased, and the staff to service the program increased accordingly, reaching a total of 152 temporary and full-time staff in 1978.

Program

The data program, based as it is on the need for long-term records of surface flow and ground-water levels, suffered less from the decrease in the Cooperative Program in 1969 than did the interpretive studies in upstate New York. Although there was some decline in the number of gaging stations supported by the State, the support of most of the stations was taken over by other State and local agencies. The same was true of the ground-water-monitoring program. The data-collection program on Long Island was mostly financed by local counties and placed strong emphasis on ground-water levels. An attempt was made to close out the projects that were terminated in 1969 by writing progress reports or by compiling the data and information that had been collected. Unfortunately, in some cases, the investigators were transferred and no one was left to compile or interpret the information.

The direction of the interpretive studies in upstate New York changed after 1969 to place much more emphasis on problems associated with the environment and water-quality problems. Many of the new projects included important elements of applied research. Space permits the mentioning of only a few of the projects: Ted Elke studied the symbiotic relations between certain bacteria and blue-green algae, and Allan Randall studied the movement of gases and leachate from the Cairo landfill. Randall and David Prudic investigated the movement of radioactive leachate from low-level nuclear waste deposits at West Valley, N.Y. John Turk studied the movement of PCB's in the sediments of the Hudson River. The potential effects of the disposal of acid-brine into a dolomite aquifer at 4,000 feet below the surface was studied by Roger Waller, John Turk, and Robert Dingman. The geochemical effects of this injection were studied in the laboratory by Steve Ragone, Francis Riley, and Robert Dingman. One of the first studies of the effect of acid rain on lakes was conducted by John Turk and Roy Schroeder.

Ground water is the source of water supply for the central and eastern parts of Long Island; therefore, the hydrologic program on Long Island tended to concentrate on the recharge and movement of the ground water. Public interest in the water supply was intense, and it was not unusual for the findings of water-resources studies to be the subject of headlines in the local newspapers. Recharge of the aquifers—natural, artificial, or induced—was the subject of many of the WRD investigations. The Bay Park series of studies was concentrated on the effect of using tertiary-treated sewage as a fluid to inject through recharge wells located in the Long Island aquifers. Other recharge studies included Robert Prill's study of surface recharge of tertiary-treated sewage through a sand deposit, and in 1978 and 1979, the commencement of a full-scale attempt to recharge tertiary-treated sewage along the surface-water divide.

During the 1970's, increased attention was paid to the timely completion of reports developed from the data-collection program and from the interpretive projects. A system of reports tracking was introduced that reduced delays in processing of reports through the District review system. Over 460 reports ranging from Professional Papers and Water-Supply Papers to data reports, maps, and open-file reports were produced by the staff of the New York District during the period from 1966 to 1979.

For a number of years, a chemistry laboratory had been operated in the Albany office. The laboratory analyzed the water samples from the New York District and, on occasion, from several of the surrounding Districts. The laboratory established its own charges based on its costs. The volume of samples was relatively small, and the costs were quite high. The Chemist-in-Charge of the laboratory, Felix Pauszek, was one of those transferred out of the District in 1969. His assistant, Al Mattingly, was placed in charge. The challenge was given to him to increase productivity and reduce costs to be in line with other laboratories and in particular to the level of charges of the fledgling Division laboratory. A through-flow system was developed so that the raw samples came in one door and moved on carts through the laboratory as they were processed. The chemists and technicians were assigned to perform analyses for specific constituents in the hope of increasing efficiency and accuracy. Charles Morgan was brought on detail from Kansas to develop water-quality computer programs to assist in the processing of chemical data and to improve the reporting of chemical analyses. He also developed a checking program to assist in detecting errors in analyses. The laboratory continued to improve in efficiency and productivity over a period of several years. In 1974, the laboratory was incorporated into the Central Laboratories System, and Bernard Malo was transferred from Pennsylvania to Albany to take charge of the coordination of the laboratory with the other laboratories in the system.

OHIO

by Darwin Knochenmus

At the beginning of the Hendricks/Cragwall era in 1966, Ohio offices already had been organized as a WRD District. The reorganization officially occurred in July 1965, but physical integration of the Branches did not occur until August 1967. Prior to that date, the District Chief and ground-water staff were located on Marconi Boulevard, the water-quality staff and the laboratory were located on Main Street, and the surface-water staff on Hess Street, all in Columbus.

However, all three branches—Surface Water (SW), Ground Water (GW), and Quality of Water (QW)—operated under a single District Chief. By August 1967, the District Office and all personnel were housed in the same facility at 975 West Third Avenue, Columbus, Ohio, and remained there throughout the period.

In addition to the District Office, a Regional water-quality and sediment laboratory and an Instrument Development Laboratory were located in the same facility. The water-quality laboratory serviced the States of Michigan, Illinois, Indiana, Kentucky, West Virginia, and Ohio until 1973, when the Central Laboratories were implemented. The Instrumentation Development Laboratory, under the supervision of the Regional Hydrologist, expanded its function and relocated to Bay St. Louis, Miss., in 1972.

Organization and Personnel

John J. Malloy was the first District Chief of Ohio, and by the late 1970's, he had organized the District into a District Chief's Office, Administrative Services Section, Special Studies Section, Data Section, Laboratory Unit, and Subdistrict Office. He served until December 31, 1973, when he retired from Federal service and was succeeded in June 1974 by James F. Blakey.

The new organization under John Malloy had an Associate District Chief (Charles R. Collier), and two Assistant District Chiefs (Harold P. Brooks and Earl E. Webber). Jack Pickering was the second Associate Chief, succeeding Chuck Collier when Pickering transferred to Ohio in 1965 from Oak Ridge, Tenn. In 1970, Pickering was succeeded by Roger Waller, who remained until he transferred to New York District in 1973.

By 1975, the Associate District Chief position had been abolished, and one Assistant Chief was made responsible for Operations and the other for Programs and Plans. As Assistant District Chiefs, Art Westfall managed the Hydrologic Data Section, and Darwin Knochenmus the Hydrologic Studies Section. Richard O. Hawkinson succeeded Knochenmus, who transferred to California. In 1977, David E. Click was named District Chief, succeeding Jim Blakey, who transferred to the Central Region staff.

Following reorganization of the Division and during this entire report period, Stanley E. Norris served on the District Chief's staff as Ground Water Specialist and senior ground-water consultant to the District. Earl E. Webber, Ronald I. Mayo, and Donald K. Roth, throughout the period of this report and for most of their careers, were active in the SW discipline, conducting investigations of extreme hydrologic conditions.

Ohio was an early player and probably the first in the Nation to operate a network of continuous QW monitoring recorders. This network was operated by the Data Section with Max S. Katzenbach as a key person in developing continuous monitoring techniques and in designing instrumentation. Katzenbach spent most of his career perfecting techniques, procedures, and equipment.

Surface-water data collection and processing operations also were conducted from the New Philadelphia Subdistrict Office. Vincent D. Herreid was Subdistrict Chief until 1974, at which time he was succeeded by Glen D. Francis.

Space constraints preclude mentioning all who were employed in the Ohio District during this time, but the efforts of all contributed to make the District successful.

District Management 1966–1979

District Chiefs	Associate District Chiefs
1. John J. Malloy (1966)	1. Charles R. Collier (1966)
2. James F. Blakey (1974)	2. Ranard J. Pickering (1967)
3. David E. Click (1977)	3. Roger M. Waller (1970)
Assistant District Chiefs	
1. Harold P. Brooks (1966)	1. Earl E. Webber (1966)
2. Arthur O. Westfall (1972)	2. Darwin Knochenmus (1975)
	3. Richard Hawkinson (1977)

Cooperating Agencies

Eight State and local agencies and 10 Federal agencies cooperated at various times with the Ohio District. The prime State cooperator was the Ohio Department of Natural Resources (DNR). Its cooperation was directed mostly toward basic-data programs in four disciplines: surface water, ground water, water quality, and sediment. Cooperation to a lesser degree came from DNR for investigations of ground water as a source of industrial supply.

In addition to USGS funds for collection of basic data, other basic-data programs for the operation of gaging stations, observation wells, water-quality sites, and sediment stations were supported by the Miami Conservancy District, Ohio Environmental Protection Agency, Three Rivers Watershed District, City of Columbus, City of Canton, and the U.S. Army Corps of Engineers. At times, there were five Corps Districts participating in the Ohio basic-data program.

Surface-water investigations were supported by U.S. Department of Housing and Urban Development for flood studies, the Ohio Department of Transportation for flood studies and urban hydrology, and the Ohio Environmental Protection Agency for low-flow investigations.

There was a developing interest at this time in obtaining a greater understanding of ground-water systems and consequent impacts from human activity. The City of Columbus and the Miami Conservancy District cooperated with the District in modeling studies of ground-water systems. The U.S. Agricultural Research Service and the U.S. Geological Survey participated in a research project to investigate the changes to hydrologic systems from surface mining of coal.

Ground-water availability studies were supported by Geauga County and the U.S. Department of Energy. Sediment yield investigations in the Columbus area were done in cooperation with the Ohio Department of Transportation.

Summary of Program

At the beginning of this era, the water-resources program was basically a data program for the collection, processing, and publication of water records. By the end of the 1970's, with Federal, State, and public interest in environmental impacts, the Ohio District had undertaken and conducted many hydrologic investigations.

Also during this period, the mode of collection and processing of hydrologic data changed rapidly. Instruments that continuously sensed and recorded water-quality and water-level information on paper tape for computer processing were used. Ground-water data, including well information, were put in digital format and stored automatically. This huge initial effort and the continual process of storing all water records collected from hydrologic networks provided the State with ready access to a large hydrologic data base called the USGS National Water Data Storage and Retrieval System (WATSTORE).

Selected Projects

Three projects are presented to indicate the District's advance in the 1970's from a basic-data program to one using advanced technology to collect and process data and solve complex problems.

In 1962, the Ohio District was the first in the Nation to install continuous monitors for recording QW data. The first monitor was installed on the Cuyahoga River at Cleveland. By 1966, the District operated 55 installations, 39 of which were 4-parameter monitors measuring temperature, pH, specific conductance, and dissolved oxygen. Twenty-four of these sites were equipped with equipment for transmitting data directly to the District office. This activity of operating a real-time-data network was also a first in the Nation. There were no established operating procedures at this time, and Max Katzenbach and others on the field teams not only developed procedures and techniques but also modified existing equipment and designed new equipment. As a result, the Ohio District became a leader in the continuous monitoring of QW data, acting as consultants to other Districts and interacting with manufacturers on the design of new instruments.

The Ohio District, as a member of a team with the U.S. Agricultural Research Service (ARS), formulated a study in 1975 to investigate the effects on the hydrology and water quality of four watersheds subjected to surface mining. The Survey's responsibilities in the study were to describe the hydrogeology, document the ground-water flow and water-quality characteristics for pre- and post-mining conditions, and develop a ground-water model. This model was coupled to a basin model developed by ARS. John O. Helgesen was the Project Chief.

Another unique project headed by Helgesen was a study to investigate the potential of abandoned underground coal mines as a source of water. There was interest in producing methane from coal gasification, but such a process required large amounts of water. It was suggested that perhaps abandoned coal mines as reservoirs could supply the necessary water. The study was a challenge because non-classical methods were used to deal with the wide variations in transmissivity values and recharge potential as a result of changes made by humans to the geologic framework.

Hydrologic Records

The basic-data program was always important in the Ohio District. Even though in the later years of the period investigations increased in number and importance. Basic-data collection did not decline. The following statistics for the number and type of stations are for 1979:

Surface-water records of daily discharge were collected at 155 sites. Daily stage records were collected at another 15 stations. Records of daily water levels at lakes and reservoirs were collected at 32 sites. Stations for recording peak flows were operated at 58 sites, 30 of which were part of a special project to investigate floodflows from small basins in reclaimed strip-mine or forested areas. Records of low-flow characteristics of Ohio streams also were kept.

Ground-water level records were collected at 40 stations equipped with recorders for providing daily stage. Geophysical and aquifer characteristic data were available for 14 of these stations.

Water-quality samples were collected at 23 surface-water stations. Continuous water-quality monitoring was done at 32 sites.

Sediment concentrations and yield data from Ohio streams were very important to the Ohio Department of Natural Resources and were collected in a statewide network. Daily sediment records were collected at 24 stations and partial records at 6 sites.

Other Activities

The 1970's was a time of rapid increase in the use of digital models for analyzing ground-water systems. Ohio accepted the call, and Richard E. Fidler pioneered the way for using flow models to evaluate stream-aquifer systems. The first modeling project began in 1973 for the Dayton area. Other modeling projects were initiated for the City of Columbus and small basins in the coal regions of Eastern Ohio. Dick was the first Ohio employee to be trained in ground-water modeling, but he was followed by several hydrologists who began their careers working on ground-water modeling projects.

In the latter 1960's, Ohio served as a multi-State District for both QW and sediment activities. At first, Ohio personnel traveled to the surrounding States and collected water samples for analysis at the Columbus laboratory. Later, when States became WRD Districts, they continued to ship their samples to Columbus until the advent of the Central Laboratories System.

The water-quality laboratory also provided analytical services to the Ohio River Sanitation Commission (ORSANCO). ORSANCO was one of the first organizations in the Nation to monitor river quality in a comprehensive manner.

PENNSYLVANIA

By Janice Ward, Lloyd Reed, and David McCartney

INTRODUCTION

The period 1966 to 1979 was a time of major transition for the Water Resources Division (WRD) in Pennsylvania. It included the reorganization from Surface Water, Ground Water, and Water Quality Branches to a District Office with Subdistrict Offices and Field Offices. The period also saw the move of the District Headquarters from Philadelphia to Harrisburg. The number of full-time employees remained essentially unchanged, 78 in 1966 and 90 in 1979, as did the number of full-time surface-water streamflow-gaging stations (about 200 statewide), the number of water-quality stations (about 90), and the number of water-level observation wells (about 65).

ORGANIZATION AND MANAGEMENT

In 1966, activities of the WRD in Pennsylvania were conducted from four offices: surface water, ground water, water quality, and the Delaware River Master. The Surface-Water District Office was in Harrisburg, headed by Robert E. Steacy. Subdistrict Offices were in Philadelphia (Earl L. Smith) and Pittsburgh (Ernest A. Burti). The Ground Water District Office was in Harrisburg and was headed by Joseph E.

Barclay. A Ground-Water Field Headquarters was in Meadville (George R. Schiner). The Water Quality District Office was in Philadelphia and was headed by Norman H. Beamer. This office included a chemical laboratory headed by David McCartney. A Water Quality Subdistrict Office was located in Harrisburg, headed by John R. George, and included a sediment laboratory headed by Allen B. Commings. There was also a Water-Quality Field Office in Glenmoore (John Troxell). The Office of the Delaware River Master was in Milford headed by Robert E. Fish. Two Field Offices were located at University Park (Penn State University), one in the Chemistry Department (Warren W. Miller) and one in the Civil Engineering Department (Sam Shulits).

The first step toward reorganization was completed by 1967 with the promotion of Norman H. Beamer to the position of District Chief. The Surface-Water District Office in Harrisburg was divided into two offices, a District Office headed by Steacy and a Subdistrict Office headed by Leland V. Page. The Philadelphia Surface Water Subdistrict Office was retained and headed by David W. Moody; the Pittsburgh Subdistrict was not directly affected.

Significant changes occurred in 1968 with a move of the Office of the District Chief and the chemical analytical laboratory from Philadelphia to Harrisburg. Also, all Harrisburg operations were centralized in the newly completed Federal Building. The District Office was reorganized into the District Chief's Office (Beamer, Barclay, and Steacy), the Administrative Services Section (James P. De Marte), Hydraulics and Design (David D. Dickstein, Jr.), Operations (Page), Basic Records (David Barton), Water Quality Projects and Sediment Laboratory (Arthur N. Ott and Al Commings), Chemistry Laboratory (Bernard A. Malo), and Hydrologic Studies (Charles W. Poth). Subdistrict Offices were located in Philadelphia (David McCartney) and Pittsburgh (Burti). A Field Headquarters was maintained in Meadville, and the two offices at University Park were not affected. New Field Headquarters were opened in West Chester (Bruce W. Lium), in Johnstown (George Kleban), and at Bucknell University, Department of Geology and Geography, in Lewisburg (Denis E. Marchand).

Subtle changes, some temporary and some with lasting significance occurred during the period from 1971 through 1979. Several of the sections were combined and/or renamed. A Hydraulic Reports Section was established in 1972 and later combined with the Hydrologic Records Section. The Chemistry Laboratory was renamed the Interdistrict Laboratory (B.A. Malo) and then moved to Albany, N.Y., in 1973 to form one of three central laboratories for the Water Resources Division. A Special Projects Section was established (Richard W. Paulson) in 1972 to implement the use of satellites in data transmission. In 1974, a Field Headquarters was established in Clarion (Harry E. Koester) and a Field Office was established in Williamsport (Orville B. Lloyd). An Urban Hydrology project office was opened near Pittsburgh in 1971 (Robert M. Beall).

Ernest Burti, head of the Pittsburgh Subdistrict Office, died in 1974 and Carl J. Rossow was promoted to Engineer-in-Charge. The Field Office in Williamsport was upgraded to a Field Headquarters (John F. Truhlar) in 1975. In 1977 the Delaware River Flow Modeling Office was established in Harrisburg (James O. Shearman), and in 1978 the Schuylkill River Quality Assessment Office was established in Harrisburg (Gary L. Pederson). Also in 1978, a Hydrologic Analysis and Computer Applications Unit was formed in Harrisburg (Joanne V. Funt).

A strong commitment was made to the regional subdistrict approach in 1970. Subdistrict Offices were charged with all data collection and project work within areas defined by river-basin boundaries. The Subdistrict Office in Philadelphia was moved to Malvern and charged with work in the Delaware River Basin. This office was headed by John J. Murphy. A Subdistrict Office was created in Harrisburg and charged with data collection and project work in the Susquehanna and Potomac River Basins. The office was headed by Donald L. Bingham. The Subdistrict Office in Pittsburgh was charged with work in the Ohio River Basin. Carl Rossow retired from the Pittsburgh Office in 1977, and Joseph B. Lescinsky served as the acting Subdistrict Chief until David B. Richards assumed the duties in 1978.

Activities common to the entire District and projects that involved more than one State or more than one river basin were administered by the District Office in Harrisburg. Activities common to the entire District included the Administrative Services Unit, which was headed by Ralph E. Zettlemoyer after the retirement of Pat De Marte in 1976, the Hydrologic Data Collection Section headed by Carney P. Humphreys, Jr., the Project Coordination Section headed by John R. Ritter, the Sediment Laboratory headed by Commings, and the Hydrologic Analysis and Computer Applications Unit headed by Funt.

A new unit to expedite the preparation and processing of reports was created at the District level in 1979. The unit, Reports and Publications, was headed by Charles W. Poth and employed three typists and one professional draftsperson.

PRINCIPAL PROGRAMS

Many reports that were published during this reporting period were prepared in whole or in part by personnel from the Water Resources Division in Pennsylvania. Included in the list are 20 Water-Supply Papers, 8 Professional Papers, 2 USGS Bulletins, 21 USGS Circulars, 3 articles for the Journal of Research of the USGS, 9 USGS Hydrologic Investigations Atlases, 19 Water-Resources Investigations Reports, 27 USGS Open-File Reports and Maps, and 40 publications of Pennsylvania State agencies that were prepared in part or entirely by the USGS.

From 1966 through 1970, water-resources data for Pennsylvania were published in two volumes—one contained surface-water records and one contained water-quality records. Beginning in 1971, water data for streams and wells were published in a series of three volumes, one for the Delaware River Basin, one for the Susquehanna and Potomac River Basins, and one for the Ohio River Basin. During the period from 1966 to 1979, data were published annually from about 200 continuous-record streamflow-gaging stations, about 90 water-quality stations, and about 65 observation wells.

Brandywine Creek Basin

Continuing studies were conducted in the Brandywine Creek Basin to assess the health of the streams from both a water-quality and biological standpoint. The studies continued early work done by M. Gordon Wolman (Johns Hopkins) in the 1950's. Luna Leopold (Chief Hydrologist) and Ruth Patrick (Academy of Natural Sciences) were among the authors of several papers that assessed water quality and biology as it related to land use (PP 701–A, 1972; C–544, 1968; and C–645, 1971). This work provided the understanding needed for land-use planning used by the local agencies to protect the health of the streams from effects of urban development.

Ground-Water Studies

During the period 1966 through 1979, much effort was devoted to county ground-water studies, and results of these studies were published in a series of Pennsylvania Geological Survey Water Resources Reports. Results of about 26 studies were published. Authors included A.E. Becher, L.D. Carswell, D.J. Growitz, J.R. Hollowell, H.E. Johnston, G.E. Kimmel, H.E. Koester, O.B. Lloyd, D.B. MacLachlan, Harold Meisler, T.G. Newport, L.B. Platt, C.W. Poth, G.R. Schiner, and C.R. Wood.

Delaware Drought

Extensive droughts occurred in much of the Northeastern United States during 1956–66. These droughts significantly affected flow in the Delaware and Schuylkill Rivers, allowing the salt front in the Delaware Bay to move upstream in the estuary and toward the freshwater intakes for Philadelphia. Several reports, done in cooperation with the City of Philadelphia, were published by the USGS (WSP 1586–B and 1586–G). During 1966 the USGS operated, and continues to operate, water-quality monitors that measure dissolved oxygen and salinity at selected key locations on the Delaware estuary.

Remote Sensing of the Delaware Estuary

The objective of this project was to determine the feasibility of using satellite-mounted remote sensors to gather useful data for analyzing hydrologic problems. A proposal was formulated to conduct an experiment from the Earth Resources Technology Satellite (ERTS) using the Delaware River estuary and basin as a test. Remote-sensor data gathered by aircraft were analyzed, and an ERTS experiment based on the results of the analysis and the spacecraft characteristics was prepared. The analysis indicated the viability of conducting an ERTS-based experiment for the Delaware River estuary and drainage basin.

The Greater Pittsburgh Regional Project

The purpose of the Greater Pittsburgh Regional Project was to gather water-quality information for a large urban center. Most of the work on the project was done under the direction of the Northeastern Region, and several reports were published, including WRI 50–74 by Beall and C–747 by R.P. Briggs.

Sediment

Sediment transport rates in tributaries to and in the Susquehanna and Delaware River were determined, and the results were published in two reports (WSP 1532–F, K.F. Williams; and WSP 1532–H, L.J. Mansue).

Highway and other construction involving earth moving can result in streams carrying excessive quantities of sediment. Several projects conducted in cooperation with the Pennsylvania Department of Transportation were designed to evaluate different methods of sediment control that could be used during construction. These studies led to the use of automatic suspended-sediment sampling and turbidity-monitoring equipment by the District.

Highway-construction/sediment-transport studies were conducted on four watersheds: Conodoguinet Creek near Harrisburg, Applemans Run near Bloomsburg, the headwaters of the Schuylkill River near Port Carbon, and Blockhouse Creek north of Williamsport. Several reports were published, including WSP 2054 (L.A. Reed), WRI 76–111 (D.A.V. Eckhardt), WRI 78–35 (R.E. Helm), and WRI 80–68 (R.A. Hainly).

Coal Mining and Acid Mine Discharge in Pennsylvania

Acid water from abandoned mine workings, both surface and deep mines, is a severe problem for both water quality and water supply in much of Pennsylvania. The State of Pennsylvania and the USGS cooperated in many projects to document the extent of acid mine drainage and to study the interrelation of geology, mineralization, and movement of water. Results from one of the first of these projects was published in 1966, C–526 (J.E. Biesecker and J.R. George).

In 1968, the results of an extensive study of the water resources of the Schuylkill River Basin were published as Pennsylvania Water Resources Bulletin No. 3 (J.E. Biesecker, J.B. Lescinsky, and C.R. Wood). In 1978, a second extensive study of the impact of acid mine drainage on the water quality of the Schuylkill River was undertaken. The objective of this study was to evaluate the effect of mining on trace metals, sediment, and biological populations in the river.

The impacts of acid mine drainage on fish and macroinvertebrate populations in sections of Babb Creek, Loyalsock Creek, and the Tioga River were described by J.L. Barker (unnumbered USGS open-file reports, 1972).

Extensive studies of water in abandoned mines in the anthracite region of eastern Pennsylvania were done from 1975 through 1977, and results were published in two reports. Two additional large projects were started during the period—one in the Big Sandy Creek Basin in the western part of the State (started in 1977) and one to measure acid loads in all first-order streams in the State that drained areas with coal measures (started in 1979).

Floods

Extensive flooding occurred along many streams in southeast Pennsylvania in September 1971. Record stages were recorded at several gages on Skippack, Stony, and Chester Creeks. The flooding resulted from as much as 8 to 12 inches of precipitation. Results of the flood study were reported in an open-file report by Page and L.C. Shaw.

During June 1972, floods of unprecedented magnitude occurred over a widespread area of the Middle Atlantic States as a result of Hurricane Agnes. Historical stages set in March 1936 at numerous stream-gaging stations were exceeded by significant amounts. Although not as widespread, heavy rains in September 1975 caused even higher stages at a few locations. Brian Reich and Donald Jackson, professors of Civil Engineering at Pennsylvania State University who analyzed data from the flooding that occurred during March 1936, said that when they were looking at the 1936 flood data they considered it to be a true anomaly because of two factors: the unusually large amount of snow on the ground in mid-March, and the unusually heavy rains (Report 68–26, Civil Engineering Department, Penn State University, 1971). They believed each of these factors had to be precisely synchronized for massive flooding to occur on such a large drainage as the Susquehanna River. Data on these and other floods are in Pennsylvania Water Resources Bulletin No. 13 (H.N. Flippo, Jr.).

Johnstown Flood, 1977

Over 100 people lost their lives on July 19 and 20, 1977, when record flooding occurred along the Conemaugh River and many of its tributaries in and around the city of Johnstown. The flood was the second flooding disaster for the city, exceeded only by the catastrophic failure of the dam on the South Fork of the Little Conemaugh on May 31, 1889, that resulted in the loss of over 2,000 lives. Personnel from the USGS offices in Pittsburgh, Williamsport, and Harrisburg joined USGS personnel from other States, personnel from the U.S. Army Corps of Engineers, and personnel from the State of Pennsylvania to document the magnitude of flooding, both stage and stream discharge. Results of these surveys are published in the annual data report, in OFR 78–963 by S.A. Brua, and in PP 1211 by L.R. Hoxit, R.A. Maddox, C.F. Chappell, and S.A. Brua.

Low Flow

Several low-flow projects were undertaken. They included evaluation of low-flow data collected at continuous-record gaging stations and evaluation of measurements made during low flow at about 60 stream sites. The low-flow measurements were correlated with data from long-term gages to estimate low-flow statistics. These data were published in 1977 in Pennsylvania Water Resources Bulletin No. 12 by Page and L.C. Shaw. The data also were used in later studies to develop regional equations to predict low flow at sites on ungaged streams in the State.

Time of Travel Studies—Lehigh and Susquehanna Rivers

The objective of these projects was to determine time of travel for low to medium low flows by introducing a fluorescent dye tracer into the river and taking samples to detect the first arrival and the arrival of the peak of the dye cloud at downstream locations. Results of these studies are published in two reports, OFR 76–247 and 82–861 by C.D. Kauffman.

Lakes

Comprehensive data on recreation lakes in the State of Pennsylvania were gathered in cooperation with the Pennsylvania Department of Environmental Protection and published in Pennsylvania Water Resources Bulletin No. 14 (J.L. Barker). Several preimpoundment studies were conducted for planned lakes in cooperation with the State of Pennsylvania and with the U.S. Army Corps of Engineers. The studies include Foster Joseph Sayer in Centre County (unnumbered open-file report by H.N. Flippo), Tioga-Hammond and Cowanesque in Tioga County (WRI 76–66 by J.R. Ward), Blue Marsh in Berks County (WRI 77–55 by Barker), and Raystown in Huntingdon County (WRI 76–57 by D.R. Williams).

Agricultural Conservation Practices

An evaluation of agricultural conservation practices on the hydrology of small watersheds was completed in 1967. These studies were conducted to evaluate changes in sediment loads transported by streams draining basins to which agricultural soil conservation measures had been implemented. Results from these studies were published in three reports, including WSP 1532–C by B.L. Jones.

Nonpoint Agricultural Studies

A number of water-quality studies began in the 1970's to measure the concentrations and fluxes of sediment, nitrogen, phosphorus, and various pesticides in areas with intense agricultural land-use practices, particularly in the lower Susquehanna River Basin and the Chesapeake Bay. These nonpoint-source studies related water quality to land use and provided an understanding of the nonpoint-source loadings relative to the point-source loadings, which were being markedly reduced. These types of studies continued into the 1990's. Published reports on these studies included WRI 79–88 by J.R. Ward and D.A. Eckhardt.

The Schuylkill River Project

A 3-year study was begun in the lower Schuylkill River Basin in 1978 that was one of four studies in the Division that used a multidisciplinary approach to evaluate specific issues in that basin. The Schuylkill study focused on the occurrence and flux of water- and sediment-borne trace metals and organic compounds. Techniques developed in these studies, and studies in other States, were used in the planning and development of the National Water-Quality Assessment Program, which began in the 1980's.

Calculations

In 1966, many calculations were done by hand, by slide rule, or with an adding machine. Hand-inked copies or manual typing was used to produce copies of final data. In the late 1960's, a centralized computer facility in Virginia was established for use by WRD offices by using a remote terminal and card reader. "Jobs" (decks of punch cards) were "read in" at the WRD office, transmitted by phone line to the central computer, processed, and results returned, usually overnight. "Jobs" with punch cards continued until the 1980's, when computer technology advanced to the point where computers could be installed and maintained in most offices. During the 1970's, hand-held calculators that could be programmed became available for short calculations. Reports, tables, graphs, and maps were produced by hand, without computer capability other than electric typewriters with memory cards. A programmable calculator was purchased in 1972 to compute cross-section data for flood surveys. The machine could store 50 key strokes of instruction; for example, 6.35*A is six keystrokes. It could add, subtract, multiply, divide, and take square roots. All this for $3,200, or about the price of a new Buick.

SUMMARY

In summary, the Pennsylvania Water Resources District during the period 1966 through 1979 reorganized to meet work requirements and commitments to customers. The organization can be characterized as initially being functionally aligned without the synergistic effects of cross pollination. As organizational changes were made, the Water Resources Division District became more aligned with geographic and work responsibilities. Personnel assignments also were made to support new structures and remained fairly stable for key managers and leaders. These individuals normally remained in positions for more than 3 years. Senior positions, such as the District Chief and Engineer-in-Charge, enjoyed the stability of Beamer for 12 years and Fish for 14 years. When position titles changed, the grade structure also followed to allow assignment of more senior and more qualified individuals to meet the greater responsibilities.

VIRGINIA

By Joseph S. Cragwall, Jr.

INTRODUCTION

This period of District operations began on an optimistic note in contrast to the previous decade, 1957–66. That period began with termination of cooperation with Virginia's principal water agency, the Department of Conservation and Economic Development, under mandate by the General Assembly forbidding transfer of State funds to any Federal agency for water resources investigations. That mandate was lifted, and cooperation was resumed in fiscal year 1967 (see Water Resources Division History Volume VI, Virginia).

The 1967 renewal of cooperation, even though at a modest level of funding, enabled the District gradually to rebuild a balanced program. By the end of this period (1979) the District was again providing a satisfactory level of water-data collection, hydrologic investigations, and water-information services. The WRD also took action in July 1966 to designate Virginia as a WRD District with J. Wyatt Gambrell as District Chief. Reorganization and restaffing were quick to follow.

Acknowledgment

Reviewed by district retirees Gary S. Anderson, J. Wyatt Gambrell, Earley M. Miller, and Robert L. Wait and District actives Clairiece O. Humphrey and Floyd L. Snow. Program, personnel, and financial records assembled and supplied by Sandra A. Edwards, District Administrative Officer. Their assistance is gratefully acknowledged.

Organization and Personnel

With the resumption of State cooperation, the decision was made to relocate the District Office from Charlottesville to Richmond. The official move was accomplished by November 25, 1966, when Gambrell opened the new office at 200 West Grace Street, where it remained throughout this period.

By May 1967, Robert L. Wait, a ground-water geologist from the Brunswick, Ga., office, arrived to serve as principal assistant; he later was officially designated Assistant District Chief. Stanley M. Rogers, chemist, had transferred in from Baton Rouge, La., to head water-quality activities. Sandra A. Nichols (now Edwards), who later became Administrative Assistant, had transferred from another Federal agency in April. Moving from Charlottesville during this time were Earley M. Miller, Edward Nuckols, and Donald H. Rapp, hydraulic engineers, and A. Wayne Clingenpeel and Roger N. Pollard, engineering technicians.Virginia C. McCranle (later Lawrence) and Cynthia M. Mulligan, newly recruited as clerk typists, completed the initial staffing of the District Office in 1967. As the program regained strength, in both size and diversity, District staffing grew moderately through the 1969–79 period.

Gambrell retired in early 1973, and William E. Forrest of the Towson, Md., office succeeded him and served as District Chief for the remainder of this period. In 1979, the staff consisted of five hydrologists, one chemist, five technicians, five administrative/clerical persons, and four part-timers. Gary S. Anderson was serving as Assistant District Chief, having transferred in from Alaska in January 1978 to succeed Wait, who earlier (September 1976) accepted an assignment to Saudi Arabia.

Others not previously named who served in the District Office for more than about 2 years during the period 1967–79, or were on the rolls in 1979 and onward, were: hydrologists G. Allan Brown, Oliver J. Cosner, Prentis M. Frye, John H. Harsh, Herbert T. Hopkins, William F. Lichtler, Byron J. Prugh, Jr., and Patrick N. Walker; chemists James L. Chisholm and William D. Silvey; technicians Richard J. Ahlin, Charles J. Blankenship, William V. Daniels, and Joel R. Guyer; and clerk-stenographers Nancy L. Childress, Mary B. Fussell, Cherokee C. Haab, Carylyn Y. Hix, Penelope E. McNerney, Bonnie P. Pfaff, and Diane J. Williams.

Following the District office move to Richmond, Charlottesville was designated a Subdistrict Office in addition to the continuing Fairfax and Marion Subdistricts. A Field Headquarters was maintained in Norfolk from 1968 through 1974.

The Charlottesville office, relocated to 1936 Arlington Boulevard, was responsible for field work and records preparation in central Virginia and for preparation of the District's annual data report. Carleton W. Lingham served as Hydrologist-in-Charge until he retired in 1976. Roger N. Pollard, a senior hydrologic technician, was moved from Richmond to head the office, which was then redesignated a Field Headquarters. Others stationed in Charlottesville during 1966–79 were: chemist Jolly D. Thomas; technicians Harvey M. Peyton, Phil N. Shackelford, Floyd L. Snow, and Warner C. Wood; and secretary-stenographer Clairiece G. Humphrey.

The Marion Subdistrict Office, located at 144 West Main Street until moving to 554 South Main Street in 1969 and then to 1021 Terrace Drive in 1975, handled field operations and records preparation throughout southwestern Virginia and the upper parts of the James and Roanoke River Basins. S. Grady Anderson, hydraulic engineering technician, headed the office until he retired in 1972, after 27 years of service in Marion from 1945 when that office was established. He was succeeded by Walter E. Hendrick, Jr., acting, until Donald F. Farrell was appointed in 1974 as Hydrologist-in-Charge. Following Farrell's transfer to Albany, N.Y., in late 1976, Hendrick became Hydrologic Technician-in-Charge and served for the remainder of this period and beyond. Others who served in the Marion office were technicians Charles R. Burchett, James M. Gemmell, Harold G. Henderlite, and Howard D. Williams, and clerk-typists Peggy H. Sayers and Jean M. Stone.

The Fairfax Subdistrict Office continued its urban flood studies in Fairfax County, hydrologic data collection in northern Virginia, and other projects in that area. Daniel G. Anderson served as Engineer-in-Charge until reassigned to WRD Headquarters in November 1967 to conduct research in hydrologic remote sensing. Anderson was succeeded by Frederick P. Kapinos, who headed the office until November 1970 when he transferred to the Federal Water Quality Administration (FWQA). Pat L. Soule succeeded Kapinos until February 1975 when he was transferred to Albuquerque, N. Mex. Ewell H. Mohler, Jr., then moved in from the Maryland District to head the Fairfax work for the remainder of the period. The Fairfax Office, located originally at 4055 Chain Bridge Road, moved to 9673 Lee Highway in 1974, where it remained for the rest of the period. Others who served in the Fairfax Office included hydrologists Richard H. Johnston, John W. Lanier, Jerry D. Larson, Charles E. Novak, Donald H. Rapp, and Chester Zenone. Technicians included Terry L. Clayton, Frederick G. Gugel, Joel R. Guyer, P. Michael Shackelford, and Ralph Wills.

Cooperation with the City of Norfolk to investigate the feasibility of freshwater storage in underlying brackish aquifers led to setting up a Field Headquarters there in late 1967. Donald L. Brown, hydrologist (geologist), moved in from Nashville, Tenn., to conduct the project, where he remained until the investigation was completed in 1974. His office was located at 3361 East Virginia Beach Boulevard.

Cooperation and Funding

The Virginia program was supported throughout the 1966–79 period with funding from USGS Federal appropriations (FED), the Federal cooperative program (Coop), other Federal agencies (OFA), and licensees of the Federal Power Commission (FPC). Fiscal year (FY) funds from these program sources are listed in the accompanying table.

Annual District funding, Fiscal Years 1967–79 ($ thousands)

FY	Fed	Coop	OFA	FPC	Total
1967	37.0	264.7	126.1	7.9	435.7
1968	38.8	439.3	106.0	8.6	592.7
1969		506.0	90.3	9.7	
1970		489.5		9.7	
1971		593.7		10.2	
1972	110.0	629.5	162.0	10.6	912.1
1973	116.0	656.0	177.1	11.2	962.2
1974	107.4	676.6	269.9	12.2	1106?.1
1,975	106.2	635.4	257.7	15.0	1,014.4
1976	176. 1	544.2	276.0	17. 2	1,013.6
Tr Q*	34.8	126.4	104.8	4.6	270.7
1977	140.4	482.6	403.3	17.7	1,044.2
1978	142.4	561.5	476. 1	19.4	1,199.4
1979	365.7	686.9	479.3	20.8	1,552.7

*Tr Q: Transition quarter, June–September 1976.
1972–79 funding furnished from District files.
1967–71 funding derived from available program documents from District files (records incomplete for 1969–71).

USGS Federal Program

Throughout the period, USGS Federal funds supported the collection of basic surface-water, ground-water, and water-quality records at stations of national importance. In addition, Survey funds supported a number of specific-term projects including flood studies, areal hydrologic investigations, and other projects that were parts of national program thrusts in land investigations and analysis (LIA) and energy resources. Funding ranged from $37,000 in FY 1967 to a high of almost $366,000 in FY 1979.

Federal-State Cooperation

The resumption of cooperation in July 1966 (FY 1967) with the Virginia Department of Conservation and Economic Development was continued from FY 1973 onward with the Virginia State Water Control Board (VWCB) following the State's consolidation of water-resources and water-pollution control functions into VWCB. Program funding (both sides) increased from $61,000 in FY 1967 to $524,000 in FY 1979. The total program supported the statewide collection of basic water records, areal hydrologic investigations, and other special, problem-related studies. One-half to two-thirds, or more, of the State's share was in the form of evaluated (direct) services, mostly collection of basic records (CBR).

The Virginia Department of Highways (later Highways & Transportation [VDH&T]) cooperated throughout the period in the collection and analysis of flood data and special flood studies, with annual funding ranging between about $30,000 and $89,000. Significant portions of this activity were fully funded by VDH&T using 90 percent pass-through funds from the Federal Highway Administration's research program.

The County of Fairfax supported countywide flood-plain-delineation studies, including additional hydrologic data collection, until the project was completed in FY 1976. Annual funding ranged from $100,000 in FY 1967 to a high of $222,000 in FY 1973 and then tapered off to $37,000 in FY 1976.

The City of Norfolk supported its freshwater recharge and storage project in FY's 1967–74 and continued collection of basic records throughout the period, 1966–79. The recharge study totaled about $556,000 over the 8 years, and the basic records collection was about $40,000 for the 13 years.

Sedimentation in the Occoquan River Basin was evaluated in cooperation with the Virginia Polytechnic Institute and State University during FY's 1973–75 at a cost of $86,000.

An assessment of the hydrology of James City County was begun in 1977 and continued beyond the end of this period. It was funded at $194,200 for FY's 1977–79.

Other local jurisdictions cooperated in the collection of basic streamflow records to fill their specific needs, namely Chesterfield County (1967–75) and the cities of Alexandria, Newport News, Roanoke, and Staunton for the entire 13-year period, 1966–79, all at a total annual funding ranging between $7,100 and $12,900.

Other Federal Agencies

The U.S. Army Corps of Engineers strongly supported the collection of streamflow and water-quality records throughout the period and also requested assistance on several special investigations.

Annual funding ranged from about $80,000 in the early years to about $200,000 by 1979.

The Tennessee Valley Authority continued its funding of streamflow-data collection in the Tennessee River Basin with annual funding to Virginia ranging between about $20,000 and $35,000.

The Federal Water Quality Administration (FWQA), later the U.S. Environmental Protection Agency (USEPA, December 2, 1970) funded the collection of basic water-quality data during FY's 1970–74, and work on areal ground- and surface-water-quality assessments in FY's 1973–75 and 1978–79. Annual funding ranged between about $30,000 and $45,000 during 1970–74 and $19,000 and $15,000 in 1978 and 1979, respectively.

Housing and Urban Development (HUD) (after 1978 the Federal Emergency Management Administration (FEMA), funded flood mapping in specified areas in FY's 1971 and 1975–79, totaling $103,000 for those 6 years.

The National Park Service requested ground-water supply assessments for Prince William National Park and along the Blue Ridge Parkway. Funding totaled upwards of $170,000 for FY's 1972–79.

For hydrologic study of the Great Dismal Swamp, the Fish and Wildlife Service supplied funds totaling $59,000 in FY's 1977–79. Special data requests of the Bureau of Mines were filled in FY 1972 and FY 1975 at nominal cost.

The U.S. Department of Agriculture's Soil Conservation Service (SCS) required surface-water quality assessments in a number of selected watersheds in the State. The work was accomplished in 1977 and 1978 with funding of $72,500. The SCS also funded special surface-water data collection in 1979 for $13,000. The U.S. Forest Service provided partial support of a streamflow-gaging station during 1967–73.

For this 13-year period, the OFA program made up about one-third of the District's funding.

Federal Power Commission

Eight streamflow stations were wholly or partially funded under provisions of the Federal Power Commission licenses by Appalachian Power Company, Virginia Electric and Power Company, and the City of Radford. Funding ranged from $7,900 in FY 1967 to $20,775 in FY 1979.

Summary of Program

The collection of basic records continued as the major program component in most years of this period. In addition to the station networks of surface-, ground-, and quality-of-water data, systematic collection of water-use data was begun in 1979.

The remainder of the program, nearly half in some years, consisted of topical and areal hydrologic project studies with objectives responding to information needs for water-resources planning, development, and design.

Active, documented projects conducted during the 13-year period numbered 42, including 5 for CBR, 7 for special flood studies, and the remainder for topical analyses and hydrologic field investigations. Most projects were reported on in one or more of the USGS publication series and are referenced for Virginia in Open-File Report 92–69 (superseded, 1994) as compiled by J.A. McFarland.

Collection of Basic Records

For about the first 3 years of this period, Gambrell supervised surface-water data activities statewide, Wait the ground-water data, and Rogers the water-quality data. After 1970, Walker headed all CBR activities until succeeded by Frye from 1976 onward. Humphrey of the Charlottesville office prepared the manuscript copy for all the annual District-level data reports published during this period.

Surface-water records—The 1978 issue of "Water Resources Investigations in Virginia" reported that continuous records of streamflow and stage were being collected at 191 stations (as compared to 151 in 1966) and stage-only records at 2. There were 11 lake and reservoir stations, of which 9 included records of content as well as stage. A network of 90 peak-flow stations rounded out the currently operated streamflow network. Discontinued gaging stations from which streamflow records were available totaled 51.

Ground-water records—The 1978 publication cited above reported 179 stations in the statewide network of water-level observation wells. An additional 25 water-level stations were being operated in support of specific-term projects. Only one well was being sampled periodically for water quality at that time. Systematic collection and compilation of geohydrologic data proceeded statewide through most of the period as a basic-records component of the ground-water data base.

Water-quality records—As of 1978, water-quality data collection was concentrated on surface water, and sampling sites were mostly at stream-gaging stations. Water temperature and specific conductance were monitored at 24 stations and pH at 10. Sediment data were collected at 15 stations, inorganic chemicals were monitored at 23 stations, organic constituents at 10, biological data at 10, and radiological data at 1 station. Frequency of sampling was generally quarterly or more often. Additional water-quality data were collected throughout the period in support of specific-term areal projects.

Water-use records—With the availability of Federal-State cooperative funds for water-use data collection beginning in FY 1979, a Virginia program was launched in cooperation with the VWCB. Noteworthy was the reverse-flow funding feature to provide for State services on this activity above the State's normal 50-percent share of contributed services. The VWCB provided a full-time project coordinator to work closely with Herbert T. Hopkins of the District staff. The Virginia water-use data system was to become a continuing component of the Cooperative Program in future years.

Flood Studies

This activity involved field investigations and documentation of major flood events, analyses of the magnitude and frequency of floods, statewide flood-inundation mapping, and urban flood studies.

A number of flood events during the 1967–79 period merited follow-up field surveys and special reports. Most notable, hydrologically and damage-wise, were those associated with Hurricanes Camille (August 1969) and Agnes (June 1972). Miller coauthored with J.D. Camp (on detail from the Illinois District) "Floods of August 1969 in Virginia" (OFR, 1970) which documented Hurricane Camille. Miller also prepared several quadrangle hydrologic atlases (HA's) showing areas of inundation by the Camille event in the Richmond area. He headed a District assignment to define the mean sea-level elevations and flood profiles along major streams. G.P. Williams and H.P. Guy of WRD Headquarters reported on the erosional and depositional aspects of Hurricane Camille in Virginia (PP 804, 1973). The Virginia Division of Mineral Resources documented photographically the natural-features damage wrought by Hurricane Camille in a special issue of "Virginia Minerals," October 1969. Donavan Kelly of the USGS Information Office authored a special pictorial bulletin on the effects of the hurricane in the James River Basin of Virginia.

The Hurricane Agnes floods in Virginia were documented in PP 924 (1975), "Hurricane Agnes Rainfall and Floods, June–July 1972" coauthored by J.L. Patterson (USGS) and J.L.H. Paulus (NWS). Other significant floods of lesser areal extent that merited special reports occurred in 1967 and 1969 (northern Virginia), 1968 (Craig County), 1973 (Petersburg area), and 1977 (Appalachian region).

In addition to the intensified flood-data collection on small streams, work continued throughout the period to define the magnitude and frequency of floods. In 1966, Miller and Kapinos open-filed a summary of flood discharges on drainage areas less than 120 square miles. Miller followed in 1969 with an open-file report on "Floods in Virginia, Magnitude and Frequency." Later in 1978, he described the techniques for estimating the magnitude and frequency of floods in Virginia (WRI 78–5).

The District was much involved in flood-hazard analysis and mapping throughout this period. The District was called upon to delineate the extent of flooding in specified areas of Virginia as prioritized by HUD, and, later by FEMA. Areas mapped included Herndon, Franklin, Vienna, Falls Church, Stanley, Luray, and Leesburg.

Other Hydrologic Studies and Reports

Ground-water conditions—water levels, supply potential, and quality—with major emphasis on the coastal plain areas of the State, received much attention during this period. Much effort was directed also to water-quality assessment, both ground and surface, in response to national and State priorities for water-quality control and improvement, and for environmental protection.

At USEPA's request, Silvey in 1973–74 assembled, organized, and transferred into USEPA's STORET data base all available ground-water quality data (690 analyses) in the coastal plain of Virginia. During the same period, Walker headed a project to collect, assemble, and provide to USEPA, in a series of letter reports, data at specified sites in the State for use in that agency's National Eutrophication Study.

During 1967–75, Donald L. Brown assessed the feasibility of Norfolk's proposal to store treated freshwater atop the underlying saline aquifers in that area. Brown reported his findings of comprehensive test-well injections in PP 930 (1977, with Silvey) and, earlier in 1971, the techniques involved in the injection tests in "Ground Water" (v. 9, no. 4, p. 25–48).

During 1967–76, Cosner investigated the heavy pumping of ground water in the Franklin area south of the James River and its consequences associated with the depth and extent of the enlarging cone of depression. He developed a predictive model of that Lower Cretaceous aquifer (WRI 51–74, 1975) and reported on measured and simulated ground-water levels in WRI 76–83 (1976).

Harsh delineated the major aquifers underlying James City County and the water quality of each during 1977–79 (OFR 80–961). In 1979, Hopkins began an assessment of coastal-plain land subsidence in southeastern Virginia, working with the VWCB, which drilled the wells. This project was to extend into the mid-1980's. Increasing concerns about ground-water withdrawals in that area led to a second project that year headed by Larson (reported later in OFR 81–1013).

In response to a request from the Corps of Engineers, Lichtler and Wait in 1974 summarized the ground-water resources of the James River Basin (OFR 74–139).

In 1974, Lichtler conducted a geohydrologic reconnaissance of the Great Dismal Swamp in support of Department of the Interior consideration of the swamp as a national wildlife refuge, and with Walker prepared OFR 74–39. Later in 1978–79, Harsh and others on the staff provided the U.S. Fish and Wildlife Service with additional information on the hydrology of the Great Dismal Swamp.

As part of the Survey's LIA program, Zenone with Larson in 1976–79 reviewed hydrologic information available in Fairfax County and summarized findings on special investigation maps (I–1473, 1982). In 1979, Zenone began a hydrogeologic assessment of the Culpeper basin as part of an LIA project to complete earth-science factor maps of the area, an assessment which continued into the mid-1980's. Other water-resources studies in Fairfax County involved Johnson and Larson who, separately or together, reported their work in a series of open-file reports published during 1976–79 (see OFR 92–69, superseded in 1994).

Water-supply availability studies were conducted during 1974–79 in Prince William National Park and during 1978–80 along the Blue Ridge Parkway; findings were reported to the National Park Service in WRI 84–4009 and WRI 84–4168, respectively, by Hopkins.

The District was called upon to provide hydrologic information for two environmental-impact assessments of some uniqueness. The first involved the construction of Highway I–77 and its potential for degrading the water quality of spring flows providing water to the Wytheville National Fish Hatchery. The Marion Subdistrict monitored the flow and quality of the water during 1976–79, and Hendrick reported the results in OFR 82–6. The second required a ground-water-resources evaluation of a site in Suffolk where the Corps of Engineers was considering the disposal of contaminated dredged soil. Harsh led the field investigation in 1978–79, which was then terminated for lack of funds. Findings to that date were transmitted to the Corps. Disposition of the dredged material is unknown.

Another rather unusual project was led in 1973–76 by Walker to assist Fairfax County in the design, installation, and operation of a network of rainfall and streamflow stations to provide data for a deterministic model for urban-drainage management. County staff were also trained to operate the network and process the data.

Other special studies included an assessment for the VWCB by Rogers of the water-quality and streamflow-variability characteristics at specific industrialized locations in the James River Basin. In 1977, Rogers also assessed the water quality of two watersheds in Louisa County for the SCS (OFR 77–460). In 1978–79, he studied the effects of coal mining on water quality in southwest Virginia (OFR 80–769).

As the period came to a close, the Marion office led in the establishment of a water-quality sampling network in southwest Virginia to provide a data base for the coal-mining permitting process mandated by Public Law 95–87, Surface Mining Control and Reclamation Act. A plan to analyze and summarize the low-flow characteristics of Virginia streams was developed in 1979 by Prugh and approved for implementation in the years to follow.

A number of other hydrologic studies and reports were conducted during the 1967–79 period by WRD Headquarters and Northeastern Region personnel, some of which involved District assistance. The resulting reports are listed in the previously mentioned McFarland's OFR 92–69 (superseded in 1994).

WEST VIRGINIA

by David H. Appel

Review and additional comments by Gene Friel are gratefully acknowledged.

West Virginia is a relatively small, mountainous State that has a low population density. It is not an economically rich State. It was going through some fairly rough times, at least during the latter part of this period of WRD history (1966–79). The State and Federal managers of water-related agencies worked together to develop a hydrologic program that provided the most "study" for the least amount of State funds. This, at times, led to some innovative funding for projects in order to conduct priority studies.

Organization and Personnel

The West Virginia District had been reorganized from the individual Branches to the Division concept in early 1966, with William Griffin the first District Chief. Prior to reorganization, the surface-water (SW) operations were headquartered in Charleston and the ground-water (GW) operations in Morgantown. After reorganization, the District Office was located in the New Federal Building in Charleston with Subdistrict Offices in Morgantown, Elkins, and Charleston. By 1967 and with reorganization complete, the three Subdistrict Offices were headed up by George Bain, Lunsford Holland, and Prentis Frye, respectively.

William Griffin transferred to the Northeastern Region and was succeeded in 1971 by Edwin Harris as District Chief. David Appel succeeded Ed Harris when Ed transferred to the Idaho District Chief job in early 1976. Dave served as the District Chief throughout the remaining period of this history. Granville Wyrick was named Assistant District Chief in 1970 and served in that capacity until he retired after 1979.

By 1969, the Elkins office was down to one person (Fred Green) and had been downgraded to a Field Headquarters. In 1970, the Elkins office was closed, but a Field Office was established in Romney (William Hobba), and in 1971, another in Lewisburg (William Clark), to conduct special projects. Both of these offices were closed as the projects ended by or during 1973. In 1972, Eugene Friel and Frank Morris became the Subdistrict Chiefs in the two remaining Subdistricts, Morgantown and Charleston, respectively. The Elkins Field Office was reopened for about a year in 1975. These smaller offices had been necessary in West Virginia because of the difficulty in traveling around this mountainous State prior to the Interstate Highway system.

As in most Districts, integration from the old single-discipline offices to a more integrated organization did not occur overnight. However, it went fairly smoothly, and by 1972, true multidiscipline projects were being conducted by both the District Office and the Morgantown Subdistrict Offices, depending upon the geographic location of a project area. In 1979, because of program growth, the District Office was divided into a Hydrologic Studies Section headed by the Assistant District Chief, and a District Office. Multidiscipline data collection was conducted by both Subdistrict Offices. The Charleston offices generally covered the area of the State drained by the Kanawha River system and south, and Morgantown covered the area north of the Kanawha drainage.

The District staff numbered in the low twenties during the period 1966 to 1972. Between 1973 and 1975, it grew to about 30 and did not change much until 1979, when staffing increased to about 40 in order to conduct the large, federally funded Coal Hydrology Project. Only six of the West Virginia staff members were in the District for this entire period of WRD history. They were Eugene Friel, Frank Morris, Gerald Runner, Alvin Jack, Albert Tyre, and Orville Rose.

The Charleston offices were located in the New Federal Building during this entire period of this history. The Morgantown office was located in the Mineral Industries Building on the West Virginia University (WVU) campus as part of the Coop Program with the West Virginia Geological and Economic Survey (State Survey) through 1973. At that time, both the State Survey and the USGS required more space, and the Subdistrict Office was moved to the Morgantown Federal Building and Post Office. In 1978, the State Survey moved from WVU space and into Mont Chateau on Cheat Lake about 10 miles east of town. The State Survey provided space in this facility to house the Subdistrict as part of the Coop program. This enhanced the good working relationship between the two agencies.

Cooperating Agencies

The District had three prime State cooperators during this period—the Department of Natural

Resources-Division of Water Resources (DNR-DWR), Geological and Economic Survey, and the Department of Highways. The DNR-DWR supported the streamflow network and some streamflow portions of special studies. The State Survey supported the ground-water network, special ground-water studies, and the series of "Water Resources of *stream basin*" studies. The Department of Highways supported the flood frequency studies and sediment studies related to highway construction. Smaller cooperators during the period included the West Virginia DNR-Division of Forestry, West Virginia Office of Federal/State Relations, Morgantown Water Commission, and Clarksburg Water Board.

Five Federal agencies also supported data collection and project work during this period. They included the U.S. Army Corps of Engineers—Huntington, Pittsburgh, and Baltimore Districts (streamflow network); USDA-Soil Conservation Service (water quality and sediment data); the U.S. Fish and Wildlife Service (streamflow and sediment data), Federal Power Commission (streamflow data); and the Federal Emergency Management Agency (flood-insurance maps).

The other primary source of District funding came from the USGS Federal program. During this period, these funds supported the streamflow and water-quality networks and special projects such as stress-relief fracturing; special studies of flooding in the Guyandotte River, Martinsburg area, Buffalo Creek, and Tug Fork; and the Coal Hydrology Project. Federal funds also supported the flood-insurance mapping effort.

Other Activities

The West Virginia District participated in a tri-District conference in April 1979 with the Tennessee and Kentucky Districts. The conference, held at Bowling Green, Ky., crossed District and Regional boundaries to share expertise, experience, and information among the entire staffs of the three Districts.

Summary of Funding

Funding information for 6 years is shown in the following table to give the reader a general idea of program growth in types of funds and dollars.

Source of funds (in thousands of dollars)

Year	Federal	Coop	OFA	Total
1965	33	123	119	275
1970	-	-	-	350
1973	99	300	175	574
1975	115	556	253	924
1977	166	643	272	1,081
1979	509	658	290	1,457

The long-term data-collection networks were fairly stable during the period, with minor adjustments here and there. There were about 100 continuous-record streamflow sites, 120 water-quality sites (5 NASQAN sites and 100 streamflow sites at which physical properties data were collected), and 30 observation wells. Intensive hydrologic data collection was part of many special projects. For example, a "Water Resources of *stream basin*" project could add 200 short-term observation wells and 100 water-quality and miscellaneous streamflow sites. The small streams flood-frequency study added 60 stage and rainfall sites to the network for a period of about 13 years. The Coal Hydrology Project added about 350 water-quality sites for a 3-year period.

As shown in the table, there was very little new money coming to the District, other than enough to cover inflation, during the period 1965 to 1973. In 1974 and 1975, the network for the small streams flood-frequency study was converted from standard crest-stage gages to a dual-digital system, and the State Highway Department increased funding significantly. The small streams program ended in 1978. In 1975, a federally funded quantitative mine-water study started and continued until 1979. In 1978, two small Coop programs began with new cooperators—Department of Forestry and Office of Federal/State Relations—and State Highways began funding two sediment-transport studies to assess the effects of highway construction on sediment loads in streams. In 1979, the most significant study affecting District operations during the period began. That was the federally funded Coal Hydrology Project, which had the objective of evaluating the effects of coal mining on stream environment. Data collection at about 350 miscellaneous streamflow and water-quality sites began in the last half of 1979. Partial-year funding in 1979 was $350,000 and in 1980 constituted nearly one-half of the total District funds.

No doubt the most memorable hydrologic event to occur during the period was the infamous Buffalo Creek flood of February 26, 1972. This particular flood occurred when a coal refuse dam failed after a rainstorm. About 125 people were killed or missing, and the town of Saunders was completely destroyed. Several other small communities were also damaged. The District and the Northeastern Region produced two reports on the flood, Hydrologic Atlas HA–547 "Flood on Buffalo Creek from Saunders to Man, West Virginia" (G.S. Runner) and Circular C–667 "West Virginia's Buffalo Creek flood—A Study of the Hydrology and Engineering Geology" (Davies and others).

Other significant flood reports compiled during the period included Hydrologic Atlases HA–347 on the Guyandotte River flood (Friel and Runner), HA–427 on floods at Martinsburg (Runner and Friel), and HA–588 on Tug Fork flooding of April 1977 (Runner). This April 1977 flood also was reported in a Professional Paper by Runner and Chin. Runner also published "Runoff Studies on Small Drainage Areas" (OFR 80–1218).

Water-Supply Paper 2055 "Stress and Recovery of Aquatic Organisms Related to Highway Construction Along Turtle Creek, Boone County, West Virginia" (Chisholm and Downs) was written during this period. It was an eye catcher and opener with color photographs and findings showing quick recovery after disturbance. Wyrick and Borchers wrote WSP 2177 "Hydrologic Effects of Stress-relief Fracturing in an Appalachian Valley," which also caught the attention of the hydrologic community.

Significant reports related to mining and water supply were: "Abandoned Coal Mines in West Virginia as Sources of Water Supplies" (Lessing and Hobba), "Effects of Underground Mining and Mine Collapse on the Hydrology of Selected Basins, West Virginia" (Hobba), and "Fresh and Saline Ground Water Map of West Virginia" (Foster). All three of these reports were published as West Virginia Geological and Economic Survey publications. Many of the reports produced in cooperation with the State Survey were published in this manner in order to reduce publication time and State cost and utilize the State's publication staff. The "Water Resources of *stream basin*" report series, started during this period, were also State Survey publications. Basin reports published were Potomac, Little Kanawha, Upper New, and Monongahela. Other basin studies that were underway or ready to start at the end of the period were Coal, Guyandotte, and Elk. These "basin" studies usually included two reports—a data report and an interpretive report with several authors. Some also included a drainage-area report. Another State series of studies begun during 1979 was the "Ground Water Atlas" by river basin. These studies were completed after 1979.

WISCONSIN

by Lee Holt and Jack H. Green

Before the time of reorganization into a WRD District in 1966, the Branches in Wisconsin had only a modest budget. The staff and program were small but possessed the potential to grow into a worthy service group for the State and the Nation. The 1966 reorganization provided a starting point from which the District began a gradual but steady expansion of multidisciplinary studies of water resources. In dollar values, the District program expanded in almost straight-line increases by more than 600 percent from 1966 to 1979.

ORGANIZATION AND MANAGEMENT

In 1966, the Ground Water Branch and the Surface Water Branch joined to become the Wisconsin District of the Water Resources Division. The District Chief was Lee Holt, formerly the District Geologist. Ken Young, formerly the District Engineer, became the Associate District Chief, and Rudy Dosch became the Assistant District Chief. At this time, the District was organized along functional lines with four sections, each with roughly equivalent work loads and funding. The Water Problems and Water Relations Section, directed by Jack Green, conducted studies of ground-water/surface-water relations and water-problem areas. The River Basin Studies Section, directed by Dale Cotter, carried out studies of the 10 principal river basins of the State. The Hydrologic Characteristics Section, directed by Bill Gannon, studied low flows, spring flows, and floodflows. The Basic Records Section, directed by Fred Dreher, collected and analyzed ground-water and surface-water data. A Field Office at Waukesha, directed by Rick Hutchinson, was responsible for all studies in the nine counties of southeastern Wisconsin.

The following two charts show the organization of the Wisconsin WRD District in 1966 and 1972. Because of space limitations, it is not possible to mention these employees' individual efforts, which made the transition succeed and enabled the District to undertake an increasing number of interdisciplinary studies.

The Quality of Water Regional Office in Columbus, Ohio, served District needs for laboratory analyses of water and sediment. Earl Skinner, District Chemist, guided the collection of water-quality data.

Because there was no WRD ground-water program in Illinois, the Wisconsin District conducted water-supply and other studies at the Argonne National Laboratory of the Atomic Energy Commission near Chicago. In addition, the Wisconsin District Chief served as ground-water representative of the Illinois WRD council.

In 1967, Rudy Dosch transferred to the Illinois District. In 1974 Ken Young transferred to Boston. From this time forward, the District functioned without an Associate District Chief, and the duties of the Assistant District Chief were distributed among four Assistant District Chiefs (formerly called Section Chiefs).

To advance technical cooperation among the North-Central Districts of Wisconsin, Illinois, Michigan, Minnesota, and Iowa, the Wisconsin District promoted and hosted the 1966 and 1967 WIMMI Conferences for key personnel. Later conferences were held at each of the WIMMI Districts.

By May 1972, the WRD District organization, shown in the 1972 organizational chart, reflected the management and operations changes necessitated by the expanding number and complexity of interdisciplinary studies, including data collection, low flow and flood flow, surface-water/ground-water relations, wetlands, ground water in county and problem areas, and other special work. Personnel had nearly doubled since 1966. Jack Green was Assistant District Chief in charge of operations in the District Chief's office. Dale Cotter was Assistant District Chief in charge of the combined River Basin Studies and the Water Problems and Water-Relationships Section. Bill Gannon was Assistant District Chief in charge of the Hydrologic System Section. Fred Dreher was Assistant District Chief in charge of the Water Environment Monitoring Section. In 1971, Rick Grover began directing the Administrative Services Section as Administrative Assistant.

By 1975, the Water Environment Monitoring Section, under Fred Dreher, had been expanded to include sediment research studies and a sediment laboratory under Steve Hindall. A southeastern area Field Office had been reestablished in Waukesha; a southwestern area Field Office had been designated in Madison, with Joe Habale in charge; a northeastern area Field Office was in Merrill, with Jim George in charge; and a northwestern area Field Office was in Rice Lake, with Jack Freshwaters in charge. The Hydrologic Systems Section, under Warren Gebert, had been expanded to conduct streamflow-modeling studies, flood-plain delineation studies, and special stream and drainage research studies. Bill Gannon had been transferred to New York.

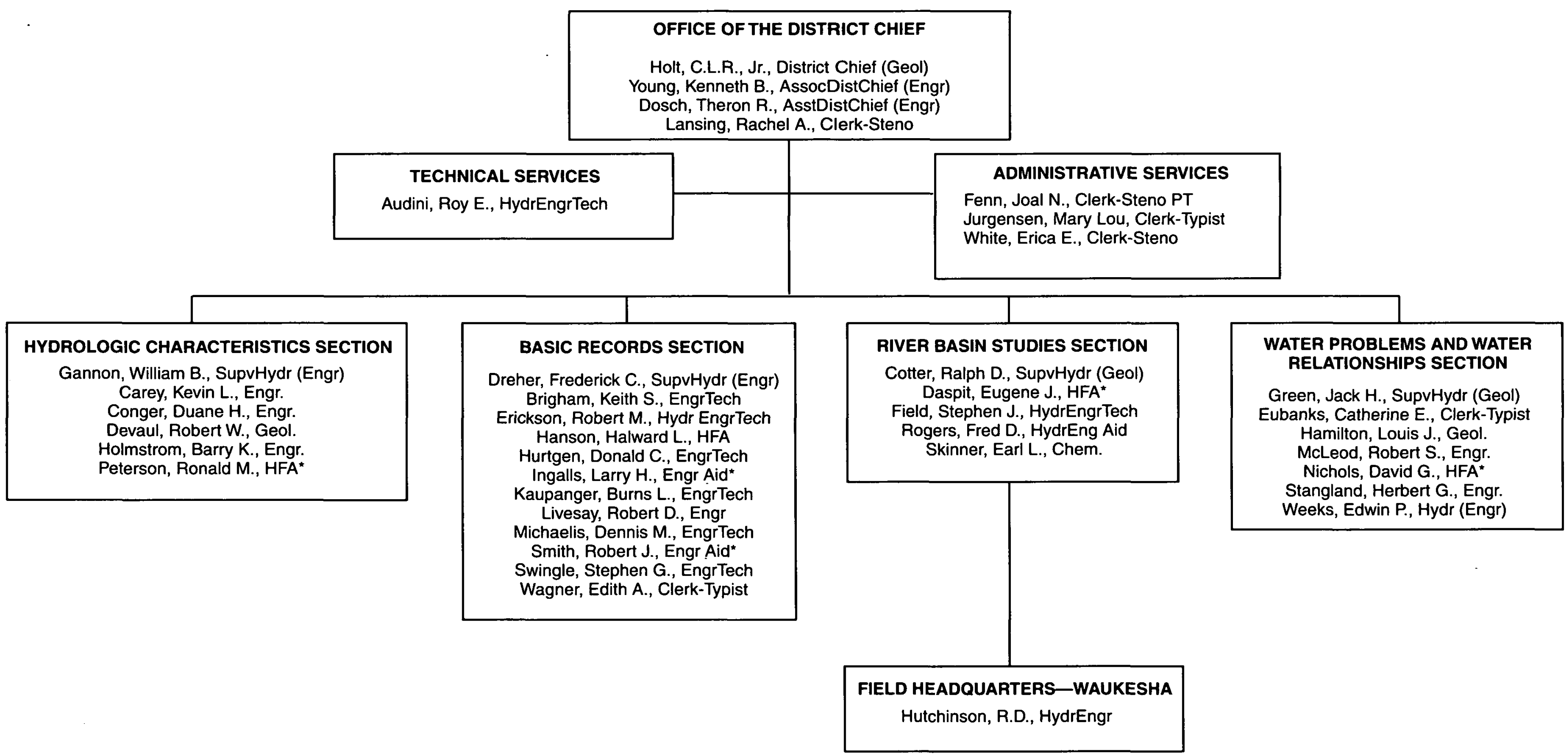
The Hydrologic Studies Section, under Dale Cotter, had expanded to include statewide and local hydrologic studies of wetlands and lakes, ground-water quality, including contamination, and computerization of data files.

In 1975, Lee Holt, Wisconsin District Chief since 1966, was transferred to Atlanta, Ga. Bill Barnwell became District Chief in the fall of 1975, having transferred from the Alaska District. He remained District Chief until 1978 and was replaced in 1979 by Bill Mann who had been Assistant District Chief in the Minnesota District.

Funding

Funds for the District's programs were from four sources: The Federal-State Cooperative Program (Coop); the Survey's Federal Program (Fed); and the Other Federal Agencies Program (OFA), which included the Federal Power Commission. Total funds increased sixfold from about $360,000 in FY 1966 to $2,196,000 in FY 1979. The Coop Program funds increased from $292,000 (81 percent) in FY 1966 to $1,555,000 (71 percent) in 1979. The Federal Program funds increased from $19,000 (6 percent) in FY 1966 to $272,000 (12 percent) in FY 1979, and the OFA Program increased from $47,000 (13 percent) in FY 1966 to $369,000 (16 percent) in FY 1979. The following table shows the steady increase of funding through the 1966–79 historical period, a period in which the District steadily enlarged its ability to serve most needs prescribed by the Division.

PERSONNEL ORGANIZATION CHART, 1966
Wisconsin WRD District



*University student working part time

PERSONNEL ORGANIZATION CHART, 1972
Wisconsin WRD District

OFFICE OF THE DISTRICT CHIEF

C.L.R. Holt, Jr., Hydr-14, E-8828-W, District Chief (4)
J.H. Green, Hydr-13, 0-8779-W, Staff Hydr (4,8,11,12)
E.L. Skinner, Hydr-12, 0-2114-M, Staff Hydr (4,16)
Rachel Lansing, Secy-Steno-6, 0-2262-M

TECHNICAL SERVICES

R.E. Audini, Tech-11, 0-1722-M (3)
Cathy Eubanks, Ed.Asst.-6, 0-2155-M (2,3)
Chris Sternberg, HFA-4 (2)

ADMINISTRATIVE SERVICES

R.L. Grover, Admin. Asst.-7, 0-2404-M (4)
Betty Hamre, Clerk-Steno-4, 0-1194-M (3)
Pat Stark, Clerk-Typist-4, 0-1945-M (1,2)
Kathy Weden, Clerk-Typist-4, 0-1945-M

WATER ENVIRONMENT MONITORING SECTION

F.C. Dreher, Hydr-13, 0-0636-W,
Asst. Dist.Chief (2,3,4,5)
R.E. Campbell, Hydr-12, 0-2054-M (2,3,10)
E.E. Zuehls, Hydr-11, 0-2391-M (17)
W.J. Rose, Hydr-9, 0-1639-M (3)
R.M. Erickson, Tech-9, 0-1792-M (3)
S.J. Field, Tech-9, 0-2105-M (19)
H.L. Hanson, Tech-6, 0-1687-M
C.A. Lee, Tech-6, 0-1687-M
R.A. Lidwin, Tech-4, 0-1546-M (3)
J.Z. Taylor, Tech-6, 0-1687-M WAE
J.A. Reinartz, HFA-3 WAE
J.A. Sayles, HFA-3 WAE

NE FIELD HEADQUARTERS-Merrill

G.G. Plantz, Tech-9, 0-2124-M (2,3)
R.C. Baumann, Tech-6, 0-1687-M (2)
R.H. Biller, Tech-6-0-1687-M (2)

NW FIELD HEADQUARTERS-Rice Lake

J.T. Freshwaters, Tech-9, 0-2172-M (2,3)
K.J. Hedmark, Aid-3, 0-1545-M (2,3)

HYDROLOGIC SYSTEMS SECTION

W.B. Gannon, Hydr-13, 0-0881-W,
Asst. Dist. Chief (1,3,4,6)
D.H. Conger, Hydr-12, 0-9039-M (1,15)
R.W. Devaul, Hydr-12, 0-9042-M (3)
W.A. Gebert, Hydr-12, 0-2260-M (1,14)
C.L. Lawrence, Hydr-12, 0-0396-M
R.S. Grant, Hydr-11, 0-2423-M
B.K. Holmstrom, Hydr-11, 0-1894-M
R.J. Smith, Hydr-7, 0-1248-M WAE
L.C. Trotta, HFA-5
J.D. Parkyn, HFA-4 WAE
L.R. Whiting, HFA-4 WAE
J.A. Dammer, HFA-3 WAE
Betsy Reems, HFA-2 WAE
D.O. Welck, HFA-2 WAE

HYDROGEOLOGIC STUDIES SECTION

R.D. Cotter, Hydr-13, 0-0882-W,
Asst. Dist. Chief (1,2,4,7,9)
E.A. Bell, Hydr-12, 0-7321-M
R.P. Novitzki, Hydr-12, 0-2412-M (13)
E.L. Oakes, Hydr-12, 0-8465-M
H.L. Young, Hydr-12, 0-9388-M (1)
J.B. Gonthier, Hydr-11, 0-1646-M (13)
S.M. Hindall, Hydr-11, 0-2244-M (1,18)
P.A. Kammerer, Hydr-11, 0-2096-M (1,16)
R.A. McLeod, Hydr-11, 0-1603-M (13)
M.G. Sherrill, Hydr-11, 0-1603-M
R.G. Borman, Hydr-9, 0-1693-M
D.B. Radtke, Tech-5, 0-1547-M WAE
G.J. Allord, Tech-4, 0-1546-M WAE
Deanna Peterson, HFA-2 WAE

Additional duties in-

(1) Water Environment Monitoring Section
(2) Hydrologic Systems Section
(3) Hydrogeologic Studies Section
(4) Staff Advisory Group

District specialists-

(5) EEO Officer
(6) Special Recruiter
(7) Training Officer
(8) Reports specialist
(9) ADP Coordinator
(10) Safety Officer
(11) Environmental impact
(12) Remote sensing

District specialists-

(13) Ground-water modeling
(14) Stream-system modeling
(15) Floods
(16) Water quality
(17) Urban runoff
(18) Sediment
(19) Monitoring equipment and instruments

Wisconsin District budgets, 1966–79, in approximate $1,000's

Fiscal year	Federal funding	Federal Cooperative funding	Other Federal funding	Total
1966	19	292	47	358
1967	19	522	31	572
1968	25	654	35	714
1969	43	683	39	765
1970	65	706	52	823
1971	50	771	57	878
1972	43	842	208	1,093
1973	54	867	276	1,197
1974	57	956	250	1,263
1975	76	1,211	472	1,759
1976	86	1,336	495	1,917
1977	89	1,378	531	2,007
1978	96	1,474	505	2,075
1979	272	1,555	369	2,196

PRINCIPAL PROGRAMS

Cooperative Programs—State and Local

Close cooperation and coordination with State and local agencies ensured that the District's programs were responsive to real needs for information. In 1966, the State legislature appropriated new funds for water-resources research. As a result of increased Coop funding, studies were expanded to provide water information concerned with environmental, socioeconomic, and management factors.

The University of Wisconsin Extension (Geological and Natural History Survey) was a primary State cooperator for statewide information on ground water, assessment of water resources of major river basins, modeling of ground water systems, hydrologic and geologic studies of counties and areas of municipal and industrial development, and research into effects of ground-water/surface-water relations, impoundments, and lakes.

The Wisconsin Department of Natural Resources (DNR), and its predecessor, the Wisconsin Conservation Department, were major cooperators for the collection of statewide streamflow, sediment, and lake data. They supported studies of the effects of irrigation on streamflow, the hydrology of wetlands and lakes, the water effects of fish-hatchery management, environmental effects of drainage, and impoundments. The DNR program also included the earlier Public Service Commission's contributions for regional low-flow frequency studies and duration tables of streamflow to determine allowable surface-water diversions. Also included was the earlier Wisconsin Department of Resource Development, which supported the evaluation of the effectiveness of watershed improvement practices, the study of interrelations of ground water and surface water, and studies of environmental effects of impoundments, lakes, and drainages.

The Wisconsin Department of Transportation, Division of Highways, supported a statewide program to develop flood-frequency relations for small drainage areas. This included the hydrologic analyses of specific bridge sites. Madison Metropolitan Sewerage District continued funding the gaging of a small stream that carried treated effluent to a lake. The Southeast Wisconsin Regional Planning Commission (SEWRPC) supported a water-resources study of the southwestern Wisconsin-Fox River Basin and gaging stations on several small streams. The Coop Program also was supported by the Dane County Regional Planning Commission, the Madison Water Utility, the City of Middleton, the Village of Oregon, and the Town of Schleswig.

Federal Program

The Survey's Federal Program supported gaging stations, surface-water compilation reports, quality-of-water network evaluations, research on rating characteristics of hydropower plants, delineation of flood-prone areas, Mississippi River flood reports, the effects of impoundments on Nederlo Creek, and the Northern Midwest Regional Aquifer Study.

Other Federal Agencies

The U.S. Army Corps of Engineers, Districts of Rock Island, St. Paul, and Chicago, continued to fund gaging stations on major rivers. The U.S. Fish and Wildlife Service funded the collection of streamflow data in the Horicon Refuge area. The Soil Conservation Service funded the collection of streamflow data needed to evaluate several watershed-protection projects. The Bureau of Indian Affairs funded a study of the hydrology of the Sokaogan Chippewa community. Streamflow data were collected on the Chippewa, Red Cedar, Wolf, Wisconsin, and Flambeau Rivers concerning five hydroelectric power companies licensed by the Federal Power Commission. The National Park Service funded a flood-frequency and water-quality study of the St. Croix River and a water-resources appraisal of the Apostle Islands.

The U.S. Forest Service funded a hydrologic study of Lake Owen in northern Wisconsin. The U.S. Department of Housing and Urban Development (HUD) funded studies of flood characteristics at communities and data for flood zoning.

Epilogue

After 1966, the District programs shifted perceptibly and rapidly from water supply and water quality to river and aquifer character and quality, and to the management of water resources to meet the water-data needs of Wisconsin. The Wisconsin Legislature's 1966 appropriation of funds for water research, the U.S. Water Quality Act of 1965, and the U.S. Environmental Quality Act of 1969 helped to usher in a new era of information needs.

By FY 1967, the results of District reorganization were the development of interdisciplinary studies, a unified approach to data collection, and an increased emphasis on hydrologic studies oriented toward solving water problems. By FY 1975, the District program had expanded to 50 projects with trained staff collecting and analyzing the hydrologic, geologic, and water-quality data needed to understand hydrologic systems and to supply information needed to manage water resources.

Because of space limitations, it is not possible to describe each of the many projects completed and in progress during this report period. Brief summaries of selected segments of the District program during this period are as follows:

The collection, interpretation, and publication of surface-water, ground-water, and quality-of-water data continued to be a strong and growing component of the District program. A water-use data project was added in 1978. Studies of the hydrology of water problems and water-data needs around the State, plus the use of network concepts, aided the data-collection processes to meet expanded data needs and objectives. Increasing applications of automated monitoring equipment and computer technology improved the timeliness of data collection, processing, and publication.

Studies on the probability and extent of future floods were expanded greatly as areas became urbanized and data were needed for flood warning and flood zoning. By 1979, 420 flood-prone areas had been mapped on quadrangle topographic maps. In a flood-insurance program funded by HUD, 82 community studies had been completed or were in preparation.

Low-flow studies were increasingly important to evaluate effects of watershed protection structures, withdrawal of irrigation water, and the waste-assimilation capacity of streams. Studies of Wisconsin River low flow and low-flow stream geometry began about 1976.

Interpretive investigations were expanded from studies that concentrated attention on needs of the present to those that develop readiness for needs of the future. During this period, numerous studies were made of streams, lakes, impoundments, and wetlands. Of great importance were effects of land development and land-use practices on the hydologic system. County water-resource evaluation studies were continued to supply planning information for urban and rural areas. Analog and digital-computer model studies described effects of water withdrawal on the ground-water system in the Madison area. Comprehensive river-basin reports and hydrologic atlases were prepared for the entire State. Other areal hydrologic studies included availability of ground water for irrigation and fish hatcheries, a hydrogeologic map series of southeastern Wisconsin, and a statewide map series. Studies were made of the natural chemical quality in different ground-water systems and of the effects of pollution, especially in shallow aquifers, such as irrigation areas and carbonate rock areas such as Door and Waukesha Counties.

Studies of pollution potential, nonpoint pollution, sources of pollutant loading, and sediment transport were expanded in the 1970's. In 1978, the Wisconsin part of the Midwest Regional Aquifer study began with the assembling of geologic and hydrologic information on Paleozoic rocks. Studies of pollution potential, nonpoint pollution, sources of pollutant loading, and sediment transport were commenced in the 1970's.

Reports, the objectives of all studies, were produced in abundance—15 Water-Supply Papers, 17 Hydrologic Atlases, 36 Water-Resources Investigations, 5 Professional Papers, 42 Open-File Reports, 10 Open-File Maps, 9 Administrative Reports, 24 Wisconsin Geological and Natural History Information Circulars and Maps—and may be inspected at the WRD District Office, 8505 Research Way, Middleton, Wisconsin.

SOUTHEASTERN REGION, 1972–79

by Leslie B. Laird
(with review and assistance by James L. Cook, Malcolm D. Hale, and John R. George)

Regional Office

The Southeastern Region of the Water Resources Division was established in 1972. The restructuring grouped the States of Alabama, Florida, Georgia, Kentucky, Mississippi, North and South Carolina, Tennessee, the Commonwealth of Puerto Rico, and the Territory of the Virgin Islands. From 1956 through 1971, WRD personnel working in the States of Florida, Georgia, North and South Carolina, the Commonwealth of Puerto Rico, and the Territory of the Virgin Islands reported to George E. Ferguson, Regional Hydrologist, Atlantic Coast Region. Alabama, Mississippi, and Tennessee reported to Harry D. Wilson, 1966–68, and Elwood Leeson, 1968–71, Regional Hydrologists for the Mid-Continent Area. Reorganization in 1972 established the Southeastern Region and Northeastern Region, eliminated the Mid-Continent Area, and revised the regional boundaries somewhat.

The new Southeastern Regional Headquarters was established at 1459 Peachtree Street NE in Atlanta, Ga. In 1978, the Regional Headquarters moved to the Richard B. Russell Federal Building, 75 Spring Street SW, in Atlanta. Personnel occupying the positions shown below in the Regional Office from 1972 through 1979 were as follows:

Regional Hydrologist
- Rolland W. Carter, 1972–74
- Leslie B. Laird, 1975–78
- Robert J. Dingman, 1978–

Assistant Regional Hydrologist
- Rex R. Meyer, 1972–74
- Malcolm D. Hale, 1974–76
- James L. Cook, 1977–

Regional Program Officer
- Malcolm D. Hale, 1972–74
- C.L.R. (Lee) Holt, 1974–

Branch Specialist—Surface Water
- Richard H. Tice, 1972–75
- Vernon B. Sauer, 1975–

Branch Specialist—Ground Water
- Alcee H. Turcan, 1972–74
- James R. Daniel, 1974–79
- Harlan B. Counts, 1979–

Branch Specialist—Quality of Water
- Robert A. Krieger, 1972–

Regional Computer Specialist
- James M. Bergman, 1975–

Regional Administrative Officer
- Marilyn S. Whittaker, 1972–78
- Robert D. Hudson, 1979–

Regional Reports Specialist
- Donald G. Jordan, 1974–

Regional Research Hydrologist
- Stanley P. Sauer, 1972–73
- Robert A. Baker, 1974–

Hydrologic Personnel Specialist
- John P. Monis, 1972–74
- Garald G. Parker, Jr., 1975–78
- Ann C. Beam, 1978–

Project Offices

- Matthew I. Rorabaugh, 1972–, Research Hydrologist
- Hubert J. Tracy, 1972–78, Research Hydraulic Engineer

Chattahoochee River Intensive River Quality Assessment

- Rodney N. Cherry, 1974–79
- Robert E. Faye, 1975–79
- John K. Stamer, 1974–78

Southeastern Limestone Aquifer Project (RASA)

- Richard H. Johnson, 1977–
- Peter W. Bush, 1979–
- Craig L. Sprinkle, 1978–
- James A. Miller, 1978–

Southeast Coastal Plain Regional Aquifer Study (RASA)

- Harlan B. Counts, 1979
- Robert L. Wait, 1978–
- Roger W. Lee, 1979–
- Rene A. Barker, 1979–

In 1973, the Central Water Quality Laboratory was established in Doraville, Ga., a suburb of Atlanta, under the supervision of Donald K. Leifeste, who continued to direct the facility through 1978. This laboratory performed chemical, physical, and biologic analyses of water samples for WRD Districts in the Northeastern and Southeastern Regions. In 1974, the laboratory had 29 employees. The workload of the laboratory grew steadily in all analytical areas: employment totaled 51 in 1979—28 professionals, 20 technical support, and 3 administrative. When first established, the laboratory functioned under the Regional Hydrologist of the Southeastern Region. In late 1974, supervision and technical direction was shifted to the Quality of Water Branch and the Assistant Chief Hydrologist, Research and Technical Coordination.

In 1975, the Southeastern Regional Office developed a Career Development Program that was later adopted in large part by the WRD. Regional office staff designed individual employment history and comment forms and performance evaluation forms. The Regional Hydrologist and Assistant Regional Hydrologist visited each District Office and most Subdistrict Offices to hold career development discussions with each full-time employee. The career development visits were well received by the employees and continued each year through 1979. Each employee had a chance to better learn the requirements for desired positions. The Regional staff became familiar with all of the employees in the Region, their goals and aspirations, and were able to identify a great deal of talent for future assignments with the WRD. The Division Manpower Section modified the forms developed for this purpose, and the forms were placed in use nationwide in 1976.

The budget for the entire Southeastern Region more than doubled during the late 1970's. Program growth from coal hydrology began in 1975 with new data programs and special studies in Alabama, Kentucky, Mississippi, and Tennessee. New fund sources included the Bureau of Land Management, several State mine-permitting agencies, and of course, WRD's own Federal and Cooperative Programs. A major nationwide drought brought new appropriated funds to evaluate the Nation's ground-water resources. By 1979, the Southeastern Region was leading two of these studies.

From 1975 to 1978, Les Laird served on the Southeastern Region's Emergency Preparedness Committee. During this period, several "drills" were held to prepare the State and Federal agencies to react to emergencies such as marine and freshwater oil spills, floods, and storms. Throughout 1972–79, the Regional Hydrologist served as the USGS representative on the Interior Department Southeast Field Committee: Rolland Carter, 1972–74; Les Laird, 1975–78; and Bob Dingman, 1978–79.

DISTRICTS

ALABAMA

by Hillary Jeffcoat

In 1966, the Alabama District was still in the process of a reorganization that began in 1964. A first effort included integrating long-standing programs and personnel from the Surface and Ground Water Branches. The new water-quality component of the District established data-collection networks that would later support multidisciplinary work relating to energy resources. By 1979, the District experienced significant growth resulting from coal hydrology studies.

ORGANIZATION AND MANAGEMENT

During this period, the District consisted of the following offices: District Office in Tuscaloosa, Subdistrict Offices in Tuscaloosa and Montgomery, and a Field Office in Cullman. Data-collection activities were distributed throughout the State, and interpretive studies were conducted in the Tuscaloosa and Montgomery offices. In 1966 the District Office consisted of District management, technical specialists, administration, and a field data-collection unit.

At the beginning of the period, William L. (Bill) Broadhurst was District Chief. Broadhurst was succeeded by William (Bill) J. Powell in 1972. The administrative duties were headed by Alma Jean Roberts during the entire period. Principal assistants in the District Office included the following: William J. Powell (1966–72), James Daniels (1972–75), Ernest F. Hubbard (1975–78), and Hillary H. Jeffcoat (1978–79). The Montgomery Subdistrict was headed by Harold Golden until mid-1966; Golden was succeeded by Charles O. Ming in 1972 and James Bowie in 1977. The Cullman Field Office was headed by Joe R. Harkins, who was succeeded by Paul W. Cole in 1974. The final phase of reorganization occurred in 1972 when a Subdistrict Office was established in Tuscaloosa, headed by James Averett. The action was made to accommodate participation in the Division's Coal Hydrology Program and new programs with Birmingham, the State's largest city. New staff members were added by Roy H. Bingham's transfer from Oklahoma and Celso A. Puente's transfer from Texas.

DISTRICT OFFICES

The District Office was in the Oil and Gas Board Building on the campus of the University of Alabama in Tuscaloosa. The building also was occupied by the District's principal cooperator, the Alabama Geological Survey.

Tuscaloosa Subdistrict—The Subdistrict Office, located in Wood's Square, also included the office of the Bureau of Land Management (BLM). The function of the office included the major thrust of data-collection activities for coal hydrology and urban hydrology activities in Birmingham. The staff during the peak years (1978–79) included 24 employees.

Montgomery Subdistrict—The Subdistrict Office was located on Ann Street in Montgomery. Major functions included hydrologic and hydraulic analyses of bridge sites and data collection in southern Alabama. The size of the staff remained fairly constant with 15 employees.

Cullman Field Headquarters—This office was in the Post Office Building and was staffed by four hydrologic technicians. The primary function of the office was data collection in the Tennessee River Valley and liaison with the Tennessee Valley Authority (TVA).

FUNDING

Funding for the Alabama District at the beginning of the period was primarily in the Federal-State Cooperative (Coop) Program. There were two major cooperators: the Alabama Geological Society and the Alabama Highway Department. Funding remained fairly constant until the mid-1970's when energy programs, USGS, and other Federal agencies (OFA) began to provide the majority of funds for the District. Major OFA's included the U.S. Army Corps of Engineers, Mobile District, the Bureau of Land Management, TVA, and the Alabama Power Company. District funding more than tripled by the end of the period, largely because of hydrologic information needed to determine the impacts of increased coal mining.

Alabama District budget

	1966	1973	1979
Cooperative Program	$480,000	$560,000	$1,030,000
Federal Program	13,000	20,000	420,000
Other Federal agencies	73,000	110,000	880,000
Total	$566,000	$690,000	$2,330,000

HYDROLOGIC DATA PROGRAMS

Several factors influenced the scope of data programs during this period. For the first time, surface-water networks were evaluated following long-term operation, primarily on larger rivers. Hydrologic activities associated with interstate highway construction identified a void in data networks and the need for new stations on small streams. Ground-water data programs were influenced by county water-availability studies. At the conclusion of these studies, selected wells were added to a monitoring network of approximately 20 wells.

Surface-Water Stations

Most of the network consisted of stations on the major rivers such as the Coosa, Alabama, Tombigbee, Black Warrior, and Tennessee Rivers. In addition, a network of gaging stations was maintained on "natural streams" for the purpose of data transfer and hydrologic modeling. The number of surface-water stations ranged from as few as 71 in 1971 to a maximum of 85 in 1979. Supplemental data collected during two major floods, 1973 and 1979, added significantly to the data base.

Water-Quality Stations

About 35 daily and monthly water-quality stations on streams were operated at some time during the period. By far, the major thrust consisted of data from partial-record and miscellaneous stations. More than 1,000 water samples from these stations were analyzed in association with the county water-availability program, coal-hydrology programs, and construction of the Tennessee-Tombigbee waterway. In addition, more comprehensive data were collected at several Federal Hydrologic Bench-Mark and National Stream-Quality Accounting Network (NASQAN) Stations. Most of these water-quality activities received the careful overview of the District Water-Quality Specialist, James Averett.

Hydrologic Investigations

This period marked the beginning of interdisciplinary studies that were related to Alabama's economic growth. Development of the State's infrastructure for highways and waterways provided additional opportunities for studies. Toward the end of the period, the coal-hydrology programs produced the largest expansion of studies and related work in the history of the District.

John L. Powell, former Alabama District Chief, reported that sinkholes throughout the limestone areas of Alabama became a recognized problem in the late 1960's. Sinkholes had caused major problems to highways, rail lines, sewer and water mains, and other structures. For much of this period, John G. Newton worked with personnel from the State Geologist's office, State and Federal highway agencies, and the City of Birmingham to map land areas with existing or potential sinkhole activity. The resulting maps proved invaluable to planners, government, developers, and real estate interests. The report, "Early Detection and Correction of Sinkhole Problems in Alabama," by J.G. Newton (1976), Alabama Highway Department HPR Report 76, proved to be a very popular contribution to the geohydrologic literature of Alabama.

Cooperative County Investigations

In cooperation with the Geological Survey of Alabama, countywide studies were completed during this period. The studies involved surface-water and ground-water availability with expanded emphasis in the high-growth metropolitan areas of Huntsville and Birmingham. One major product of the studies was a statewide geologic map.

Coal Hydrology Programs

The oil-shortage crisis of the mid-1970's produced an intense focus on the energy resources of the United States. Considerable attention was directed toward coal, an abundant resource. A need for hydrologic information and analysis was required by Public Law 95–87, the Surface Mining Control and Reclamation Act of 1977. Several intensive investigations began in collaboration with BLM and the Office of Surface Mining (OSM). Data and information from these investigations were used to assess potential impacts of coal mining on water resources. Much of this effort came under the strong technical direction of Joe Harkins. These and other related studies also provided valuable information for BLM's permitting process.

HYDROLOGIC EVENTS

This period in Alabama was dominated by floods and hurricanes.

- In August 1969, Hurricane Camille moved across coastal Alabama and Mississippi. Many lives were lost and property damage was extensive, primarily in Mississippi.
- Torrential rains within a 48-hour period caused severe flooding in the upper Tombigbee and Tennessee River Basins. Peak discharges had greater than a 100-year recurrence interval on the Buttahatchie River.
- Record floods occurred on streams in central Alabama during March and April 1979. The flood destroyed a bridge over the Tallapoosa River. Total damage was about $75 million.
- Hurricane Frederick, in September 1979, was one of the more intense hurricanes of record to enter the United States mainland. Total property damage was about $2 million.

SIGNIFICANT PUBLICATIONS

Floods in Alabama, magnitude and frequency, by C.F. Hains, 1973, Alabama Highway Department Special Publication.

Low-flow characteristics of Alabama streams, by R.H. Bingham, 1979, U.S. Geological Survey Open-File Report 79–0208—later published as U.S. Geological Survey Water-Supply Paper 2083.

Effect of surface mining on the hydrology of Crooked and Turkey Creek Basins in Jefferson County, Alabama, by Celso Puente and J.G. Newton, 1979, U.S. Geological Survey Water-Resources Investigations Report 79–91.

Acknowledgment

William J. Powell and Robert E. Kidd provided information for this article or commented on the manuscript.

FLORIDA

by Clyde S. Conover, Thomas J. Buchanan, Joseph S. Rosenshein, Charles H. Tibbals, George A. Irwin, John Vecchioli, and Robert T. Kirkland

Dedicated to George E. Ferguson, Regional Hydrologist, Atlantic Coast Area (Retired), for his strong support and encouragement.

The Florida Water Resource Branch offices were established as a Water Resources Division District Office in February 1965. Clyde Conover was designated as the first WRD District Chief, with Headquarters in Tallahassee. The reorganization and transition were accomplished chiefly with personnel in place as much as feasible. A goal was set to reorganize the District to better fit the demands of emerging water problems and proximity to the cooperating agencies as could best be envisioned at the time. Increased population and emerging water problems dictated that the District establish Subdistrict Offices corresponding with the hydrologic systems and the boundaries of the emerging five Florida Water Management Districts. Accordingly, Subdistrict Offices were located at Miami, Orlando, Tampa, and Tallahassee.

Acknowledgments

The authors gratefully acknowledge the assistance of many of the staff of the Florida District Office in locating and furnishing background data. In particular, Mildred Glenn, Program Assistant, furnished information on annual investigative summaries. Debbie Weldon, Administrative Officer, located annual funding summaries, and Teresa Embry, Publications Editor, provided a tabulation of reports published during the era and editorially reviewed the report. Roz Czajkoski (retired), Publications Editor, assembled tabulations of personnel and prepared an inventory of water records. Ron Spencer, Illustrator, provided material for the Florida map.

In particular, Nevin Hoy, Senior Staff Hydrologist (Retired), provided his usual excellent review, and Irwin Kantrowitz, Area Hydrologist, Southeastern Region, kindly took time to add his comments. Last, but most importantly, thanks go to Linda Proto, Executive Secretary, for converting basic draft into final typed copy.

Thanks go especially to John Vecchioli, District Chief, for lending his support and serving as a joint author. The authors gladly devoted their time to this worthy endeavor and accomplished an almost insurmountable task covering many years of effort expended long ago.

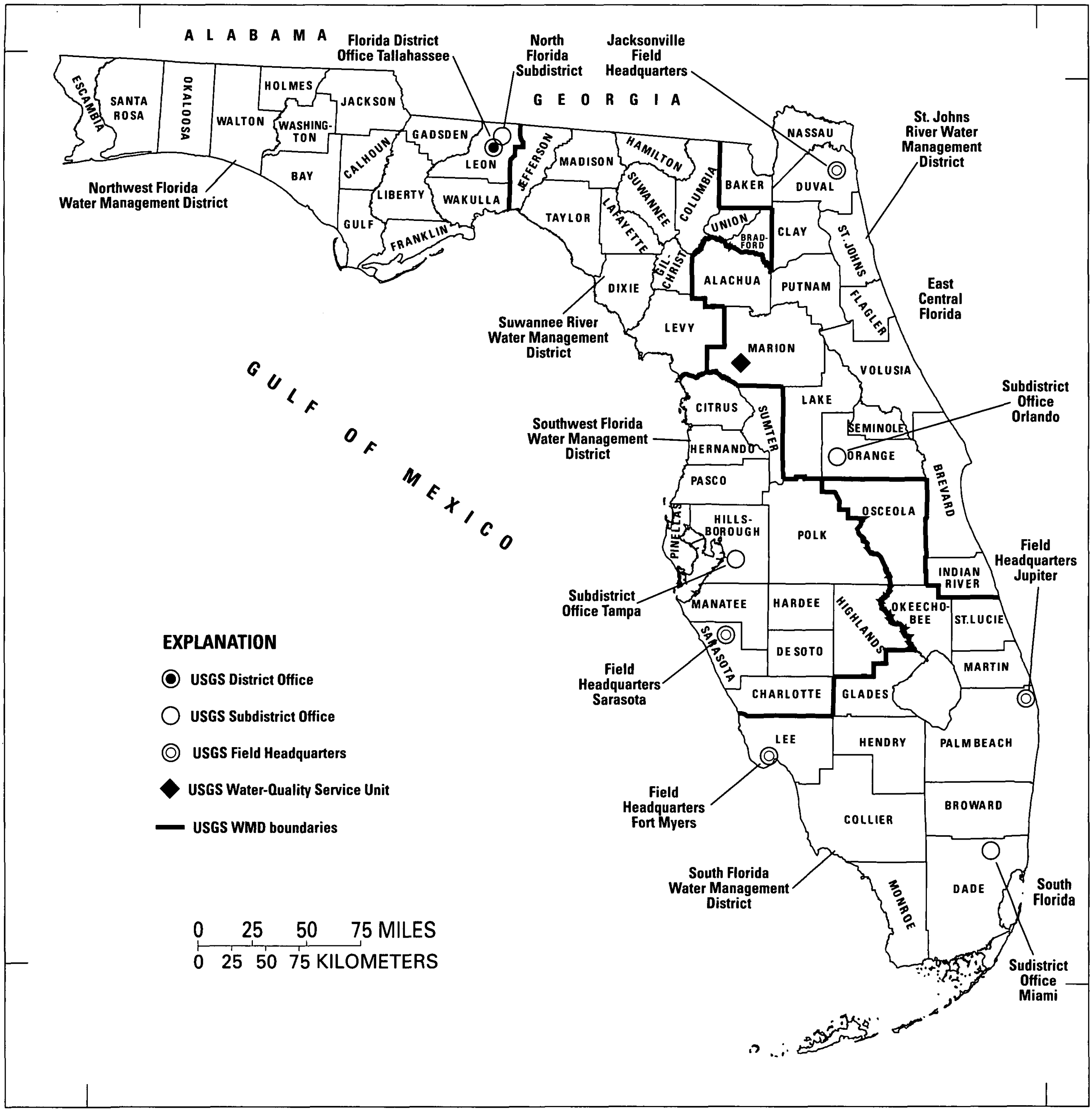
ORGANIZATION

Prior to reorganization, Surface Water Branch personnel were located at the District Office at Ocala, at a Subdistrict Office at Miami, and at a Field Office at Sebring. The Quality of Water Branch maintained a major water-quality laboratory in Ocala that provided analytical service for Georgia, Alabama, South Carolina, and North Carolina as well as for the Florida District. The Ground Water Branch had a District Office in Tallahassee, a Subdistrict Office in Miami, and five Field Headquarters.

At the beginning of this period of history, existing offices at Miami and Ocala were designated Division Subdistrict Offices, with Howard Klein and Leonard Snell in charge, respectively, and a Field Headquarters at Tampa, with Joe Stewart as Hydrologist-in-Charge. In 1967, Joe Rosenshein transferred to Tampa from Rhode Island to be Subdistrict Chief. In 1968, Tom Buchanan transferred from New Jersey to become Subdistrict Chief in Miami. In 1969, Snell retired, and Joel Kimrey was assigned as Subdistrict Chief in Ocala. In 1972, the Ocala Subdistrict was transferred to Winter Park, closer to the Headquarters of the St. Johns River Water Management District. Kimrey continued as Subdistrict Chief, and Richard C. Heath was in charge of the Ocala Field Headquarters. In 1973, Richard Heath transferred to District Headquarters at Tallahassee as Chief of Operations, and Dick Hedges took charge of the Ocala Field Headquarters. In 1976, the Winter Park Subdistrict was moved to Orlando.

The Water Quality Service Unit remained in Ocala for this period. Initially, Boyd F. Joyner was Chemist-in-Charge. In 1973, Joyner transferred to the Tampa Subdistrict as Supervising Hydrologist, and Robert T. Kirkland assumed responsibility for the Water Quality Service Unit.

In 1969, a North Florida Subdistrict Office was established in Tallahassee with Jack Rosenau in charge. In 1975, Bill Mann transferred from Minnesota as Chief of the North Florida Subdistrict. In 1979, Mann transferred to Wisconsin, and Jack Rosenau became Acting Chief of the Subdistrict Office.



87°
80°
31°
25°
ALABAMA
GEORGIA
GULF OF MEXICO
Florida District Office Tallahassee
North Florida Subdistrict
Jacksonville Field Headquarters
St. Johns River Water Management District
East Central Florida
Northwest Florida Water Management District
Suwannee River Water Management District
Southwest Florida Water Management District
Subdistrict Office Orlando
Field Headquarters Jupiter
Subdistrict Office Tampa
Field Headquarters Sarasota
Field Headquarters Fort Myers
South Florida Water Management District
South Florida
Sudistrict Office Miami
ESCAMBIA
SANTA ROSA
OKALOOSA
WALTON
HOLMES
WASHING-TON
JACKSON
BAY
CALHOUN
GADSDEN
LEON
LIBERTY
GULF
FRANKLIN
WAKULLA
JEFFERSON
MADISON
TAYLOR
HAMILTON
SUWANNEE
LAFAYETTE
COLUMBIA
BAKER
NASSAU
DUVAL
UNION
BRAD-FORD
CLAY
ST. JOHNS
GIL-CHRIST
DIXIE
ALACHUA
PUTNAM
FLAGLER
LEVY
MARION
VOLUSIA
LAKE
CITRUS
SUMTER
SEMINOLE
HERNANDO
ORANGE
PASCO
BREVARD
OSCEOLA
PINELLAS
HILLS-BOROUGH
POLK
INDIAN RIVER
MANATEE
HARDEE
HIGHLANDS
OKEECHO-BEE
ST.LUCIE
SARASOTA
DE SOTO
MARTIN
CHARLOTTE
GLADES
LEE
HENDRY
PALM BEACH
COLLIER
BROWARD
DADE
MONROE
EXPLANATION
USGS District Office
USGS Subdistrict Office
USGS Field Headquarters
USGS Water-Quality Service Unit
USGS WMD boundaries
0 25 50 75 MILES
0 25 50 75 KILOMETERS

In 1972, both the District Office and the North Florida Subdistrict Office moved to the Woodcrest Office complex in Tallahassee because the Gunter Building on the Florida State University campus had become overcrowded.

Roland Pride served as Assistant District Chief of the District from February 1965 until his retirement in 1973. Rufus Musgrove was appointed to the position in 1973 and continued through the period.

In 1976, George A. Irwin transferred from California to Tallahassee as the District Water Quality Specialist. In 1977, John Vecchioli transferred from New York to Tallahassee as the District Ground Water Specialist. As Stan Leach had previously been designated District Surface Water Specialist, the District now had a full complement of hydrologic specialists.

In 1975, Joe Rosenshein transferred to Kansas, and John Moore transferred from Colorado to be Chief of the Tampa Subdistrict office. In 1976, Tom Buchanan transferred to Reston to be Assistant Chief Hydrologist of Operations of the Water Resources Division. In 1976, Al LaSala transferred to Miami from Idaho to be Subdistrict Chief. In 1978, John Moore transferred to Reston, and Bob Knutilla was named Subdistrict Chief at Tampa.

In 1977, the Subdistricts were renamed regionally rather than by location. That is, the Subdistrict Offices were designated as South Florida, North Florida, Southwest Florida, and East Central Florida Subdistrict Offices, rather than Miami, Tallahassee, Tampa, and Orlando. This change recognized the geographic areas of responsibility of each office.

In summary, at the beginning of the period, the Florida District had 4 principal operating offices with a total of 137 personnel. In 1979, there were 5 principal offices, and 4 Field Headquarters with 288 personnel. The following table presents a staffing comparison from 1967 to 1979.

The staff consisted of a wide range of interdisciplinary talent: 121 engineers, geologists, hydrologists, biologists, chemists, mathematicians, cartographers, and oceanographers, plus aides, technicians, clerks, and typists.

Number of District personnel, by office, 1967 and 1979

Office	Number of personnel
January 1967	
FLORIDA DISTRICT OFFICE, Tallahassee	27
Field Headquarters, Ft. Myers	1
Field Headquarters, Jacksonville	1
Field Headquarters, Orlando	1
Field Headquarters, St. Augustine	1
Quality Water Service Unit, Ocala	15
Subdistrict Office, Miami	29
Subdistrict Office, Ocala	30
Field Headquarters, Sebring	4
Subdistrict Office, Tampa	17
Field Headquarters, Sarasota	1
TOTAL	122*
January 1979	
FLORIDA DISTRICT OFFICE, Tallahassee	36
Northeast Florida Field Headquarters, Jacksonville	13
Quality of Water Service Unit, Ocala	7
South Florida Subdistrict Office, Miami	50
Field Headquarters, Ft. Myers	9
Field Headquarters, Jupiter	5
North Florida Subdistrict Office, Tallahassee	40
Southwest Florida Subdistrict Office, Tampa	77
Field Headquarters, Sarasota	3
East Central Florida Subdistrict Office, Orlando	41
Field Headquarters, Ocala	7
TOTAL	288*

*Includes vacancies, part-time, and when actually employed.

FUNDING AND COOPERATION

Following the pattern of many years, most of the funds for the District programs were from two sources: (1) the Federal-State Cooperative Program (Coop), generally shared equally, and (2) other Federal agencies (OFA). Of the total program, consisting of about $10 million in 1979, more than 80 percent of the available funds was furnished by the Coop Program. OFA funds and Federal funds each constituted less than 10 percent of the program. The large growth in population and consequent increase in water demand and use are reflected by the large increase in programs. The funds available to the District in 1966, 1973, and

1979 are shown. The total funds increased six times during 1966–79.

Florida District funds, Fiscal Years 1966, 1973, and 1979 (thousands of dollars)

Funding source	1966	1973	1979
Coop	1,266.4	3,054.8	7,288.7
OFA	142.2	1,024.3	858.8
Federal	18.2	151.5	843.7
USGS*	--	39.8	594.0
Federal Power Commission	2.5	--	--
TOTAL	$1,429.3	$4,270.4	$9,585.2

*Repay from other Divisions for services rendered.

In 1979, there were some 60 State, county, and city agencies in the Coop Program, including 7 statewide agencies: the Florida Department of Environment Regulation, Florida Department of Natural Resources, and the 5 Florida Water Management Districts, 17 counties, 24 cities, and 11 water authorities. Nine Federal agencies were represented: National Park Service, U.S. Air Force, Bureau of Land Management, Civil Service Commission, U.S. Army Corps of Engineers, Department of Housing and Urban Development, U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, and the U.S. Navy.

The program with each agency was mutually agreed upon to fit the goals and objectives of each and the public needs and interests. In general, funds were allocated for: (1) comprehensive continual accounting of the sources, movement, amount, storage, quality, and use of water supplies; and, (2) investigations of the causes and effects of human activities and natural events. In Florida, water-resources appraisals were highly diversified because of the continual human activities brought on by the large population increase. The Florida environment is largely water sensitive, and most environmental problems are water related.

The Florida hydrologic program in 1979 was categorized as 30 percent hydrologic records and 70 percent investigations. This contrasts with the 1966 program, which was divided equally between records and investigations.

COOPERATING AGENCIES

The Bureau of Geology, Florida Department of Natural Resources (FBG), has been the principal cooperator for statewide water-resource programs for many years as well as for a large part of the period of this history. Long-term records of streamflow, groundwater levels, and water-quality networks supported by this program were the basis of many areal studies and indicators of the changes in the hydrologic conditions brought about by development. The FBG was the agency responsible for publishing nearly all reports on water resources prepared by the WRD in Florida during the period. R.O. Vernon, Director of the FBG, was an enthusiastic supporter of the WRD program and assisted in arranging for local funding by many counties and municipalities to supplement matching funds of the FBG for the Coop Program.

Cooperative funding by the FBG during the period was adversely affected by inflation and the need for expansion of the Bureau's geologic and mineral resources program. As a result, cooperative funding of the WRD program by the FBG was terminated in 1972. This funding deficiency was alleviated by the increase in funding of other cooperators, particularly that of the Water Management Districts and some counties and cities. However, publication by the FBG of reports produced by the Survey continued sporadically for the rest of the period. Publication of the remaining investigative reports was done by the U.S. Geological Survey.

By the time publication of USGS hydrologic reports by the FBG ceased, two long-term prime objectives of the program had been virtually met. The objective of assessing the water-supply and water-quality characteristics of the 67 counties was met mostly by publication of nearly 80 Reports of Investigations. The statewide assessment of hydrologic conditions in the "water atlas" series was portrayed in more than 70 maps.

The U.S. Army Corps of Engineers supported a statewide network of gaging stations allied primarily with their overall responsibility for floodwater documentation. Also, they supported hydrologic investigations of various developmental works such as that of the Cross-Florida Barge Canal, the Tampa Bay Estuarine Hydrology study, evaluation of the potential subsurface storage of freshwater in the saline aquifer near Miami, the estuarine environmental assessment of the Loxahatchee River, and effects of withdrawals from the Floridan aquifer in Duval County.

SUMMARY OF PROGRAM

The cooperative water-resources program in Florida expanded significantly during the period in response to the needs for water development and management brought about in part by the large increase in resident and transient population. Population increased from about 5.9 million in 1965 to 9.8 million in 1980, as shown in the following table, while freshwater use increased from 4.8 billion gallons per day to 6.6 billion gallons per day.

The increase in the program resulted in a significant number of investigative projects that required a formalized approach to programming. Consequently, in 1970, every investigation was given a serial number and was documented by a description of the approach, objective, progress, cooperator, period of investigation, and principal investigator annually in a booklet titled "Water Resources Investigations in Florida." The number of investigations listed in 1970 was 58, and 90 were documented in 1979. The listing in 1979 did not include about 200 projects that were completed in the interim period. As of 1979, the total number of completed and current investigations was 318.

Freshwater withdrawals in Florida, by source, 1950–80

[All values are in million gallons per day; R.L. Marella, U.S. Geological Survey, written commun., 1993]

Year	Population (in millions)	Freshwater withdrawn, by source		
		Ground water	Surface water	Totals
1950	2.77	590.0	2,333.0 [a]	0.0
1955	3.60	1,035.0	1,150.0	2,185.0
1960	4.95	1,560.0	2,198.5	3,758.5
1965	5.91	2,218.5	2,623.3	4,841.8
1970	6.79	2,786.7 [b]	2,825.6 [b]	5,612.3
1975	8.49	3,214.6 [b]	3,453.6 [b]	6,668.2
1977	8.90	3,429.5 [b]	3,023.5 [b]	6,453.0
1980	9.75	3,677.2 [b]	2,937.3 [b]	6,614.5

[a] Fresh and saline water withdrawal totals were not delineated for 1950.

[b] Water withdrawal values have been adjusted from the originally published numbers.

Water Records

The water records, or hydrologic data programs, consist of networks of stations for the collection and publication of records of streamflow, stream and lake stage, ground-water levels, and quality of water. All data were obtained either as part of a basic-data program or were allied with a particular investigation. The number and kinds of data collected each year are thus quite variable. The collection and processing of these data were the responsibility of the Subdistricts. Beginning in 1966, James Simmons was responsible at the District level for coordinating, processing, quality control, and annual publication of the data.

The number of stations in the surface-water, ground-water, and quality-of-water networks increased significantly in the decade 1969 to 1979, as shown in the following table.

Much of the increase was allied with the data needs of the increased investigations program.

The periodic measurement of water levels in wells includes a network measured annually in May or June, when water levels are generally at their lowest. This program, initiated in 1962, provides the data to prepare annual synoptic potentiometric maps of the Floridan aquifer.

Quality of Water Service Unit

By the summer of 1966, the Ocala Laboratory (under the general direction of Clyde S. Conover, District Chief) was one of the largest and best equipped District laboratories in WRD. The laboratory, under the direct supervision of Boyd F. Joyner, had a staff of 16. The laboratory staff annually analyzed about 2,000 ground- and surface-water samples from throughout Florida and operated one of the first USGS mobile laboratories. The Ocala Laboratory continued to expand its capabilities and capacity, analyzing samples from U.S. Air Force installations in Greenland and Canada, environmental impact studies of the Cross-Florida Barge Canal, and intensive studies of Tampa Bay. The importance of nitrogen and phosphorus speciation in the latter studies caused an increased focus on these determinations beginning in 1968. In 1968, Florida's District Chief initiated the "mass-sampling" of 600 to 700 surface-water sites in the State. The Ocala Laboratory provided major ion, nutrient, and trace-metal analyses for samples from these sites twice a year, which provided a valuable

Water-records monitoring network

Classification	Number of stations	
	1969	1979
Streams		
Continuous or daily discharge	203	272
Periodic discharge	112	86
Continuous or daily stage	244	90
Periodic stage		62
Peak discharge		73
Peak stage		14
Total	559	597
Lakes		
Continuous or daily stage		113
Periodic stage		106
Total		219
Wells		
Continuous water levels	908	504
Periodic water levels	700-800	3,528
Quality of Water		
Surface water	217	359
Ground water	470	923

synoptic inventory of background surface-water quality in Florida.

The laboratory initiated sampling and analysis of Florida's Hydrologic Benchmark Network (HBN) station in 1969. This introduced the District to bacterial determinations as indicators of water quality, and over the next few years, the laboratory staff performed bacterial analyses and trained USGS personnel throughout the District in the analyses. Segmented-flow autoanalyzers were added to the laboratory's instrumentation in 1969, greatly expanding the laboratories analytical capacity for nutrient analysis, necessary to meet the growing demand for rapid data turnaround time.

In the late 1960's, the Florida District was involved in numerous quality-of-water investigations that provided background for intensive hydrologic studies of the next 3 decades. The deepest test well in Duval County was drilled in an attempt to locate saltwater, which was thought to lie at relatively shallow depths beneath the aquifer; but the water remained fresh to 2,500 feet. The investigation was conducted by Warren Levy, Warren Anderson, and Donald Goolsby. Andrew Lamonds headed an early study of the effect of the channelization of the Kissimmee River on water quality of Lake Okeechobee. Boyd Joyner's Lake Okeechobee Project found that precipitation was a major contributor of nitrogen and phosphorus to Florida's largest lake and that the lake was "in an early eutrophic condition." In South Florida, Aaron Higer, Milton Kolipinski, and Ben MacPherson conducted innovative studies in the Everglades which introduced the term "hydrobiology" into the WRD literature and produced some of the first data on pesticides in sediment, precipitation, and vegetative and animal tissue. Analytical data required by these studies caused the Ocala Laboratory to develop methods for determination of nutrients and trace metals in whole-water samples, bottom material, and plant and fish tissue.

Studies of deep-well waste injection in Pensacola and Belle Glade, headed by Donald Goolsby and Matthew Kaufman, led the Ocala Laboratory into implementation and development of methods to sample and to analyze for industrial wastes in the late 1960's and early 1970's.

The centralization of WRD laboratories resulted in closing most District laboratories by early 1973. The Ocala Laboratory staff was reduced from 19 chemists and technicians to 6 employees who were reassigned as Florida's Quality of Water Service Unit (QWSU), supervised by Robert Kirkland. The unit continued to produce analyses of nonconservative constituents and data for time-sensitive projects, operate the District's second mobile laboratory, and provide technical support and training for all water-quality activities. The QWSU also acted as a liaison between the Central Laboratories System and the Florida District and provided monthly status reports on samples sent to the Central Laboratories.

The QWSU began to provide repair and calibration of water-quality instruments for field use and procurement and supply services to Florida offices. In 1977, the QWSU initiated the first field quality-assurance (QA) program, supplying monthly reference samples to each Florida office and evaluating the data in proficiency reports. Quality-assurance activities continued to increase in 1978 and 1979, as District cooperators were added to the field QA program, and the Ocala Laboratory began to provide QA support to cooperator laboratories.

By 1979, the QWSU had developed a reputation for activity in quality assurance and training. The Unit Chief and members of the staff were invited to lecture at water-quality training courses at the USGS National

Training Center and at meetings of Florida cooperator agencies. The Ocala Laboratory provided assistance to several cooperator laboratories on specific analytical problems and expanded its services to include the preparation, supply, and quality assurance of various standards and chemical solutions used in the field.

Hydrologic Investigations

The major program growth during the period was primarily in cause and effect relations engendered by the large increase in population. The emphasis and objectives of many of the investigations were of a routine nature. However, some of the investigations were somewhat unique, either because of a particular environmental concern or conflict of public interests.

During the period from 1966 to 1979, some 200 investigations were initiated, and about 650 reports were published. Tabulation of reports by year and title can be obtained from the computerized system of indexing visualized by Conover and Hoy and implemented by Nevin Hoy, Jim Simmons, Teresa Embry, and others of the Reports Section. All reports were catalogued routinely by author, by geographic location, and by 22 hydrologic subjects.

District Office Activities

Stan Leach, as District Project Coordinator, with assistance from Wayne Bridges and others, began the HUD Type 15 Flood Insurance Studies in 1973, as part of the nationwide program financed by the Department of Housing and Urban Development. The objective was to delineate the flood hazards on quadrangle maps by using prescribed criteria. The project was completed successfully with the issuance of about 45 maps of flood-prone areas in various counties and cities.

Wayne Bridges, in cooperation with the Florida Department of Transportation, evaluated the magnitude and frequency of floods on drainage areas in Florida of less than 20 square miles, with emphasis on basins less than 10 square miles. Also, flood equations were developed to estimate the probable 2-, 5-, 10-, 25-, 50-, and 100-year floods for ungaged basins.

Jack Rosenau, Glen Faulkner, Charles Hendry, Jr. (FBG), and Robert Hull prepared an updated inventory of the springs of Florida which documented the physical characteristics of the 27 first-magnitude springs and nearly 175 other springs. The results were published in FBG Bulletin 31 (revised, 1977).

Gil Hughes, starting in 1965 as part of the Coop Program with the FBG, began a long-range analysis of the hydrologic characteristics of Florida lakes. By the end of the era, Gil had authored or jointly authored about a dozen reports on various hydrologic aspects of lakes.

In 1979, Dick Heath prepared a comprehensive U.S. Geological Survey Flood Operation plan for the Florida District. The plan contained detailed instructions and reference material and listed emergency contacts to make in the event of a flood. As part of the plan, Dick formed the first Flood Operations Advisory Committee for Florida, which identified Federal agencies concerned with various aspects of flooding.

Water use—With the increasing water use in Florida, it became apparent in 1975 that a more formalized approach was needed to assemble related information. Accordingly, a continuing assessment was organized in cooperation with the Florida Water Management Districts (WMD) and the Florida Department of Environmental Regulation. Stan Leach was designated as District Project Coordinator with participation by each Subdistrict and WMD. The objective of the cooperative effort was to provide a reliable estimate of annual water use by counties, by WMD's, and by hydrologic events. The annual evaluation would aid the WMD's in developing water-use plans and issuing water-use permits. Of special interest is the "Octopus diagram" in the report issued in 1978 on the "Source, Use, and Disposition of Water in Florida in 1975." This diagram was an innovation and since has been used as a basis for similar reports nationwide.

Osceola National Forest—The Secretary of the Interior in 1975 directed the USGS to conduct a 2-year investigation of the hydrologic consequences of potential phosphate mining in the Osceola National Forest of north-central Florida. The Florida District completed the study on time through the efforts of Bob Hull, Jim Miller, Paul Seaber, Gil Hughes, and John Vecchioli and the consultative help of Frank Riley, Stavros Papadopulos, Hilton Cooper, Irv Rorabough, and several others outside the District. A comprehensive report was prepared and published that described the geology and hydrology of the Osceola National Forest and the potential impacts of phosphate mining on the forest's hydrologic system. The report formed the first detailed description of the geology and hydrology of north-central Florida.

Subsurface waste injection—Injection of industrial and municipal wastewaters into saline zones of the Floridan aquifer was the subject of considerable research by Florida hydrologists during the period. Fred Meyer, Matt Kaufman, and Don McKenzie reported on the hydrogeology and geochemical effects of waste injection in South Florida. Jack Hickey conducted extensive studies of the hydrogeologic conditions related to injection of treated waste into the St. Petersburg–Tampa area. Don Goolsby, Glenn Faulkner, and Jerry Pascale described the widespread buildup of pressure in the aquifer associated with injection of industrial wastes near Pensacola. Goolsby evaluated subsurface geochemical effects of the industrial waste injection at one of the Pensacola sites. Late in this period, Jerry Pascale and John Vecchioli, collaborating with Western Region researchers Garry Ehrlich and Mike Godsy, studied the microbially mediated chemical alteration of the injected industrial wastewater at another Pensacola site.

Southeast limestone aquifer systems analysis—In late 1978, the District initiated three phases of a five-phase aquifer-system analysis of the limestone aquifer in Southeast United States. The analysis was one of the Regional Aquifer-System Analysis studies (RASA) under the national plan. The three phases in Florida were the aquifer in west-central Florida, which was assigned to Paul Ryder at Tampa; in east-central Florida, assigned to Charles Tibbals at Orlando; and in South Florida, assigned to Fred Meyers at Miami. Simply, the objective of the analysis was to develop a dynamic model of the regional artesian aquifer system. A decision was made to formally designate the aquifer as the "Floridan Aquifer System."

South Florida Subdistrict

The South Florida Subdistrict Office in Miami was a fully integrated office in June 1966, when this chronology begins. It continued to grow and produce scientifically significant reports and information during the entire 13-year period. The office was responsible for programs in these counties: Dade, Broward, Palm Beach, Martin, St. Lucie, Collier, Lee, Hendry, and Monroe.

Personnel

Howard Klein was the Subdistrict Chief during the period June 1966 to May 1968, and was followed by Tom Buchanan, who became Subdistrict Chief in June 1968 and stayed until July 1976. Al LaSala became Subdistrict Chief late in 1976 and continued until the end of the period. Jim Rollo became Assistant Subdistrict Chief in 1974 and was replaced by Steve Johnson in late 1976.

Howard Klein, Fred Meyer, Ed Hull, and Chuck Appel, joined later in the period by Bill Pitt and Don McKenzie, concentrated on studies in Dade County. C.B. Sherwood led the efforts in Broward County, assisted by Jack McCoy and Wayne Bearden. Harry Rodis led the reactivated program in Palm Beach County, assisted by Larry Land, Bill Scott, and Al Knight. Jack McCoy and Howard Klein led the investigative efforts in Collier County, and Durward Boggess was in charge of the Field Headquarters in Lee County. He was later joined by Tom Missimer and Tom O'Donnell. In limited studies, Wayne Bearden handled St. Lucie County, Bob Miller was responsible for Martin County, and Tom O'Donnell worked in Hendry County.

The Data Information Program was led by John Warren, assisted by Dave Maddy, Frank Galliher, and Jim Schneider; Ed Beaumont, Joe Voegtle, and Ted Miller were the principal hydrologic technicians.

Milton Kolipinski, Aaron Higer, Jim Hartwell, and Ben McPherson led the extensive investigative program in Everglades National Park.

With initiation of studies in the Big Cypress area, the "Resource and Land Information" (RALI) Program, and the South Florida ecological study, Ken Vanlier, Herb Freiberger, and Jeff Armbruster were transferred to Miami to assist in the investigations. Hal Mattraw and Bob Miller joined the office in 1973 and, in 1976, conducted extensive studies on urban-runoff quality.

In 1976, a Field Headquarters was opened in Jupiter with George Hill in charge. The office helped with the logistics and gave WRD a presence in Palm Beach County.

Cooperators

The Miami office had many State and local cooperators and other Federal agencies that funded challenging water-resources investigations during this period. In the early 1970's, some significant Federal funding became available for the Big Cypress, Resource and Land Information (RALI), and the south Florida Ecological Studies.

Central and Southern Florida Flood Control District (FCD)

The FCD was the largest contributor of cooperative funds, and during this period they were in transition from a flood-control district to a water-management district. The FCD funded a large part of the hydrologic data network in the eastern coastal counties of south Florida. In addition, they funded studies on water-management effects, underground storage of potable water, analog modeling of the Biscayne aquifer, and the water quality of Lake Okeechobee and the canal systems.

Dade County and Cities of Miami and Miami Beach

Dade County and the cities of Miami and Miami Beach funded much of the hydrologic data network in Dade County. Significant effort was devoted to the impacts, evaluation, and protection of the major well fields operated by the City of Miami. The water supplies in Dade County were placed under the control of a joint city and county agency in the mid-1970's.

Broward County and the City of Fort Lauderdale

Broward County and the city of Fort Lauderdale funded almost half the data network in the county. In addition, the county funded studies on the water quality of canals and the impact of landfills on groundwater quality. The cities of Pompano Beach, Hollywood, Deerfield Beach, Hallandale, and Dania supported cooperative studies, well-field evaluations, and monitoring efforts.

Palm Beach County

The Palm Beach County program was restarted in the early 1970's, with studies on the shallow aquifer, saltwater intrusion, and well-field protection. The cities of Boca Raton, Riviera Beach, Tequesta, Juno Beach, and Jupiter also supported these cooperative studies.

Collier County and the City of Naples

Most of the effort in Collier County related to the shallow aquifer in the western part of the county and to the impact of the new and proposed drainage canals.

Lee County and the City of Fort Myers

Lee County has a complex aquifer system, and most of the cooperative studies were to describe the hydrologic characteristics of the system. Also, studies were done on the impacts of landfills, recharging the city well field with water from the Caloosahatchie River, and the impacts of plugging deep artesian saline wells on the water quality in the shallow aquifer system.

National Park Service

Investigations in Everglades National Park included impacts of water-level change, changes in water quality, and pesticide magnification as these compounds move up the food chain. Pesticide analyses were done not only in water but also in sediment, plants, and animal tissue. Some of this work was on the frontier of technology at the time.

U.S. Army Corps of Engineers

The Corps supported the major hydrologic-data stations that included all outflows from Lake Okeechobee and flow into Everglades National Park along the entire Tamiami Trail, which included flows in Canal 111, and the St. Lucie and Caloosahatchie Rivers. Studies also were made on seepage beneath Hoover Dike around Lake Okeechobee and salinity in Canal 111 that supplied water to the eastern panhandle of the park.

U.S. Fish and Wildlife Service (FWS)

Water quality and vegetative studies were done for the FWS in the Loxahatchee Slough located in Conservation Area No. 1, which the FWS operates as the Loxahatchee National Wildlife Refuge.

U.S. Air Force and U.S. Navy

Small well-field salinity protection programs were conducted for the Air Force at Homestead Air Force Base and for the U.S. Navy at their Dade County wellfield that supplied the pipeline to the Florida Keys.

Selected Programs

Several major investigations were undertaken during the period; five of particular significance are described:

Big Cypress Study

The proposed construction of a jetport in the Big Cypress National Preserve prompted the Secretary of the Interior in November 1969 to request the USGS to conduct a water-resource study of the Big Cypress Swamp and present a report in 6 months. Surface-water runoff from the Big Cypress flows into the Everglades National Park, so it is of major importance. The report was timely and provided the information and interpretation needed to evaluate the effect of a jetport on the water resources of the area. Later, a vegetative map of the entire Big Cypress, a classic work, was completed. The WRD also was asked to do the onsite monitoring of a planned training jetport in the Big Cypress.

Resource and Land Information (RALI)

The USGS selected four locations nationwide in the early 1970's to demonstrate the use of resource and land information. Southern Dade County was one of the locations selected, and Tom Buchanan was designated project manager. Six Federal agencies, the University of Miami, the Miccosukee Indian Tribe, and Dade County participated in the study. The study covered urbanization, natural hazards, mineral resources, water management, environmental quality, outdoor recreation, Everglades National Park, coastal zones, fish and wildlife, and Miccosukee Indians. The report was well received in Dade County and was used extensively as a teaching aid by those concerned with the environment and by the universities.

South Florida Ecological Study

As a supplement to the RALI demonstration project, the Department of the Interior funded another RALI demonstration project on the south Florida environment. The USGS, National Park Service, and U.S. Fish and Wildlife Service participated in the study, with the USGS in the lead. Ben McPherson and Howard Klein headed the effort. The report documented the components and processes that constitute the south Florida environmental system and assessed the resources of both man and nature and how they can be made to fit together to form alternative viable futures.

Urban Runoff Water Quality

The quality of stormwater runoff became a major issue in the 1970's. Hal Mattraw, Bob Miller, and C.B. Sherwood looked at runoff quality from three urban environments—a residential area, a shopping center parking lot, and a major highway. They pioneered in the instrumentation, the sampling methods, and data handling and interpretation. This resulted in the best data set available at the time to document the character of urban runoff.

Aquifer Storage of Freshwater and Wastewater

Fred Meyer pioneered a study to evaluate the feasibility of storing drinking water in the Upper Floridan Aquifer and the subsequent recovery of the water during peak demand periods. The feasibility of the technology was shown, and the concept now is used widely in Florida and throughout the United States. In the Miami area, Howard Klein and Fred Meyer did much of the early work related to the storage of treated wastewater in the "Boulder Zone." This technology also is used widely in Florida.

Southwest Florida Subdistrict

At the beginning of this chronology, the Subdistrict had been established for less than a year. In July 1967, Joe Rosenshein transferred from Providence, R.I., to Tampa to be the first Subdistrict Chief, and Joe W. Stewart, Hydrologist-in-Charge of the former Tampa Field Office, became the Assistant Subdistrict Chief. In 1977, the Subdistrict was designated the Southwest Florida Subdistrict.

The water-records collection and processing phases of the program were carried out under the direction of Bob Murphy. Luther Mills and Mac Woodham were the ground-water and surface-water technicians, respectively.

In 1975, John Moore replaced Joe Rosenshein who transferred to Kansas to be the District Chief. In 1978, John Moore transferred to Reston, and Bob Knutilla transferred from the Michigan District to be the Subdistrict Chief. He continued in that role to the end of the period.

The period from 1967 to 1979 was a dynamic period for the Southwest Florida Subdistrict. The many problems that were in the making with the strong growth in the southwest area of Florida came to focus for local and State governments. During this period, the Southwest Florida Water Management District (SWFWMD) began to play a strong role in the development and management of water resources in southwest Florida. The SWFWMD became the leader in water-management activities and through their activities set the stage for the establishment of Water Management Districts to cover all of Florida. The District Executive Directors, especially Dale Twatchmann, and later Don Feaster, were receptive to the development of a strong cooperative program with the U.S. Geological Survey that was based heavily on interpretive investigations. By the end of the period, the SWFWMD had become the largest single cooperator in the Federal-State Coop Program.

The Subdistrict's program during this period grew from about $200,000 to more than $2 million and by 1975 was the seventh largest Coop Program in the Division—larger than most Districts. From its beginning, the Subdistrict Office was involved in water-resources issues that were key to the future economic development and expansion of southwest Florida. The program grew to the point where the Subdistrict was involved in all the major ground-water, surface-water, and water-quality issues of significance to the area. By 1975, the Subdistrict was conducting more than 30 investigations that were supported by local cooperators and the Corps of Engineers. The staff had grown from about 20 to 80 by the end of the period.

The senior staff were continually sought out by the cooperators for their advice and guidance on sensitive water-resource issues and participated in numerous public hearings related to these issues. The program and its activities were highly visible to the public and were frequently reported in the news media—newspapers, radio, and television.

The esteem in which the U.S. Geological Survey was held in southwest Florida led to a request from SWFWMD to the U.S. Geological Survey for a 2-year assignment of Rod Cherry to the SWFWMD through an Intergovernmental Personnel Agreement (IPA). While at SWFWMD, Rod played a significant role in: (1) developing the approaches that SWFWMD used to approve and manage ground water in the Water Management District and (2) strengthening the technical capability of the Water Management District's staff.

Highlights

The program of the Subdistrict Office, as previously indicated, grew from about $200,000 from 1967 to more than $2 million by 1975. This dynamic growth resulted in a program that was about 60 percent investigations and 40 percent water records. The investigations addressed issues that were key to the continued development of the area.

The principal cooperator of the Subdistrict from its inception was the SWFWMD. Other cooperators during this period included the cities of Clearwater, Dunedin, St. Petersburg, Sarasota, and Tampa; Hillsborough, Pinellas, Manatee, and Sarasota Counties; the Englewood Water District; the Tampa Bay Planning Commission; the Tampa Port Authority; the Winter Haven Boat Course District; and the U.S. Army Corps of Engineers.

During the early part of the period, Joe Rosenshein, Joe Stewart, and Rod Cherry concentrated their efforts on the program with SWFWMD. Rod Cherry's principal effort was to finish his report, co-authored with Joe Stewart and Jim Mann, on the general hydrology of the Middle Gulf area. This report and a prior report on the hydrology of the Green Swamp became the principal references on the hydrology of the heavily populated coastal area of the SWFWMD area as well as the Green Swamp and the foundation for many water-management decisions of the SWFWMD.

During this early period in the life of the office, Jim Mann was involved in completing a study on the hydrology of old upper Tampa Bay and prepared a popular brochure on the major springs of the Middle Gulf area in cooperation with the Florida Geological Survey. By 1969, they were joined by Bill Sinclair, Bill Wilson, Dave Hunn, Al Robertson, Ron Reichenbaugh, Jim Turner, and Ron Coble, all of whom initially worked on cooperative studies with SWFWMD.

NOTEWORTHY ACTIVITIES

Remote Sensing

In 1969, Gene Coker began a project in cooperation with the National Aeronautics and Space Administration and the U.S. Geological Survey's Office of Remote Sensing, involving the application of remote sensing to hydrologic problems in the Peace and Alafia River Basins and including detection of land subsidence owing to potential sinkhole collapse. This effort served as the foundation for a long period of successful collaboration between Gene Coker and Aaron Higer of the Miami Subdistrict on innovative and imaginative applications of remote sensing technology to hydrology.

Regulation of Ground-Water Withdrawals

The first major effort to regulate ground-water withdrawals in Florida took place in the Tampa Bay area when the SWFWMD held public hearings on the issue in the summer of 1968. Joe Stewart's landmark report on the hydrologic effects of pumping from the Floridan aquifer in northwest Hillsborough, northeast Pinellas, and southwest Pasco Counties provided the hydrologic background for public hearings. The SWFWMD subsequently adopted rules regulating the use of ground water in the area. This was the first action by a quasi-State governmental agency in Florida to regulate ground-water withdrawals and apparently was the first major regulation of ground-water withdrawals in the eastern part of the United States.

Hydrology of Lakes

The decline of lake levels at homesite or real estate lakes was a major underlying cause for the pressure to have the SWFWMD regulate ground-water withdrawals for water supply to serve the rapidly developing coastal zone of the SWFWMD. One solution to the problem of declining lake levels, evaluated by Joe Stewart and Gil Hughes, was the pumping of ground water from the Floridan aquifer into the lakes to maintain acceptable levels.

Because of the strong interest in the lakes of the Tampa Bay area and their importance in issues related to regulation of ground-water withdrawals, studies of selected lakes were begun in 1970. These map-type reports provided basic background on the general hydrology of the lakes, configuration of the lake basins, and an evaluation of the interrelation of the lakes and the associated ground-water system. The first of these studies was carried out by Dave Hunn prior to his transfer to the North Florida Subdistrict.

Hydrologic Impact of Landfills

Joe Stewart began a series of landfill investigations in the early 1970's, in cooperation with Hillsborough and Pinellas Counties, concerning the impacts of landfills on ground-water resources. These investigations helped pioneer the Geological Survey's entry into the study of contamination of aquifers by hazardous landfill wastes. Tony Buono, Dan Duerr, and Mario Fernandez were a part of the investigative team.

Hydrologic Concerns About Waste Disposal

The Tampa Bay area in the 1970's became the focus of concerns about contamination of the Gulf of Mexico and Hillsborough and Tampa Bays from discharge of sewage-treatment-plant effluent. These concerns spawned a series of studies in cooperation with St. Petersburg and Pinellas County on alternative approaches for disposal/storage and(or) reuse of this effluent. During this period, Rod Cherry, Carol Goetz, Dave Brown, and Ron Reichenbaugh carried out process-oriented experimental studies on the effects of spray application of large volumes of secondary-treated effluent on the shallow ground-water system. These studies produced major scientific contributions to the understanding of the hydrobiochemical processes involved in the movement of the effluent through the unsaturated zone to the saturated zone and the contamination hazards to the shallow aquifer systems.

At the same time, Jack Hickey began studies in cooperation with St. Petersburg and Pinellas County on the potential for storage (and eventual recovery for reuse) of advanced secondary-treated effluent. The effluent was to be stored in the highly permeable saline part of the Floridan aquifer system underlying Pinellas County. These studies, in turn, resulted in major original scientific contributions to the understanding of the hydraulic processes governing the movement, storage, and recovery of a nonsaline fluid from highly permeable zones in a saline aquifer system.

Estuarine Hydrology of Tampa Bay

Because of the importance of the Port of Tampa to the economy of the area, the Tampa Port Authority proposed a deepening of the ship channel in Tampa Bay so that ships with a greater draft could use the port. In 1971, the concerns about the impact of deepening this channel on the water quality of Tampa Bay led to a major study of the hydrologic environment of Tampa Bay by the Subdistrict. This highly visible study was initiated by Joe Rosenshein in cooperation with the Tampa Port Authority and later was carried out with the Corps of Engineers. In 1971, Carl Goodwin was designated Project Chief of the study, which continued to the end of the period and made use of many innovative approaches. Bob Baltzer and Ray Schaffranek of the National Research Program worked with Goodwin to develop a validated computer model of the bay. Tony Jurado of the South Florida Subdistrict mapped the bay bottom to depths of about 15 feet below mean tide level using photogrammetric techniques. These bay-bottom contours were used in the model to define the geometry of the bay. The model developed by Carl Goodwin was effective in determining the impact of dredged material on circulation patterns in the bay. The study also provided insights into many of the water-quality problems of the bay.

Hydrology of Middle Peace River Basin

Bill Wilson started an investigation of the water resources of DeSoto and Hardee Counties in the early 1970's in cooperation with the SWFWMD. This investigation included special studies on the hydrologic impact on the shallow aquifers and the Floridan aquifer system by use of ground water to irrigate the largest orange grove in Florida. This study led to modeling the potential hydrologic impact of proposed phosphate ore mining in the middle Peace River Basin.

Water-Supply Development (SWFWMD)

Regulation of the development of water supply for the rapidly growing coastal areas of Pinellas County and for the city of Tampa was a critical issue faced by the SWFWMD. The Subdistrict, in cooperation with the SWFWMD, evaluated the hydrologic potential of new well fields being developed in Citrus and Hernando Counties by the City of Tampa and Pinellas County under SWFWMD guidance. Linked to this effort was an evaluation of the feasibility of artificial recharge to the Floridan aquifer in the tri-county area of Hillsborough, Pasco, and Pinellas Counties. Joe Stewart, Al Robertson, Craig Hutchinson, and Bill Sinclair participated in these studies.

Hillsborough River Basin Modeling

Uncontrolled residential development resulted in marked encroachment on the flood plain of the Hillsborough River. At a relatively modest high-water stage of the river, the SWFWMD received many complaints about flooding. Jim Turner, in cooperation with the SWFWMD, began an investigation of modeling of the Hillsborough River. The results of this modeling effort were used by the SWFWMD, in conjunction with National Weather Service predictions, to define the extent of flooding that could be anticipated in the heavily developed flood-plain areas at river flows equal to or greater than the mean annual discharge.

Decline of Water Levels in the Floridan Aquifer

The decline of water levels in the Floridan aquifer and the significance of this decline were major concerns of the general public, the news media, and the SWFWMD. In response to these concerns, Joe Stewart and Luther Mills prepared a map showing a decline of more than 20 feet in the potentiometric surface of the Floridan aquifer in Polk County between 1961 and 1974. The published map report frequently was referenced and used extensively at all public hearings related to the control and regulation of ground-water withdrawals in SWFWMD. Sometimes referred to as the "big red hole" map, it was one of the most influential products produced by the Subdistrict during this period.

Sarasota Field Headquarters

The Sarasota Field Headquarters was affiliated with the Tampa Subdistrict Office at the time the Subdistrict was established. The office staff consisted of Horace Sutcliffe and Moe Bowman. Although a small office, the staff played a significant role in the development of the water resources of the area. The Field Headquarters was responsible for the Coop Programs with Sarasota and Manatee Counties, the City of Sarasota, the Englewood Water District, and the newly established Manasota Basin Board. These programs included studies of deep-well disposal of sewage-treatment-plant effluent by the City of Sarasota, the suitability of the shallow aquifer in the Sarasota area for public water supply, the hydrology of west-central Sarasota County, evaluation of hydrologic conditions in Manatee County, and the urban hydrology of the Englewood Water District. In addition, Sutcliffe provided technical assistance to the Manasota Basin Board.

East Central Florida Subdistrict

The East Central Florida Subdistrict, Ocala/ Orlando offices, was responsible for all programs in the east-central Florida area including the counties of Orange, Seminole, Lake, Marion, Volusia, Flagler, Putnam, Clay, St. Johns, Sumter, Brevard, Osceola, Okeechobee, Indian River, and portions of Alachua, Pasco, Hernando, Citrus, Polk, Highlands, and Glades. The Subdistrict contained all of St. Johns River Water Management District, the Kissimmee River Basin part of South Florida Water Management District, and the Withlacoochee River Basin part of the Southwest Florida Water Management District. The Orlando Subdistrict was the largest in area of any of the Florida USGS Subdistrict Offices.

The Orlando Subdistrict's roots were established in January 1960, when Bill Lichtler transferred from the Ground Water Branch Subdistrict Office in Miami to a Field Office in Orlando. The office, actually in Lichtler's home, was participating in a 6-year study of the water resources of Orange County with representatives from surface water and quality of water.

Personnel

Leonard Snell was the Subdistrict Chief in Ocala from 1965 to 1970, followed by Joel Kimrey in 1970. The Subdistrict Office was moved to Orlando in 1973.

In Ocala, Jim Rabon, Warren Anderson, Bill Kenner, and Wayne Bridges conducted surface-water studies and analyses as part of several multidisciplinary studies in Orange, Lake, Volusia, and Marion Counties. Larry Toler, Bud Bermes, Rod Cherry, Darwin Knochenmus, Jerry Pascale, and Bill Lichtler specialized in the ground-water and water-quality aspects of those studies and were the Chief Investigators. The Data Section was headed by Dick Heath, who was ably assisted by Ray Charnley, who later took over the section.

In early 1967, Glen Faulkner entered on duty in Ocala to begin a comprehensive study of the hydrology of the Cross-Florida Barge Canal area. This study, funded by the Corps of Engineers, signaled the emergence of the Ocala Subdistrict as an important office in the field of quantitative ground-water hydrology. Charles Tibbals was hired in mid-1967.

Bud Bermes was located in St. Augustine and did some of the early ground-water work in Volusia, St. Johns, Putnam, and Clay Counties; Darwin Knochenmus conducted definitive studies in Volusia and Lake Counties; and Bill Lichtler focused on lake/ ground-water interactions in Orange County.

In 1965, Orlando's staff doubled with the addition of Fred Phischner, and the office moved from Lichtler's home to a three-room office in an old converted house shared with the county agriculturist. In 1968, Charles Tibbals transferred from Ocala and began a study to evaluate the efficacy of storing freshwater in a saline aquifer in the Cocoa Wellfield in east Orange County, to assess ground-water availability in Seminole County, and to develop an analytical model to determine the effects of paving on ground-water recharge. In 1974, Tibbals became Ground-Water Specialist in Orlando and became RASA study chief of the East-Central Florida unit of the Southeast Limestone Regional Aquifer Study.

In early 1969, it became apparent that future hydrologic studies would center around the Orlando area of east-central Florida and that additional staffing would be required.

By mid-1969, Lichtler and Tibbals had been joined by Les Crain from New York, who conducted a study of the water resources in Indian River County, Herb Stangland from Wisconsin, who did some early work in the Reedy Creek Improvement District (RCID –Disney World), and Jenny Hulsey from the Atlantic Coast Region (ACR). Also about that time, the Orlando Field Office moved into a small office complex in Winter Park. In late 1969, Joel Kimrey became Subdistrict Chief. In early 1970, Frank Watkins and Lou Burgess conducted artificial recharge experiments using "connector wells," and Jim Frazee was engaged in a large-scale well-mapping program in Brevard County. Also in 1970, the Sebring Field Office was closed, and Richard Hedges, Bob Bird, and Al Summerlin transferred to Winter Park to establish a Hydrologic Data Section.

Tragedy struck in early 1972 with the death of Les Crain, who succumbed to a brief bout with a virulent type of leukemia. Les already had made his mark in the New York District and in Florida and was destined to become a knowledgeable hydrologist in the WRD.

In late 1972, Andy Lamonds initiated important water-quality studies on Lakes Faith, Hope, and Charity in Maitland and in the Cross-Florida Barge Canal area as part of a Federal court-ordered environmental impact statement.

In 1973, the Ocala Subdistrict became a Field Office; Winter Park became a Subdistrict Office. Later in 1973, Peter Bush initiated a hydrologic computer model and a wetlands map of Volusia County. Charles Laughlin, Eddie Simonds, and Max Brogdon transferred from Ocala to lend technical support to hydrologic studies. In 1974, Warren Anderson and Wayne Potter transferred from Ocala. Anderson engaged in studies in determining how ground-water levels in artesian aquifers can cause certain lakes to flood even in the absence of large amounts of surface-water runoff. Also in 1974, Art Putnam studied the water resources of Reedy Creek Improvement District; Hayes Grubb made some exploratory studies in Brevard County and prepared a computer model of the Green Swamp area; and Bill Hopkins, Fred Taylor, Carl Cash, and Howard George were added to the Hydrologic Data Section in 1975.

In 1976, Harry Rodis transferred from Miami to become Assistant Subdistrict Chief, Russ Harkness became Chief of the Hydrologic Data Section, Al Rutledge worked in Volusia County, and Anne Bradner worked in the Hydrologic Data Section. Also in 1976, the office moved into the newly constructed Federal Building near downtown Orlando. The staff remained essentially unchanged through 1977. In 1978, Ed German became Water-Quality Specialist, and Roger Belles started a reconnaissance study in Osceola County.

In 1979, Bob Miller transferred from Miami to become Chief of Hydrologic Studies; Larry Fayard transferred from Louisiana to become Hydrologic Data Chief; Mike Planert, assisted by Walt Aucott, started a computer modeling study in Osceola County; and George Schiner transferred from Pennsylvania to work in Indian River and Osceola Counties. Tony Navoy conducted an important RASA-related study on a 2,000-foot-deep core hole in the Green Swamp.

The Ocala/Orlando office had numerous county and city cooperators even before the creation of the five Water Management Districts. The early principal cooperators were Orange, Volusia, Brevard, Seminole, and Lake Counties, and they continued to support local investigative and data programs in cooperation with the Water Management Districts.

North Florida Subdistrict Office

The Subdistrict, located in Tallahassee, was organized in 1969 to take responsibility for hydrologic activities associated with the Northwest Florida Water Management District (NWFWMD), Suwanee River Water Management District (SRWMD), and other agencies in the area of concern.

The Subdistrict had a full complement of personnel to handle the expected programs with particular emphasis on developing a long-range hydrologic monitoring program. One of the first endeavors was preparation of a report for the SRWMD and one for the NWFWMD by Ken Vanlier and others, setting forth the hydrologic setting, existing water developments, and principal water-management concerns in the Districts. An inventory of existing data networks was provided, and the presumed need for additional networks and information was portrayed as given the Districts by the enabling act of 1972. No significant water problems were identified in the SRWMD, and those in the NWFWMD for the most part had been portrayed in past investigations under other cooperative programs, particularly FBG, and local counties and cities. As a consequence, essentially only the water-data program emerged as a cooperative activity with the SRWMD. Miscellaneous cooperative studies were conducted in the NWFWMD area in addition to the water-data program. For example, a significant study of the Fort Walton Beach area was started by Larry Hayes in 1977 in cooperation with the NWFWMD.

A detailed evaluation of the quantity and quality of water available from the sand and gravel aquifer in Escambia County was started in 1970 by Henry Trapp in cooperation with the City of Pensacola. One product of the investigation was a lay-reader leaflet on Pensacola's water supply.

A cooperative study with the City of Tallahassee to evaluate the hydrologic effects of disposing of treated sewage effluent by spray irrigation of wastewater began in July 1972 under the direction of Larry J. Slack. A report "Hydrologic Environmental Effects of Sprayed Sewage Effluent, Tallahassee" was prepared.

GEORGIA

by John R. George

The author gratefully acknowledges the review of this document by Harold Golden and Harlan Counts.

The Georgia District was organized as a Water Resources Division (WRD) District in late 1966. The District Headquarters for surface-water (SW) and water-quality (QW) operations was located in the Peachtree-Seventh Building near midtown Atlanta. The District ground-water staff was located in offices provided by the State Geologist (then, Georgia Department of Mines, Mining, and Geology) in the State Agriculture Building in downtown Atlanta. In 1967, District Headquarters moved to adjacent office space at 900 Peachtree Street, N.E. A year later, the ground-water operations moved into space provided at the District Office, and the District was finally housed under one roof.

In February 1974, the entire District Office relocated to 6481 Peachtree Industrial Boulevard in suburban Doraville, to the same building first occupied in 1973 by WRD's Atlanta Water Quality Laboratory. WRD's Chattahoochee River Intensive River Quality Assessment Team also leased offices in this facility during the mid-1970's. The District Office remained at this address through the balance of the period covered by this report.

ORGANIZATION AND PERSONNEL

In 1966, the Division District was placed under the direction of Albert N. (Abe) Cameron as District Chief. Harlan B. Counts was selected as Assistant District Chief. Lucille Cain was designated the Administrative Assistant. Cameron served as District Chief until the spring 1968, when he was reassigned to the Office of Director, U.S. Geological Survey, as the Director's senior WRD representative. In August 1968, John R. George was assigned as District Chief for Georgia. He remained in that position through this period of WRD history and was ably assisted by Harlan B. Counts (1966–79) and Harold G. Golden (1969–79).

During the period 1966–79, the District was supported by Subdistrict Offices in Brunswick (Bob Wait to 1967, Dean Gregg, 1967–70, Everett Zimmerman, 1970–75); Tifton (Luther Mills to 1970, Darrell Dorminey, 1970–); Athens (E.J. Tharpe, 1966–69); and Atlanta (Audie Bradley, 1974–79). In support of special data/operations, Field Offices were maintained in Calhoun (1965–74), Savannah, and Albany (1975–79). Expanding data operations were led very capably by William R. (Bill) Stokes, III (1970–). The District was fortunate to have a cadre of senior Hydrologic Technicians including George Condrey, Darrell Dorminey, Harry Blanchard, and Audie Bradley. Each provided strong leadership to the data programs. Each devoted entire WRD careers to the pursuit of high-quality hydrologic data for Georgia. Each mentored hosts of new employees in the ways of dedication and quality work.

Ground-water studies were led by Harlan B. Counts until 1974, when his unique quantitative ground-water skills were needed full-time for ground-water modeling. Counts advanced the art of ground-water-flow modeling for Savannah and Brunswick, two areas of greatest ground-water use in Georgia during the 1970's. In the mid-1970's, he also did pioneer work with John Bredehoeft in modeling the transport of contaminants in the ground water beneath Brunswick, Ga.

In 1974, Harold E. Gill returned from a foreign assignment to assume the position of Chief of Hydrologic Studies. Gill's knowledge, experience, and tireless leadership in ground-water hydrology and geology brought outstanding skills to the District during an era of rapidly expanding needs for ground-water information.

A.M.F. (Al) Johnson took charge of the District's Information Services project in 1969 and provided the standard for that important project until his retirement in 1977.

From 1966 to 1973, Hubert J. (Hugh) Tracy, Research Hydraulic Engineer, maintained an office in the District while conducting research in the Hydraulics Laboratory of the Civil Engineering Department of the Georgia Institute of Technology. In 1973, Tracy moved to WRD's newly formed Southeastern Region Office at 1459 Peachtree Street. Until his retirement in 1973, Steven Herrick remained in the offices of the State Geologist, where he continued his research in aquifer delineation through microfossil analyses. His efforts contributed significantly to hydrogeology throughout the Southeastern United States.

During this period, the Georgia District developed an extraordinarily diverse group of surface-water projects led by several highly skilled hydrologists. The following table summarizes these efforts:

Clyde Bunch	Rainfall/runoff projects; flood frequency; open channel hydraulics
McGlone(Mac)Price	Flood frequency; hydraulics; bridge sites
T.R. (Bob) Dyar	Estuarine processes; computer processing and analyses
Tim Hale	Quality control; open channel hydraulics; time of travel
Ernest J. (Joe) Inman	Rainfall/runoff analyses; urban runoff
Lamar Sanders	Rainfall/runoff studies
Marvin Franklin	Rainfall/runoff studies
E.J. Tharpe	Rainfall/runoff studies
Gary Tasker	Estuarine processes

The District's water-quality program grew significantly both in size and complexity during this period. Rodney Grantham initiated the cooperative statewide sampling network in 1967. Bill Norris and Gary Tasker led the Southeastern Region in water-quality monitoring excellence. Jim McConnell, who became the District Water-Quality specialist in 1976, led water-quality studies of West Point Reservoir and, later, investigations dealing with agricultural chemicals in ground water.

Beginning in 1970, the Georgia District rapidly developed a wide range of expertise in computer processing and analysis. Supported by T.R. (Bob) Dyar, and later with the addition of S. Jack Alhadeff, the District was a leader in WRD in sophisticated computer analyses including small drainage-area rainfall-runoff modeling, streamflow analyses and synthesis, river quality modeling, ground-water flow and contaminant transport, and early development of geographic information systems. Dyar and Alhadeff did a remarkable job of proliferating computer skills throughout the District. By the late 1970's, computer work station technology was actively in place for several types of hydrologic analysis.

The District technical staff grew significantly in the late 1970's in response to rapidly increasing needs for water information. Assistance in staffing by the Southeastern Region Office included recruiting several new hydrologists. By 1979, an expanded and diverse Georgia District staff included eight female professional employees, the greatest number reported for any District nationally.

In 1978, J.R. George joined the State government for 6 months under the Intergovernmental Personnel Act as Acting State Geologist. While there, he assisted the Georgia Department of National Resources in reorganization and recruited a new State Geologist. During his absence, Harold Golden served as Acting District Chief.

ISSUES AND PROGRAMS

By the early 1970's, water issues in Georgia and in the rest of the Southeastern United States focused on water quality, the water environment, and the availability of adequate water supplies. These issues, in turn, were being driven by Federal laws and(or) State legislation directed toward regulating: (1) the amount of water withdrawn from various sources and (2) the quality and quantity of wastes discharged to the water environs. In the Atlanta metropolitan area, where population had increased by 30 percent for the third consecutive decade, the Chattahoochee River was a potentially stressed resource. Questions on regulation of surface- and(or) ground-water withdrawals emerged in almost every urban and rural area. Southwestern Georgia found itself to be the most rapidly growing irrigation water-use area in the entire United States. The impacts of this large and fast-growing use of the region's ground-water resources were largely unknown and certainly unmeasured. The city of Albany on the northern edge of that agricultural area quickly grew concerned for its municipal share of that ground-water resource.

Federal Highway funds were readily available to Georgia for financing State and local highway construction. The Georgia Highway Department was especially anxious to have adequate data on the flooding characteristics of Georgia's rivers and streams for the proper and economical design of bridges and roadways. General public interest in flooding prompted a federally funded program that provided for the approximate delineation of areas flooded about once every 100 years. In the early 1970's, the Georgia District, following extensive efforts by McGlone Price and Willis Hester, produced 377 flood-prone area maps. Several hydrologists produced reports supplying more detailed flood maps for communities in northern Georgia. These later studies, funded by the Department of Housing and Urban Development, later by the Federal Emergency Management Agency, were designed to provide criteria for uniform flood-insurance rates for developing communities.

The U.S. Environmental Protection Agency's National Pollution Discharge Elimination System (NPDES) required State water-management agencies first to assess existing water conditions. The system also required Georgia to develop guidelines for upgrading the quality of wastes discharged to the water environs by industries and municipalities. Stream-quality and low-flow data not previously available became critical to address water-management issues of water-supply capacity and the waste "loading" capacity of receiving waters. In southwestern Georgia, as well as in communities along the Atlantic coast, there was concern over the effects of heavy use of ground water on the future of these valuable aquifers. Saltwater encroachment already was occurring in southeastern coastal Georgia, and there had been continuing concern over long-term use of that same ground-water system in Savannah.

In 1972, Public Law 92–500 provided mechanisms for assuring that federally supported projects would be scrutinized closely to assure minimum impact on the environment. In Georgia, an early environmental "ax" fell on a U.S. Department of Agriculture (USDA) watershed workplan that proposed to dredge over 100 miles of the Alcovy River in north-central Georgia. Harold Golden and John George took lead roles both in overview and in providing hydrologic expertise to State and other Department of the Interior agencies. These efforts ultimately contributed to the demise of the workplan for the Alcovy River Basin. The results of this 3-year controversy caused USDA to review significantly and modify future basin planning.

In 1977, the Toccoa Falls dam failure in northern Georgia destroyed a small community and killed 39 people. Vernon Sauer (Southeastern Region Office) and Lamar Sanders prepared reports on the hydrologic and hydraulic conditions produced by the dam failure. On the heels of the Teton dam failure in the Western United States, the U.S. Army Corps of Engineers, and later State and local governments, were directed to inventory and evaluate conditions of most dams. Peak-flow statistics for streams at each dam were critical to the success of this program. The District assisted the State of Georgia with these data and supplied help in using a USGS dam-break model.

By 1978, water-resources programs and interests of several agencies led to the development of the first Georgia Water Resources Information Exchange, sponsored by the USGS and the Georgia Department of Natural Resources. Goals of the conference were: (1) to provide agencies an opportunity to exchange information about current and planned programs and (2) to identify new needs for water information. The 2-day conference was attended by over 70 individuals representing 37 Federal, State, or local agencies. Attendees reported that the meeting served the objectives fully and encouraged similar conferences in the future. The Georgia District was lauded for co-sponsoring the first conference of this type in the Eastern United States.

Between 1966 and 1979, yearly program funding for the District grew from about $570,000 to nearly $2,800,000.

Georgia District funding, 1966, 1973, and 1979 ($)

Year	Federal	Cooperative		Other Federal agencies	Total
		State	USGS		
1966	51,000	216,000	216,000	83,000	566,000
1973	61,000	275,000	275,000	115,000	726,000
1979	480,000	915,000	905,000	430,000	2,730,000

These agencies were principal supporters of Georgia District WRD programs during the period covered by this report:

- Georgia Department of Natural Resources
  - Environment Protection Division
  - Georgia Geologic Survey
- Georgia Department of Transportation
- City of Albany
- City of Brunswick
- Chatham County
- DeKalb County
- Gwinnett County
- Federal Power Commission
- U.S. Army Corps of Engineers
  - Mobile District
  - Savannah District
- Tennessee Valley Authority

Water-Resources Data

In the late 1960's, most of the District's data program was devoted to the collection, processing, and publication of streamflow records. Conversion from analog to digital recorders was completed early in this period. In the 1970's, Georgia was fully applying computer technology in processing streamflow and other hydrologic records. Records of daily river stage and discharge were collected at 121 stations in 1966. Water-level data were collected at 13 lakes and reservoirs. One hundred seventy-two crest-stage and partial-record stations, 137 low-flow partial-record stations, and discharge measurements at 40 miscellaneous sites also supplied published data in 1966. Application of network concepts to stream-gaging operations followed R.F. Carter's comprehensive analysis of the Georgia streamflow-data program in 1970. This analysis resulted in a reduction of 30 daily stream-gaging stations. Savings in field operations helped support increases in needed water-resources studies. By 1978, the status of surface-water records sites was as follows: (1) records of daily river stage and discharge were collected at 101 stations, (2) daily water-level data were collected at 16 lakes and reservoirs, and (3) 96 crest-stage partial-record stations and 15 miscellaneous sites also supplied published data in 1978.

The number of sites where ground-water-level data were collected increased significantly during this period, largely because of much greater withdrawal of ground water for irrigation. In 1966, the District collected continuous records of water level at 47 observation wells. Water-level observations varying from annual to quarterly were made at 72 wells. In 1978, continuous water-level records were measured at 62 wells. Periodic observations of ground-water levels were made at 822 wells.

Since the State's responsibilities for water-quality management also expanded rapidly in the late 1960's, an extensive basic-data network of stream-sampling sites was begun in cooperation with the Georgia Water Quality Control Board in 1968. By the early 1970's, the District was successfully operating multiparameter water-quality monitors on the Altamaha, Ocmulgee, Coosa, and Chattahoochee Rivers and on Riceboro Creek, a tidal river on the Georgia coast.

Through the late 1960's, Georgia published its water data, as did all other Districts, in various report outlets and with different time periods. As high compliment to Bill Stokes and his Hydrologic Data Section, that visionary group successfully pressed WRD Headquarters for approval to integrate publication of all WRD hydrologic data for Georgia. In 1969, the Georgia District led the Nation in publishing the first data-integrated annual report "Water Resources Data for Georgia—1969." The publication process that started in Georgia became the standard for the country.

Investigative and Areal Studies—1978

At the conclusion of this period, there was an impressive array of investigative studies underway in the Georgia District. These studies were supported cooperatively by a diverse group of Federal, State, and local government agencies. Collectively, those agencies provided over half of the financial support for the Georgia District's water-information program. A summary follows of active projects, as presented in the summary report of the Georgia Water Information Exchange for 1978.

The following publications illustrate the wide range of projects completed or underway between 1966 and 1979.

Carter, R.F., and Johnson, A.M.F., 1978, Use of water in Georgia, 1970, with projections to 1990: Georgia Department of Natural Resources Hydrologic Report 2.

Counts, H.B., and Krause, R.E., 1976, Digital model analysis of the principal artesian aquifer, Savannah, Georgia, area: U.S. Geological Survey Water-Resources Investigations 76–133.

Golden, H.G., and Price, McGlone, 1976, Flood-frequency analysis for small natural streams in Georgia: U.S. Geological Survey Open-File Report 76–511,

Gregg, D.O., and Zimmerman, E.A., 1974, Geologic and hydrologic control of chloride contamination in aquifers at Brunswick, Glynn County, Georgia: U.S. Geological Survey Water-Supply Paper 2029–D.

Hayes, L.R., Maslia, M.L., and Meeks, W.C., 1983, Hydrology and model evaluation of the principal artesian aquifer, Dougherty Plain, southwest Georgia: Georgia Geologic Survey Bulletin 97.

Inman, E.J., 1983, Flood-frequency relations for urban streams in metropolitan Atlanta, Georgia: U.S. Geological Survey Water-Resources Investigations Report 83–4203.

Project	Project Chief
Flood-Insurance Study—North Georgia	McGlone Price
Water Use—Statewide	Harold R. (Bud) Stiles
Atlanta Metropolitan Area Urban-Flood Runoff Characteristics	Ernest J. Inman
Hydrology of the Albany Area	David W. Hicks
Ground Water in the Greater Atlanta Area	Charles W. Cressler
Seasonal Low-Flow Characteristics of Georgia Streams	Thomas R. Dyar
Water Quality in the Coal Region of North Georgia	James B. McConnell
Impact of Summer Storm Runoff on Water Quality in the Greater Atlanta Area	James B. McConnell
A Preliminary Appraisal of the Effects of Agriculture on Stream Quality in Southwest Georgia	James B. McConnell
Flood Studies and Bridge Site Investigations Project	McGlone Price
Flood Frequency Characteristics of Urban Streams in Georgia	Ernest J. Inman
Ground Water Models	Wanda Meeks
Time-of-Travel Studies of Georgia Streams	James L. Pearman
A Preliminary Appraisal of the Water Quality of West Point Reservoir	Dean B. Radtke
Principal Artesian Aquifer—Dougherty Plain, Southwest Georgia	Larry R. Hayes
Cretaceous-Tertiary Aquifer System	Lin D. Pollard
Georgia Streamflow Network Evaluation	Robert F. Carter
Southeast Limestone Regional Aquifer-System Analysis	Richard E. Krause
Water Monitoring in Coal Mining Areas for P.L. 95–87, Georgia	Timothy W. Hale
Southeast Coastal Plain Regional Aquifer-System Study	Robert E. Faye

McConnell, J.B., 1980, Impact of urban story runoff on stream quality near Atlanta, Georgia: Cincinnati, Ohio, U.S. Environmental Protection Agency Municipal Environmental Research Laboratory (PB–81 142 473).

Radtke, D.B., 1983, Limnology of West Point Reservoir, Georgia, Alabama: U.S. Geological Survey Water-Supply Paper (in press).

Stamer, J.K., Cherry, R.N., Faye, R.E., and Kleckner, R.L., 1979, Magnitudes, nature, and effects of point and nonpoint discharges in the Chattahoochee River basin, Atlanta to West Point Dam, Georgia: U.S. Geological Survey Water-Supply Paper 2059.

KENTUCKY

by Robert J. Faust

INTRODUCTION

Water-resources activities in Kentucky were conducted by the Ground Water (GW) and Surface Water (SW) Branches until 1967. In that year, the branches and their activities were merged to form the Water Resources Division (WRD) of the Kentucky District. Quality of Water (QW) activities were performed within the merged disciplines for the period 1966–79.

The Kentucky District was housed in Room 310 of the Center Building at 522 West Jefferson Street in Louisville until 1969 when it moved to the Federal Building at 600 Federal Place in Louisville for the remainder of the period.

Subdistrict Offices operated out of Paducah and Williamsburg during the report period and Field Offices operated in Lexington, Millard, Prestonsburg, and Shelbiana for parts of the period.

ORGANIZATION AND PERSONNEL

Floyd A. Schrader served as District Engineer of the SW Branch in 1966, and was named District Chief of Kentucky District in 1967. Robert (Bob) V. Cushman served as District Geologist of the GW Branch in 1966, as Supervisory Geologist of the Kentucky District in 1967, and as Associate District Chief for the period 1968–71. He became District Chief in 1971 when Floyd A. Schrader retired. Philip A. Emery became District Chief in 1976 when Bob Cushman retired. Howard C. Beaber and John C. McCabe became Assistant District Chiefs in 1969 and served in those positions for the remainder of the period. Arthur S. Curtis was in charge of the Paducah

Office in Western Kentucky until 1974. He was succeeded by Wilson G. Bonham who served for the remainder of the period. Chester H. Minehan was in charge of the Williamsburg Subdistrict Office in Eastern Kentucky for the entire period.

The number of personnel in the Kentucky District was fairly stable from 1966 to 1973. The numbers ranged from the middle to upper thirties during this period. The numbers increased to the middle forties in 1974, to the low fifties in 1975, and remained at that level for the remainder of the period.

Ground-water investigations were conducted under the general direction of Bob Cushman. Personnel playing key roles in these investigations included Robert W. Davis, Robert J. Faust, Hayes F. Grubb, Arnold J. Hansen, Herbert T. Hopkins, John M. Kernodle, T. William Lambert, John H. Morgan, Donald S. Mull, Raymond O. Plebuch, Paul D. Ryder, Douglas V. Whitesides, and Harold H. Zehner.

Surface water and QW investigations were conducted under the general supervision of Howard C. Beaber. Key personnel in those investigations included William F. Curtis, Russell F. Flint, Timothy W. Hale, Curtis H. Hannum, James L. Kiesler, David W. Leist, John S. Santos, Richard V. Swisshelm, Jr., and John S. Zogorski.

Data collection was conducted under the general supervision of Howard C. Beaber. Key personnel in data collection included Wilson G. Bonham, Arthur L. Curtis, Timothy W. Hale, Herbert J. Freiberger, William H. Jackson, Thomas W. Kollar, Chester H. Minehan, Thomas R. Oglesby, Ferdinand Quiñones-Marquez, Billy L. Raney, Charles E. Schoppenhorst, John L. Spillman, John N. Sullavan, and Douglas V. Whitesides.

Administrative activities were performed by Mary P. Hays, Maxene T. Catlett, and Irene A. Fraser during most of the report period. Robert D. Hudson became Administrative Officer in 1978.

COOPERATING AGENCIES AND FUNDING

The Kentucky Geological Survey (KGS) was the principal State cooperator during the report period. Most of the areal studies and a large part of the SW programs were supported by KGS funding. Also, a strong cooperative program by State Geologist Wallace W. Hagan of KGS with other Divisions of the U.S. Geological Survey resulted in Kentucky being the first State to be completely covered by topographic and geologic maps at a scale of 1:24,000. This program was completed during the period of this history, and the maps were important source material for subsequent water-resource investigations.

The Kentucky Natural Resources and Environmental Protection Cabinet (KNREPC) is charged with overseeing water withdrawals, oil and gas operations, and mining operations in the State. To help in these responsibilities, it provided funding for collecting data on SW, GW, QW, and low flow of streams.

The Kentucky Department of Transportation (DOT) provided funding for the operation of a network of crest-stage and partial-record stations for defining flood profiles, for indirect measurements of flood peaks, and for reports on hydraulics of bridge sites.

Two electric utility companies provided funding for stream gaging in their areas of interest.

The Ohio River Valley Water Sanitation Commission provided funding for QW data on the Ohio River.

The Lexington and Fayette County Planning Commission provided funding for a hydrologic study in their counties.

Federal support for District operations came from the United States Geological Survey (USGS), U.S. Army Corps of Engineers, Tennessee Valley Authority (TVA), Federal Emergency Management Agency (FEMA), National Park Service (NPS), U.S. Environmental Protection Agency (USEPA), National Weather Service (NWS), and the Soil Conservation Service. In addition to providing matching funds supplied by State and local cooperators, the USGS provided full support for selected streamflow stations and observation wells, for outlining flood-prone areas on topographic maps as part of a nationwide Federal program for managing flood losses, for collecting water-use data, for collecting hydrologic data at the Maxey Flats Nuclear Waste Disposal Site, and for an analysis of the stream-gaging program. The greatest support from other Federal agencies came from the Corps of Engineers. Corps funding came from Districts in Louisville, Huntington, and Nashville and supported stream-gaging and sediment stations and a study of the Lexington area. The TVA provided funding for stream-gaging and sediment stations on the Tennessee River and its tributaries. FEMA provided funding for the preparation of flood-insurance studies for a number of communities in the State. The NPS provided funding for hydrologic data in the

Mammoth Cave area. The USEPA supported a study of chloroform contamination in Louisville. The NWS provided support in the form of services. The Soil Conservation Service provided some support for the stream-gaging and QW data. Participation in WRD's Coal Hydrology Program resulted in a significant increase in funding in 1979.

Kentucky District funding, 1966 and 1979

	Federal	Cooperative		Other Federal agencies	Total
		State	USGS		
1966	$40,000	$164,000	$164,000	$160,000	$528,000
1979	$1,160,000	$530,000	$530,000	$410,000	$2,630,000

HYDROLOGIC DATA COLLECTION

Hydrologic data networks were an important part of the water program during the period 1966–79. They were modified from time to time to meet needs of cooperating agencies and new programs. Changing technology during the period was an important factor in the collection, storage, and retrieval of water data. The conversion from analog to digital records was completed, and the application of computer technology in the processing of data became standard procedure. Many SW stations supported by the Corps of Engineers were equipped with devices that could be interrogated for real-time data. By the end of the period all data were being stored in the National Water Data Storage and Retrieval System (WATSTORE). Also, current GW data were being stored in the Ground Water Site Inventory System (GWSI), and some historical data were being added to that system.

Surface-Water Records

The number of SW stations changed from year to year to meet changing needs. At the beginning of the period, records of daily stream stage and discharge were collected at 144 stations and at 112 stations at the end of the period. Records of daily water levels were collected at 8 lakes and reservoirs in 1966 and at 15 in 1979. High-flow and low-flow partial records were obtained at 112 sites in 1966 and at 124 in 1979.

Several reports on network characteristics were published in the period 1966–79. Beaber (OFR, 1970) proposed a streamflow-data program for Kentucky. Shearman and Swisshelm discussed the derivation of homogenous records in the upper Kentucky River Basin (OFR, 1973).

Swisshelm completed a report of the low-flow characteristics of Kentucky streams (OFR, 1974). Hannum discussed a technique for estimating the magnitude and frequency of floods in Kentucky (WRI 76–62). Zorgoski and Kiesler compiled a report on temperatures of Kentucky's streams (WRI 76-86). Hale discussed the derivation of homogenous streamflow records for the Green River Basin (WRI/OF 79-1006).

Ground-Water Levels

Ground-water levels were collected at 135 wells in 1996 and at 70 in 1979. Whitesides, Kernodle, and Leist compiled ground water-level data for Kentucky (OFR 78–129). Kernodle and Whitesides wrote a report on the rising ground-water level in downtown Louisville (WRI 77–92).

Water-Quality Records

Water-quality data were collected at 52 sites in 1966 and at 39 sites in 1979. Suspended-sediment data were collected periodically at eight sites in 1966 and at 43 sites in 1979. Near the end of the report period, 12 stream stations were incorporated in the Survey's National Stream Quality Accounting Network (NASQAN). The purpose of this network was to detect trends in water quality throughout the Nation.

AREAL AND SITE INVESTIGATIONS

Many studies were conducted during 1966–79 in western Kentucky, known as the Jackson Purchase region. This region contains the best regional aquifers in the State. Hydrologic Atlases (HA) 165–186 were completed at a scale of 1:24,000 in this region. The publication of these atlases also completed statewide coverage of Kentucky by HA's. In addition to atlases, the geology and ground-water resources of the region were discussed by Davis, Lambert, and Hanson (WSP 1987).

Localized aquifers in alluvial deposits along major rivers in Kentucky were the subject of reports by Grubb (WRI 2–74), Ryder (WRI/OF 4–75), Ryder (WRI/OF 53–73), Kernodle (WRI 77–24), and Whitesides and Ryder (KGS Information Circular 18).

Reports on hydrologic investigations in coal fields of Kentucky were published in four reports. Davis (KGS Report of Investigations 15) discussed deep sandstone aquifers in parts of the Western Coal

Field Region. Effects of strip mining on water resources were discussed by Collier, Pickering, and Musser (PP 427–C) and by Grubb and Ryder (WSP 1940). Hopkins discussed the occurrence of freshwater in the Lee Formation (WSP 1867).

Other reports during 1966–79 on water resources of selected areas of Kentucky included those by Curtis, Flint, and George (WRI/NTIS 77–123), Davis (MF 76–113), Faust (WRI 76–113), Hopkins (WSP 1867), Lambert (KGS, series 10, Report of Investigations 17, and WRI/OF 79–53), Mull and Pickering (KGS, series 10, Report of Investigations 9), Plebuch (WRI/OF 76–43 and 78–25), Sullavan, Quiñones, and Flint (OFR 79–977), and Zehner (OFR 79–1329).

A fairly comprehensive list of publications on water resources is in "Water Resources Activities in Kentucky, 1993–94" (OFR 93–157).

MISSISSIPPI

by Lamar E. Carroon

ORGANIZATION AND PERSONNEL

The Mississippi District was formed in 1966 using staff already on board in the Ground Water and Surface Water Branch offices in Jackson. The only employee not located in Jackson at that time was Billy J. McCollum, a hydrologic technician engaged in streamflow-data collection who was located in a Field Headquarters in New Albany.

Offices were in the Post Office building at Capital and West Streets in downtown Jackson. In 1970, the offices were relocated to leased space at 430 Bounds Street in north Jackson. In 1979, a new Federal Office Building was completed in downtown Jackson, and the WRD District Office was moved into it, joining a Conservation Division office transferred from Louisiana.

William H. Robinson was named District Chief in 1966. In 1968, he was succeeded by Lamar E. Carroon, who served through 1979.

Senior staff who served throughout the period were E.H. Boswell, James D. Shell, Kenneth V. Wilson, Billy E. Wasson, James A. Callahan, James W. Hudson, Paul E. Grantham, Sidney H. Bishop, Billy Joe McCollum, and Merle A. Hudson. Roy Newcome, Jr., served as Assistant or Associate District Chief until his transfer in 1976. He was succeeded by Andrew G. Lamonds. E.H. Boswell was in charge of areal studies for most of the period, James Shell was in charge of surface-water basic-data collection, succeeded by C.H. Tate, and K.V. Wilson was the principal investigator in highway hydraulics and flood-data collection, assisted by James W. Hudson.

Summary of data-collection stations, 1966, 1973, and 1979

Activity	1966	1973	1979
Surface water	85	80	80
Water quality	18	30	30
Ground water	--	--	320
Sedimentation	--	--	17

Amer T. Wilkinson was administrative clerk in 1966, succeeded by Ruth D. Bourland in 1968, when Wilkinson retired. Bourland continued as chief clerk for the balance of the period.

The staff throughout the period consisted of about 30–45 persons at any one time with the mix of professional to technician remaining near equal. The number of part-time employees varied over time.

Many capable people worked in the District from time to time, producing a body of work invaluable to the development of the State and upholding the Survey's reputation for technical quality and freedom from technical bias.

PROJECTS AND PROGRAMS

A major program component was a Federal-State Cooperative (Coop) Program with the Mississippi Board of Water Commissioners and the Mississippi Geological Survey to provide base data on surface water and ground water. A computerized ground-water data inventory was in place and continually was being expanded and supplemented by information on all new water wells drilled in the State. Inventory and logging of water wells was a continuing activity. The State Highway Department funded an ongoing Coop Program to collect and analyze data on the hydraulic performance of highway structures and flood hydrology of streams. Other program components were studies of local areas where problems of water supply and use had occurred or were anticipated. These studies were funded cooperatively by the Mississippi Research and Development Center and local agencies. At the beginning of the period, ground-water studies at the Tatum Salt Dome, the site of an earlier experimental atomic explosion, Project Dribble, were being concluded.

External events affecting the District included Hurricane Camille in August 1969. It was one of the most intense storms of this century. It came ashore near Bay St. Louis, Miss., and resulted in widespread flooding and loss of electrical power across all of the Mississippi coast. This resulted in cessation of pumping in the coastal region of the State, an area of intensive ground-water use. Water levels, which had been reduced to well below land surface, rose rapidly, and in a few hours many wells began to flow. The flowing wells ceased almost as soon as electrical power was restored.

Following Hurricane Camille, an experimental series of hydrologic atlases (HA's 395–408) was developed under the leadership of Harry H. Barnes in Reston to summarize the data on available 7.5-minute series quadrangle sheets and to get the data out in a timely manner.

A great flood in April 1979 occurred on the Pearl River, causing widespread damage. It gave impetus to flood-abatement studies by the Corps of Engineers and others and significantly affected USGS collaborative programs. It was reported in HA–655.

Construction of the Tennessee-Tombigbee Waterway by the U.S. Army Corps of Engineers in the period about 1970 to 1985, significantly affected stream- and ground-water systems along the Mobile-Tennessee River divide. USGS programs were refocused for water-data needs of all levels of government.

Predictive studies by WRD were given to the Corps of Engineers from time to time to allow them to minimize adverse impacts of construction on the hydrologic environment.

FUNDING

Mississippi District funding, 1966 and 79

Year	Federal	Cooperative		Other Federal agencies	Total
		State	USGS		
1966	$16,000	$160,000	$160,000	$101,000	$437,000
1979	205,000	375,000	375,000	671,000	1,627,000

In 1971, the Gulf Coast Hydro-Science Center (GCHC) was established at the NASA Mississippi Test Facility at Bay St. Louis to allow the USGS as well as other agencies to use the physical plant left idle by reduction and redirection of NASA programs.

Stanley P. Sauer was named coordinator under the Office of the Regional Hydrologist. Three physical models of hydrologic systems were built by NASA and turned over to the Geological Survey to operate. One was a replacement for the Bureau of Standards tow-tank in Washington, which had been used to rate current meters, and the second was a model to allow study of wide flood plains. The third was a submerged jet to allow study of high-velocity flow.

An instrument development laboratory, previously located in Columbus, Ohio, was relocated to the GCHC. Several research projects were relocated to the GCHC to utilize the facilities made available by NASA. In 1973, Robert Baker replaced Stanley Sauer and was given the title Director of the Center.

NORTH CAROLINA

by Ralph C. Heath

The author acknowledges the assistance of N. Macon Jackson, who reviewed and commented on drafts of this writeup.

North Carolina was reorganized as a WRD District on June 1, 1965, under the direction of Edward B. Rice, who had been District Engineer of the Surface Water Branch program since his transfer to North Carolina from Louisiana in July 1947. Reorganization provided the opportunity to bring peace to a District that had long suffered from acrimonious relations between the District leaders of the Surface Water and Ground Water Branches.

Rice retired on December 30, 1966, and was succeeded as District Chief by Ralph C. Heath who was, at that time, Chief of the New York District. Heath assumed the duties of District Chief in April 1967. Between Rice's retirement and Heath's arrival, the District was led by Nathan O. Thomas, who had been appointed Assistant District Chief in October 1966, when Robert A. Krieger, who had been named Assistant District Chief at the time of reorganization, transferred to the Mid-Continent Regional Staff in St. Louis. Thomas continued to serve as Assistant District Chief until his retirement in 1975. Hugh B. Wilder succeeded Thomas and served during the remainder of the period.

At the beginning of the period, the District program was focused largely on the collection and compilation of streamflow and surface-water-quality data. This unbalanced program had resulted from the failure of the District's Ground Water Branch leadership to maintain cooperative relations with the ground-water staff of the North Carolina Department of Water Resources, which resulted in the loss of State support for all ground-water programs except the observation-well network.

FUNDING

Funds for WRD operations in North Carolina were from the Cooperative (Coop) Program, other Federal agencies (OFA), the Federal (Fed) program, and from licensees of the Federal Power Commission (FPC). Funds available from these sources for years at the beginning, middle, and end of the period covered by this history are shown in the following table.

ORGANIZATION AND PERSONNEL

Shortly after his arrival in 1967, Heath reorganized the District staff along functional lines in order to place increased emphasis on the analysis and interpretation of the large volume of basic data that had been collected. All data-collection activities were placed in a Hydrologic Records Section, which was under the direction of Wilson G. Bonham, following his transfer from Albany to Raleigh in January 1968. All data analysis and interpretive studies were assigned to a Hydrologic Studies Section under the direction of G.C. Goddard. After reorganization, the Administrative Services Section, which was headed by Margaret Harrington, and the Water Quality Records Processing Center, headed by Alma Hulsey, continued to operate under the District Chief's office. Harrington retired in September 1967, and was succeeded by Maudie Ellis, who headed the Administrative Services Section until her retirement in 1975. Ellis was succeeded by Nancy Williams, who headed the section during the remainder of the period. Hulsey resigned in 1969 and was succeeded by Phyllis Joyner.

Activities of the Hydrologic Records Section were divided among four units (Subdistrict Offices) and five Field Headquarters. The Asheville Records Unit was headed by Thomas Johnson and included direction of Tom Dillard in the Bryson City Field Headquarters. The collection of records in the eastern Piedmont and Coastal Plain was the responsibility of the Raleigh Records Unit, under N. Macon Jackson, and included direction of James Futrell in the Wilmington Field Headquarters. Record collection in the central and western Piedmont was the responsibility of the Statesville Records Unit, under Ernst Wollin, and included direction of Field Headquarters at Charlotte (Harold Eddins), Morganton (Duncan Murrow), and Winston-Salem (Clarence Ray). The Water Quality Laboratory was the fourth unit of the Records Section and was headed by Edward Phibbs until his transfer to the Florida District in 1971, when Ann Beam became head of the laboratory.

Work of the Hydrologic Studies Section was originally divided among five units as follows:
1. Geochemistry and sedimentation - Hugh B. Wilder
2. Ground water - Edwin Floyd
3. High flows and floods - Herbert Hinson
4. Low flows - James Turner
5. Urban rainfall runoff - William Haire

As funding and program commitments permitted, the professional staff of the Hydrologic Studies Section were assigned to specific interpretive studies conducted under Goddard's direction with the result that by about 1970, the units identified above had ceased to exist as organizational entities and were replaced by the establishment of a Technical Support

North Carolina District funding, in thousands of dollars

Funding source	1966	1967	1968*	1972	1973*	1978	1979*
Coop	558.6	604.6	641.8	687.7	721.4	1,084.1	1,196.8
OFA	145.3	136.9	133.9	146.7	175.7	278	164
Fed	36.2	38.9	38.9	60.9	48	0	0
FPC	9.5	9.9	9.9	12.7	13.3	18.3	19.4
Total	749.5	790.3	824.5*	893.8	958.3*	1,380.4	1,380.2*

Source: District program documents. * Estimates at beginning of fiscal year.

Section. Goddard was placed in charge of the new section, and E.F. Hubbard became head of the Hydrologic Studies Section. Following Goddard's death in February 1972, the Technical Support Section staff was transferred to the Hydrologic Studies Section.

In an effort to improve intra-District communication, a monthly District newsletter, "Currents and Undercurrents," was started in July 1967, under the editorship of Ruth Rachal, District Clerk, who, incidentally, suggested the name. Publication of "Currents and Undercurrents" was discontinued in December 1973, after admirably serving its intended purpose.

During the period of this history, the permanent full-time staff of the District decreased from 56 to 48 as a result of phasing out the Water-Quality Laboratory with a Regional Unit and replacement of the District Water Quality Laboratory with a Central Laboratory at Doraville, Ga. Personnel changes also included a decrease in the number of hydrologists assigned to the collection of streamflow data and their replacement with technicians.

SURFACE-WATER PROGRAM

In 1966, the surface-water data-collection program of the District was among the most extensive and comprehensive in the Nation, as shown by the following list of activities:

Streamflow-gaging stations
- Continuous-record stations....177
- Crest-stage stations....135
- Low-flow partial-record stations....200

Water-quality stations
- Continuous water-quality monitors....17
- Daily sampling stations....17
- Monthly sampling stations....21

Sediment stations
- Daily sampling stations....3
- Periodic and monthly stations....69

Temperature stations
- Daily....34

Estuary (tidal) discharge stations

Cape Fear River at Wilmington (slope station)

Chowan River at Gatlington Landing (deflection vane)

Urban rainfall-runoff studies (dual-digital and flood-hydrograph stations)
- Charlotte....21
- Durham....10
- Lenoir....5
- Morganton....3
- Winston-Salem....15

Lake-evaporation studies

Lake Michie (a water-supply reservoir)

Hyco Lake (an electric powerplant cooling lake)

As a part of a nationwide program, the District undertook in 1968 a comprehensive review, analysis, and evaluation of its streamflow-data program. The results were published in "A Proposed Streamflow Data Program for North Carolina" (Open-File Report, 1970) by Goddard, Jackson, Hubbard, and Hinson.

The results of the lake-evaporation studies were presented in "Evaporation Study in a Humid Region, Lake Michie, North Carolina" (PP 272–G, 1966) by J.F. Turner; in "Evaporation from Lake Michie, North Carolina, 1961–1971" (WRIR 3–73, 1973) by W.L. Yonts, G.L. Giese, and E.F. Hubbard; in "The Effect of Heated Water on the Temperature and Evaporation of Hyco Lake North Carolina 1966–1972" (WRIR 11–74, 1974) by Yonts and Giese; and in "Thermal Loading of Hyco Lake, North Carolina—The Effect of Heated Water on Temperature and Evaporation 1966–1974" (WRIR 76–48, 1976) by Giese. Collection of data related to lake evaporation was discontinued by early 1975.

The results of the urban rainfall-runoff studies were presented in "Flood Inundation and Effects of Urbanization in Metropolitan Charlotte, North Carolina" (WSP 1591–C, 1968) by L.A. Martens, and in "Effects of Urban Development on Floods in the Piedmont Province of North Carolina" (Open-File Report, 1972) by A.L. Putnam. The report by Putnam was a "best seller" and stimulated expansion of research by the North Carolina Water Resources Research Institute into urban rainfall-runoff problems.

The first report that utilized data from the estuary discharge stations was "Flow of the Chowan River, North Carolina—A Study of the Hydrology of an Estuary Affected Primarily by Winds" (Open-File Report, 1968) by N.M. Jackson, Jr. Beginning in 1970, the Chowan River was increasingly affected by nuisance algal growths, and a massive algal bloom in the summer of 1972 resulted in the start of a complex, multiagency Chowan River Project, with the goal of providing regulatory agencies with the information needed to reduce nutrient loads in the estuary. The U.S. Geological Survey's contribution to the project consisted of developing a digital flow model of the estuary based on the continuity equation. The results of this modeling effort, which proved to be one of the most successful estuary models developed up to that time, were presented in "Digital Flow Model of the Chowan River Estuary, North Carolina" (WRIR 77–63) by C.C. Daniel, III.

The North Carolina District, for many years prior to the period covered by this history, had been a leader in flood studies and flood-frequency analyses. The District was among the first to publish flood-plain zoning maps, in a report by W.G. Stamper on the City of Charlotte and Mecklenburg County area (Open-File Report, 1975). As part of a nationwide program, the District had, by the end of the period, delineated flood-prone areas on 480 1:24,000-scale topographic maps. An updated report on the magnitude and frequency of floods in North Carolina was prepared by Macon Jackson (WRIR 76–17, 1975).

The stream-quality basic-data-collection program was substantially reduced in scope in 1967 in order to permit the preparation of reports that presented, in a readily usable format, the data that had been collected over many years. One of the most useful products resulting from this effort was "Summary of Data on Chemical Quality of Streams of North Carolina" (WSP 1895–B, 1971) by H.B. Wilder and L.J. Slack.

The North Carolina District established daily and monthly water-quality sampling stations and specific-conductance recorders in the tidal portion of the State's major streams, beginning with the Cape Fear River in 1946. Data were collected in this program at 33 different sites for periods ranging from 2 to 21 years, making it perhaps the most intensive estuarine water-quality-sampling program in the United States until its termination in October 1967. The first interpretive report that used data collected in this program was "Seawater Encroachment in the Cape Fear River Estuary, North Carolina" (Open-File Report, 1968) by H.B. Wilder and E.F. Hubbard. A comprehensive report that includes not only the water-quality data but streamflow data related to the State's estuaries, including data collected at the estuary discharge stations and in the Chowan River digital flow model study, was prepared by G.L. Giese, H.B. Wilder, and G.G. Parker, Jr. The report, "Hydrology of Major Estuaries and Sounds of North Carolina," was first published in 1979 as WRIR 79–46 and was reprinted in 1983 as WSP 2221.

From the early days of the Quality of Water Branch operations in North Carolina, the District had been a leader in the collection of suspended-sediment data. The program included operation of a Federal-Index station on the Yadkin River at Yadkin College, beginning in 1951. In response to concern about the effects of highway construction on sediment loads, the District, as part of its Coop Program with the North Carolina Department of Transportation, conducted an intensive study along the route of I–40 west of Raleigh during the construction phase in the late 1960's and early 1970's. The results are presented in a report prepared by Howard Reeder (Open-File Report, 1973).

An extensive periodic suspended-sediment sampling program was begun in 1969 with a network of 28 stations which, by 1975, had been expanded to 152 sites. During most of the period covered by this history, the sediment-data-collection program was under the direction of C.E. Simmons. A comprehensive report "Sediment Characteristics of North Carolina Streams, 1970–79" shows the effects of different land uses on sediment loads (WSP 2364, 1993).

Over a period of several decades, both the U.S. Soil Conservation Service and the North Carolina Mosquito Control Program had straightened and deepened hundreds of miles of natural stream channels. In response to concerns about the effects of this program on suspended-sediment loads and ground-water storage, the Soil Conservation Service began to fund a series of studies by the District in the early 1970's. These studies included pre- and post-construction data collection in the Creeping Swamp, Chicod Creek, and the Black River. Reports on these studies by Winner and Simmons (WRIR 77–26, 1977), Simmons and S.A. Watkins (WRIR 82–4083, 1982), and by R.R. Mason, Simmons, and Watkins (WRIR 90–4031, 1990) and increasing public opposition to wetland drainage resulted in a substantial reduction in "drainage-improvement" programs.

Increasing concern about stream pollution led, in the early 1970's, to the establishment in North Carolina of a major cooperative program with three goals:

1. To determine the areal and temporal variations in the water quality of the State's major streams,
2. To determine the pollution loads of the streams, and
3. To determine trends in water quality.

This program, which was known as the Large Rivers Study, involved several major innovations in studies of stream quality. The first innovation consisted of establishing a natural water-quality network of stations on small streams where human effect on water quality was minimal. This network provided the data needed to determine what the water quality in the large rivers would have been in the absence of pollution. The analysis of the data obtained from this network was presented in "Water Quality Characteristics of Streams in Forested and Rural Areas of North Carolina" (WSP 2185–B, 1979) by C.E. Simmons and R.C. Heath.

Determining pollution loads and long-term trends in the water quality of the State's large rivers also involved the separation of streamflow hydrographs into base-flow and overland-runoff components, using a method developed by M.I. Rorabaugh and J.F. Daniel of the USGS, and the development of methods for compensating for variations in stream discharge, which were developed by D.A. Harned, C.C. Daniel, and Kent Crawford. The methods for compensating for variations in stream discharge were an important original scientific contribution of the District staff and are described in an article published in 1981 in Water Resources Research (v. 17, no. 5).

Sampling stations also were established at key sites on large streams. Another innovation of the Large Rivers Study was to sample these stations on the basis of flow conditions with emphasis on defining water quality during periods of high flow and low flow rather than on a predetermined time schedule. Only one of the reports dealing with the pollution loads and water-quality trends was published during the period of this history. It was "Water Quality of the French Broad River, North Carolina—An Analysis of Data Collected at Marshall, 1958–1977" (WRIR 79–87, 1979) by C.C. Daniel, III, H.B. Wilder, and M.S. Weiner. Reports on the Neuse River (by D.A. Harned), Yadkin-Pee Dee River System (by Harned and D. Meyer), and the Cape Fear River (by K. Crawford) were published later as chapters in WSP 2185.

The goals of the Large Rivers Study were the most ambitious of any water-quality study undertaken by the USGS up to that time. As far as can be determined, the North Carolina District is the only one ever to undertake such a study.

GROUND-WATER PROGRAM

In 1966, the District's ground-water program was devoted largely to completing reports on several regional and county studies that had been supported, prior to the cutback in State Coop funds, by both the North Carolina Department of Water Resources and by the counties involved. These studies, report authors, and years of publication include the Belhaven area (O.B. Lloyd, Jr. and E.O. Floyd, 1968), Chowan County (O.B. Lloyd, Jr., 1968), Craven County (E.O. Floyd, 1969), Martin County (G.G. Wyrick, 1966), New Hanover County (G.L. Bain, 1970), and Pitt County (C.T. Sumsion, 1968).

When Heath arrived in 1967, the District's ground-water staff consisted of one professional (E.O. Floyd), one technician (J.E. Shoffner), and one typist (M. Hansen), and there was little possibility of expanding the State Coop Program because the funds that would otherwise have been available for the Federal-State Coop Program then were being used by the State to maintain its own staff.

Fortunately, from the District's standpoint, the National Park Service expanded its support of ground-water studies in both the Cape Hatteras National Seashore and the Great Smoky Mountains National Park. The Cape Hatteras report, by M.D. Winner, Jr., was published in 1975 as HA–540. The Great Smoky Mountains study was a joint effort of the North Carolina and the Tennessee Districts. The report on the study was prepared by W.M. McMaster (TN) and E.F. Hubbard (NC) and was published in 1970 as HA–420. The District also prepared ground-water reports for the National Park Service on the Blue Ridge Parkway (Winner, WRIR 77–65, 1977) and on the Cape Lookout National Seashore (Winner, WRIR 78–52, 1978).

The only areal ground-water study that was undertaken as a part of the Coop Program during the period of this history was of Wilson County; the study was supported partly with county funds. The most significant ground-water study undertaken as a part of the Federal-State Cooperative Program involved review by M.D. Winner of both the USGS and State-operated observation-well programs and the design of a statewide network to meet clearly defined objectives. This is believed to be the only study of this type ever undertaken by the USGS, and it resulted later in expansion of the Federal-State Cooperative Observation-Well Network.

WATER-RESOURCES PROGRAM

One of the results of the WRD reorganization was increased emphasis on water-resources studies that included ground water, surface water, and water quality. In the mid-1970's the Wilmington office of the Corps of Engineers supported a study of the water resources of northeast North Carolina. The report, by Wilder, T.M. Robinson, and K.L. Lindskov, was published in 1978 as WRIR 77–81.

One of the most significant water-resources studies undertaken in the 1970's as a part of the Federal-State Cooperative Program involved the collection and analysis of data on public water supplies. The results are contained in five reports covering different parts of the State, prepared singly or jointly by Jackson, Robinson, and L.T. Mann, Jr., and a sixth, a summary report prepared by Mann.

In the early 1970's, massive land-clearing operations were undertaken by private landowners on the Albemarle-Pamlico peninsula. In order to put the land in cultivation, a dense network of drainage channels had to be installed. These channels efficiently diverted runoff to the adjoining estuary nursery areas, and as a result, there was concern about the effect of the land-clearing operations. At the request of the North Carolina Department of Natural and Economic Resources, Heath prepared a report on the hydrology of the area (WRIR 9–75, 1975).

Heath and N.O. Thomas prepared a report on the water resources of the State that was included in Chapter 8 of the North Carolina Atlas, published by the University of North Carolina Press (1975).

Only the most significant publications generated by the North Carolina District during the period of this history are mentioned in the preceding program discussions. For titles of those referred to only by publication series and number and for a more complete listing, see "Bibliography of Selected Water-Resources Publications by the U.S. Geological Survey for North Carolina, 1886–1995" by Winner (Open-File Report 95–775, 1996).

Finally, the training officer of the State Cooperator arranged for Heath and Wilder to teach a series of short courses on ground-water hydrology and water quality to the field staff of the State Division of Environmental Management. The courses were presented during the summer and fall of 1978 at five locations around the State. Heath expanded his lecture notes, which were published the year after the period covered by this history as "Basic Elements of Ground Water Hydrology, with reference to conditions in North Carolina" (WRIR 80–44, 1980).

The preceding discussion covers the events and accomplishments judged to be the most significant. There were many other events, some probably equally as important, and many staff members involved which space limitations did not permit mentioning.

PUERTO RICO AND U.S. VIRGIN ISLANDS (CARIBBEAN DISTRICT)

by Donald G. Jordan (with assistance from J.R. George and others)

For the period of 1966–79, the Caribbean District continued the task of gaining basic knowledge of the water resources of Puerto Rico and the U.S. Virgin Islands. Basic-data programs were relatively stable in the number of stations operated but still lacked sufficient length of record for meaningful analysis. Throughout the decade, however, the data programs were very active in establishing and maintaining surface-water, ground-water, and quality-of-water data sites needed to support ongoing projects and to continue to develop a base of long-term hydrologic record. Data collection and a suite of special studies were designed to address past, present, and projected water-resource issues throughout the Commonwealth. Water-resource issues and long-term basic-data needs identified by the USGS and local and Commonwealth agencies included:

1. Regional and local streamflow data and analyses to serve public needs for water supply, waste disposal, and flooding.
2. Expanded information for proper development, use and management of the islands' abundant ground-water resources.
3. Data to assess existing river and ground-water quality and the factors that may affect the quality of these resources.

In 1966, the Caribbean Office had been operating as a WRD District for nearly 4 years and was one of the first to be established. The coming years saw the development of analog ground-water models, regional aquifer studies, major floods, the integration of ground-water, surface-water, and water-quality disciplines, and early use of computer technology. The District showed a steady expansion until 1973–74 when funding was severely reduced, resulting in a reduction in investigative projects and transfer of professional personnel. Then, District efforts were directed mainly to maintaining a data-collection network. It was not until the late 1970's that the program once again began to expand.

ORGANIZATION AND MANAGEMENT

As the period began, Dean Bogart was District Chief, a position he held until his retirement in 1971. John Murphy was the assistant District Chief and also supervised the Water Quality Section. Irby Hickenlooper was the Surface Water Section Chief. Oliver Cosner was Geologist-in-Charge of the Virgin Islands Field Office. Rosario V. de Fuentes provided administrative services to the office until her retirement in 1970.

Throughout the period, engineers, geologists, and chemists in the District were primarily transfers from stateside offices because of the dearth of qualified Puerto Rican professionals. Those that were qualified generally went to local industries due to much higher salaries. The District started the period with three Puerto Rican professionals and ended with four. The District was fortunate in that it always had a strong and stable group of Puerto Rican technicians and support people.

In 1966, Jack Reed arrived to head the Water Quality Section, and he established a first-class water-quality laboratory. In 1968, Hickenlooper and Murphy returned to the States. Jamie Rickher replaced Hickenlooper as head of the Surface Water Section. The Assistant District Chief position remained open until 1969 when it was filled by Don Jordan. Also in 1968, Oliver Cosner returned to the States and Tully Robinson became Geologist-in-Charge in the Virgin Islands until the Virgin Islands Field Office was closed in late 1968.

The District was reorganized in late 1969 to better define responsibilities. The Surface Water Section was split into a Hydrologic Records Section headed by James Rickher, a Floods Section headed by Bill Haire, and a Data Development and Hydrologic Modeling Section headed by Miguel López. Fred Fields, who had been in charge of flood studies, was moved to the Data Development Section because of his computer skills. Jack Reed continued in charge of the water-quality laboratory.

In 1970, there was a reorganization in Puerto Rican government departments. As a result, the District gained two new cooperators—the Department of Natural Resources and the Environmental Quality Board—in addition to the original cooperators, the Aqueduct and Sewer Authority, Water Resources Authority, the Department of Transportation and Public Works (new name), and Industrial Development Company. Additional funding support came from the USGS and the U.S. Army Corps of Engineers.

In 1971, Dean Bogart stepped down as District Chief and was succeeded by Don Jordan. Bruce Gilbert transferred to Puerto Rico to fill the Assistant District Chief position. Late in 1971, Vito Latkovich became head of the Hydrologic Records Section. The Ground Water Section was renamed Areal Studies and headed by Gordon Bennett.

Reduced funds in 1973–74 had a severe impact on projects and personnel for most of the remaining period, and the program was reduced primarily to data collection. As a result, most of the professional personnel and several technicians were transferred to the States.

FUNDING AND PERSONNEL

Puerto Rico funding, 1966 and 1979

Year	Federal	Cooperative		Other Federal agencies	Total
		State	USGS		
1966	--	$168,000	$168,500	$11,000	$348,000
1979	$56,000	529,000	529,000	64,000	1,130,000

Personnel

WRD hydrologists who served as District Chief during this period include Dean B. Bogart, 1956–71; Donald G. Jordan, 1971–74; Ernest D. Cobb, 1974–78; and Craig B. Bentley, 1979–80.

District personnel, 1966, 1973, 1979

	1966	1973	1979
Hydrologists	16	19	9
Hydrotechs	9	10	15
Administration	3	4	4
Total	28	33	28

In 1966 the District staff was officed at 12 Arroyo Street in Hato Rey, P.R. Soon after, they occupied the second floor of Building 653 at Fort Buchanan. Later, the District occupied Building 652 at Fort Buchanan and remained in those offices through 1979.

VIRGIN ISLANDS

Funding

Virgin Islands funding, 1966, 1969, 1979

Year	Federal	Cooperative		Other Federal agencies	Total
		State	USGS		
1966	--	$32,500	$32,500	$40,000	$105,000
1969	$3,000	20,000	20,000	4,000	47,000
1979	*	*	*	*	*

*Data not available.

In 1966, the Field office on St. Thomas Island was addressed:
USGS-WRD
c/o Dept. of Public Works
PO Box 476, Charlotte Amalie,
St. Thomas, Virgin Islands
USA

Personnel

Field Office staff on St. Thomas between 1966 and 1979 included the following personnel for varying durations during the period: Oliver J. Cosner, L. Grady Moore, Donald G. Jordan, and Tully M. Robinson.

In addition to the water-data sites:

* Several flood-stage only gages were also operated. The District also collected low-flow data for a large number of sites throughout the island.

* Many additional observation wells provided annual and(or) seasonal ground-water-level data. During this period, the District collected hundreds of well samples for chemical and biological analyses of water.

Areal Studies in Puerto Rico

The years from 1964 through most of 1970 were a period of severe drought. Ground-water levels in the South Coast Alluvial Plain and in the adjacent alluvial valleys declined strikingly, reflecting the lack of recharge and the demands put upon the aquifer by agriculture, industry, and public supplies. A ground-water level, chloride-concentration network was established to monitor the aquifers. The first of several annual maps provided contours of the ground-water surface and chloride ion concentrations. Because of previous work on the south coast, it also was possible to compile a pre-drought map of ground-water levels and chnloride concentrations for comparison. Major declines in ground-water levels occurred throughout the south coast and especially in pumping centers. By 1969, water levels in pumping centers within 2 miles of the coast were as much as 40 to 50 feet below sea level. Seawater encroachment toward the pumping centers occurred, however, at a much slower rate than expected. By the mid-1970's the aquifer had not recovered to pre-drought levels, and increasing chloride concentrations became a problem in the pumping centers of several major industrial and public supplies.

Areal investigations at the beginning of this period still were concentrated in the South Coastal Plains and adjacent alluvial valleys. Ennio Giusti studied the Juana Díaz and Coamo areas, completing the areal investigations of the South Coast Alluvial Plain proper. By the end of the decade, areal studies were underway or completed on nearly all the coastal alluvial valleys and in the North Coast Limestone—Raul Díaz in the Putillas and Añasco valleys. Donald Adolphson, Michael Seijo, and Tully Robinson were working in the Maunabo valley, Robert Anders in the Guanajibo, Henry Anderson in the Lajas valley and San Juan area, and Ennio Giusti in the North Coast Limestone.

In the late 1960's, Ennio Giusti began the first areal investigation of the North Coast Limestone. At the time, about all that was known about the aquifer was that the Ayamon and Aguada limestones formed the principal aquifer. It was known that yields of as much as 1,000 gallons per minute could be obtained and that in some areas, seawater encroachment was an existing or potential problem. About the time the investigation started, a deep well was drilled into the underlying Montebello member of the Cibao Formation and the underlying Lares Limestone. Previously unknown artesian aquifers were penetrated that had heads of as much as 200 feet above land surface and 400 feet above sea level. Some wells flowed as much as 2,000 gallons per minute. Giusti made a comprehensive study of the aquifer system. He investigated the relations of surface water and ground water as well as the relation between recharge and discharge. He also assessed the effect of evapotranspiration on recharge and developed estimates of aquifer transmissivity. A major surprise was evidence of the extremely low transmissivity of the artesian aquifer. This was verified later when heads and water yields declined. Giusti also acquired data and evaluated variances in surface- and ground-water chemistry This important project was reported by Giusti and Bennett in 1976 as USGS Water-Resources Investigations Report 75–42.

The arrival of Gordon Bennett in 1969 brought ground-water modeling experience to the District. Data collection for the development of electric-analog models began in the Guayama area on the south coast by Raul Díaz. Data collection also started on the east coast in the Yabucoa valley by Robert Anders, with Bennett advising. Bennett began development of an electric-analog model of the South Coast Alluvial aquifer. The result was the largest and one of the last electric-analog models developed by the WRD. Built on a scale of 1:20,000, it was nearly 50 feet long and 5 feet high. The model forecast major changes in the water levels in the aquifer caused by increasing industrial and urban development. A major impact on the aquifer was the gradual decline in the 1950's and 1960's in the use of surface water to irrigate sugar cane. This change probably eliminated a major source of recharge to the aquifer. The results of Bennett's modeling were published in USGS Open-File Report 74–4.

Early on, Bennett became involved in determining the effects of dredging the Río Bucana to the sea to relieve flooding in the city of Ponce on the south coast. Bennett's model showed that the floodway would cause serious seawater encroachment in the Coast Plain Alluvial aquifer. It also suggested seawater encroachment into a new well field that was to be the principal water supply for the city of Ponce. Unfortunately, a political decision was made to construct the floodway. The results were as predicted and the well field was never put into production.

The floodway led to a second project to determine the effect of dredging the Laguna Tortuguero, located on the north coast, west of the city of San Juan. Once again, the Bennett model revealed serious seawater encroachment, this time into the North Coast Limestone aquifer. The harbor construction proposal was dropped. In the late 1960's, two copper deposits were discovered in the upper Río Grande de Arecibo Basin on the north coast. Planned development of the deposits would require the disposal of 15,000 to 20,000 tons of pyritic tailings daily. It was proposed to put the slurried tailings on the limestone terrain between the Río Grande de Arecibo and its major tributary, the Río Tanama. There were concerns for where the water from the tailings slurry might go. Would the tailings move through the suspected cave systems to the rivers? Dye studies in the karst and on the rivers indicated that flow in the karst was toward the Río Tanama Basin. The Río Tanama flows in a collapsed cave system, now partly a canyon 200 to 300 feet deep and accessible only at a few points along its course. Because of the inaccessibility, the potential discharge points to the river were theoretical. They were not verified until December 1972, when two members of the National Speleological Society, two members of the New York Explorer's Club, and two members of the Caribbean District of WRD floated the Río Tanama. To our knowledge, this was the first time the underground reaches of the river had ever been traversed. An initial dye study led to an intensive background water-quality study of the area by Commonwealth agencies and Eloy Colón-Dieppa and Larry Mansue of the Caribbean District. These authors later reported on the hydrology of the proposed mining area in Open-File Reports 76–1 and 76–2.

One of the more intriguing projects was a study of San Juan Bay and a chain of four interconnected lagoons that stretch eastward from the bay through the San Juan metropolitan area. The study involved two issues: (1) characterizing the hydraulics of the tidal flow system in which the physical characteristics of the lagoons played an important role, and (2) determining the chemical and biological quality of the water in the bay and lagoons. The study showed that the bay and lagoons were moderately to grossly polluted. A sidelight of the study was the discovery that the easternmost lagoon, which is adjacent to the San Juan International Airport, has a phosphorescence equal to that of the famous Phosphorescent Bay of southwestern Puerto Rico. The results of these unique studies were reported by Sherman Ellis and Fernando Gómez-Gómez in Open-File Reports 75–2–PR and 75–38.

Water Quality

The District's water-quality program received a major boost in the late 1960's when a modern water-quality laboratory was established. Jack Reed, newly transferred chemist from the Arkansas District, quickly set up facilities and equipment. Goals for the laboratory included analyzing several constituents normally found in surface and ground water. Soon the laboratory began to analyze quantitatively: common dissolved constituents, trace elements, and even coliform. Beginning in the late 1960's, water analyses were performed on samples collected from rivers in Puerto Rico and the Virgin Islands. Water-quality analyses also were performed on hundreds of samples collected from wells throughout Caribbean District.

SURFACE WATER

Another unusual study was that of marehadas, huge waves caused by cyclonic storms moving off the coast of North America and stalling out over the North Atlantic. In many ways, the waves are similar to those generated by hurricanes. Mike López established several stations along the north coast of Puerto Rico to measure the inland penetration of wave "runup" during a marehada. With data collected over a number of years, Fred Fields and Don Jordan were able to establish a relation between wave "runup" and the distance from shore at the 10-fathom line. They also described the approximate frequency of occurrence of the waves.

The frequent onset of intense tropical storms in the Atlantic/Caribbean produces innumerable floods in the mountains and plains of Puerto Rico and the Virgin Islands. Between 1966 and 1979, flood-data collection and analysis were directed by a series of skilled hydrologists. They were Miguel (Mike) A. López, Irby J. Hickenlooper, Fred K. Fields, and William J. Haire. During this period, this group collected, analyzed, and published flood data for 13 events in Puerto Rico and 2 events in the Virgin Islands. Additionally, the staff published a Hydrologic Atlas showing limited data on historical floods in five river basins in Puerto Rico. In 1978, the District staff completed a report addressing annual peak-flow data and flood-frequency analyses for 50 sites in Puerto Rico. This information is found in a report by M. López, E. Colón-Dieppa, and E.D. Cobb, USGS Water-Resources Investigations Report 78–141.

Puerto Rico data sites

Type of site	1966	1973	1979
Gaging stations	37	37	35
Observation wells	78	79	58
River-quality sampling	0	75	74

Floods of October 1970

The drought that started in the mid-1960's was still in force in October 1970, and the rivers throughout the island were dry or nearly so. The Río Grande de Loiza and Río de Bayamon, which supplied most of San Juan with water, were near zero flow, and the metropolitan area was on a rotating rationing system.

One sometimes thinks of surface-water projects as rather prosaic operations. Not necessarily, as a good part of the Caribbean District could attest during the October 1970 floods. Then, an easterly wave, a cold front that occasionally sweeps down from continental North America, arrived in Puerto Rico and stalled over the island. This does not happen often, but when it does, it rains and rains. Major rainfall began on October 5 and ended on October 9, with maximum rainfall of more than 38 inches in an area east of a line between Arecibo and Ponce. Peak flows at 11 gaging stations equaled or exceeded a 50-year recurrence. Rain fell in three major waves of about 8, 10, and 15-plus inches. Crews sent to the south coast were holding their own until the third wave hit duringthe nights of October 8 and 9. Then the south coastal plain went under water. All communication with the south coast was cut off, and the District Office in San Juan sat wondering what happened to the crews. Finally word came trickling in that all crews were safe, having made it to high ground before the peaks hit, and were heading back to the field to flag high-water marks.

PROJECTS IN THE VIRGIN ISLANDS

In the late 1960's, areal investigations for the three main islands were winding down. Individual reports were in process. These reports included "Water in St. John, U.S. Virgin Islands," by O. Cosner (Open-File Report, 1972); "A Survey of the Water Resources of St. Thomas, Virgin Islands," by D. Jordan and O. Cosner (Open-File Report. 1973); and "Ground-Water in Central St. Croix, U.S. Virgin

Islands," by T. Robinson (Open-File Report 72–319). Later, Tully Robinson investigated ground-water resources in the Kingshill Marl of central St. Croix.

In 1970, the Virgin Islands office closed and the remaining USGS hydrologist, Tully M. Robinson, transferred to the District Office in Puerto Rico. Limited data collection on St. Thomas continued, but no permanent staff were housed on the Virgin Islands during the period 1970–79.

DISTRICT PERSONNEL

It should be noted that several talented, senior, stateside hydrologists served in Puerto Rico and the Virgin Islands for 2–4-year tenures during this period. They each brought unique technical skills and experience to the District during a time of considerable program growth. These individuals advanced District technical efforts and products years ahead in a comparatively short period. A partial list follows:

Irby Hickenlooper (SW), Tully Robinson (GW), Ollie Cosner (GW), Don Jordan (GW), Bruce Gilbert (SW), Gorden Bennett (GW), Fred Fields (SW), Bob Anders (GW), Russ Curtis (SW), Jim Heisel (GW), Jack McCoy (GW), Vito Latkovich (SW), Ennio Giusti (GW), Jack Reed (QW), Ed Qose (Math), Jim Rickher (SW), Henry Anderson, (GW), Sherman Ellis (QW), and Ernie Cobb (SW).

Technicians were almost all Puerto Rican. The District started the period with two professional employees who were native Puerto Ricans—Eloy Colón-Dieppa and Jose Díaz. Ferdinand Quiñones-Marquez joined the District in 1969, and Hector Colón-Ramos earned the position of hydrologist in 1971. Fernando Gómez-Gómez came to the District in 1973. Michael Seijo was with the District for about a year in 1973–74. At some point after the mid-1970's, the staff began to expand with the technical expertise derived from citizens of Puerto Rico. At that time, the District became largely self-supporting through the efforts of experienced local hydrologists.

By 1979 most of the stateside help had returned to the mainland leaving behind many "jewels" for future hydrologists.

SOUTH CAROLINA

by John S. Stallings

INTRODUCTION

Following the retirement of Albert E. (Al) Johnson, who had served as District Engineer of the Surface Water (SW) Branch for about 3 decades, the office was reorganized as a WRD District in late 1965. Rolland W. Carter was appointed District Chief. He brought to the District a charismatic leadership that set a pattern of consistent growth throughout the period. He believed that individuals at all levels should be provided freedom to grow through training and encouragement. His philosophy influenced seven employees to rise to the level of District Chief or higher. They were Jeffrey T. Armbruster, Timmy R. Cummings, Larry R. Hayes, Hillary H. Jeffcoat, Arthur L. (Art) Putnam, John S. Stallings, and Allen L. Zack. Other dedicated and talented employees who were qualified to be in that group chose to remain in the District, contributing significantly to its program.

ORGANIZATION AND PERSONNEL

Prior to reorganization to Division-level status, the Surface Water (SW) office was staffed by the District Engineer Johnson, four SW Engineers, two Engineering Technicians, one Engineering Technician (student, part-time), and two clerks—all of whom were located in the Veterans Administration Regional Headquarters building on Assembly Street in Columbia. The Ground Water (GW) staff included the District Geologist George E. Siple, one additional geologist, one physical science technician (part-time), and one clerk—all of whom were located in the Geology Department of the University of South Carolina. The Quality of Water (QW) program was managed mostly by the North Carolina QW District, and data collection was done by South Carolina personnel.

The reorganized District consolidated the GW and SW offices and relocated its headquarters to leased space on Two Notch Road during 1966–71, to leased space on Assembly Street during 1971–78, and to the J. Strom Thurman Federal Building on Assembly Street in 1979.

Carter was appointed District Chief of the reorganized District in late 1965, but he did not assume the position until January 1966. He then was appointed Chief, Surface Water Branch, and transferred to Washington in mid-1967.

Siple and Stallings were appointed Assistant District Chiefs by Carter in 1966. Stallings remained in that position until he succeeded Carter in August 1967. Siple served as District Chief until he was appointed Staff Hydrologist in 1971. Kay F. Harris transferred from Water Resources Division Headquarters to succeed Siple as Assistant District Chief, and he served in that position until he retired from Federal service in 1978. Art Putnam (later to become District Chief of Tennessee) transferred from the Florida WRD District in 1978 to succeed Harris.

Stallings continued as District Chief until December 1978, when he retired from Federal service. He was succeeded in that position by Rodney N. Cherry, who transferred from the Georgia WRD District after successfully completing a project designed to develop and demonstrate techniques for studying river quality.

Throughout most of the period, the District was organized into three operations sections while the administrative management personnel worked directly with the District Chief. The Hydrologic Data Section collected and processed basic data and prepared statewide reports for publication. The Hydrologic Studies Section conducted areal and topical studies and conducted studies specifically related to flooding.

Hydrologic Data Section

Upon assuming charge of the District, Carter immediately hired four Engineering Technicians so that the Engineers who had been involved mostly in basic-data collection and processing could become involved in project activities. Seven additional technicians were hired within the next few months as the District program grew. Cummings (later to become District Chief of Michigan) transferred from Wyoming to lead the QW program. In addition to being the District QW Specialist, Cummings also served as Section Chief until he transferred to Michigan. Beginning in 1971, Harris served as Section Chief as well as continuing to serve as Assistant District Chief. Curtis S. Bennett, III, succeeded Harris as Section Chief and served in that position throughout the rest of the period.

Jeffcoat (later to become District Chief of Alabama), John W. Gissendanner, and Bill W. Church contributed greatly to the work and success of this section.

Hydrologic Studies Section

George Siple, in addition to his duties as Assistant District Chief, served as Section Chief until 1971. He was succeeded by Ira W. Marine, who had conducted a study related to radioactive-waste storage at the Savannah River Plant (SRP) during the period 1967–71. Marine had been located at a Field Headquarters at SRP along with his assistant, Donald I. Cahal, who also transferred to the District Office. Phillip W. Johnson, who transferred from West Virginia to conduct areal GW studies in the South Carolina Coastal Plain, was appointed Section Chief in 1972 when Marine resigned from Federal service. Phil Johnson served as Section Chief throughout the rest of the period.

Allen Zack (later to become District Chief of Puerto Rico) transferred from Louisiana in 1973 to conduct an areal GW study of the Grand Strand area. He served in that position at his Field Headquarters in Conway throughout the rest of the period.

Larry Hayes (later to become District Chief of Tennessee) joined the District in 1974. He transferred later in 1974 from the District Office to a Field Headquarters in Yemassee to conduct an areal GW study of the Low Country area. He remained there until 1977, when he accepted a transfer to the Florida District.

James M. Cahill transferred from Colorado in 1975 to conduct a study of the effects of radioactive waste burial in Barnwell County. He continued in that effort throughout the rest of the period.

Francis A. (Frank) Johnson and William M. Bloxham were productive and dedicated members of this section throughout the period.

Results of studies performed by this section were published in a variety of ways. Neil C. Koch's investigation (made prior to 1966) of GW resources of Greenville County was published as South Carolina State Development Board (SCSDB) Bulletin No. 38 in 1968. Stallings' report on low-flow frequency and flow duration of South Carolina streams was published as a USGS open-file report. Cummings' report on saltwater encroachment in the South Edisto estuary and his and F.A. Kilpatrick's report on a tracer study in Port Royal Sound were published as USGS WSP 1586–I and

1586–J. A report on water resources of Dickens County by Frank Johnson, Siple, and Cummings was published as South Carolina Water Resources Commission (SCWRC) Report No. 1; and a similar report by Bloxham, Siple, and Cummings on Spartanburg County was published as SCWRC Report No. 3. Frank Johnson's report on reconnaissances of the hydrology of Winyah Bay Estuarine Zone, Edisto and Ashepoo Estuaries, and the Intracoastal Waterway were published as SCWRC Reports 4, 6, and 7, respectively. His report on flushing time of the Sampit River was published as SCWRC Report No. 10. Bloxham's report on low-flow characteristics of streams in the Piedmont and Lower Coastal Plain was published as SCWRC Report No. 14. Marine's report on feasibility of bedrock storage of waste at SRP was published by the Atomic Energy Commission (AEC). Armbruster's report on the SW data program was published as a USGS open-file report. Zack's report on the occurrence and availability of ground water in the Grand Strand area and a similar report by Hayes on the Low County area were published as SCWRC Reports 8 and 9, respectively. Cummings' compilation and statistical summary of water quality of gaging stations was published as an USGS open-file report.

Hydraulic Studies Section

Benjamin H. Whetstone served as Section Chief throughout the period.

Along with the ongoing program of bridge-site evaluations and subsequent reports to the South Carolina State Highway Department (SCSHD), major effort was directed toward the study of flood frequencies on small-area streams. Stage and rainfall dual-digital recorders were operated on approximately 50 small streams throughout the period. Data from these stations were processed continually, and report preparation was begun late in the period.

COOPERATING AGENCIES

From the time it was created in 1946 until 1967, the SCSDB supported short-term areal and topical studies and a low-flow partial-record station network to provide data for topical studies at potential industrial sites.

The South Carolina Department of Health and Environmental Control (SCDHEC) supported acquisition of QW and SW data.

The South Carolina State Highway Department (SCSHD) supported acquisition and interpretation of data related to flooding at existing or proposed bridge sites.

The South Carolina Public Service Authority (SCPSA) supported the SW program as it related to its electric-power generation and as a Federal Power Commission Licensee.

The SCWRC was created in 1967 by the South Carolina General Assembly to coordinate water interests of the several State agencies; thereafter, it supported most of the GW and interdisciplinary areal studies of general and significant statewide interest. It also collaborated with other State and local agencies to provide for interdisciplinary areal studies as well as operation of SW gaging stations for management purposes.

Federal support came from the Geological Survey, which provided funds to match funds provided by State and local agencies; full support for selected SW gaging stations, GW observation wells, and QW operations at several SW stations; an in-depth analysis of the SW gaging-station network; definition of flood-prone areas on topographic maps; and a study of low-level radioactive waste burial.

The U.S. Army Corps of Engineers provided funds in support of large part of the SW gaging-station network and to a lesser degree to a study of the effort of rediversion of the Cooper River on the GW regime in the rediversion canal area.

The AEC provided funds for operation of SW gaging stations of the SRP, studies relating to the effect of plant operations on water temperatures of the Savannah River, and GW studies related to storage of radioactive waste.

The U.S. Environmental Protection Agency (USEPA) supported collection of QW data at selected SW gaging stations during part of the period.

South Carolina District funding, 1966 and 1979

Year	Federal	Cooperative		Other Federal agencies	Total
		State	USGS		
1966	$18,000	$54,000	$54,000	$89,000	$215,000
1979	270,000	490,000	460,000	305,000	1,525,000

SUMMARY OF PROGRAM

Reorganization to WRD District status quickly began to relieve some of the deficiencies caused by single-discipline management. The existing SW program, which consisted mostly of basic-data collection and processing, became fully equipped with digital recorders. A Statewide study of flood frequencies on small streams was initiated, and an in-depth evaluation of the streamflow data program was conducted. The SW data program subsequently was revised to meet full agreement with the recommendations of that evaluation.

Ground-water studies previously had been mostly limited to application of well data from private driller's records and a few observation wells to short-term small-area studies. The AEC studies provided for the addition of three interdisciplinary professionals to the staff. Creation of the SCWRC provided the opportunity and funds to conduct areal GW studies of large areas.

The QW program, as managed by the North Carolina District Chemist, previously consisted totally of basic-data collection at SW gaging stations or GW observation wells. Upon reorganization and the arrival of Cummings, management of the program was taken over by the District. The SCDHEC and the District initiated a cooperative program through which continuous QW monitors were experimentally installed on several representative streams statewide. This effort, although experimental, was successful enough to warrant installation of additional monitors on an operational basis.

Cummings integrated QW concerns into two countywide water-resources studies, and from that beginning, every project was planned on an interdisciplinary basis. Reconnaissance-level studies of the major estuaries with emphasis on QW parameters were begun early in the period.

Summary of data-collection stations, 1966, 1973, and 1979

Type of station	1966	1973	1979
Surface water	63	65	60
Water quality	9	136	25
Ground water	--	21	46
Sedimentation	3	3	9

Editor's note: A major WRD project on Port Royal Sound in the early 1970's called for defining flow and dispersion characteristics in a huge tidal channel. Calls for both help and boats went out to experienced WRD personnel along the entire Atlantic coast. T. Ray Cummings, the Project Chief, reported a long 6 weeks of little sleep, mud-stranded boats, dye-coated hydrologists (especially Nobu Yotsukura), and peace-making among his many advisors. Even so, the effort provided invaluable data for the State of South Carolina in assessing a site application for a large chemical plant.

TENNESSEE

by Charles R. Gamble

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After the District Headquarters moved from Chattanooga to Nashville in 1965, the District offices were located in the Customs House Building at 7th and Broadway in Nashville until 1972, when they were moved across the street to the new U.S. Courthouse Building Annex at 8th and Broadway. Subdistrict Offices were maintained in Knoxville, Memphis, and Nashville, and Field Offices were maintained in Chattanooga (until August 1976) and Pulaski (1967–69).

Organization and Management

An era of change in Tennessee marked the 1966–79 period with several changes in the District Chief position and the death or retirement of several key personnel. During this period, there were three District Chiefs in Tennessee; these were Edward J. Kennedy in 1967, Harry H. Barnes, Jr., in 1971, and Stanley P. Sauer in 1973. The Knoxville Subdistrict Chief was Bernard J. Frederick, the Memphis Subdistrict Chief was Edwin A. Bell, succeeded by James H. Criner in 1967, succeeded by Charles W. Boning in 1975, succeeded by Braxtel L. Neely in 1979. Elliott M. Cushing served as the Mississippi Embayment Project Chief in Memphis until 1968. Milburn Hassler was in charge of the Chattanooga Field Office until his retirement in 1968. After that, Derward Edwards was in charge until the Field Office closed in 1976, and

Derward transferred to the Nashville Field Office. Woodford J. Perry served as Chief of the Nashville Subdistrict until his death in 1967. After that, the office was made a Field Office with various people in charge, including George H. Woods, Edward B. (Bush) Boyd, Curtis S. Bennett, Derward Edwards, and Charles R. Burchett. Robert L. Reed and Fred A. Crossley operated the Pulaski Field Office until 1968, when Crossley resigned and Reed moved to Nashville. William D. (Darwin) Hatfield operated the office until 1969, when it was closed, and he transferred to the Tennessee Valley Authority (TVA).

Other key personnel in the District were Donald R. Rima as Assistant District Chief, William Johnson (John) Randolph in charge of the Hydraulics and Hydrology Section, V.J. (Jeff) May in charge of the Hydrologic Data Section (1974), and Thomas J. Quarles in charge of the Administrative Services Section. Rima also exercised technical oversight over the ground-water programs of the District.

PERSONNEL

The number of employees in the Tennessee District remained relatively stable during 1966–73, as shown in the following tables. Then in 1974, a large increase occurred in response to a fairly large increase in District funds and a large number of new project start-ups for that year.

The ratio of the number of professional to technician classification remained about the same throughout the period, and the number of administrative personnel remained fairly stable. As programs gradually increased over the period and ceilings limited the number of personnel, a large number of Coop students were hired beginning in 1974 to help carry out the increased workload. The large majority of these Coop students were from Tennessee Tech University in Cookeville, Tenn., a State-supported school with a good engineering program. A few were from the University of Tennessee and other schools.

Cooperating Agencies

The Tennessee Valley Authority (TVA), the U.S. Army Corps of Engineers, and the Tennessee Division of Water Resources were the principal cooperators for the collection of surface-water basic data. Other State agencies provided a lesser amount of financial support to District programs in order to collect data for their particular programs. These included the Tennessee Department of Highways (now Tennessee Department of Transportation), which provided cooperative funds to establish a network of crest-stage gages for collection of flood data and to make special studies at proposed bridge crossings. This became a fairly extensive program, with total funds of $40,000 in 1966 and $149,400 by 1979. During this period, approximately 140 special studies at proposed bridge sites were completed. Additional studies of this type were also completed for the Metropolitan Government of Nashville and Davidson County, for which they contributed $13,450 in 1979. The Tennessee Department of Public Health, Division of Stream Pollution Control (now Tennessee Department of Environment and Conservation), provided cooperative funds for the operation of a network of low-flow partial-record stations to define low-flow characteristics. The Tennessee Game and Fish Commission (now Tennessee Wildlife Resources Agency) provided cooperative funds for collection of data on Reelfoot Lake and vicinity. Some cities provided funds for collection of data during some or all of the reporting period, including Chattanooga, Memphis, Lawrenceburg, Murfreesboro, Franklin, Oak Ridge, and the Metropolitan Government of Nashville and Davidson County.

Other Federal agencies contributed to the collection and analysis of water-resources data in Tennessee, including the Atomic Energy Commission (now U.S. Department of Energy), U.S. Fish and Wildlife Service, Federal Power Commission (now Federal Energy Regulatory Commission), U.S. Forest Service, the Federal Water Quality Administration (now the U.S. Environmental Protection Agency), Arnold Engineering and Development Center, and the Flood Insurance Administration (now Federal Emergency Management Agency).

Funding

Funding figures for fiscal years 1967–72 were not readily available and therefore are not included here. Figures for 1966 are given in the report for the period 1958–66. Funding for fiscal years 1973–79 are summarized in the following table.

The large increase in Federal funds for 1979 reflects the start-up of the Coal Hydrology Program, which resulted from the Surface Mining Control and Reclamation Act of 1977 (Public Law 95–87). This act contained specific requirements regarding hydrologic

Number of Tennessee District employees by year and location

Location	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Nashville	24	20	20	23	24	22	22	20	28	33	37	38	42	44
Chattanooga	7	6	5	3	3	3	3	3	4	4	3			
Knoxville	8	9	8	8	6	6	6	5	10	11	7	8	8	11
Memphis	4	4	3	3	3	4	4	4	5	7	8	7	10	11
Pulaski		2	1	1	--	--	--	--	--	--	--	--	--	--
Total	43	41	37	38	36	35	35	32	47	55	55	53	60	66

Number of Tennessee District employees by year and classification

Classification	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Professional	21	17	16	15	14	14	15	13	14	19	22	22	22	21
Technician	16	17	16	17	16	15	14	13	17	19	19	17	22	24
Administrative	6	7	5	6	6	6	6	6	6	7	7	6	7	5
Coop students	--	--	--	--	--	--	--	--	10	10	7	8	9	16
Total	43	41	37	38	36	35	35	32	47	55	55	53	60	66

information needed prior to mining, evaluation of the potential effects of proposed mines, measures to control these effects, and measures to provide land reclamation.

HYDROLOGIC DATA PROGRAMS

Much of the District's total program was devoted to the collection, processing, and publication of streamflow data. The conversion from analog to digital recorders was mostly completed during the period, and the application of computer technology in the processing and storage of data became standard procedure. Ground-water data collection and geologic studies were mostly limited to specific problem areas such as the Memphis area, where large amounts of ground water are withdrawn for public and industrial water supplies.

Surface-Water Records

Continuous records of stream stage were collected, and daily mean discharge records were computed for 103 stations in 1966 and for 110 stations in 1979. Flood peaks were collected at varying numbers of crest-stage partial-record stations through the period (126 in 1966, 105 in 1979). Low-flow measurements were made at varying numbers of low-flow partial-record stations (93 in 1966, 48 in 1979). Also in 1966, discharge was measured at 33 miscellaneous sites and at 27 springs (temperature was measured at all, and pH and specific conductance were measured at several). In 1979, discharge was measured at 25 miscellaneous sites and 19 springs (temperature and specific conductance were measured at most). Also in 1979, data were collected at 80 coal-hydrology stations (discharge measurements and water-quality analysis in support of the Federal Coal Hydrology

Tennessee District funds, FY 1973–79 in $ thousands

[Source, WRD Management Information System through Branch of Operational Support, Reston]

	1973	1974	1975	1976	1977	1978	1979
Coop	547.4	779.3	900.7	1,009.7	1,239.6	1,319.2	1,362.6
OFA	230.2	304.1	270.7	317.6	538.3	562.5	522.9
Fed	37.3	25.4	113.8	149.7	137.5	126.6	468.7
Total	814.9	1,108.8	1,285.2	1,477.0	1,915.4	2,008.3	2,354.2

Program). Two hydrologic bench-mark stations (03497300 Little River above Townsend and 03604000 Buffalo River near Flatwoods) were operated during the period as part of a national network to monitor hydrologic response in mostly natural basins. The Little River drainage basin above Townsend lies mostly in the Great Smoky Mountains National Park and the Buffalo River drainage basin above Flatwoods is mostly a forested basin with little agricultural or industrial activity.

Ground-Water Records

Water levels were collected at 31 observation wells in 1966 and at 27 in 1979. Periodic water-quality parameters were measured at 31 observation wells in 1975 and at 27 in 1979. As indicated previously, most of the ground water data-collection activity was centered in the Memphis area where large amounts of ground water are withdrawn.

Several Seepage Investigations were performed during 1971–79. These involved intense discharge measurements of surface-water streams in a basin to define the gaining and losing reaches of streams, indicating ground-water contributions and listed below.

1971–Duck River (30 sites).

1972–W.F. Stones River (8 sites, 10/29/71; 10 sites, 11/3-4/71); Duck River (61 sites). Special study in Elk River Basin, Tims Ford Dam to Prospect, Tenn. (22 sites).

1974–E.F. Stones River (166 sites); W.F. Stones River (88 sites).

1975–Harpeth River (132 sites); West Harpeth River (99 sites).

1976–Harpeth River (76 sites); Sulphur Fork Red River (49 sites).

1977–Sulphur Fork Red River (55 sites, 10/12–13/76; 55 sites, 07/21/77).

1979–Dickson, Tenn. (95 sites); Fairview, Tenn. (54 sites).

Water-Quality Records

In 1966, chemical analyses for 9 gaging stations and 31 miscellaneous sites were performed and published. Continuous temperature data were recorded (daily maximum and minimum published) at 13 gaging stations in 1966. In 1979, chemical analyses were performed and published for 32 gaging stations, 27 wells, 80 coal hydrology sites, and 35 miscellaneous sites.

HYDROLOGIC INVESTIGATIONS PROGRAMS

Tennessee is blessed with an abundance of both surface and ground water in most areas of the State. However, in some years and in some areas, there is either too much (floods) or too little (droughts). It is during these times when a great interest in the water resources of the State occurs.

Many significant studies and investigations were performed during the period to help solve problems or provide data for a particular area of the State or to help provide regional hydrology information for the entire State. A list of the projects conducted during the period 1966–79 follows.

Summary of Program

Much of the District's program was devoted to the collection, processing, and publication of streamflow data. The conversion from analog to digital recorders was mostly completed during the period, and the application of computer technology in the processing and storage of data became standard procedure. Ground-water data collection and geologic studies were mostly limited to specific problem areas, such as the Memphis area where large amounts of ground water were withdrawn for public and industrial water supplies.

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Floods

For many years, the Tennessee District has maintained a strong "floods" program supported by funds and interest from the USGS, TVA, and the Tennessee Department of Highways. It provided important data for the USGS's regional hydrology and urban studies programs and support for the reservoir operations programs of both TVA and the U.S. Army Corps of Engineers. The floods program also provided important data to complement that collected at regular

Projects in Tennessee, 1966–79

Project number	Short title	Project Chief	Begin date	End date
TN010	Flood investigation	W.J. Randolph	53/07	Cont.
TN011	Metro floods project	L.G. Conn	63/10	75/06
TN012	Small streams modeling	H.C. Wibben	65/07	76/10
TN013	Hydro data transfer	J.F. Lowery	65/07	82/09
TN014	Memphis aquifer studies	D.D. Graham	67/01	82/08
TN015	Water resources Upper Duck	C.R. Burchett	69/10	77/01
TN016	Terrace deposits	W.S. Parks	71/06	79/07
TN017	Upper Caney Fork basin	D.R. Rima	70/07	77/06
TN018	Flood hazard mapping	C.R. Gamble	67/07	78/09
TN019	Basin characteristics from ERTS	E.F. Hollyday	72/07	76/01
TN020	Hydrology of linear features	D.R. Rima	73/07	77/06
TN021	Water for Murfreesboro	D.R. Rima	74/02	77/08
TN022	Memphis urban flood frequency	B.L. Neely, Jr.	74/01	84/04
TN023	National eutrophication study	V.J. May	73/07	75/02
TN024	Radioactive waste burial	D.A. Webster	73/11	75/06
TN025	Tennessee flow characteristics	R.L. Gold	74/01	78/09
TN026	Tennessee bridge scour	W.J. Randolph	74/07	82/11
TN027	Metro urban hydrology	H.C. Wibben	74/07	76/10
TN028	Hydrologic effects strip mining	S.P. Sauer	74/10	79/12
TN029	Memphis ground-water model	J.V. Brahana	75/06	84/06
TN030	ORNL burial ground	H.H. Zehner	75/07	89/09
TN031	Hydrology New River coal areas	W.P. Carey	75/07	81/08
TN032	Tennessee ground-water appraisal	Ann Zurawski	75/07	77/09
TN033	Tennessee wetlands delineation	E.F. Hollyday	76/01	77/09
TN034	Pesticide migration	C.L. Sprinkle	76/01	78/10
TN035	Hydrology hard rock aquifers	E.F. Hollyday	76/07	80/09
TN036	Ground water in Nashville area	D.R. Rima	77/05	79/05
TN037	Urban flood frequency	C.H. Robbins	77/07	84/06
TN038	Water use in Tennessee	R.L. Gold	77/07	Cont.
TN039	Landsat basin characteristics	E.F. Hollyday	78/10	82/10
TN040	Lignite hydrology	W.S. Parks	78/10	80/05
TN041	Coal hydrology	V.J. May	78/10	82/09
TN042	Water quality Big South Fork	R.D. Livesay	79/01	82/09

gaging stations to define areal relations for use by the Tennessee Department of Highways for the design of drainage structures, and others.

During this reporting period, major floods occurred in water years 1973 and 1975, producing discharges of 50-year recurrence intervals or greater. There were four separate storm periods in water year 1973: (1) a December 10, 1972, storm was centered mostly in the Cumberland River Basin; (2) a storm on March 14–17, 1973, over most of the Tennessee River Basin downstream from Knoxville produced 5–10 inches of rainfall, most of which fell in a 48-hour period and caused extensive damage, especially in the Chattanooga area; (3) a storm on May 27–28, 1973, struck the upper Cumberland River Basin and produced high runoff rates; and a storm during the middle of April hit mostly the western part of the State; (4) on March 12–14, 1975, a major flood hit the central Cumberland River Basin, which includes the Nashville Metropolitan Area, caused by 10 inches of rainfall—7 inches in a 24-hour period in many localities. Record or near record stages and discharges occurred in the Harpeth and Red River Basins. The Cumberland River at Nashville reached an all-time high.

Other floods that occurred during this reporting period but covered smaller areas or were less intense are as follows: July 1967 in the Oliver Springs area; June 23, 1969, in Macon and Sumner Counties (Red Boiling Springs area); and April 1977 in the Appalachian Region of Tennessee.

The District expended a lot of time and resources collecting data to document these floods. During water year 1973, a total of at least 60 indirect discharge measurements were made (including 26 for the March 14–17 storm and 20 for the May 27–28 storm), in addition to the many current-meter measurements that were made during the floods, all by in-district personnel. Key personnel in the indirect measurement work were W.J. Randolph, H.C. Wibben, and C.R. Gamble, assisted by field personnel of the Nashville, Chattanooga, and Knoxville offices. In addition, at least 130 other indirect measurements were made for other floods that occurred during the period 1966–79.

Additional information about people who were involved in projects of particular subject areas is presented in the following paragraphs. Generally, the people mentioned are authors of reports on these subjects. (See "Additional Information" for sources of information on complete titles of reports on water resources in Tennessee.)

E.H. Chin, John Skelton, and H.P. Guy (1975) documented the 1973 flood in the Mississippi River Basin with information on the meteorology, streamflow, and sediment. George W. Edelen, Jr., and J.F. Miller (1976) documented the floods of March–April 1973. Charles R. Gamble documented the July 1972 flood at Oliver Springs and the 1975 flood in Macon and Sumner Counties. L.G. Conn and E.B. Boyd collected data and performed hydraulic studies on several streams in Nashville and Davidson County.

Flood Frequency

W.J. Randolph and C.R. Gamble (1976) provided regional flood-frequency relations for the Tennessee Department of Highways, and H.C. Wibben (1976) used a rainfall-runoff simulation model to improve flood-frequency estimates for small streams in Tennessee. Wibben (1976) also analyzed the effects of urbanization on the flood characteristics in Nashville-Davidson County. C.W. Boning (1977) developed preliminary flood-frequency relations for urban areas of Memphis. These reports provided information to aid in the design of many bridges and other structures in the State.

Flood Depth

C.R. Gamble and J.G. Lewis (1977) developed methods for estimating the depth of selected frequency floods for most streams in Tennessee. The results of this study were useful in flood-prone area mapping and to the Tennessee Department of Transportation in deliberately designing selected roadway elevations to be overtopped by floods of a selected frequency.

Flood-Mapping and Flood-Insurance Studies

The Tennessee District was one of six Districts chosen to do pilot flood-insurance studies in the mid-1960's. Browns Creek in Nashville was chosen for the study in Tennessee. These pilot studies were instrumental in the development of methods used later in the Federal Flood Insurance Program.

Many flood-prone areas in Tennessee were delineated on topographic maps using existing flood information. Several flood-insurance studies were made for particular areas and involved detailed hydraulic calculations for stream reaches to define flood profiles for floods of various frequencies.

Droughts and Low Flow

The "droughts" program has traditionally received less funding than the "floods" program but is no less important. The droughts program has mainly been conducted by the USGS in cooperation with the Tennessee Division of Water Resources in support of low-frequency programs and water-supply and waste-disposal programs. H.F. Mathai (1979) provided information on the hydrologic and human aspects of the 1976–77 drought in the United States, including Tennessee. C.H. Robbins (1979) described the low-flow hydrology of the Sulphur Fork Red River Basin in Robertson County.

Water-Resource Studies in Particular Areas

C.R. Burchett (1977) studied the water resources of the Upper Duck River Basin. G.K. Moore and J.M. Wilson (1972) studied the water resources of the Center Hill Lake region. Moore, Burchett, and R.H. Bingham (1979) reported on the water resources and the limestone hydrology of the Upper Stones River Basin. E.F. Hollyday and P.L. Goddard (1979) studied the ground-water resources in the Dandridge area, and Ann Zurawski (1979) described the hydrology of the Gatlinburg area. W.M. McMaster and E.F. Hubbard (1970) described the water resources of the Great Smoky Mountains National Park in Tennessee and North Carolina. D.R. Rima, M.S. Moran, and E.J. Woods (1977) described ground-water supplies in the Murfreesboro area.

Geology and Ground-Water Studies in the Memphis Area

Many investigators studied the geology, ground-water levels, flow patterns, and the potential for leakage and contamination of ground water in the Memphis area during this reporting period. Among these were E.A. Bell (1966), D.J. Nyman (1968), E.H. Boswell, E.M. Cushing (1970), R.L. Hosman (1968), J.H. Criner (1970), G.K. Moore (1969), D.R. Rima (1979), D.D. Graham (1979), and W.S. Parks (1973, 1974, 1975, 1976, 1979). Some of these, as well as other investigators, have also published other reports outside this reporting period. The reader is referred to the section "Additional Information" for information on these publications.

Clinch River and the Oak Ridge Area

Several significant studies and reports on radioactive waste burial on the Oak Ridge Reservation and radioactive sediments in the Clinch River were produced during the period. Some of these investigators were P.H. Carrigan, Jr. (1966, 1968, 1969), R.J. Pickering, (1966, 1969, 1970), R.G. Godfrey (1970), E.G. Struxness (1967), and D.A. Webster (1976, 1979). These were state-of-the-art studies at the time which provided important information and data for use in managing the Oak Ridge Reservation and for planning and conducting future investigations. A report providing hydrologic data for the Oak Ridge area was authored by W.M. McMaster (1967).

Water-Quality Studies

A.L. Reesman and A.E. Godfrey (1970) described the chemical quality of streams draining the central basin of Tennessee. C.L. Sprinkle (1977) described the Tennessee ground-water sampling program for fiscal year 1977. D.R. Rima, E. Brown, D.F. Goerlitz, and L.M. Law (1967) estimated the potential for contamination of the environment from a pesticide waste-disposal site in Hardeman County. C.L. Sprinkle (1978) later described the leachate migration from this pesticide waste-disposal site.

Sediment Studies

W.P. Carey (1970) described the sediment characteristics of the New River Basin, and S.P. Sauer (1978) reported a summary of data from the Hatchie River sediment project.

Wetland Classification and Mapping

Virginia Carter and J.H. Burbank (1978) described a wetland classification system for the Tennessee Valley region. Virginia Carter, D.L. Malone, and J.H. Burbank (1978) described wetland classification and mapping in western Tennessee. Patricia Gammon, Donald Malone, Paul Brooks, and Virginia Carter (1977) reported three approaches to the classification and mapping of inland wetlands.

Water Use

A.M.F. Johnson, J.M. Wilson, and H.B. Nichols (1968–70) documented water use in Tennessee for agricultural, municipal, and industrial uses in an individual report for each category during 1968–70. A summary report by J.M. Wilson and A.M.F. Johnson was published in 1970.

Other Activities

During this reporting period, the Tennessee District held several District Conferences to discuss operational procedures, to keep employees informed of District activities, and to provide an opportunity for all to foster camaraderie among employees. Also, in 1976 and 1979, special conferences were held with other Districts. On May 12–14, 1976, a joint District Conference was held by the Tennessee and Arkansas Districts. In April 1979, a Tri-District Conference was held by the Tennessee, Kentucky, and West Virginia Districts. The primary purpose for these special conferences was to exchange information on District programs and meet people in these other Districts doing similar work.

Additional Information

The report "Water Resources Publications of the U.S. Geological Survey for Tennessee, 1906–1987" by E.G. Baker and R.C. Massingill, published in 1988 as Open-File Report 87–552, is a bibliography of all known water-resources reports for Tennessee through 1987. The reader is referred to that report for more complete information and specific titles of water-resources studies in Tennessee. Additional information about Tennessee District programs during this period may also be obtained from a pamphlet series entitled "Water-Resources Investigations in Tennessee (year)."

CENTRAL REGION

by Hugh H. Hudson (reviewed by Thad G. McLaughlin and Alfred Clebsch, Jr.)

Regional Office

This is a brief account of the Office of the Regional Hydrologist, Central Region (CR), during the period 1966–79. Its emphasis is on staff and assignments to staff members during a 13-year period when Thad G. McLaughlin, E.A. Moulder, and Alfred Clebsch, Jr., served successively as Regional Hydrologists. Although the basic functions and responsibilities of the office changed little during this period, there were major changes in staff and their assignments with changing national and regional programs. Staff turnover was large during those 13 years, but the turnover was triggered by normal rates of retirement, transfers to other jobs, and occasionally by organizational changes at the District level. Except for several long-term clerical and administrative members of the staff, there were only two staff members remaining in 1979 who occupied Central Region staff positions in 1966.

Within the CR Field Headquarters, there were other units of WRD that answered administratively to the Regional Hydrologist but were organizationally detached from that office and whose day-to-day operations were separate from those of the Regional Office. Such units at the beginning of this period were largely service projects, established to provide technical assistance to hydrologic investigations (usually at the District level), research projects, and data-processing projects. Within this period, the Central Laboratory was established and was, with more than 80 employees in 1979, the largest organizational unit of the Division at the CR Field Headquarters. Also during this period, formal training of hydrologists and newly hired WRD professional employees evolved into the Geological Survey National Training Center, also located in the CR Field Headquarters. Details of these other units are covered elsewhere in Volume VII.

In February 1967, Thad McLaughlin became the Central Region's second Regional Hydrologist, succeeding S. Keith Jackson, who had retired 2 months earlier. The Office of the Regional Hydrologist was in Building 25 of the Denver Federal Center, where it had been since its inception. The quarters were still rather drab, uncarpeted, and painted a bilious, institutional green. The WRD Districts in Arizona, Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming constituted the 12-State area of the CR.

On McLaughlin's immediate staff were Tyrus B. Dover, Frank C. Ames, Hugh H. Hudson, Marvin S. Petersen, P. Eldon Dennis, Mary Helen Hawks, Irene Paulsen, and Lois Lingle. Dover was soon selected as Assistant Regional Hydrologist; Ames was the point person in water-quality affairs; Hudson coordinated the Missouri River Basin program and assisted with the Regional recruiting effort; Petersen was the floods and later the surface-water specialist; Dennis handled reports; and Hawks, Paulsen, and Lingle were the clerical backbone of the office. Paulsen transferred to the Office of the Assistant Director, Central Region, in 1972.

Housed within the Office of the Regional Hydrologist, but not exactly on McLaughlin's staff, were G. Earl Harbeck, Jr., Paul T. Vogeli, and Phebe Turechek. Harbeck, an internationally recognized expert in the evaporation phase of the hydrologic cycle, not only pursued his own research interests but shared his expertise with others, domestic and foreign, who sought his advice. Until the Branch of General Hydrology was dissolved early in this period, Harbeck was its Denver representative. He informally occupied the position that later was to become that of Regional Research Hydrologist. His technical assistant was Vogeli, and Turechek was his clerical and administrative aide. By January 1, 1969, Harbeck was fully involved in research, Vogeli had been reassigned to the Atomic Energy Commission-funded nuclear hydrology project, and Turechek had retired. Vogeli died while on duty in 1970.

At the time McLaughlin became Regional Hydrologist, the Division was in the final stages of the most extensive reorganization in its history. All Districts in the CR had been reorganized as Division Districts except Colorado and Oklahoma. In early 1967, John W. Odell was selected to head the Oklahoma District. With Odell's move to Oklahoma, Alexander A. Fischback, Jr., became available for reassignment and was offered a position on McLaughlin's staff. He reported to Denver in July 1967. Among Fischback's duties were those of overseeing the refurbishing of the Regional offices and serving as liaison with the newly formed Regional Administrative Services Section. Later, Fischback became the Chairman of and Federal representative on the Rio Grande Compact Commission. He retired in June 1972. Anna M. Haywood provided clerical assistance to Fischback and, at times, to other members of the Regional staff.

There was not a Regional Administrative Services Section at the time McLaughlin became Regional Hydrologist. The local Administrative Services Section, headed by Howard B. Boyden, reported to the Colorado WRD Council. Boyden's assistants included Dorothy E. Niles and Marjorie M. Buteau. By July 1, 1967, Boyden, Niles, Buteau, and others were reconstituted as the Regional Administrative Services Section. Boyden retired in 1972 and was succeeded by Niles. Niles and Buteau remained on the Regional staff for the remainder of the period—Niles as Chief of the Section and a member of the Regional management staff, and Buteau as secretary to the discipline specialists after about 1968.

Immediately before McLaughlin became Regional Hydrologist, the Wyoming District was reorganized with Leon A. Wiard as District Chief. This, in effect, made Ellis D. Gordon available for a new assignment. At about the same time, Eldon Dennis announced his resignation plans. Gordon was offered the job of overseeing reports improvement for the Region and began his new assignment in March 1967. He enjoyed a brief but fortuitous overlap with Dennis and remained in the position through the remainder of this period.

Coincident with McLaughlin's appointment as Regional Hydrologist, a need emerged for an adequate training facility for newly hired hydrologists, many of whom were entering on duty with WRD from universities in the Central Region. The need was fostered by an agreement with the U.S. Civil Service Commission in which WRD would provide 6 months of classroom training to new hires as a key factor in a fast-track promotion procedure—an important recruiting pitch. Also, Denver was the site of a training facility initiated by A. Ivan Johnson in the Hydrologic Laboratory to train foreign hydrologists. That facility was expanded to accommodate the agreement with the Civil Service Commission, but the facility had inadequate space, support, and equipment. At McLaughlin's request, Johnson was reassigned to the Regional staff in mid-1967 and given improved classroom space adjacent to the Regional Office. This accomplished an important step in the development of the National Training Center. Johnson remained in charge of the local training facility until January 1971, when he transferred to National Headquarters.

River basin planning, sponsored by the U.S. Water Resources Council, promoted by river basin commissions, and embraced by water-resources management and development agencies at State and Federal levels, flowered during the mid- to late 1960's. WRD's role in this effort generally was limited by lack of funds and staff, and by the Director's policy, to the presentation of available hydrologic data. Hudson handled the Division's involvement in this activity until early 1968, when Charles C. McDonald completed the Lower Colorado River Project and was transferred to Denver. McDonald had a successful record in similar challenges elsewhere, and it was hoped that he could identify and occupy a more prominent niche for WRD in river basin planning. He handled the job until July 1970, when he retired.

The position of Regional Research Hydrologist was created in 1967 to provide assistance to each Regional Hydrologist in managing the growing research program. McLaughlin chose Robert W. Stallman as the first Regional Research Hydrologist for the Central Region, and Stallman entered into his new job with gusto in September 1967. Stallman's management style was a joy to observe. He had a rubber stamp that he used on deficient report manuscripts that emblazoned, in two 4-letter words, the bovine equivalent of horse manure.

Delbert W. Brown, a ground-water hydrologist with considerable knowledge of aircraft, was assigned to the Regional Office in August 1968, by a circuitous route. He was in Bismarck, N. Dak., when asked to undertake the job of providing management assistance to Herbert E. Skibitzke's research projects based in Phoenix—projects that involved the extensive use of aircraft. It turned out, however, that more than familiarity with aircraft and more than management assistance was needed in Phoenix. Brown soon was reassigned to the Regional Office in Denver—Bismarck to Phoenix to Denver, all within 2 months. Brown was heard to say on his arrival in Denver that he was an itinerant WRD worker. After a couple of years helping with Regional Office tasks, Brown succeeded Johnson as Chief of the Training Center, effective December 1970, approximately at the same time the Training Center was moved to remodeled space in Building 53.

Another new position was created in each Regional Office in 1970, partly to give greater field visibility to the Office of Water Data Coordination (OWDC). The position was that of field representative for OWDC, and its incumbent was to serve also as Regional Planning Officer. The Regional Offices had played a strong role in getting OWDC operational following OWDC's creation in 1965. Hudson provided much of the staff assistance from the CR until 1970, when Joe L. Poole was reassigned from the Mid-Continent Regional Headquarters in St. Louis to Denver to fill the new position. Poole remained in that position until August 1976. When Poole retired, Jim Blakey succeeded him as Regional Program Officer, transferring from Ohio where he was District Chief. After a year, Blakey transferred to the Colorado District as District Chief (1978). Hudson succeeded Blakey as Regional Program Officer.

It also was in 1970 that Eleanor L. Simpson, formerly of Skibitzke's office in Phoenix, joined the Regional staff and remained on the staff until 1978, when she transferred to the Colorado District office. She was a key player in the office details of recruiting, river basin planning, programming, budgeting, and the various tasks assigned to Hudson and also to Brown, Poole, and others.

Digital modeling of ground-water systems was becoming a valuable analytical tool by the early 1970's, but no one on the Regional staff had hands-on experience with ground-water modeling. In order to reinforce staff expertise and to provide investigators at the District level with a source of assistance in other modern aspects of ground-water investigations, McLaughlin asked John E. Moore of the Colorado District to join his staff as the principal ground-water specialist. Moore reported to his new assignment in 1971.

In early 1972, McLaughlin began a new style of onsite District reviews. The reviews, which were both technical and administrative, were primarily to keep McLaughlin and his staff better informed of project progress and possible project problems and of project and District management. The reviews served also to acquaint Moore with those projects where he might be of technical assistance. W. Arthur Beetem, Ames' successor as water-quality specialist, provided technical assistance to the reviews after he joined the Regional staff in 1972. District reviews of this type were in effect for about a year, long enough for one round of reviews of this type.

With the abolishment of the Mid-Continent Region in 1972, Regional boundaries were reconfigured with the WRD Districts in Arkansas, Colorado, Iowa, Kansas, Louisiana, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, Texas, Utah, and Wyoming becoming the 14-State geographic area of the Central Region. There were no further changes in the geographical make-up of the Region during this period.

The position of Assistant Director, USGS, was created in each Region in 1972, and McLaughlin was named Assistant Director, Central Region. He selected Irene Paulsen to join him in establishing the new office. His successor as Regional Hydrologist, effective September 1972, was Edward A. Moulder; however, after only 6 months, Moulder was named Assistant Chief Hydrologist for Research and Technical Coordination at National Headquarters. Dover, who had served as Assistant Regional Hydrologist, first with McLaughlin, once again served effectively as Acting Regional Hydrologist.

During Moulder's brief tenure as Regional Hydrologist, he maintained the modus operandi that he had inherited from McLaughlin but was faced with a major new program that initially was almost entirely within Central Region. That program was to determine the hydrologic effects of coal and oil-shale mining and processing, and the availability of water for their conversion to energy, for coal-slurry transportation, and for mined-land reclamation. The program focused on coal and oil-shale deposits in the Central Region. Hudson provided the principal staff assistance for the effort.

For many years, Hawks had kept track of program documents in addition to her duties as secretary to the Regional Hydrologist; however, an increase in the demands of both responsibilities led to a division of her duties in 1973. She was promoted to the position of Program Analyst, and Lingle was selected to succeed Hawks as the Regional Hydrologist's secretary. Hawks retired in 1976, and Lingle continued as head secretary through the end of this period of history.

Jack R. Carter was transferred from Lawrence, Kans., to the CR staff in August 1972. His principal duties included the review and processing of District funding documents. He was provided assistance in this activity by Elisabeth A. Geiser, who joined the staff in 1976. Both remained on the CR staff through the end of this period.

Following the demise of interagency river-basin planning, the Bureau of Reclamation launched its Westwide Water Plan, prompted in part by the perception that large supplies of water would be needed for coal and oil-shale development. Sam W. West was assigned to the Regional Office in 1971 to provide liaison with and hydrologic assistance to the Bureau of Reclamation. His assignment was completed in 1973, and West then became Chief of the Wyoming District.

With Moulder's reassignment to WRD Headquarters, Alfred Clebsch, Jr., became the Central Region's fourth Regional Hydrologist. He reported to Denver in September 1973 and brought with him a hands-on management style, more familiarity with the research program than District operations, a strong belief that the Regional Office had an obligation to provide technical support along with management and supervisory responsibilities, and a desire to see more women of the Division occupy higher level positions.

During the next several years, Clebsch supervised several major changes in Regional Office operations, including the initiation of a new procedure for annual District reviews and an enhancement of the functions and services provided by the Regional Administrative Officer. The change in program reviews was effected by bringing key District officers to Denver for discussions with Regional staff regarding their current and planned activities. The Denver reviews were followed by a summary session in Reston with Headquarters staff that provided a basis for the allocation of Cooperative Program funds.

Among the significant staff and program changes during the period of Clebsch's management of CR affairs was the transfer of Charles W. Lane to the Regional staff in 1974 from Lawrence, Kans., where he had served as District Chief. Lane's staff job was to help with WRD's heavy involvement in the preparation and review of environmental impact statements; he retired in 1976. The transfer of J. Kenneth Reid to WRD Headquarters in 1975 eliminated from the Regional Headquarters a small, one-person project launched a couple of years earlier that was deemed incompatible with the broader responsibilities of the office.

Moore left the Regional staff in 1975 for a new assignment in Florida. The following year, Marion S. Bedinger moved from the Colorado District, where he had been Chief of the Studies Section, and became the ground-water specialist for the CR. Bedinger remained in that position for the remainder of the period.

Worsening health led to Stallman's disability retirement in May 1975. Clebsch chose Lee C. Dutcher as Regional Research Hydrologist, and Dutcher reported to Denver in August 1975.

Also in 1975, Beetem was transferred to Reston, and Clebsch selected Robert C. Averett as water-quality specialist for the Region. Averett arrived in Denver in August 1975 from Sacramento, Calif., and became Regional Research Hydrologist in February 1979, succeeding Dutcher, who was reassigned as energy studies coordinator. Averett remained as Regional Research Hydrologist through this period and beyond.

Central Region involvement in the hydrology of energy development continued to increase, and in Fiscal Year 1975 funds became available for an investigation of the Madison Limestone Formation in an aquifer underlying coal deposits in the Northern Great Plains as a possible source of water for converting coal to energy and particularly for transporting coal slurry by pipeline to other parts of the country. Elliott M. Cushing was selected to head the Madison Limestone investigation, a project that was to become the forerunner of the national program of regional aquifer-system analyses.

It was in 1976 that Joe R. Wilmon transferred to the Regional staff from the Manpower Section in Reston to help Dover with personnel details. Wilmon remained on the Regional staff through this period of history.

Dover decided to retire in midsummer of 1977. John P. Monis was transferred later that year from Carson City, Nev., where he was District Chief, to become Assistant Regional Hydrologist.

Warren E. Hofstra, formerly of the Colorado District, joined the Regional staff in 1977 after a brief tour with a Regional Assistant Secretary of the Interior. Hofstra remained on the staff, helping with the water-use program and OWDC matters, for the remainder of the period.

Except as previously noted, there were no major changes in the size of the staff during the final 2 years of this period.

DISTRICTS

ARKANSAS

By Charles T. Bryant and reviewed by Marion S. Hines, John H. Hubble, and A.H. Ludwig

ORGANIZATION AND PERSONNEL

The Arkansas District of the Water Resources Division had been reorganized in 1964 from the Ground Water (GW), Surface Water (SW), and Quality of Water (QW) Branches. District Headquarters was located in the Federal Office Building in Little Rock, and most District personnel were housed there. The SW Branch previously had been located in Fort Smith. After reorganization, the Fort Smith office was converted to a Field Headquarters and remained open throughout the period. The SW Branch had maintained a one-man Field Headquarters in De Queen. That office remained open until 1970.The QW Branch had been located on the campus of the University of Arkansas at Fayetteville. That office was closed and all QW personnel were moved to Little Rock. The GW Branch had been located in Little Rock prior to reorganization.

Richard T. (Dick) Sniegocki, who had been District Geologist of the GW Branch, served as District Chief for the entire period. Ivan D. (Dale) Yost, former District Engineer of the SW Branch, assisted Sniegocki in District operations until 1966 when he transferred. James L. (Pat) Patterson served as Assistant District Chief, then Associate District Chief, from 1969 until his retirement in 1970. John H. Hubble, formerly District Chemist of the QW Branch, served as Chief of the Basic Records Section in 1966 and then as Staff Assistant for the remainder of the period. As Staff Assistant, he was primarily responsible for program planning and direction. At the same time, he continued with significant input to the District water-quality activities.

Evelynne May served as Administrative Assistant for the Administrative Services section until her retirement in 1972. The position of Administrative Assistant was abolished upon Evelynne's retirement but was re-established in 1975; and Bobbie Vines of the Fort Smith Field Headquarters was selected to fill the position and served for the remainder of the period.

Two major sections were established to carry out data collection and interpretation. These were the Basic Records Section and the Hydrologic Studies Section. The Basic Records Section was later designated the Data Section and in 1976 became known as the Hydrologic Surveillance Section. Phil Mathews served as Chief of the Basic Records Section from 1967 until his retirement in 1975. He also served as Assistant District Chief from 1970 until 1975. He was replaced in 1976 by Lou Ducret, who transferred from Portland. Ducret served as Chief of the Hydrologic Surveillance Section for the remainder of the period. Doug Bedinger was Chief of the Hydrologic Studies Section from 1966 to 1974, when he transferred to Denver. Doug also served as Assistant District Chief from 1970 to 1974. Marion Hines was Section Chief and Assistant District Chief from 1974 until his retirement in 1978. The Hydrologic Surveillance Section was renamed the Areal Investigations Section in 1976.

The QW laboratory, attached to the Basic Records Section, was under the oversight of Charles Bryant from 1966 to 1972. With the advent of central laboratories, the District QW laboratory became the Field Service Unit and was supervised by Frank Lambert for the remainder of the period.

Field Headquarters offices in Fort Smith and De Queen were attached to the Basic Records Section. Dean Reid supervised the Fort Smith office until his retirement in 1973. Bob Kennedy (1973–76) and Johnnie Cottingham headed the office for the remainder of the period. Oscar Jacobs ran a one-person office in De Queen until his retirement in 1970.

A Technical Services Section was added in 1976 to provide computer and drafting services for the District. Charles Bryant headed this section through 1979.

COOPERATING AGENCIES AND FUNDING

The Arkansas Geological Commission (AGC) was the primary State cooperator during the period. All hydrologic investigations involving ground water, most stream-gaging programs, the ground-water-level network, and several QW stations were partially supported with matching funds from AGC. Annual matching funds from AGC almost doubled during the period from $96,000 in 1966 to $190,000 in 1979. The State Geologist and Director of AGC for this period was Norman F. Williams.

The Arkansas Highway Department (AHD), later designated the Arkansas Highway and Transportation Department (AHTD), provided funding for a network of partial-record crest-stage stations for defining flood profiles on the State's principal streams, for reports on the occurrence of outstanding flood events, for indirect measurements of flood peaks, and for reports on the hydraulics of bridge sites. Annual matching funds from the AHTD amounted to $26,000 in 1966 and increased annually, amounting to $58,000 in 1979.

The Arkansas Pollution Control Commission, later renamed the Arkansas Department of Pollution Control and Ecology (ADPC&E), provided U.S. Environmental Protection Agency (USEPA) pass-through funding to support a statewide waste assimilative capacity study of streams from 1973 to 1975. This amounted to $350,000 over a period of 2 years in 1973 and 1974. The ADPC&E also provided funding for discharge data at their stream-water-quality sites. Additional State funding came from the University of Arkansas Agricultural Experiment Station.

Federal support for District operations came from the Geological Survey's National Headquarters, the U.S. Army Corps of Engineers, the Federal Water Quality Administration (later the U.S. Environmental Protection Agency), the U.S. Department of Agriculture, Soil Conservation Service, and the Federal Emergency Management Agency. The Geological Survey National Headquarters provided matching funds for cooperators. In addition, National Headquarters provided full support to the District for selected streamflow-gaging stations, water-quality stations, and ground-water observation wells. Also, Headquarters provided for an in-depth analysis of the streamflow-gaging program and for delineating flood-prone areas on topographic maps as part of a nationwide Federal program for managing flood losses. In 1966, funding from National Headquarters amounted to $124,000. Except for the years 1968 through 1970, these funds increased annually. By 1977, funding from National Headquarters had reached $446,000.

Other than the USGS National Headquarters, the greatest support from Federal agencies came from the Corps of Engineers. Of particular interest to the Corps were the Mississippi River forming the eastern boundary of the State and the White, Arkansas, and Red Rivers flowing across the State. Corps funding came through the Tulsa, Little Rock, Memphis, and Vicksburg District Offices. The Soil Conservation Service provided funding for several watershed studies. The WRD District Offices in Missouri and Tennessee and military bases in Arkansas, Missouri, and Tennessee provided funding for analytical services by the Arkansas District laboratory. The Federal Water Pollution Control Administration provided funding for water-quality sampling at a few stream and lake sites.

Funding from various sources is shown in the following table.

HYDROLOGIC DATA PROGRAM

Changing Technologies

Several technological changes during the period speeded up data collection and dissemination. The most significant change was in the use of computers to store and retrieve surface-water, ground-water, and water-quality data. This provided rapid responses to data requests. It also speeded up publication of data. By the end of the period, all water records collected were stored in the WRD's National Water Data Storage and Retrieval System (WATSTORE).

Improved technologies also speeded up field acquisition of data. A number of gaging stations were equipped with devices that could be remotely interrogated to supply real-time data. A few automated

Estimated Arkansas District funds by source, fiscal years 1966–79 (in thousands of dollars)

Fund source	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Coop program	276.7	273	287	321	335	--	--	--	797	693	713	881	925	971
Other Federal agencies	242.7	243	255	268	180	--	--	--	--	--	--	29	--	--
Federal	24.3	25	27	28	30				40	45	50	60	60	75
Federal Power Commission	1.4	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	545.1	541	569	617	545	--	--	--	837	738	763	970	985	1.04 6

water-quality monitors were put into use during the period.

Laboratory methodology underwent significant changes that increased analytical accuracy and decreased time required for analysis. One of the most significant additions was the flame photometer, which greatly improved trace-element analysis. Another change was in direct-reading dissolved-oxygen meters. With the advent of central laboratories, even greater improvements were made in instrumentation.

Surface-Water Records

Records of daily river stage and discharge were collected at 113 stations in 1966 and at 66 stations in 1979. The reduction in numbers of daily stations resulted from an in-depth study showing that sufficient streamflow data existed for a number of stations. Daily discharges were no longer needed at these stations. During this period, conversion from strip-chart recorders to digital recorders took place for all daily discharge stations. In 1966, the District operated 86 partial-record stations where limited streamflow data were collected. In 1979, the District operated 51 partial-record stations. In 1979, the District operated 105 crest-stage stations for obtaining maximum annual discharges for the AHTD. In 1979, there were 125 crest-stage stations.

A hydrologic benchmark station was established on North Sylamore Creek near Fifty Six in 1966, as part of a nationwide network to monitor hydrologic responses to purely natural forces. This station was operated throughout the period. Another benchmark station was established on the Cossatot River near Vandervoort but was operated for only a short period.

Completion of the McClelland-Kerr Navigation System on the Arkansas River from Tulsa, Okla., to the Mississippi River resulted in the construction of 12 locks and dams in Arkansas. The District installed instrumentation on Trimble Lock and Dam near Van Buren and Murray Lock and Dam near Little Rock. The instrumentation recorded gate openings, headwater and tailwater elevations, and number of lockages hourly. Daily discharge was computed from the relation between discharge, lockage, and gate openings.

In 1971, the District began to furnish discharge data to the ADPC&E at a large number of their stations where water-quality samples were collected on a regular basis. The discharge data were computed either from U.S. Geological Survey or Corps of Engineers annual publications, estimated from gaging station records, or defined by approximate stage-discharge curves. All discharge and stage data were published annually in "Surface Water Records for Arkansas," later "Water Resources Data for Arkansas."

Ground-Water Records

Water levels were measured once or twice a year in 1,451 wells in 1966. More than 1,000 of these wells were located in the Arkansas River Valley in conjunction with construction of the navigation system on the Arkansas River. Wells in the Arkansas River Valley were measured to determine the effects on ground-water levels from the installation of a series of locks and dams. After completion of the navigation system in 1969, most wells in the Arkansas River Valley were no longer measured.

An ongoing program of water-level measurements in several hundred wells continued through the period. In 1966, water levels were measured in 536 wells tapping seven aquifers. Included were 16 wells where continuous water levels were obtained. In 1979, the observation-well network had been increased to 589 wells tapping 17 aquifers. Of the 589 wells, continuous water-level records were obtained at 12. Also of the 589 wells, 458 were screened in the alluvial and Sparta Sand aquifers. Most ground-water uses, primarily agricultural, industrial, and municipal, came from these aquifers. As a result, water-level declines were occurring in several areas of these two aquifers, necessitating comprehensive monitoring. Beginning in 1973, water-level data were published annually as "Ground-Water Levels in Observation Wells in Arkansas."

Water Use

Water is one of Arkansas's most valuable natural resources. Much of the State's agriculture and industry, as well as several municipalities, depend upon an adequate supply of good quality water. As part of a national water-use program, the Arkansas District, in cooperation with AGC, began in 1965 to make a periodic inventory of ground- and surface-water withdrawals in the State.The first comprehensive inventory was published in 1965, and water-use data were published at 5-year intervals thereafter.

In 1965, 1,231 million gallons per day (MGD) was from ground-water sources and 911 MGD was from surface-water sources. Water use more than doubled by 1980, when 5,253 MGD was used. Of this amount, 4,053 MGD was from ground-water sources and 1,200 MGD was from surface-water sources.

Water-Quality Records

In 1966, there were 35 stream stations where water-quality data were collected, including one sediment station. By the end of the reporting period, water-quality data were collected at more than 100 stations and sediment data were collected at 15 stations. All inorganic chemical, physical, and sediment samples were analyzed at the District laboratory from 1966 to 1972, when central laboratories were established.

Several streams in Arkansas became important nationally. In 1966, the Arkansas River at Van Buren was part of the National Tritium Network. As stated previously, two stations, North Sylamore Creek near Fifty Six and Cossatot River near Vandervoort, were part of the National Hydrologic Benchmark Network. In 1973, three stations—Mississippi River at Memphis, St. Francis River at Parkin, and St. Francis River at Riverfront—became part of the National Stream Quality Accounting Network (NASQAN). By 1979, five more stations had been added to the NASQAN network.

In 1973, the Field Service Unit began collecting water-quality data on several southwest Arkansas reservoirs for the Vicksburg District of the Corps of Engineers. In 1974, the Field Service Unit began collecting data on four reservoirs for the Little Rock District of the Corps of Engineers. Three more reservoirs operated by the Little Rock District were added in 1975, and one more was added in 1978.

In 1967, the Arkansas WRD District became involved in stream bacteria enumeration as part of a national thrust to evaluate the impact of sewage-treatment plants on ambient water quality. Ed Morris led this effort for the District. Fewer than five stations were sampled initially for bacteria. By 1979, 15 stations were sampled. Macroinvertebrate sampling and identification began in 1968 at North Sylamore Creek, one of the National Hydrologic Benchmark Network stations. Numerous stream biology sites related to lignite mining were added in south Arkansas in the mid-1970's.

In 1966, 25 wells were selected statewide as part of a "master well" network. These wells tapped aquifers that were used as water supplies for municipalities, agriculture, industry, and households. Five selected wells were sampled annually until all 25 were sampled. Sampling would then begin again. Thus, each well was sampled every 5 years. Initial sampling defined water quality, and sampling thereafter would identify changes in water quality that might have occurred. Samples were analyzed for inorganic constituents, metals, nutrients, and in some cases, organic constituents. This program continued throughout the period.

Water-quality records were published annually in "Water-Quality Records for Arkansas," later "Water Resources Data for Arkansas."

HYDROLOGIC INVESTIGATIONS

Multidiscipline Studies

Prior to reorganization as a District, the GW Branch had completed a number of ground-water investigations in the Gulf Coastal Plain by county or multicounty units. These investigations concentrated primarily on ground-water occurrence, availability, movement, recharge, and discharge with limited information on ground-water quality. Following reorganization, these studies were expanded to include surface-water resources and also placed more emphasis on water quality.

The first two investigations completed under the multidiscipline approach were reported in Water-Supply Paper 1839–B, "Water Resources of Pulaski and Saline Counties, Arkansas," by Ray Plebuch (geologist) and Marion Hines (engineer), and Water-Supply Paper 1839–G, "Water Resources of Jackson and Independence Counties, Arkansas" by Don Albin (geologist), Marion Hines, and John Stephens (hydrotechnician). These reports were published in 1967. These were followed in 1968 by Water-Supply Paper 1857 "Water Resources of Grant and Hot Spring Counties, Arkansas," by Henry Halberg (geologist), Charles Bryant (chemist), and Marion Hines. Two reports, Water-Supply Paper 1879-A, "Water Resources of Clark, Cleveland, and Dallas Counties, Arkansas," by Ray Plebuch and Marion Hines, and Water-Supply Paper 1879-B, "Water Resources of Randolph and Lawrence Counties, Arkansas," by Andy Lamonds (chemist), Marion

Hines, and Ray Plebuch were published in 1969. Water-Supply Paper 1998, "Water Resources of Hempstead, Lafayette, Little River, Miller, and Nevada Counties, Arkansas," by Gus Ludwig was published in 1972. Ludwig was a geologist with some experience in surface water. One multidiscipline investigation, "Water Resources of Clay, Green, Craighead, and Poinsett Counties, Arkansas," by Hines, Plebuch, and Lamonds, was published in the Hydrologic Atlas series in 1972 as HA–377.

A different approach was used for the mountainous regions of the State where ground water is not as abundant as in the Gulf Coastal Plain. An investigation of the water resources of the Ouachita Mountains was published in 1965 as Water-Supply Paper 1809–J, "Water Resources Reconnaissance of the Ouachita Mountains, Arkansas," by Don Albin. Andy Lamonds investigated water resources in the Ozark Plateaus of northern Arkansas. This investigation was published in 1972 as HA–383, "Water Resources Reconnaissance of the Ozark Plateaus Province, northern Arkansas." This was the last of this series of county, multicounty, and regional studies of water resources. Some counties were not included in these investigations but were included in a broad study of the Mississippi embayment.

Ground-Water Studies

Some regional studies of ground water were done based on aquifers or aquifer systems. The alluvial aquifer underlying the Arkansas River flood plain from Muskogee, Okla., to Fort Smith, Ark., was investigated by Harry Tanaka and Jerrald Hollowell and was published in 1966 as Water-Supply Paper 1809–T. Bob Hosman described characteristics of the aquifer systems underlying the entire Gulf Coastal Plain of eastern and southern Arkansas in HA–309, "Geohydrology of the Coastal Plain Aquifers," published in 1969. The aquifers were presented in three-dimensional drawings showing areal and vertical distribution. Water-quality characteristics were demonstrated on the drawings by use of diagrams. Water-Supply Paper 1971, "Methods and Applications of Electrical Simulation in Ground-Water Studies," by Doug Bedinger and Joe Reed of the Arkansas District and C.J. Wells and B.E. Swafford of the Little Rock District of the Corps of Engineers, was published in 1970. This study made use of the analog model developed for predicting water-level changes in ground water resulting from the construction of locks and dams on the Arkansas River. Professional Paper 1044-C, "The Waters of Hot Springs National Park—Their Nature and Origin," by Doug Bedinger, Joe Pearson, Jr., Joe Reed, and Dick Sniegocki of the Geological Survey and Charlie Stone of the AGC, was published in 1979.

Additional ground-water investigations were performed which included multi-State regions or were parts of nationwide studies.

District offices in the States of Arkansas, Missouri, Tennessee, Mississippi, and Louisiana were involved in a series of hydrologic investigations of the Mississippi embayment. These investigations described aquifer characteristics in the embayment.The aquifers were grouped according to geologic age into pre-Cretaceous, Cretaceous, Tertiary, and Quaternary. Reports authored or co-authored by Arkansas District personnel included: HA–221, "Map Showing Altitude of the Base of Fresh Water in the Coastal Plain Aquifers of the Mississippi Embayment," by Elliott Cushing (1966); Professional Paper 448–D, "Tertiary aquifers in the Mississippi Embayment," by Bob Hosman (1968); Professional Paper 448–E, "Quaternary Aquifers in the Mississippi Embayment," by Ernie Boswell of the Mississippi District and Bob Hosman and Jeff Jeffery of the Arkansas District (1968); and HA–434, "Analog Simulation of Water-Level Declines in the Sparta Sand, Mississippi Embayment," by Joe Reed (1972).

Because of the Arkansas District's expertise in ground-water modeling, which was developed during the Arkansas River navigation study, the Louisiana District requested assistance from the Arkansas District to analyze the ground-water regime in the lower Red River in Louisiana. The project began in 1968 under the oversight of Gus Ludwig of the Arkansas District. The project task was to model six lock-and-dam sites on the river downstream from Shreveport. This project was transferred to the Louisiana District in 1975, after the modeling phase was completed.

In the 1970's, interest was developing in lignite as an inexpensive source of energy. This interest sparked the need to determine potential environmental problems created by strip mining for lignite. South-central Arkansas had significant deposits of lignite. With matching funds from the AGC, the Arkansas District performed a hydrologic investigation of the lignite area. Open-File Report 79–924, "Water-Resources Appraisal of the South Arkansas Lignite Area," by John Terry, Charles Bryant, Gus Ludwig, and Joe Reed, resulted from this study.

Studies of national interest were summary appraisals of the Nation's ground-water resources. These summaries gave overviews of water resources in regions of the Nation divided by major river basins. Two of these appraisals were completed in the Arkansas District: Professional Paper 813–H, "Summary Appraisal of the Nation's Ground-Water Resources—Arkansas-White-Red Region," by Doug Bedinger and Dick Sniegocki (1976), and Professional Paper 813–N, "Summary Appraisal of the Nation's Ground-Water Resources—Lower Mississippi Region," by John Terry, Bob Hosman, and Charles Bryant (1979).

Surface-Water Studies

In the surface-water discipline, investigations focused on bank storage, flood studies, low-flow studies, and drainage-area delineations. The first surface-water study, "Water-supply Characteristics of Selected Arkansas Streams," was done by Marion Hines and published in Water Resources Circular 9 in 1965. Water Resources Circulars were a series of reports published in cooperation with the Arkansas Geological and Conservation Commission, now the AGC. Water Resources Circular 10, "Storage Requirements for Arkansas Streams," by James Patterson was published in 1967. Water Resources Circular 12, "Flow-Duration and Low-Flow Determinations of Selected Arkansas Streams," by Marion Hines was published in 1975. Determining low-flow characteristics of streams was also a part of the Mississippi embayment study. Reports coauthored by Arkansas District personnel included Profession Paper 448–F, "Low-Flow Characteristics of Streams in the Mississippi Embayment in Northern Arkansas and in Missouri," by P.R. Speer and Mel Janson of the Missouri District and Marion Hines of the Arkansas District (1966) and Professional Paper 448–G, "Low-Flow Characteristics of Streams in the Mississippi Embayment in Southern Arkansas, Northern Louisiana, and Northeastern Texas," by P.R. Speer, Marion Hines, Anthony Calandro of the Louisiana District, and Jeff Jeffery (1966).

Water Resources Circular 11, "Floods in Arkansas, Magnitude and Frequency Characteristics Through 1968," by James Patterson, was published in 1971. Clifford Gilstrap authored three flood reports: Water-Supply Paper 1970–A, "Floods of May 1968 in South Arkansas" (1972); Water-Resources Investigations Report WRI 73–89, "Floods of December 1971 in Western Arkansas," (1973); and Water-Resources Investigations Report 76–337, "Flood-Flow Characteristics of Illinois River Tributary near Siloam Springs, Arkansas" (1976). In 1972, James Patterson and John Sullavan authored two unnumbered open-file reports, "Floodflow Characteristics of Little Creek at State Highway 286, near Conway, Arkansas," and "Floodflow Characteristics of East Fork Horsehead Creek at Interstate Highway 40, near Hartman, Arkansas." In 1976, Sullavan authored Open-File Report 76–179, "Floodflow Characteristics of Mulberry River at Interstate Highway 40, near Mulberry, Arkansas." In two Water Resources Summary reports (as distinguished from Water Resources Circular reports), Marion Hines presented graphs for determining the approximate elevations of 50-year floods (1977) and 100-year floods (1978) in Arkansas. Doug Bedinger authored Professional Paper 750–C, "Forest Species as an Indicator of Flooding in the Lower White River Valley, Arkansas."

Drainage Areas of Streams in Arkansas were delineated in a series of numbered and unnumbered open-file reports. The first of these was an unnumbered open-file report, "Drainage Areas of Streams in Arkansas, Arkansas River Basin," by John Sullavan and John Terry, published in 1970. This was followed by an unnumbered open-file report, "Drainage areas of streams in Arkansas, White River Basin," by John Sullavan in 1974. In 1978, Marion Hines and John Yanchosek authored Open-File Report 78–555, "Drainage Areas of Streams in Arkansas, Red River Basin."

Water-Quality Studies

A number of investigations that dealt primarily with water quality were done during the period. In 1970, William Buller authored an unnumbered open-file report, "Hardness of Ground Water in Arkansas." Also in 1970, John Sullavan performed a thermal survey of Dardanelle Reservoir on the Arkansas River where a nuclear reactor for power generation discharged warm water into the reservoir.

In the 1970's, State and Federal environmental agencies had become concerned about how to deal with the effects of pollutants discharged to streams.

In 1973, the ADPC&E requested assistance from the Arkansas District in determining the effects of municipal wastewater discharges into large and small streams. Using a water-quality model developed by Marshall Jennings and Dan Bauer of the WRD research facility at Bay St. Louis, Miss., Charles Bryant headed the project, which resulted in 21 unnumbered reports. One report, "Water-Quality Modeling for Waste-Load Allocation Studies in Arkansas Streams, Dissolved Oxygen and Conservative Minerals," authored by Jennings and Bryant, was used as a guide for performing the waste-load allocation study. Twenty reports were then prepared on streams, or stream segments, that received, or were expected to receive, wastewater from municipal wastewater-treatment plants.

Also in the 1970's, there were concerns of nonpoint discharge of pollutants to streams, particularly agricultural runoff. The State Office of the USDA, Soil Conservation Service, requested assistance from the Arkansas District in evaluating selected watersheds for stream-water quality prior to implementing land and water improvement programs. Terry Lamb of the Arkansas District was named project chief, and six investigations were completed during the period. These were Open-File Report 78–175, "Water-Quality Investigation of the Tyronza River Watershed" (1978); Open-File Report 78–497, "Water-Quality Data for the Village Creek Watershed, Northeast Arkansas" (1978); Open-File Report 78–903, "Water-Quality Investigation of the Vache Grasse Creek Watershed" (1978); Open-File Report 78–904; "Water-Quality Investigation of the Yellville Watershed, Arkansas" (1978); Open-File Report 79–1064, "Water-Quality Investigation of the Caney Creek Watershed, Northeast Arkansas" (1979); and Open-File Report 79–1300, "Water-Quality Investigation of the Flat Bayou Watershed, Jefferson County, Arkansas" (1979).

The ADPC&E was also interested in determining the effects of nonpoint discharges of contaminants into Arkansas streams and requested assistance from the Arkansas District in assessing the impact of agricultural runoff into the L'Anguille River in east Arkansas. The L'Anguille River is located in a primarily agricultural area where rice, soybeans, and cotton were principal crops and where pesticide application was widespread. The investigation resulted in Open-File Report 79-1482, "Water-Quality Assessment of the L'Anguille River Basin, Arkansas" (1979), by Charles Bryant, Ed Morris, and John Terry.

Special Activity

In 1976, The Arkansas and Tennessee Districts held a joint conference at Pickwick Landing State Park on the beautiful Tennessee River. The purpose of the conference was to discuss common problems and solutions in the field of hydrology. Milt Hackett of National Headquarters, Les Laird of the Southeastern Region, and Hugh Hudson of the Central Region attended. Discussions were held between members of the same disciplines of each District Office. The conference proved to be of mutual benefit to personnel of both Districts as well as building camaraderie between the Districts.

COLORADO

by John B. Weeks, G. Louis Ducret, Jr., George H. Leavesley, and Richard B. Luckey

PROLOGUE

In Colorado, 1966 through 1979 were years of great change. The two events most responsible for that change were District reorganization and the OPEC oil embargo. Reorganization from Branch districts to an integrated District focused WRD on State water issues and brought closer association with State agencies. OPEC's restrictions on oil exports to the United States caused the "energy crunch," which resulted in rapid inflation of energy prices, energy conservation awareness, interest in alternative fuels, and new Federal programs for energy development. Because of Colorado's wealth in energy and mineral resources, the District grew rapidly to meet the challenges of the 1970's.

ORGANIZATION AND MANAGEMENT

Prior to 1967, the Colorado District was organized under the Branch districts, as described in Volume VI of the WRD history series. In 1967, water-resources activities were reorganized by combining the Branch districts in Colorado to form an integrated Colorado District. District offices were moved from commercial space in Lakewood to Building 53 at the Denver Federal Center.

Edward A. (Ted) Moulder transferred from the Pacific Coast Region office to become the first District Chief for Colorado. Leonard A. Wood, former District Geologist, transferred to the Ground-Water Branch at Headquarters. John W. Odell, former District Engineer, transferred to Oklahoma. Edward J. Tripp, former Hydraulic Engineer, became the first Assistant District Chief for Colorado. The operations of the integrated District were organized under a Studies Sections headed by John E. Moore, former Project Chief, and a Records Section headed by Richard V. (Dick) Grozier, who transferred from San Angelo, Texas. Subdistsrict offices operated from Lakewood, Augustine N. DePaulo in charge, and Grand Junction, Russell E. Whiteman in charge. Field offices operated in Alamosa, Durango, and Lamar.

The newly formed District went through some growing pains, which resulted in the formation of specialized units within the District organization. One that endured was the Reports Section supervised by Don Hillier, who transferred from Headquarters. The Reports Section was divided into a Manuscript Preparation Unit headed by Lucy Laughlin and an Illustrations Unit headed by Xava W. (Billie) Dutton. Beverly J. Tirrell was Chief of the Administrative Services Section and Charles D. Nethaway, Jr., was in charge of the Computer Services Section.

Ted Moulder became the Regional Hydrologist in Denver in 1973 and Jim Biesecker became Colorado's second District Chief and the person most responsible for the rapid program and technical growth of the District during this period. Biesecker was the youngest person selected as District Chief, and in 1978, he would become the youngest person chosen for Regional Hydrologist. Biesecker had been Ted Moulder's Studies Chief after John Moore became the Central Region Ground-Water Specialist. John F. Ficke replaced Biesecker as Studies Chief until Ficke transferred to the Water Quality Branch in Reston in 1974. Biesecker recruited Doug Bedinger from Arkansas for Studies Chief. Bedinger left the District in 1975 to head up a Central Region team that evaluated prospective hazardous-waste repositories. John B. (Jack) Weeks succeeded Bedinger as Studies Section Chief and was in turn succeeded in 1978 by Jerald F. McCain when Weeks took charge of the High Plains Regional Aquifer Study.

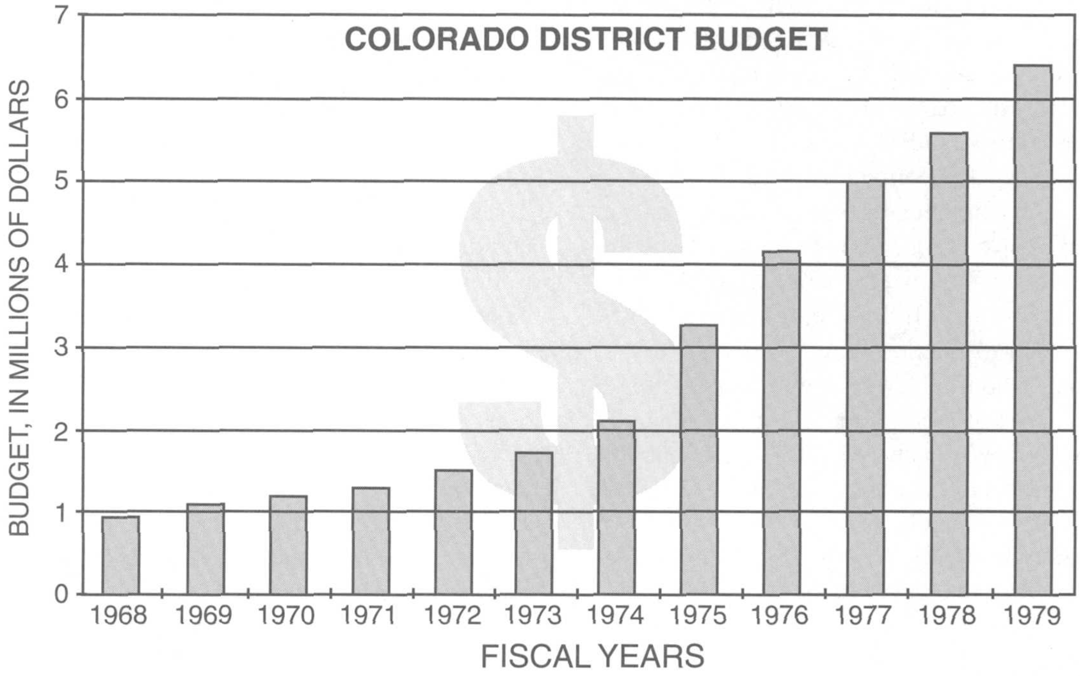
Federal programs for hydrologic studies related to coal and oil-shale development provided the funding for rapid growth. When the Colorado District was formed under Ted Moulder in 1967, there were 30 employees in the District office and 31 employees in Subdistrict and Field Offices. In 1979, the District Chief, James F. Blakey (who replaced Biesecker in 1978), managed 73 employees in the District Office and 69 employees in Subdistrict and Field Offices. The Colorado District staff had more than doubled, and the District budget had grown from less than $1 million (mainly Federal funds) in 1966 to a well-balanced $6.4 million (45 percent Cooperative Program, 31 percent Other Federal Agencies, and 24 percent Federal funds) in 1979.

The program in Colorado was well funded and technically advanced. As a result, it attracted many talented people whose expertise attracted new programs. It was common to have 20–30 applicants for vacancies in Colorado. Many in the District quickly moved on and up the career ladder to more responsible technical and management positions.

Hydrologists and Engineers who worked in the District Office during this time included Donald R. Albin, Clifford T. Jenkins, Edward J. Tripp, Frank A. Welder, John E. Moore, Lloyd A. Hershey, R. Theodore Hurr, Harold E. Petsch, Donald R. Minges, Timothy D. Steele, Daniel P. Bauer, Robert E. Brogden, Alan W. Burns, William F. Curtis, Warren E. Hofstra, Eugene R. Hampton, Leonard F. Konikow, Stanley G. Robson, O. James Taylor, John T. Turk, Dennis A. Wentz, John L. Ebling, Robert D. Jarrett, Randolph S. Parker, Richard R. Luckey, James W. Warner, John E. Costa, Frederick J. Heimes, Norman E. Spahr, George H. Leavesley, Edmund D. Andrews, Linda J. Britton, Robert Brennan, Theron R. Dosch, Michael W. Gaydos, and Sherman R. Ellis.

Technicians included Elizabeth Anderson, Thomas J. Major, Paul A. Schneider, Jr., Jack E. Veenhuis, Charles A. Onions, Larry L. Jones, Robert C. Ugland, Johnnie W. Gibbs, and Woodrow W. Wilson. Administrative, editorial, and secretarial support was provided by Joan J. Olsen, Jo Ann Schnepf, Lula M. Smith, Marjorie M. Bisant, Wendy Joachim, Berniece R. Canzona, Joy L. Anderson, Martha M. Vaught, Judith H. Cornwell, and Virginia R. Jesser. Support for technical illustrations was provided by Margaret E. Olsen and Robert J. Olmstead. Computer support was provided by Sandra R. Turner, Pauline Juarez, and Mary K. Namba.

To meet the challenges of the programs in Colorado, Subdistrict Offices were established in Pueblo and Meeker. In 1971, Philip A. Emery moved from



Colorado District Budget, 1968–79

Alamosa to become the first Subdistrict Chief in Pueblo. He was followed by O. James Taylor (1973), Richard E. Fidler (1975), and Jerry L. Hughes (1977). Charles E. Keliher moved from Lamar to be the Lead Hydrologic Technician in Pueblo. Personnel who worked in Pueblo during this period included professionals Donald L. Bingham, Douglas L. Cain, Patrick J. Emmons, Kimball E. Goddard, Alan P. Hall, Lloyd A. Hershey, John M. Klein, Russell K. Livingston, Clark Londquist, and Ross W. Moor; technicians Ronnie D. Steger, Robert D. Penley, Charles T. Warren, Bernard M. Jessik, William F. Payne; aids Gerald G. Hesseltine and Timothy C. Cheatum; and clerks Peggy L. Sutton and Debra Sandoval.

Vernon W. Norman transferred from Alaska in 1974 to be the first Subdistrict Chief in Meeker. Norman's staff included professionals Frank A. Welder, Robert L. Tobin, Kenneth J. Covay, Thomas R. Ford, and George J. Saulnier, Jr.; Charles E. Keliher moved from Pueblo to be lead hydrologic technician; technicians Robert Boulger, Jr., Richard G. Carver, Henry J. Coufos, Stanley L. Breshears, Paul von Guerard, Robert C. Conklin, Ronnie D. Sumner, Phyllis G. Mann, Perry M. Parker, Eddie A. Wilson (replaced Keliher in 1979), Judy A. Tackman, Helen Stranathan, Caroline Pease, Donald Hayes, William D. Mechem, Patrick Key, and aid Eric North.

Auggy DePaulo retired in 1972 and G. Louis Ducret, Jr., became the Subdistrict Chief in Lakewood. Ducret transferred to Little Rock, Ark., in 1976 and Russell K. Livingston became Subdistrict Chief. Personnel who worked in the Lakewood Subdistrict during this period included professionals Ronald G. Borman, Joe L. Blattner, Terence W. Danielson, Robert L. Einarsen, Neville G. Gaggiani, Gerhard Kuhn, Dennis C. Hall, Donald R. Minges, Martha H. Mustard, and Charles V. Reeter; technicians Eugene J. Charbonneau, Richard M. Neam, James D. Martinez, Betty J. Cochran, Harold E. Hodges, Michael J. Werito, Kerry N. Howey, Marvin W. Quinlan, Albert C. Duncan, Curtis W. Roberts, and aid Michael J. Poulsen.

As the District reorganized its operations, it closed field offices in Alamosa and Lamar. From Alamosa, Robert J. Snipes moved to Grand Junction and Philip A. Emery moved to Pueblo. From Lamar, Ross W. Moor and Charles E. Keliher moved to Pueblo and then Meeker.

During this period, the Subdistrict Office in Grand Junction and the Field Office in Durango remained in place and anchored the data-collection activities on the Western Slope of the Rocky Mountains. In Grand Junction, Russell E. Whiteman retired in 1971 and was replaced as Subdistrict Chief by Robert J. Snipes. Snipes transferred to San Angelo, Texas, in 1977 and was replaced by Dannie L. Collins who transferred from Bay St. Louis, Miss. During this time, professionals who were stationed in Grand Junction included Dee Briane Adams, Timothy F. Giles, Kimball E. Goddard, Ralph O. Patt, and Roger Smith; technicians included Robert G. Kretschman (lead), Carl E. Lesher, Robert A. Jenkins, Clyde H. Corneille, Jr., Orlando M. Chaparro, Michael E. Whiteman, Blaine H. Dwyer, Kenneth C. Galyean, Kurt A. Homan, Stephen H. Shelton, and Mary H. Freese; aids Thomas W. Hale, Mark A. Leslie, Steve R. Sturm, and clerk Patricia M. Houser.

The Field Office in Durango was staffed by technicians Everett A. Hopper, James D. Bennett, Harold E. Burch, and Orville H. McCoy during this period.

HYDROLOGIC DATA COLLECTION

The hydrologic-data networks in 1966 consisted of 370 streamflow stations, about 100 water-quality stations, and 40 ground-water observation wells. The networks were supported by nine Federal, State, and local cooperators. By 1971, the number of cooperators had increased to 16, but the number of data-collection sites remained about the same as in 1966.

The networks began to expand in the mid-1970's because of the energy programs, and by 1979, 27 cooperators supported the networks. The streamflow stations numbered 470, water-quality stations 273, and ground-water observation wells 55. Many more data collection sites were operated directly by projects. The Colorado Division of Water Resources (State Engineer) operated a number of streamflow stations in the 1960's and 1970's. They collected the data and computed the records and the Colorado District reviewed, stored, and published the records.

HYDROLOGIC INVESTIGATIONS PROGRAMS

Hydrologic investigations were greatly aided by the rapid development of computer technology during this period. Hydrologic modeling advanced from nomographs and analogs to digital computer models. District management recruited numerous hydrologists with math and computer backgrounds and trained many others in computer modeling techniques. This expertise enabled the District to offer the latest technology to its cooperators and attracted funding for major investigations such as oil-shale hydrology, urban hydrology, coal hydrology, and the hydrology of the Arkansas River.

These projects incorporated the latest technology in data collection and computer models as the principal analytical tool. They established the future direction of most hydrologic studies that the District would conduct for the next decade. They brought national attention to the Colorado District and helped the District achieve a reputation for being progressive and on the cutting edge of applied hydrologic science.

Arkansas River Valley Investigations

The history of the Arkansas River Valley Project illustrates how the Colorado District advanced technically. The District capitalized on the opportunity provided by the project to recruit the talent needed to develop its expertise in modeling.

The Arkansas River Valley Project was one of the first, and initially was the best funded project in the reorganized Colorado District. This was a cooperative project with the Southeastern Colorado Water Conservancy District and the Colorado Water Conservation Board. The conservancy district was a major political force in water management in southeastern Colorado. They funded and managed transmountain diversions of water to irrigate the lower Arkansas Valley.

The initial purpose of the project was to define the water resources of the Arkansas River Valley from a point upstream from Pueblo (beginning at what is now the Pueblo Reservoir dam) downstream to the Kansas State line. The interrelationship between the river and the alluvial aquifer was of particular interest. Prior to the 1950's, most irrigation had been done with surface water. The area was serviced by 23 major canals that owned 77 water rights, many of which had priority dates into the 19th century. In the 1950's, ground-water irrigation from the alluvial aquifer along the river was becoming common, and canal companies were concerned that the numerous high-capacity wells in the valley were lessening the flow of the river. The situation reached a crisis in 1964 when the Colorado State Engineer issued a cease and desist order against well owner Felderhoft, whom the State claimed was diverting water out of priority with his relatively new well. The order had immediate and far-reaching implications for the more than 1,400 irrigation wells in the valley. Colorado water law had recognized surface-water/ground-water interaction as early as the late 1800's, but the Felderhoft case threatened the economic order of a large area. The crisis precipitated an immediate need to determine the nature of the interaction between the river and the aquifer and to devise new ways to manage water resources of the valley.

An electric analog model of the aquifer was constructed and calibrated relative to water levels and streamflow gains and losses. The model was constructed on pegboard, was more than 30 feet long, and contained thousands of resistors and capacitors. The river was generally a line sink (a wire), but in areas of intense pumping, resistance was placed between the river and the aquifer in the model to simulate the limited connection between the systems; this was necessary to match gain-loss data. A segment of the model near the town of La Junta was copied to be used as a demonstration model. This model was shown to water managers and irrigators at numerous public meetings; it became a teaching tool used at numerous high schools and science fairs. In the early 1970's, thousands of Boy Scouts saw the model at their National Jamboree at the Air Force Academy in Colorado Springs.

Clifford T. Jenkins had been working on analytical solutions that described the effects that pumping wells had on a nearby river. The analytical solutions were limited to relatively simple problems and were computationally intensive. With the analog flow model, he was able to extend this work to complex, real-world problems. Jenkins tested the analog model at hundreds of points to determine the "stream-depletion factor" (SDF), an integrated parameter that could then be used in simple equations. He mapped the SDF over the entire valley and subdivided the valley into bands of equal SDF's.

Ivan C. James of the Systems Analysis Group used the mapped SDF's to construct a digital water-accounting model of the valley. The model subdivided the length of the valley into 27 reaches, with the division between reaches being a stream-gaging station or canal headgate. Each reach of the valley was divided into as many as 10 SDF bands on each side of the river. The 77 major water rights were incorporated into the model in priority order, and pumpage was added for each cell (defined by reach number, band number, and side of the river). Evapotranspiration (ET) was added to the model for cells within two bands of the river.

O. James Taylor and Richard R. Luckey calibrated the model by using field data and determined ET rates and the amount of recharge that results from applied irrigation water. The input to the model was streamflow at the upstream gage. The model would determine which priority rights should receive water and would then calculate return flow caused by using diverted water for irrigation and depletion caused by pumping. The return flows and depletions would change streamflows along the river and thus streamflow would have to be reallocated to the various water rights. The model would iterate within a time period until the streamflow was properly allocated and it would then go to the next time period. The model was calibrated against observed streamflows at downstream gages for the period 1964–68 in monthly time steps. They then used the calibrated water-accounting model and 1941–65 river flows at Pueblo to study water management alternatives.

When digital ground-water flow models became available, they were tested to determine if they could be used to determine the distribution of SDF's in the valley. Some digital models could determine SDF values very accurately, and techniques were developed to rapidly determine SDF's. This knowledge allowed a follow-up project in the South Platte River Valley to begin using water-accounting models early in the project. Later, Alan W. Burns added water-quality accounting to the models for both valleys.

Leonard F. Konikow and John D. Bredehoeft constructed a digital flow and salt transport model for a segment of the Arkansas Valley near La Junta. This work represented some of the initial USGS efforts in modeling transport. Data to calibrate the model were available only for a short period of time in the early 1970's. After calibration, the model was used to project water-quality trends over the next decades. In the mid-1980's, Konikow collected additional data and did a "postaudit" on the model projections. He found that the calibration data covered an anomalous period and as a result, the projections were incorrect. In the mid-1990's, another postaudit was being conducted.

Russell K. Livingston conducted reservoir-release studies, first in the upper reaches of the river and later in the lower reaches. He determined the time of travel of the releases, the bank-storage characteristics, and losses of the released water. The tests in the upper reaches allowed the water conservancy district to determine how to most efficiently bring transmountain water from upstream reservoirs to Pueblo Reservoir, then under construction. The tests in the upper reaches allowed the conservancy district to plan a winter water-release program for Pueblo Reservoir. That program was put into effect soon after the reservoir was completed.

Douglas L. Cain studied water-quality issues related to return flow from irrigation. He determined that water quality progressively degraded downstream; but within any one section of the valley, the differences between the quality of the surface water and the ground water were small compared to the downstream changes. He later did detailed water-quality and water-budget studies on the area serviced by the Buffalo Canal in the lower valley.

Oil-Shale Investigations

Another project that provided the technical focus for the development of computer modeling expertise in the District was the oil-shale hydrology project. State interest in oil-shale development and its impact on water resources began in the mid-1960's. In 1971, the Department of the Interior announced plans for a prototype oil-shale development program in Colorado, Utah, and Wyoming. Two tracts of land in the Piceance Creek Basin were leased for prototype development in 1974. In anticipation of oil-shale development, the USGS and the Colorado Department of Natural Resources (CDNR) entered into a joint funding agreement in 1972 for a 2-year study of the basin to define the hydrologic system, to determine baseline conditions, and to predict the effects of development of the hydrologic system. The project was initially headed by John F. Ficke and staffed by John B. Weeks, who transferred from Alaska, Frank A. Welder, George H. Leavesley, and George J. Saulnier, Jr.. When Ficke became Studies Chief in 1973, Weeks became the Project Chief. Working with State agencies and industry, this group of scientists evaluated the impact of proposed mineral-resource development on hydrology. Using data from public and private sources, the project team developed computer models of the aquifer and surface-water systems, which were used to estimate the effects of hypothetical development on the system. Their findings were reported in Professional Paper 908.

The oil-shale hydrology project was followed by several studies funded in cooperation with the CDNR, which extended the work to the south into Roan and Parachute Creeks, monitored hydrologic conditions, and provided additional data to refine the models. Funding for the study of oil-shale hydrology continued until 1981, when it became evident that the prototype leases were not economical to develop. When private interest waned, Federal and State funding soon ended.

Coal Hydrology Program

In 1974, the Energy Mineral Rehabilitation Inventory and Analysis (EMRIA) program of the Bureau of Land Management (BLM) was initiated and provided a major focus for the development of the Colorado District Coal Hydrology Program. The BLM contracted with the Colorado District to provide baseline hydrology information for Federal coal lands and to assess hydrology issues that might represent major problems for the reclamation of mined lands. The basic objectives of the EMRIA hydrology program were to evaluate the hydrology of selected coal areas and to develop watershed-modeling tools to assess and predict hydrologic impacts. These impacts included the spatial and temporal variations in hydrology that would result from changes imposed by surface mining and the subsequent land-surface reclamation activities.

Study basins were established on several tributaries to the Yampa River near Steamboat Springs and Craig, several streams in the North Park Region, and a few streams in the Raton Basin near Trinidad. These basin studies provided the data needed to develop hydrologic knowledge of the coal regions and modeling tools to simulate the regional hydrology and anticipated effects of surface mining. The USGS Precipitation-Runoff Modeling System (PRMS) was selected as the watershed model tool. George Leavesley, Randy Parker, Mike Norris, and Gerhard Kuhn were involved with the modeling studies.

The ground-water conditions of these coal regions were also monitored using a system of shallow and deep wells that were installed cooperatively with the Conservation Division. Core holes were drilled for coal assessment studies by the Conservation Division, and Colorado District personnel completed these core holes as observation wells. This work was led by Joe D'Lugosz with the help of Tim Giles.

Following the work with the Conservation Division, various other ground-water studies were undertaken to evaluate the hydrologic setting and geochemistry of areas that were being considered for coal mining. These studies were led by Bob Williams, Nancy Driver, and Steve Hammond with assistance from other employees and graduate students.

Water-quality investigations were conducted at each of the study sites with the measurement of a range of chemical constituents and sediment. In the Yampa River Basin, a basin-scale assessment of the effects of coal development on the Yampa River was conducted by Tim Steele, Dan Bauer, Don Hillier, Dennis Wentz, and Jim Warner. Results were published in a multipart series of Water-Resources Investigations Reports. The water-quality characteristics of the smaller tributary basins to the Yampa were summarized by John Turk and Randy Parker in several reports.

As coal mining increased in the Yampa River Basin, there was interest in defining the cumulative effects of dissolved solids on surface water from new and proposed mines. A synoptic water-quality data-collection program was initiated at about 47 sites in the Yampa River Basin. Data were collected and data reports written by Wendy Maura. Using these data, Randy Parker, Mike Norris, and Dave Litke developed an accounting model of dissolved solids for the basin.

The effects of reclaimed coal spoils on water quality was studied in a project that evaluated the leachate of mine spoils at the Seneca mine near Hayden. The project was led by Bob Williams, with assistance from Steve Hammond, and involved the construction of five watertight concrete structures in the spoils. Construction was done by District and Lakewood Subdistrict personnel led by Joe Blattner. The crew tied over 5,000 feet of steel rebar and poured about 40 yards of concrete. Each lysimeter was back-filled with spoils material, and each structure had a different surface-reclamation procedure applied. Leachate taken from a drain in the bottom of each structure was analyzed for chemical quality.

In the North Park area, streamflow, water quality, and sediment data were collected from 1976 to 1980 at five locations near Coalmont and from 1978 to 1983 at four locations near Walden. Two of the monitored basins near Walden were modeled using PRMS to assess the effects of mining. These studies were made by Gerhard Kuhn with assistance from Ben Kelley.

The Coal Hydrology Program involved a large number of site and regional studies whose results are published in a large number of reports in the Water-Resources Investigations Reports and Open-File Reports series. Many of these reports are summarized or cited and referenced in the USGS Professional Paper 1464, "Summary of the U.S. Geological Survey and U.S. Bureau of Land Management National Coal-Hydrology Program," edited by L.J. Britton, C.L. Anderson, D.A. Goolsby, and B.P. Van Haveren.

Small-Watershed Flood-Frequency Investigations

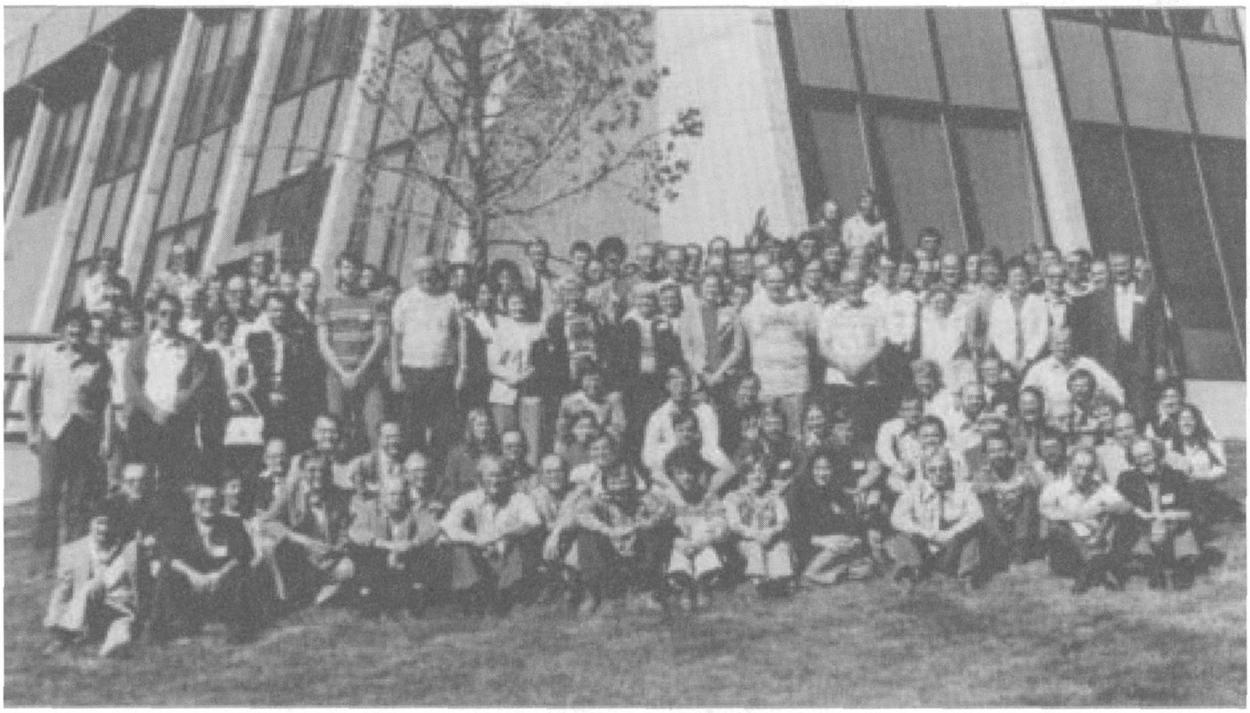
Louis Ducret arrived at the Colorado District in July of 1968 from the District Office in Portland, Oreg. He worked for Don Diego Gonzalez on the Colorado Highway Program funded jointly by the Federal Highway Administration and the Colorado State Engineer. Approximately 50 dual-digital stations were installed on small watersheds statewide. Dual-digital sites consisted of instrument-size shelters mounted atop vertical standpipes—one to serve as a stilling well for stream stage and one to serve as a collector for rainfall. Both gages were in close proximity, located at the basin outfall, were operated with a single timer and battery supply, were electrically connected, and collected stage and rainfall data simultaneously at 5-minute intervals. These data were to be used in the fledgling WRD rainfall-runoff model published by Dawdy, Lichty, and Bergman. Data collection was to span a 10-year period in order to acquire data from enough events to calibrate the model. Gonzalez left in 1971 to work for Nuclear Hydrology, and Ducret transferred in 1976 to the Arkansas District. Responsibility for the investigation was assumed by Russell Livingston.

Shortly after the Highway Program got underway, a cooperative program with the Denver Regional Council of Governments was started in order to develop flood-frequency relationships for basins with urban development. Dual-digital stations were installed throughout the metropolitan area, including Boulder, and provided rainfall-runoff data from basins with varying degrees of impervious cover. One station, Concourse D Storm Drain at Stapleton Airport, was unique because it provided data from a basin with 100-percent impervious cover and monitored runoff from runways and tarmac. It was also unique in that it used a Palmer-Bowlus, Modified-Venturi flume constructed in a 72-inch storm drain as control for discharge computations. Gonzalez and Ducret prefabricated the flume and installed it as the Concourse D storm drain was being constructed. The installation took place while a section of pipe was above ground and, to ensure proper orientation for stage sensing and discharge computations, they supervised placement of the section in a 16-foot-deep ditch. Operation of the urban-hydrology network was under the direction of Livingston after the departure of both Gonzalez and Ducret.

These are only a few of the projects in the Colorado program from 1966 to 1979. These projects and others incorporated the latest technology in data collection and computer models as the principal analytical tool. They established the future direction of most hydrologic studies that the District would conduct for the next decade. They also brought national attention to the Colorado District and helped the District achieve a reputation for being progressive and on the cutting edge of applied hydrologic science.

In 1977, the Colorado District management team planned an all-employee District conference at an off-site facility. The purpose was to train and familiarize all personnel—"veterans" plus the many new folks—with the programs in the rapidly growing District. This was the first such conference for the Colorado District. After a lengthy search for a suitable site, Steamboat Springs, Colo., was selected. In addition to all District personnel, the Chief Hydrologist and Regional Hydrologist attended from WRD, along with representatives from adjacent Districts. Officials from cooperating agencies, Federal and State, were the Colorado State Engineer, the Director of the Denver Urban Drainage and Flood Control District, the Director of the Southeastern Colorado Water Conservancy District, the Director of the Colorado River Water Conservancy District, the Director of the Missouri River Basin of the Bureau of Reclamation, the Chief Hydrologist of the Bureau of Land Management Oil Shale Office, a hydrologist from the Oil Shale office of the USGS Conservation Division, the Chief of Research from the Denver Board of Water Commissioners, and a representative of the Rio Grande Water Conservancy District.

In addition to plenary sessions with presentations by key personnel, technical sessions were held on ground-water flow modeling, water-quality field techniques, indirect measurements, computing streamflow records, administrative procedures, report processing, and project management. District personnel reported that the conference raised morale even higher than before. In addition, feedback from USGS officials and cooperators in attendance was that the conference increased respect for the talent and abilities of Colorado District personnel. The District Conference was a worthwhile and memorable experience!



Attendees of the Colorado District Conference, Steamboat Springs, Colorado, 1977.

IOWA

by Sulo W. Wiitala

Organization and Management

In Iowa, organization as a WRD District did not occur until 1967. Prior to that time, water-resources investigations were conducted separately by the Surface Water (SW) and Ground Water (GW) Branches. Inasmuch as there were no separate water-quality programs in Iowa, the Quality of Water (QW) Branch was never formally involved in District operations.

District Headquarters for SW operations was located in the Hydraulics Laboratory Building, Iowa Institute of Hydraulic Research, on the University of Iowa campus until December 1968 when they were moved to Towncrest Professional Center, 1041 Arthur Street, Iowa City. Headquarters for the GW operations was located in the Geology Annex, also on the University of Iowa campus, where GW personnel shared common office space with the Iowa Geological Survey (IGS).

It was not until the move to a new Federal Building, in June 1974, that all Water Resource Division personnel at District Headquarters were housed under one roof in Iowa City. Though physical separation of the SW and GW disciplines until 1974 made operations rather awkward, it did serve to continue a close rapport with a principal cooperator, the IGS, that had evolved over the years.

Sulo W. Wiitala served as District Engineer (SW) until May 1967, when he was named District Chief of the reorganized District. He retired from Federal service in December 1978 and was succeeded in late 1979 by Donald Leifeste. Organized along functional lines, the District in 1967 was subdivided into three principal sections, the Areal Studies, Special Studies, and Hydrologic Data Sections, each headed by an Assistant District Chief. The Hydrologic Data Section was further subdivided into Subdistricts at Iowa City, Council Bluffs, and Fort Dodge. An Administrative Services Section provided support services to the District.

The Areal Studies Section, for the most part, took on the work of the former GW Branch. Walter L. Steinhilber, formerly District Geologist (GW), headed the Section until August 1978 when he transferred to Madison, Wis., to head the Northern Midwest Regional Aquifer Study. He was succeeded by Kenneth D. Wahl, who served in the ground-water discipline throughout the period. Also on the staff were Joseph W. Cagle, Robert E. Hansen, Ronald W. Coble (transferred to North Carolina District in 1970), Leon L. Steele (retired in 1975), Donald B. Aaronson (transferred to New York District in 1970), Daniel J. Gockel, William C. Steinkampf (1975–77), and Larry J. Slack (1977–). Olatha Tweedy provided support services for this group until her retirement in 1972. Iowa Geological Survey personnel were assigned to the Section from time to time as needed.

The Special Studies Section devoted most of its efforts to topical studies of hydrologic extremes in the surface-water discipline. Harlan H. Schwob was in charge until his retirement in January 1971. Oscar G. Lara transferred from the Washington, D.C., office to succeed him. Phillip J. Carpenter served in this Section until transferred to the Washington, D.C., office in 1967. Albert J. Heinitz transferred in from the Louisiana District in June 1968. Donald J. Riddle served throughout the period, Carrol W. Saboe until transferred to the Fort Dodge Subdistrict in 1967, Jack T. Freshwaters until transferred to the Wisconsin District in 1970, and John V. Roberts in 1969–70. Short-term assignees were Stanley Osborn (1969–70) and Gary R. Lundquist (1977–78).

The Hydrologic Data Section was involved in the collection, processing, and publication of streamflow and sediment discharge data. Ivan L. Burmeister headed the section throughout the period. The work was carried on through Subdistrict Offices in Iowa City, Council Bluffs, and Fort Dodge and a sediment unit in Iowa City.

Richard E. Myers served as head of the Iowa City Subdistrict until his death in May 1970. He was succeeded by Samuel Mummey, Jr., who served until his retirement in February 1976. Thereafter, Burmeister filled the dual roles of Section Chief and Subdistrict Chief. The Subdistrict staff included Theodore Sieger, Jr., until transferred to the Michigan District in 1976, Wilbur J. Matthes, Jr. (assigned to the Sediment Unit in 1970), Von E. Miller (appointed in 1967), David A. Shaull (reassigned from the Council Bluffs Subdistrict in 1970), Gerald E. Ryan (appointed in 1974), Max A. McCoy (1973–78), Philip E. Soenksen (from 1977 until assigned to the Fort Dodge Subdistrict in 1978), Josephine C. Kulik (to 1968), Errol McAlexander (to 1967), Charles R. Lamb

(1969–70), Michael J. Downes (1970–72), Craig A. Fountain (1976–72), Craig C. Hansen (1971–73), Richard C. Downes (1975–77), and Gary R. Lundquist (reassigned from the Special Studies Section in 1978).

Orlando J. Ramsvick was in charge of the Council Bluffs Subdistrict throughout the period. Eugene D. Stenstadvold, Raymond D. Burkey, and Viola S. Taylor also served throughout the period. Others on the staff were Frank E. Lindstrom until reassigned to the Fort Dodge Subdistrict in 1974, David A. Shaull until reassigned to the Iowa City Subdistrict in 1970, Albin R. Conkling until reassigned to the Fort Dodge Subdistrict in 1974, Joseph G. Gorman (appointed 1972), and Michael E. Spetman (1972–78). This office covered the Missouri River Basin stations in Iowa that included four on the Missouri River where measurements were required three to six times per month because of the shifting nature of the river channel.

Richard A. Bair headed the Fort Dodge Subdistrict until his untimely death in May 1967. He was succeeded by Carrol W. Saboe who served until transferred to Washington, D.C., in 1973. Frank E. Lindstrom then took over this position until his disability retirement in late 1978. Philip E. Soenksen, reassigned from Iowa City, was then in charge for the remainder of the period. Kathryn M. Svaleson, clerk and technician, served throughout the period. Others included Leon E. Betts until his resignation in 1970, John H. Hanneman, until transferred to the South Dakota District in 1974, Daniel J. Brown (1971–73), Darrell D. Henning (1975–76), and Robert D. Goodrich (appointed 1977).

Samuel Mummey, Jr., was in charge of the Sediment Unit until assigned to head the Iowa City Subdistrict in late 1970. Joel R. Schuetz transferred from the Nebraska District in 1971 to succeed him. Joel transferred to the Wyoming District in 1974 and was succeeded by Wilbur J. Matthes, Jr. Others on the staff included Gerald G. Plantz (transferred to the Utah District in 1970) and Shirley A. Dvorak (1974–). The Unit's laboratory facilities were housed in the Alberhasky Building, Wardway Mall, until the move to the new Federal Building in June 1974.

Elaine A. Gockel, as Administrative Assistant/Officer, was in charge of the Administrative Services Section throughout the period. Others were Sheryl A. Messenger (1968–70), Becky R. Fehl (1977), Kathleen A. Miller (1978–), and Gloria D. Stutts (1978–).

Funding and Personnel

Annual funding remained about the same from 1966 to 1971 with the Federal-State Cooperative (Coop) Program accounting for more than 60 percent of the funding. Nine State and local cooperators were providing funds. Coop funds in 1966 were about $350,000 and, through pay cost adjustments, grew to $385,000 in 1971. The District received a major increase in Federal matching funds in 1972, and for the first time in the program history, Coop funding exceeded $500,000. The program continued to grow with inflation until 1977, when with the addition of water-use funds, the Coop Program was almost $800,000. By 1979, total District funding was about 1.5 million, with 60 percent Coop, 15 percent OFA (Other Federal agencies), and 15 percent Federal funding. The U.S. Army Corps of Engineers was the major OFA, funding streamflow stations on the big rivers.

In 1966, Iowa had 42 people in the Surface Water and Ground Water Branches. With reorganization to a WRD District in 1967, the number of employees decreased to 39 in 1967, then to 31 in 1972, and remained in the low 30's through 1979.

Hydrologic Data Collection

Gaging at streamflow stations represented about 70 percent of the hydrologic data collection in Iowa. In 1966, the District operated 125 continuous streamflow stations and 127 crest-stage gages.

Annual peak discharges from the crest-stage gages were used in State flood-frequency analysis. The number of continuous streamflow stations peaked at 130 in 1970 and declined to about 115 in 1979.

Ground-water data collection was primarily from observation wells in counties where county studies were underway. Most of the water-quality data collection was part of national programs—Hydrologic Benchmark Network and NASQAN.

The District did have a large sediment program with sampling at many of the streamflow stations. The District sediment laboratory was once the largest and best equipped in WRD. The laboratory provided service to a number of other Districts and was the Division research laboratory for developing and testing new sediment instrumentation.

Interpretive Studies

Surface-water investigations made up almost two-thirds of the interpretive studies in Iowa during the 1966–79 period. Of 35 reports published, 22 were surface water. Seventeen publications (nine by Schwob, seven by Heinitz, and one by Carpenter) reported on floods that occurred during the 1960's and 1970's. Two of the most significant surface-water investigations were the studies by Lara on the effects of urban development on floodflow characteristics in the Des Moines area and his statewide flood-frequency analysis of streams in Iowa.

Twelve ground-water reports were published during the period. Hansen published five reports, mostly on the bedrock topography of the State. Steinhilber and Horick coauthored three reports, including the ground-water resources of Iowa and the Jordan aquifer of Iowa.

Slack published the only water-quality report during the period on the baseline water quality of Iowa's coal region.

KANSAS

By Charles W. Lane and Jesse M. McNellis

ORGANIZATION AND MANAGEMENT

Water Resources Division Branches Become a District

The Water Resources Division (WRD) in Kansas began in 1966 as separate branches and ended the year as a WRD District with the District Office in Lawrence on the campus of the University of Kansas. Edward J. Kennedy was District Engineer of the Surface Water Branch (SWB), which was located in Topeka. The Quality of Water Branch (QWB) with Arthur M. Díaz as Chemist-in-Charge was also in Topeka. Robert J. Dingman was District Geologist of the Ground Water Branch (GWB) in Lawrence. Reorganization to a WRD District caused some offices to close and personnel to be transferred.

A New District

The new District Office was headquartered in the old GWB office in Lindley Hall on the campus of the University of Kansas. The office was not large enough to accommodate the influx of personnel from SWB and QWB. Space was rented at the Hillcrest shopping area in a large building that also housed a bowling alley. This space was used until the summer of 1968 when the District moved from Lindley Hall and the "bowling alley" offices into Parker Hall on the west campus of the University of Kansas. Parker Hall was built by the University of Kansas Endowment Association and leased to the District. Parker Hall was named for H.N. Parker, an early-day WRD chemist from Kansas.

The District program was under the direction of District Chief Robert J. Dingman from 1966 to 1969. Charles W. Lane moved from Montana to Kansas and became District Chief in 1969 when Dingman moved to National Headquarters. Joseph S. Rosenshein moved from Florida in 1974 to replace Lane, who moved to the Regional Office in Denver; Rosenshein remained District Chief during the balance of the period.

Jack R. Carter was Assistant District Chief from 1965 to 1971. After that time, E. Robert Hedman as Chief of the Hydrologic Studies Section and Donald R. Albin as Chief of the Areal Investigation Section were principal assistants to the District Chief and had broad responsibilities in the development and operation of the District programs during much of the period. They were provided support in many District functions by senior discipline specialists with considerable experience in Kansas. These included Melvin L. Thompson (streamflow), Arthur M. Díaz (water quality), Calvin D. Albert (sediment transport), and Jesse M. McNellis (computer applications and data processing). Margaret E. Broeker and Eleanor L. Gulley provided administrative services throughout the period.

Several employees of the Kansas Geological Survey (KGS) were assigned on a permanent basis to the District ground-water program. Howard G. Downier and Charles K. Bane, senior members of the KGS, were long-time contributors to the program.

The branches and, therefore, the District had a history of strong and comprehensive cooperative programs with several agencies of the State of Kansas. Cooperating agencies included the State Geological Survey, the Water Resources Board, the State Department of Health, the State Board of Agriculture, and the State Department of Transportation. The City of Wichita had a long relationship of cooperative program activities, as did the U.S. Army Corps of Engineers and the Bureau of Reclamation.

Principal program functions in the District Office involved administrative duties, report processing for publication, data processing, and research in the areas of development of computer applications, stream-channel characteristics, surface water, sediment transport, water quality, ground water, ground-water recharge, and surface-water/ground-water relations.

Program activity in the new District generally followed the pattern of previous years; however, change was accelerating in application of multiple skills to projects and increasing use of computer facilities and applications to data processing and data analyses. The new WRD organization, although disturbing for some, made projects more comprehensive in all aspects.

Field Offices

Field offices were located in Colby, Hays, Garden City, Lawrence, Salina, Topeka, and Wichita during part or all of the period. Program and personnel assignments in the Subdistricts were determined by the ongoing activities in their respective areas. All Subdistricts participated in the basic-data programs of streamflow ground water, water quality, and sediment transport. Areal investigations in eastern and central Kansas were conducted from Lawrence, and those in western Kansas from Colby and Garden City. All Subdistricts received coordination and support from the District Office.

Colby Subdistrict

Edward D. Jenkins was in charge of the GWB Field Office in Colby prior to the reorganization and became Subdistrict Chief in 1966. The office was closed by 1973 and personnel moved to Garden City.

Hays Subdistrict

Charles W. Kennedy was the Engineering Technician-in-Charge in Hays at the time of reorganization, continuing until sometime in late 1967 or early 1968, when the office was closed. The staff transferred to Topeka or to Salina.

Garden City Subdistrict

Harold C. McGovern was Subdistrict Chief in Garden City from 1967 until 1973 when he moved to the District Office and became responsible for publications. Jenkins moved from Colby to be Subdistrict Chief when the Colby office closed. Jenkins retired in 1977 and Edwin D. Gutentag was Acting Subdistrict Chief. Gutentag transferred to Denver in 1978 and Hayes Grubb became Subdistrict Chief.

Lawrence Field Office

Glenn G. Quy was Chief of the Lawrence Field Office from its inception in 1978.

Salina Subdistrict

Kyle D. Medina was Subdistrict Chief in Salina from 1968 when the office opened until 1974 when he moved to the District office. Joe M. Alexander replaced Medina and was Subdistrict Chief in Salina from 1975 to the end of the period.

Wichita Subdistrict

Claude O. Geiger was Subdistrict Chief in Wichita from 1967 until 1973 when the office in Wichita was closed and he transferred out of the District.

Topeka Subdistrict

Lloyd E. Stulken was in charge immediately after reorganization. Gary D. Robinson was Subdistrict Chief in Topeka in 1967 and transferred out of the District in 1968. James D. Craig was in charge during part of 1969 until John L. Ebling arrived and became Subdistrict Chief. Ebling served as Subdistrict Chief until 1973 when the office was closed in Topeka and most personnel transferred to Lawrence.

PERSONNEL

A number of interesting statistics on personnel come to light when information contained in the yearly WRD Directory is examined. The number of people employed in the District ranged from 55 in 1974 to 94 in 1979. Full-time employees, however, ranged from 47 in 1974 to 49 in 1979. Thus, the percentage of full-time employees dropped from 85 percent to 52 percent in those years. Until the mid-1970's, full-time employees accounted for 70 percent or more of the personnel; then the percentage decreased. The percentage of employees with a grade of 12 or above ranged from 18 percent in 1967 to 39 percent in 1975, and then decreased to 20 percent in 1979. The grade of the District Chief rose from 13 to 14 in 1968 and to 15 in 1977. The first computer-related position was a card punch operator in 1971, followed by the first computer technician in 1975.

FUNDING

The Kansas District used cooperative (Coop) funding almost exclusively in the first 7 years after reorganization. (see funding graph). (Data for Federal program funding were not available for 1966–72.) The initial 4 years had increases in total Coop funding that corresponded with inflation, but the next 3 years had minimal increases. Total Coop funding continued to trail inflation until 1976. Consolidation of Subdistrict Offices and reassignment of personnel became necessary during the period owing to budget constraints and efforts to maintain program levels. Programs were pared down, offices were closed, and personnel were transferred so the District could remain viable. Times were hard, and "making do" was difficult.

Federally funded programs began significant growth in 1973 and continued growing through the rest of the period. Coop dollars stayed relatively flat until 1976 when growth in funding matched or slightly exceeded inflation. Coop growth continued to the end of the period.

HYDROLOGIC DATA

The hydrologic data-collection programs, basic to most District investigations and the core of long-term data-collection stations, remained stable during the period. Some change in the number and locations of data stations did occur to meet the needs of ongoing or planned investigations. The number of data stations operated during the middle of the period, in 1972, was typical for the program.

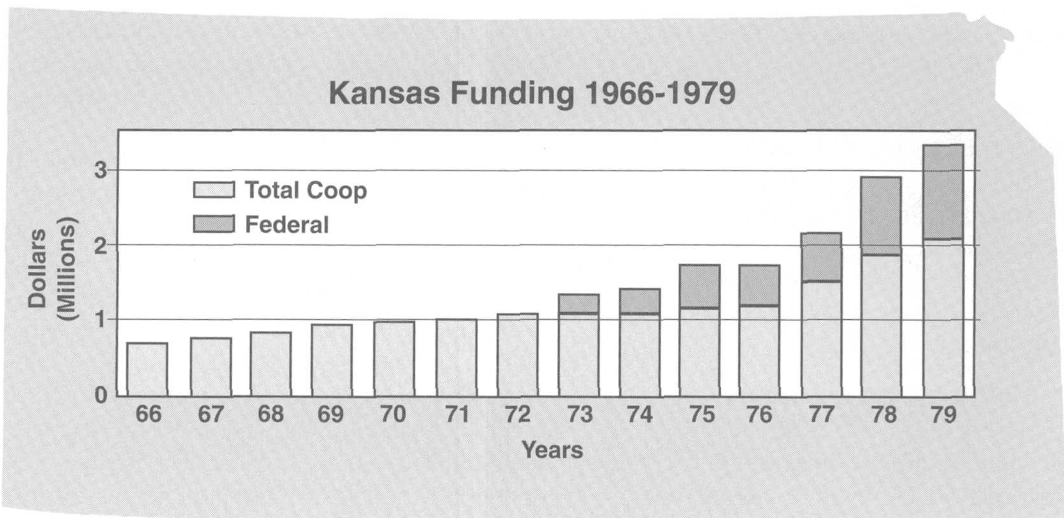
Streamflow stations of all types in 1972 totaled 299. These included 150 continuous-record stations, 147 of which measured discharge and stage; 3 measured stage only. Partial-record flow stations numbered 149, of which 126 measured peak flows only and 23 measured low flows only. Stage and contents were measured at 19 lake and reservoir stations.

Water-quality data were obtained at 65 of the surface-water stations, at 7 other stream sites where discharge and stage were measured at the time of sampling, and at 1 site where stage and discharge were not measured. The frequency of sampling at the sites included 2 measured continuously, 4 daily, 51 monthly, 4 partial record, and 5 periodically. Temperature data were collected at 59 stations. Ground-water-quality data were collected annually at about 200 wells selected to meet the data requirements of investigations in progress.

Suspended-sediment data were collected at 43 streamflow stations. Frequency of sampling included 6 daily, 16 monthly, and 21 periodically. Bed-material samples were obtained semiannually at 17 streamflow stations.

Water levels were measured in 1,956 wells throughout the State in 1972, most of them in the heavily pumped High Plains aquifer of western and central Kansas. Nineteen observation wells were measured continuously, 162 monthly, 513 quarterly, 74 semiannually, and 1,188 annually.

The District was unified in 1966, but water-level information continued to be published by the Kansas



Geological Survey (KGS) until 1976. For example, water-level records for 1966–70 and 1972–75 are found in two KGS publications. Streamflow and water-quality data were published annually by the USGS after 1966. Beginning in 1976, the USGS published annual data reports that included water levels, streamflow, and water-quality data.

HYDROLOGIC INVESTIGATIONS

Streamflow Characteristics

Investigations of streamflow characteristics of Kansas streams were an integral element of the SWB District program. These studies continued after District reorganization. Studies to refine information and develop new applications useful in the management of the resource were a significant part of the program. Active participants included Clarence V. Burns, Mark W. Busby, Lawton W. Furness, Thomas J. Irza, Ivan C. James, II, Paul R. Jordan, and David V. Maddy.

Typical studies of streamflow characteristics included determination of the accuracy equivalent of a 25-year record, and for other streams the accuracy equivalent of a 10-year record, to determine if certain gaging stations could be discontinued. Furness and Busby developed two methods of estimating base flow at ungaged sites, and James analyzed initial conditions of flood runoff in Wichita.

Burns reported on the temperature of the water in Kansas streams and also studied in-channel hydraulic geometry of streams in Kansas. Burns, Maddy, Jordan, and McNellis compiled and analyzed physical and climatic characteristics along Kansas streams.

Jordan and Irza developed relations for the magnitude and frequency of floods on unregulated streams. Jordan developed methods to determine transmission losses of high flows in western Kansas. Charles O. Peek and Jordan investigated the hydrology of streams in urban areas, particularly in and near Wichita and Topeka. Jordan developed statistical summaries of streamflow data for Kansas streams in the Arkansas River Basin and the Missouri River Basin.

Wade R. Osterkamp and E. Robert Hedman analyzed the variation of width and discharge for natural high-gradient stream channels. Henry R. (Bob) Hejl, Jr., developed a method for adjusting values of Manning's roughness coefficient for flooded urban areas. Osterkamp reported on fluvial sediment in the Arkansas River Basin.

Channel Geometry

The use of channel geometry measurements for investigation of streamflow characteristics was developed in the District, and a highly competent staff was assembled to work on the various projects. Hedman was joined by William M. Kastner, Hejl, and Osterkamp. District studies of channel geometry were coordinated and given a leadership role with ongoing research at the national level.

The studies began by trying to determine the relation of selected streamflow characteristics to the channel geometry of gaged perennial streams. These relations were then applied to determine the effectiveness of using channel size and shape for estimating flows at ungaged sites.

Hedman and Kastner determined mean annual runoff as related to channel geometry of selected Kansas streams and also reported on streamflow characteristics related to channel geometry of streams in the Missouri River Basin. Hedman, Kastner, and Hejl related active-channel geometry of streams in Kansas to selected streamflow characteristics. Osterkamp and Hedman developed discharge estimates in surface-mine areas by using channel geometry techniques.

Osterkamp was very active in developing sediment-transport and stream-discharge relations to channel geometry. He studied gradient, discharge, and particle-size relations of alluvial channels in Kansas, developed bed- and bank-sampling procedures to use at channel geometry sites, and determined the effect of channel sediment on width/discharge relationships. Reconnaissance techniques, based on measurable field characteristics of channel geometry, were developed to provide indirect measurements of runoff and sediment.

Areal Studies

Following the severe drought of the 1950's and the massive development of the High Plains aquifer for crop irrigation in semiarid western and central Kansas, most areal investigations were in these areas. Crop irrigation is not common in eastern Kansas owing to generally adequate precipitation during the growing season and low-yielding aquifers except in certain river valleys. However, water supplies from streams or ground water from bedrock sources for municipal, industrial, and domestic use in the eastern part of the State may be poor in quality and inadequate in volume. Therefore, water-resource investigations in eastern Kansas continued throughout the period.

Most areal investigations in the District during the early and middle parts of the period related to ground-water appraisals. County ground-water investigations were a mainstay of areal studies in the District. Studies were done from the District Office in Lawrence and from the Garden City and Colby offices. Some of the work cited was begun before District consolidation, but the reports noted were published during the period.

Many county reports were published by the KGS as part of the Cooperative Program. Reports on eastern Kansas geology and ground-water resources or on geohydrology included William L. Jungmann, Neosho County; Donald E. Miller, Miami County and Allen County; Charles K. Bayne and Walter H. Schoewe, Brown County; William J. Seevers, Linn County; Howard G. O'Connor, Johnson County and Montgomery County; John D. Winslow, Jefferson County; and J. Robert Ward, Nemaha County.

KGS publications in central Kansas included Donald W. Layton and Delbert W. Berry, Pratt County; Jesse M. McNellis, Rush County; Bayne and J. Robert Ward, Rice County; Bayne, Paul C. Franks, and William Ives, Ellsworth County.

Hydrologic atlases in eastern Kansas published by USGS included Jungmann and Charles C. Williams, Labette County; Bayne, Doniphan County; and Ward, Atchison County.

The offices in Garden City and Colby were very active in studying western Kansas. Notable workers in the western part of the State included Walter R. Meyer, Edwin D. Gutentag, David H. Lobmeyer, Lloyd E. Stullken, Harold E. McGovern, Steven E. Slagle, Stuart W. Fader, Curtis G. Sauer, Eddie Jenkins, Marilyn E. Pabst, Richard H. Pearl, Kathryn M. Keene, Robert S. Roberts, Thomas J. McClain, and Edward C. Weakly. These people produced thousands of records covering well inventory, water-level measurements, water-quality analyses, test-well and test-hole logs, and pumping tests. All these data were assimilated or used in one way or another in the comprehensive Regional Aquifer-System Analysis (RASA) studies, which began toward the end of the period of this history. They also wrote several reports published by the USGS, the KGS, or other cooperating agency outlets.

The USGS published hydrologic atlases for the individual counties of Kearny, Finney, Haskell, Hamilton, and Gray. Hydrologic atlases also covered northwestern Kansas and the combined counties of Gove, Logan, and Wallace. Finney County work was described in a Water-Supply Paper. Five Water-Resources Investigations Reports and 16 Open-File Reports were prepared.

A number of reports consolidated data and findings from previous and new work. These included Gutentag–percent change saturated thickness, west-central Kansas; Marilyn E. Pabst and Jenkins–water-level changes in southwestern Kansas and water-level changes in northwestern Kansas; Kathryn M. Keene, Richard H. Pearl, and Pabst–Cheyenne, Decatur, Rawlins, Sheridan, Sherman, and Thomas Counties; Thomas J. McClain, Jenkins, Keene, and Pabst–Gove, Logan, and Wallace Counties; Richard H. Pearl, Robert S. Roberts, Keene, and McClain–water resources, northwestern Kansas.

During the latter part of the period, the scope of the areal investigations program was broadened. Studies were begun of the saline water resources of the State, with strong emphasis on the Dakota Formation of central and western Kansas. The deep carbonate aquifers of southeastern Kansas continued to receive strong support and were included within the scope of the High Plains RASA. Digital models of aquifer systems were developed as an aid to ongoing investigations, and numerous studies were made to develop new techniques or improve older ones in support of ongoing work.

Other Studies

Keene and Bayne studied ground water from Lower Cretaceous rocks in Kansas. Lobmeyer and Weakly reported on the Dakota Formation in Hodgeman and Ford Counties.

Tony Gogel began work on the discharge from Permian rocks to major stream/aquifer systems in central Kansas. He also began work on test wells in the Arbuckle Formation of central and eastern Kansas.

Hugh E. Bevans developed a procedure for predicting concentrations of dissolved solids and sulfate in streams draining areas strip-mined for coal. Bevans and Díaz summarized water-quality data in the area of coal mines in southeastern Kansas.

Robert C. Prill and Meyer studied the movement of moisture in the unsaturated zone in southwestern Kansas using neutron-probe moisture measurements.

Jay B. Gillespie, Kenneth L. Lindskov, Donald W. Green, and Slagle studied artificial ground-water recharge at several sites along Wet Walnut Creek in Rush County. Gillespie and Gerald D. Hargadine did additional recharge studies in Scott and Kearny Counties.

Robert B. Leonard did a detailed study of changes in the chemical quality of ground water in the Cedar Bluff Irrigation District. He also did a comprehensive investigation of the chemical quality of water in the Walnut River Basin in south-central Kansas. Leonard and Melvin K. Kleinschmidt reported on saline water in the Little Arkansas River Basin.

Stuart W. Fader investigated the shape of the truncated cone of depression in the vicinity of an infinite well field. He also investigated land subsidence caused by dissolution of salt near four oil and gas wells in central Kansas. He reported on ground water along the Republican River in Cloud, Jewell, and Republic Counties and on ground water in the Kansas River Valley from Junction City to Kansas City.

Kastner applied statistical techniques to estimate ground-water withdrawals in northwestern Kansas. Claud H. Baker evaluated methods for estimating ground-water withdrawals in western Kansas.

David B. Richards and Timothy W. Dunaway compiled massive amounts of data for modeling the Little Arkansas River Basin.

Calvin D. Albert compiled the total sediment discharge of selected Kansas streams. Albert also reported on the fluvial sediment characteristics of the Kansas River at Wamego.

Lloyd D. Hauth and William J. Carswell documented the Kansas City, Kans., and Missouri floods of September 12–13, 1977.

Osterkamp, McNellis, and Jordan developed guidelines for the use of structural versus regression analysis in geomorphic studies, and Osterkamp applied invariant power functions to fluvial morphology.

COMPUTER ACQUISITIONS AND APPLICATIONS

Jesse M. McNellis began to develop techniques to store and analyze ground-water data, including ground-water chemical analyses, prior to District reorganization. He was joined by Charles O. Morgan, who transferred to the District from Louisiana. The District used the computer on the campus of Kansas University through the cooperative program with KGS to develop a number of computer programs. The University computer was used exclusively until 1969 or 1970 when the District acquired a Data 100 data station and began to use the computer at Headquarters as well.

McNellis, Morgan, and a student, Brent H. Lowell, developed many computer programs to facilitate collection, storage, and analyses of geologic, hydrologic, and geographic data. Very early it became apparent that checking data to ensure accuracy is the important part of using a computer.

Programs to make tables of water-quality data, well-inventory data, and stratigraphic-log data were written. Water-quality analyses were presented with Piper, Stiff, and Ropes diagrams. The USGS method of locating wells by township, range, and section was used in the table programs, but those locations were converted to latitude and longitude for mapping. Map projections were incorporated into computer programs, and locations of wells, springs, gaging stations, and other locations of interest could be plotted showing specific data items.

Digital computer techniques developed at Headquarters were established in the District for the storage and analysis of the vast quantities of data acquired in surface-water and water-quality investigations. The Data 100 made the turnaround from District to Headquarters better and more realistic. The water-quality analysis programs written in Kansas worked for water chemistry regardless of the source of the data. Magnetic tapes of all surface-water historical data were acquired from Headquarters, and programs were developed to analyze the accuracy of the information. Not surprisingly, errors were discovered and corrected.

Computer applications were developed to do most of the fiscal accounting in the District by project, cooperator, dollars, dates, personnel, and other factors. The local accounting reports were timely and highly valued by the District administration. Local reports were used by the District administration to be up-to-date on fiscal matters and also to check and make corrections on reports from Headquarters.

McNellis was assigned by WRD in March of 1976 to develop a body of information, a sort of feasibility study, on computer preferences from offices around the country. The information was used by WRD in the decision to acquire prototype minicomputers. Stan Longwill from National Headquarters, Doug Posson from New Mexico, and McNellis were charged with developing specifications for the WRD minicomputer experiment. The decision was made to acquire three minicomputers–one for Kansas, one for New Mexico, and one in Research at Reston. Harris Computer won the competition for minicomputers and a Harris was delivered to the Kansas District at Thanksgiving in 1978. Training of District personnel began in January 1979 in the library. All District personnel were given the initial training.

The first year of operation of the Harris minicomputers, 1979, was closely monitored across the Division. Kansas and New Mexico had comprehensive programs, and the Research Office in Reston was involved in numerous projects. Longwill, Posson, and McNellis were assigned to do another feasibility study on the use of minicomputers in a distributed information processing environment.

Information and data on usage, applications, training, costs, and potential savings at the Kansas and New Mexico Districts and at Reston were delineated in the study. This paved the way for the USGS to enter the computer age! The USGS did not become highly computerized until after the period under discussion, but the PR1ME minicomputers arrived in 1982 and were a direct result of the pioneering efforts of personnel at the three Harris locations.

TIDBITS

The Kansas District hosted a joint computer conference with the Oklahoma District at Wichita, Kans., in March 1978. Most employees from each District attended, and many participated in workshops and made presentations on subjects or activities of mutual interest. Regional and National Headquarters chiefs attended and participated. This conference was different from many because the complete complement of District personnel prepared for their involvement and made an important contribution to its success.

During the budget constraints of the mid-1970's, rumors about layoffs, transfers, office closings, and the like were common coffee break discussions. Several employees developed a statement of support for the District. The statement explained the monetary problem and asked each employee to offer to take leave without pay if that would help the situation in any way. Almost all employees did sign that offer. Apparently, there is no way such action could be driven from the bottom up. However, this illustrates how special people do special things and reflects positively on the Kansas District and on WRD.

The source of information used for this Kansas District section of WRD history was U.S. Geological Survey Open-File Report 95–120, compiled by Donna J. Roberts and Lanna J. Combs. It is entitled "Water-Resources Reports Prepared by or in Cooperation with the U.S. Geological Survey, Kansas, 1886–1994."

LOUISIANA

By John J. Musser and Michael W. Gaydos

Organization and Management

In 1966, the three Branch districts that had operated independent programs for many years were consolidated into the Louisiana WRD District. Rex R. Meyer, former Chief of the Ground-Water program, became the first District Chief. Mack R. Stewart, former Chief of the Surface-Water program, was designated an Assistant District Chief, as was Russell L. McAvoy, former Chief of the Quality of Water program. Stewart was basically responsible for most interpretive studies, and McAvoy for data-collection programs; but in practice, personnel of the District often operated informally under the former Branch alignments.

In 1966, the District Office was located in Baton Rouge in the Carrollton Building at 6554 Florida Boulevard. Most of the Baton Rouge personnel were assigned there; some personnel for the ground-water program were on the campus of Louisiana State University until the fall of 1967, when they moved to a new office on Florida Boulevard. By 1968, all Baton Rouge personnel were operating from the Florida Boulevard site and continued to do so through 1992.

In 1967, Mack Stewart was seriously injured in an automobile accident and never returned to duty. (Stewart's accident had a long-term impact on District personnel; renewed emphasis on safety programs was implemented.) Some sections were reorganized, and the basic organizational structure put into operation in 1968 was followed through 1979. McAvoy became the only Assistant Chief with authority to supervise all District programs. In 1970 he transferred to Salt Lake City, Utah, to become Chief of the first WRD Central Water Quality Laboratory.

In 1971, the leadership of the District changed. Meyer transferred to the Mid-Continent Regional Headquarters in St. Louis, Mo. A.N. "Abie" Cameron became the second District Chief (retired in 1981), and John J. Musser (retired 1989) became the District's first Associate Chief. Both transferred from WRD Headquarters in Washington, D.C., and served in Louisiana in these positions for the remainder of their careers.

The Louisiana District was in the Mid-Continent Region, headquartered in St. Louis, Mo. (1966–72), and in the Central Region (1972–79).

Sections in Baton Rouge, 1968–79

Data Collection Section—Joe H. Holm, Supervisor, Routine data collection in southern Louisiana and data report compilation.
Data Studies Section—Milton F. Cook, Supervisor, Special data studies, the District's water-quality laboratory, and some multidiscipline projects.
Special Studies Section—Vernon B. Sauer, Supervisor (transferred in 1970 to Washington Headquarters); succeeded by Larry A. Martens (transferred in 1974 to Illinois District); succeeded by Braxtel L. Neely, Jr. (transferred in 1978 to Tennessee District), Surface-water studies, including hydraulics, time-of-travel, assimilation capacity, and roughness coefficients.
Appraisal Section—George T. Cardwell, Supervisor, Ground-water studies in southern Louisiana, drilling program, water-use reports. Cardwell also served as Reports Specialist for many years.
Administrative Section—Ada J. Rich, Supervisor, Administrative support for all District activities.
Special Field Unit—J. Norman Payne, Research Geologist (retired in 1973), Reported to Regional Hydrologist on lithofacies studies in Arkansas and Louisiana.
Field Offices, 1966–79:

Alexandria Subdistrict–James E. Rogers, Supervisor, Located in the U.S. Department of Agriculture complex on Government Street; ground-water collection and studies in central and northern Louisiana; some surface-water data collection.

Jonesboro Subdistrict–Rufus P. Smith, Supervisor, Located in the Federal Building on Polk Avenue; surface-water data collection in northern Louisiana.

Many Subdistrict–Albert J. Heinitz, Supervisor (transferred in 1968 to Iowa District), Surface water data collection in central Louisiana; office was closed permanently in 1968 and personnel and functions transferred to the Alexandria and Jonesboro offices.

Lake Charles Field Headquarters—Alfred H. Harder, Supervisor (transferred in 1967 to Idaho District) – Ground-water data collection and project office for Chicot aquifer study in southwestern Louisiana; office was closed in 1968 and personnel and functions transferred to Baton Rouge; office was reopened in 1973 (Milton Cook supervised from Baton Rouge) for ground-water data collection and limited surface-water data collection.

Funding

District funding varied throughout the period with a continued growth through Fiscal Year 1977. Federal-State Cooperative Program funds, earlier the major source of funding, were about 50 to 60 percent of the District budget in the last 5 years of the period. Much of the growth in the OFA program during 1975–79 is a result of the District acquiring significantly more work from the U.S. Army Corps of Engineers following the major Mississippi River flood in 1973. Funding for the period is shown in the following table.

Louisiana District funding, 1966–79

[Funding information for 1966 to 1972 was no longer available in District records or WRD archives]

Year	Federal	Other Federal agencies	Cooperative program	Total
1966	25	28	954	1,007
1973	37	400	1,400	1,837
1974	61	651	1,765	2,477
1975	72	1,068	1,607	2,747
1976	69	1,458	1,590	3,117
1977	78	1,419	2,511	4,008
1978	114	1,295	1,766	3,175
1979	192	1,419	1,946	3,557

Hydrologic Data Collection

Hydrologic data networks were modified throughout the period (see "Data-collection" table). Most of the growth in data-collection activities was a result of the expansion of work done for the U.S. Army Corps of Engineers in sediment, routine water quality, elutriate studies, and water-quality monitoring in coastal areas.

Data-collection networks

Year	Surface water, continuous record	Water quality, daily	Water quality, continuous monitor	Monthly and quarterly	Ground-water observation wells
1967	97	5	8	6	Not available
1970	81	--	16	29	Not available
1973	69	--	10	27	Not available
1977	72	--	41	66	696

Louisiana Committee for Coordination of Water Data

A major effort to coordinate the data-collection activities of water agencies operating in Louisiana resulted from some unfounded public criticism concerning "duplication" of effort by Federal and State agencies involved in data collection. Throughout the 1970's, Federal and State water agencies in Louisiana met periodically as an informal committee to review the need for water data (especially water-quality data) and to discuss coordination for collecting these data. The approach copied the national effort of WRD Headquarters to coordinate data collection among the water agencies. Ernest J. Taylor (Louisiana Department of Public Works) and John J. Musser and Max J. Forbes, Jr., (Louisiana District Office) worked to establish and maintain communication on many programs with interested agencies, including the Corps of Engineers, U.S. Soil Conservation Service, National Weather Service, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, Louisiana Office of Highways, Louisiana Stream Control Commission (later the Department of Environmental Quality), and the Louisiana Geological Survey.

District Activities in the 1970's

Among the activities that A.N. Cameron stressed to move the District forward were:

1. Service to all who needed the USGS—the general public, government agencies, industries, companies, and academia. District personnel were expected to provide data and consultation for all requests. This cooperative attitude enhanced the image and programs of the District.
2. A monthly release prepared to describe the water situation in Louisiana. This brief monthly newsletter, begun in 1972, was sent to all interested in Louisiana's water resources (Michael W. Gaydos, editor).
3. Emphasis on the timely release of the annual data report—for 8 consecutive years (1972–79), Louisiana was the first District in the country to publish its basic water records. In several years, this report consisted of two to three volumes totaling more than 1,000 pages.
4. Establishment of the Student Cooperative Program—to overcome Federal hiring restrictions (and "get the job done"), college students split their year into working for the District and attending classes. Also, many field assistants were hired temporarily. Basic hydrologic training was a constant activity in the District.

The key event of the 1970's was the Mississippi River flood of 1973. District personnel worked long hours during that spring to document streamflow and water quality in the Lower Mississippi River Basin (Chin, 1975). The Corps of Engineers, impressed with the District's work and attitude, offered the District many cooperative programs for years afterward.

In 1973, the Corps transferred its sedimentation laboratory in New Orleans to the Louisiana District in Baton Rouge, greatly expanding the District's sediment operation. The District also started operating a coastal network of water-quality stations funded by the Corps. From 1974 onward, the District conducted studies of the dredging of streams and canals, to inform the Corps of the effects of leaching of dredged spoils on water quality. Beginning in 1976, the District (with Corps funding) monitored the movement of saltwater in the Lower Mississippi River during low flow to protect the water supply of New Orleans and other communities.

Interpretive Studies

Many interpretive studies were conducted by Louisiana personnel from 1966 to 1979. Reports on the results of these studies were published mainly by the State of Louisiana as part of the Cooperative Program. Citations for these reports can be found in Collier and Adams (1996).

Multidiscipline Investigations

Rex Meyer constantly promoted multidiscipline studies in river basins and parishes (counties), and the study teams reflected the interdisciplinary character inherent in the reorganization. Among these studies was the Lake Pontchartrain project, which began in 1964 and sought auxiliary water sources for the city of New Orleans. Key elements in the project were test drilling to depth of 3,000 feet or more beneath Lake Pontchartrain and assess potential surface-water supplies needed for the rapidly developing northeastern part of New Orleans, where ground water was threatened by saltwater intrusion. The final report by George T. Cardwell, Max J. Forbes, Jr., and Michael W. Gaydos in 1967 identified adequate sources of both ground and surface water.

In southeastern Louisiana, Michael D. Winner, Jr., and Larry D. Fayard conducted an interdisciplinary study of the water resources of the Amite-Tickfaw River Basins (1972), and Dale J. Nyman and Fayard reported on the water resources of Tangipahoa and Tchefuncte River Basins (1976 and 1978).

In central Louisiana, Gaydos, James E. Rogers and Rufus P. Smith studied and described the water resources of the Little River Basin (Water-Supply Paper, 1973) where declining water levels in the aquifers used in the region threatened supplies and where oil-field brine disposal caused pollution of surface-water sources. Winner, Forbes, and Woodie L. Broussard reported on Pointe Coupé Parish (1968). This latter report included a survey of two oxbow lakes, the first lake studies done by the WRD in Louisiana.

In northern Louisiana, multidiscipline studies were conducted in two parishes: Union Parish by John L. Snider, Anthony J. Calandro, and William J. Shampine (1972) and Ouachita Parish by Rogers, Calandro, and Gaydos (1972).

Streamflow Investigations

From 1966 to 1979, a number of studies can be grouped as analyses of flood hydraulics and hydrology, with emphasis on flood magnitude and frequency in both large and small basins. The goal of these studies was often to aid in the design of highway bridges and culverts. Many of the products were open-file reports or letter reports to the Louisiana Department of Transportation and Development and were prepared at various times by Vernon B. Sauer, Larry A. Martens, Braxtel L. Neely, Jr., Fred N. Lee, and Alfred S. Lowe. Of special note are (1) the compilation on the magnitude and frequency of floods in Louisiana (3d edition) by Neely (1976), (2) the compilation of magnitude and frequency of floods in small watersheds by Lowe (1979), and (3) several reports on rainfall-runoff relations and unit hydrographs by Sauer from 1967 to 1971.

A separate group of flood studies dealt with the evaluation of the roughness coefficient in equations for calculating floodflow in heavily vegetated flood plains. Under the general direction of Verne Schneider of the WRD research staff, George J. Arcement, Billy Colson, and Charles Ming documented backwater-flooding conditions at 20 bridge sites in Louisiana, Mississippi, and Alabama and published the results in a series of Hydrologic Investigations Atlases (1978, 1979).

Several major floods on the lower Pearl River from 1976 to 1983 led to a preliminary study of flood-routing by Braxtel Neely and later to intensive studies by J. Josh Gilbert and Gregg S. Wiche, using digital flow models to predict the impact on the Slidell area. Congressmen Henson Moore and Robert Livingston strongly supported all Pearl River flood studies.

Another group of studies was aimed at providing flood-hazard information for the general public. Populated areas that were prone to flooding were identified by using existing flood data and were outlined on topographic maps. The major report from this effort was Alfred S. Lowe's compilation of 15 "flood-prone area" topographic maps for East Baton Rouge Parish (1975).

In the realm of general streamflow investigations, time-of-travel studies were intensive manpower efforts in both the field and the office. These studies were aimed at forecasting the traveltime and dispersion of a pollutant in a stream by using dye-tracing techniques. The first of these studies in Louisiana was conducted in 1965 in the Mississippi River under the direction of Mack R. Stewart. Following Stewart's report (1967), several additional studies of the Mississippi River were conducted at various flow regimes and were documented by Larry A. Martens (1974) and Anthony J. Calandro (1976, 1977). An additional report compiling time-of travel studies for many smaller Louisiana streams was prepared by Calandro (1978).

Low flow of streams also received attention because low-flow characteristics are important in pollution studies. Max J. Forbes, Jr., reported on low-flow in the Sabine River Basin (1974) and updated L.V. Page's report (1963) by using Log-Pearson computer analysis to compile the low-flow characteristics of Louisiana's streams (1980).

The Louisiana District participated in the National Eutrophication Survey by assembling streamflow data through regression analysis for about 60 miscellaneous stream sites chosen by the U.S. Environmental Protection Agency. Anthony J. Calandro prepared the letter report to the USEPA (1975).

Calandro also analyzed the temperature data collected for many years from Louisiana's streams. His report (1972) describes the range, variability, and time distribution of temperature for many stream-gaging sites.

Ground-Water Investigations

The Site Studies Drilling Program expanded greatly in the late 1960's under the leadership of Rex Meyer and continued until the early 1980's when the reorganization of State agencies caused its demise. This drilling program was a major component of the District's cooperative program with the Louisiana Department of Public Works, which wanted to provide planning information to small communities wishing to install a water system. Because Louisiana lacks the outcrops needed to interpret its subsurface geology, many test holes were drilled to define the geology and the movement and quality of ground water. Many of the deeper holes were drilled by the State, and some shallower holes were drilled with an auger of the Louisiana District. James E. Rogers served as Chief of the drilling program, with considerable support from George T. Cardwell, John L. Snider, Robert L. Hosman, Charles D. Whiteman, Don C. Dials, and numerous technicians. Several small, site-specific technical reports were published by the State, and the data generated by this program were used in many other ground-water investigations.

Throughout Louisiana, the pumpage of ground water has resulted in significant declines in water levels. In coastal areas, pumpage has also enhanced the encroachment of saltwater in aquifers toward pumping centers, resulting degraded ground water. These pumpage problems caused special concern in southwestern Louisiana, where the Chicot aquifer provided the largest amount of ground-water withdrawals (for rice irrigation) of any aquifer in the State and impacted the industrial area at Lake Charles. The State published two reports with data and analysis of these problems, one by Albert H. Harder, Chabot Kilburn, Harry M. Whitman, and Stanley M. Rogers (1967) and a second by Allen L. Zack (1971). One of the tools used in the analysis was a physical analog model that simulated ground-water flow in the Chicot aquifer; this model was inadvertently destroyed in 1973.

Dale J. Nyman continued the study of the Chicot aquifer through the 1970's with the support of technicians in the Lake Charles Field Office. By the late 1970's, Nyman had developed a crude digital model to assist in his analysis. Several reports on this area were published in the 1980's.

Merrick S. Whitfield, Sr., studied the geohydrology of the Evangeline and Jasper aquifers in southwestern Louisiana in the late 1960's and early 1970's; his conclusions were published in 1975.

Studies of the ground-water resources in the industrial corridor between Baton Rouge and New Orleans began in 1958. Withdrawals from these aquifers caused water-level declines and saltwater encroachment. The study of the ground-water resources of the greater New Orleans area by James R. Rollo was published in 1966 and was followed by Rollo's documentation of saltwater encroachment in the Baton Rouge area (1969). Charles D. Whiteman continued the study of the Baton Rouge aquifer system through the 1970's and wrote a report on saltwater encroachment (1979) and another on land subsidence owing to withdrawals near industrial complexes in northern Baton Rouge (1980). By the late 1970's, Whiteman was developing 2-dimensional and 3-dimensional flow models for ground water in several of the sands of the Baton Rouge aquifer system.

Other reports on ground water in the industrial corridor included the Plaquemines-White Castle area by Whiteman (1972), the Norco area by Robert L.

Hosman (1972), and the Gramercy area by Don C. Dial and Chabot Kilburn (1980).

Harvey L. Case completed the documentation of parish (county) ground-water studies in extreme eastern Louisiana with his report on Washington Parish (1979).

For central Louisiana, James R. Marie wrote a report on the ground-water resources of Avoyelles Parish (1971). In the 1970's, James E. Rogers evaluated the ground-water resources in the Kisatchi National Forest as a possible new source of water for the expanding city of Alexandria (report in 1981).

Several interstate geohydrologic studies included information on the aquifer systems of northern Louisiana. Robert L. Hosman and others described and evaluated the Tertiary aquifers in the Mississippi Embayment (Professional Paper, 1968). J. Norman Payne published four research papers from 1968 to 1975 (Professional Paper series) on the geohydrologic significance of lithofacies of the Claiborne Group of aquifers in the lower Mississippi Embayment.

For the Red River Valley of northwestern Louisiana, the Corps of Engineers began studies in 1968 on the impact of building five navigation locks and dams along the Red River. The WRD was asked to predict the change in shallow ground-water level owing to the pool that would form behind each dam. The initial investigations to establish the preconstruction ground-water conditions in the shallow aquifer were conducted by the Arkansas WRD District. Subsequently, personnel from Arkansas developed 2-dimensional ground-water digital flow models for each of the navigation pools and used these models to predict changes in the post-construction ground-water regime. In 1975, the Louisiana District assumed project leadership, taking over all data collection and sharing with Arkansas the modeling runs and evaluations. Thomas H. Sanford, Jr., and James E. Rogers were the principal investigators for the Louisiana District. The early reports were prepared by A.H. Ludwig and others of the Arkansas District as Administrative Releases to the Corps of Engineers; they were released as open-file reports in 1979. Merrick S. Whitfield, Jr., of the Louisiana District compiled and evaluated data on the chemical character of the ground water (Water-Resources Investigation, 1980). Other reports by Louisiana personnel were published after 1980.

Of concern in the growing town of Ruston in northern Louisiana were the declining water levels of the Sparta aquifer. Thomas H. Sanford, Jr., investigated the Sparta sands of the area and reported on possible alternate supplies (1973). Sanford also evaluated the ground-water resources of nearby Morehouse Parish (1972).

Whitfield evaluated the availability of potable ground water in the Winnsboro area (1973) where saline water was often encountered during well drilling. Whitfield also evaluated the water supply of the extensive Mississippi River alluvial aquifer of northeastern Louisiana, where anomalous concentrations of iron and chloride exist and water is hard (1975).

In 1975, the U.S. Department of Energy began to study the suitability of several salt domes in Louisiana as repositories for the storage of radioactive wastes. The Louisiana District was asked to describe the general hydrology of the Northern Louisiana Salt Dome Basin (with special attention to ground water) and the detailed hydrology at several candidate domes. Robert L. Hosman prepared a report on the basin (Water-Resources Investigation Report, 1978) and Gary N. Ryals, who succeeded Hosman as Project Chief, continued investigating various aquifer systems near the salt domes into the 1980's.

John L. Snider began documenting the hydrology of areas underlain by lignite deposits in northwestern Louisiana in 1977, with special attention to the ground-water aquifers that would be destroyed or disrupted owing to future strip mining. His investigation continued into the 1980's.

Quality-of-Water Investigations

Studies of the lower Mississippi River, and especially its water quality, were significant activities in the District program. The report by Duane E. Everett (1971) was a milestone in describing the hydrology and the physical, chemical, and sediment characteristics of the river. He also included comprehensive sections of time-of-travel results and the assimilation of wastes, which were principal topics in District studies at that time. Through the 1970's, Everett, Wells, Gaydos, Fayard, and Demas continued investigations of these topics for the Mississippi River and adjacent wetlands and also studied trace metals, organic compounds, saltwater intrusion from the Gulf of Mexico, and benthic invertebrates. Frank C. Wells documented the results of all this activity in another milestone report (1980).

The capacity of streams to assimilate wastes downstream from towns received attention. Reports on dissolved oxygen, bacterial concentrations, and other aspects of assimilation capacity were prepared for the Pearl River near Bogalusa by Everett, Fayard, and Wells (1973) and for the Red River near Shreveport and Alexandria by Robert F. Martien (1978).

The historic flood of 1973 on the Mississippi River had a significant impact on its largest distributary, the Atchafalaya River. Frank C. Wells and Charles R. Demas documented the hydrology and water quality of this distributary, including the impact of 1974 Hurricane Carmen in a report (1977) in cooperation with the Corps of Engineers and the U.S. Fish and Wildlife Service.

In 1974, the Sabine River Compact Administration (for Louisiana and Texas) developed a water-quality management.plan for the Sabine River Basin. Frank C. Wells described the quality of surface and ground water for the Louisiana portion in a report to the Administration (1973).

Sediment transport and deposition had a detrimental impact in the 1960's on water supply for towns along Bayou Lafourche, a former distributary of the Mississippi River. W. Harry Doyle, Jr., Russell L. McAvoy, and Larry D. Fayard conducted a special study, with Doyle writing the final report (Water-Supply Paper, 1972).

Nearly all hydrologic investigations were concluded successfully in the 1970's, but in one instance, the District's considerable effort ended in a "failed project." In 1974–75, personnel "instrumented" the intermittent streams of the Lake Verret basin to collect streamflow, water-quality, and sediment data and thereby study the impact on Lake Verret of runoff from sugar-cane farming. Funding came from the U.S. Soil Conservation Service, which abruptly terminated the program in 1976 owing to changes in research priorities. No report was prepared.

Vignettes

In 1971, Bill Shampine talked John Musser (the Associate Chief) into playing Santa Claus for a class of preschoolers. Musser was somewhat thinner in those days and during his performance had considerable trouble with the pillows stuffed inside his red suit. He managed to "pull it off" to the delight of 30 children.

The "Water Boys" was a fast-pitch softball team composed of Baton Rouge personnel and a few relatives. The team competed in the Baton Rouge Industrial League in the late 1970's, winning the league championship in 1977 and making the playoffs in 1978. Mr. Cameron was very proud of this team.

REFERENCES

For more information on this period of WRD history in Louisiana, these documents are available to the public.

Collier, D.L., and Adams, P.A., eds., 1996, Water resources publications of the Louisiana District of the U.S. Geological Survey, 1904-96: Louisiana Department of Transportation and Development Water Resources Special Report no. 12, 155 p.

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MISSOURI

By John Skelton and James E. Bowie

INTRODUCTION

In January 1966, Missouri WRD surface-water, ground-water, and quality-of-water programs were considered separate entities. In July of that year, the programs were merged (with misgivings by some personnel) into a WRD District headquartered at 103 W. 10th Street in Rolla. Under the leadership of Anthony Homyk, Jr., District Chief (succeeded in 1977 by Donald L. Coffin); Edward J. Harvey, District Geologist; James E. Bowie, Assistant District Chief (Surface Water); and Horace G. Jeffery, District Chemist, it soon become apparent that the "one-water" concept was fundamentally and technically sound and efficient, and that engineers, geologists, and water-quality personnel could actually work in relative harmony under one roof. This was a new concept for many in the District and represented a basic change in operating procedures and interactions with cooperators.

In 1975, the District Office was moved to 1400 Independence Road in Rolla, a new building that also housed the National Mapping Division's

Mid-Continent Regional Office and the Mid-Continent Personnel Office. For the first time, all USGS personnel in Rolla were working in one location; this greatly facilitated interdivisional cooperation and understanding and would lead to many joint projects.

Principal WRD offices other than Rolla were a Subdistrict Office in St. Louis, Donald W. Spencer, Engineer-in-Charge, and a Field Headquarters in Independence where Howard W. "Woody" Ollar was Technician-in-Charge until his death in 1972. Michael C. Moody and Charles E. Watts continued operation of the Independence office until the arrival of Dale W. Blevins in 1981. A one-person Field Office also was operated at Bethany by Bob L. Shepard from 1966 until his retirement in 1973, when the office was closed. Ground-water and water-quality data collection and analyses activities were assimilated gradually into the St. Louis and Independence offices during 1966–79 as project activity increased in their areas.

FUNDING AND PERSONNEL

As shown in the following table, total District funding increased about threefold during the period.

Missouri District funds, in thousands of dollars

Funding source	1966	1980
Cooperative Program	320.9	684.5
Other Federal agencies and Federal funding	207.7	1,143.0
Federal Power Commission	1.8	--
Total	530.4	1,827.5

Although a high rate of inflation in the mid- to late 1970's had an effect, the funding increase primarily reflects a significant increase in the numbers and technical scope of interpretive studies done by the District during those years.

The District was involved only in surface-water hydrology until 1963–65, when ground-water and water-quality personnel were added to the staff. After these additions, staff numbers remained relatively stable during 1966–79. Of the 35–40 permanent employees, about 12 percent were clerical and support personnel, and the rest were about equally divided between the technician and hydrologist job classification series.

PRINCIPAL PROGRAMS

The principal State cooperator throughout the period for statewide water-resources investigations and a network of long-term streamflow and springflow stations was the Missouri Geological Survey and Water Resources (now Department of Natural Resources, Division of Geology and Land Survey). Other State agencies participating in cooperative programs with the District were the Department of Highways and Transportation, the Conservation Commission, and the Water Pollution Control Board.

Five Districts of the U.S. Army Corps of Engineers—St. Louis, Kansas City, Little Rock, Rock Island, and Tulsa—provided funding for gaging-station operation and collection of data to support their project operations in the State. Other organizations contributing funding for water-resources data collection and analysis were the U.S. Soil Conservation Service, University of Missouri, National Park Service, and Little River Drainage District.

Hydrologic Data Collection

The primary network of long-term continuous-record streamflow stations funded by the Missouri Geological Survey and Water Resources and the U.S. Army Corps of Engineers remained at about 110 stations during 1966–79, but the total number of stations varied to meet data needs for special studies. The numbers ranged from 136 in 1966 to a maximum of 168 in 1970 and declined to about 125 by 1979. Water-quality stations numbered 15 in 1966, increased to 114 by 1974, and decreased to about 32 by 1979. Ground-water data were collected in project areas by the District; statewide monitoring of ground-water conditions was done by Missouri Geological Survey and Water Resources. A statewide network of several hundred low-flow and crest-stage partial-record stations was maintained to provide basic hydrologic data. These partial-record stations were evaluated annually, and the network was modified to meet changing needs statewide and specific project requirements.

In the mid-1960's, the Poplar Street Bridge was constructed over the Mississippi River at St. Louis. As part of the bridge contract, a monorail was installed, and the District designed and built a battery-operated "car" to be used on the monorail for data collection. The equipment became operational in 1968 and was the second such unit in the District (the first was installed at the Thebes station in 1941). District Chief Anthony Homyk, in a 1968 memorandum to District personnel, called the equipment the "ultimate for streamflow measuring." The only disagreement was voiced by technicians such as George Gray and Roger Nygaard, who were occasionally stranded underneath the bridge far from shore by defective batteries or wheels that had jumped the rail. In those days (before cellular phones), heroic measures were sometimes necessary for personnel to escape the stalled car and get home in time for supper.

Basic-data collection and analysis were directed by James E. Bowie until his transfer to the Hydrologic Instrumentation Facility in Bay St. Louis, Miss., in 1972 and thereafter by Horace G. "Goobe" Jeffery. Elmer Roemer, Melvin Janson, Leland Hauth, and Elmer Sandhaus performed record computations for publication. Bill McDonald was the District's instrumentation specialist until his transfer to the Hydrologic Instrumentation Facility in 1972. In the District Headquarters, James Alexander (whose grin was reported to resemble a wave on a Missouri slop bucket and whose motto was "everyday with the Survey is like Sunday on the farm") was the lead technician and set the example for precision and accuracy in data collection. All technicians were trained and proficient in data collection in all water-resources disciplines, but each developed a specialty: Walter Oakes, ground water; Pierce Cross and Gilbert Malone, water quality; Walter Andrews, springflow inventory and computations; Leon Reed, Lester Grayson, Gary Alexander, and Henry Hauck, streamflow measurements and computations; and Frankie Franco and William "Foots" Liesman, gage construction and installation and maintenance of equipment.

In the St. Louis Subdistrict Office, under Don Spencer's leadership and the able assistance of hydraulics specialist Terry Alexander, technicians Dale Hatten, George Gray, David Carriaga, and Roger Nygaard were experts in data collection and analysis on the Mississippi, Missouri, and other large rivers. In the Independence Field Headquarters and Bethany, technicians Woody Ollar, Mike Moody, Charles Watts, and Bob Shepard also collected and analyzed data from the Missouri River and other large streams.

In the District Office, Eva Gollahon and Roedean Janson managed hydrologic data files and prepared data for publication. They were assisted by Wanietia (Susie) Kratzer, who also served as receptionist for the District Chief. Susie was noted for her ability to recognize voices and faces; her greeting made a visit to the District Office a memorable occasion for employees and visitors alike. As the District's one-person reports-processing machine (precomputer), Susie frequently typed manuscripts several times before they were finally published.

Interpretive Studies

Interpretive studies during 1966–79 were directed by Edward J. "Ned" Harvey, who had transferred to the District in late 1963 as District Geologist. Administrative detail was not Ned's forte, but he had an innovative technical mind that had been honed by years of experience with WRD and in U.S. and South American mining operations. His geohydrologic interpretations and innovative problem-solving techniques still are being used in Missouri karst studies by Federal, State, and local agencies and by consultants.

Harvey was assisted in the Special Studies Section by the following: L.F. Emmett, a geologist who was Harvey's principal advisor on ground-water data management and interpretation; E.E. (Gene) Gann, a surface-water flood specialist who transferred to the Texas District as a Subdistrict Chief in 1974 and would later become Arkansas District Chief; L.D. Hauth, a specialist in surface-water hydraulics; G.L. Feder, a geologist who specialized in geochemical studies in the Joplin area and statewide until his transfer to the Central Region staff in the mid-1970's; J.H. Barks, a water-quality specialist whose studies of the effects of lead and zinc mines and tailings piles on Missouri water resources gained national recognition (Barks would later become a Section Chief and eventually Missouri District Chief); R.R. (Dick) Luckey, a mathematician and ground-water specialist who worked closely with the Missouri Geological Survey and Water Resources to define hydrogeology and water resources of the Southeast Lowlands of Missouri, then transferred to the Central Region in 1978; and John Skelton, a surface-water low-flow specialist who served also as District Reports Specialist and would later become a Section Chief in the District.

With the "one-water" concept firmly in place by 1967, District management decided to define general hydrologic conditions within Missouri through a series of statewide or regional studies and then, as those were completed and funding developed, to use that hydrologic information as a means of proposing and beginning more detailed studies in multicounty or smaller areas.

One of the primary reasons that a generally stable number of hydrologists and technicians could maintain data networks and substantially increase participation in hydrologic projects was the increasing availability of computer technology. Because of WRD's proximity to National Mapping Division's regional facility and computer equipment, the District relied heavily on and benefited greatly from National Mapping Division expertise in computer technology through the late 1970's. Use of this technology began with storage and retrieval of basic surface-water, ground-water, and water-quality data in the mid-1960's. A memorandum from District Chief Tony Homyk to District personnel in July 1968 stated: "A new experience for the District as ground-water and water-quality data for 80 St. Louis area wells will be stored in a computer system for analysis." Mr. Homyk could not foresee the astounding advances in computer technology that were to follow this humble beginning.

Some of the statewide and regional hydrologic studies completed during 1966–79 were as follows:

1. A series of four Hydrologic Atlases covering the State to serve as guides to future water development, point out areas of deficiency in water information, and identify existing and potential water problems in each area. Senior WRD authors for these reports were E.E. Gann, E.J. Harvey, H.G. Jeffery, and J.H. Barks.
2. A series of four Hydrologic Atlases that provided reconnaissance information about ground water resources of the Missouri River alluvium in Missouri. L.F. Emmett and H.G. Jeffery were the authors.
3. Two statewide flood-frequency studies for Missouri streams published in the State Water Resources Report and USGS Open-File Report series and authored by E.H. Sandhaus, John Skelton, and L.D. Hauth.
4. A series of seven statewide reports published in the State Water-Resources Report series covering low-flow, base-flow recession, and flow-duration characteristics of Missouri streams and springs; flood-volume design data; and carryover storage requirements for Missouri streams, authored by John Skelton.
5. Multicounty studies that defined water resources and problems and presented hydrologic data in the vicinity of St. Louis, Springfield, and Joplin. WRD authors included L.F. Emmett, R.R. Luckey, G.L. Feder, and John Skelton.
6. Water quality in the Ozark National Scenic Riverways in Missouri and the effects of abandoned lead and zinc mines and tailings piles on water quality in the Joplin area was presented in a Water-Supply Paper and Water-Resources Investigations Report, respectively, by J.H. Barks. He also presented the water-quality characteristics of six small lakes in a State water-resources report.
7. Application of thermal imagery and aerial photography to hydrologic studies of karst terrane in Missouri was reported in a USGS Water-Resources Investigations Report by E.J. Harvey.
8. The Missouri Ozarks Mountains contain one of the Nation's greatest concentrations of springs. Hydrologic data and information about the fauna and flora of the springs were compiled following an intensive inventory and study, and in 1974 a report was published by the Missouri Geological Survey and Water Resources. Probably the most popular publication ever printed by the State, it was coauthored by G.L. Feder and a State author.

One of the most significant hydrologic events of 1966–79 occurred during the historic 1973 Mississippi River Basin flood that affected parts of 10 States and caused over $400 million in damages. From St. Louis downstream along the Missouri border, the river remained above flood stage for a record 97 days. Missouri District personnel were heavily involved in data collection and analysis. John Skelton was selected to compile and analyze flood data from the basin and, with H.P. Guy of Headquarters staff and E.H. Chin of the National Weather Service, co-authored a Professional Paper about the flood.

ODDS AND ENDS

The years 1966–79 were a gratifying time to be working in the Missouri District. Many of the personnel who had arrived in the mid- to late 1960's as the District began its transition from a one-dimensional entity producing compilations of surface-water data to a multifaceted District involved in all aspects of hydrology had young families that interacted socially and became personal friends. The small-town Rolla area was an exceptionally good place to raise children; the work was diverse, interesting, and continually expanding; and the WRD staff became a close-knit group. One Regional staffer was once heard to remark, "It would take a stick of dynamite to get some of those people out of Missouri." Although there were some transfers, that statement generally defined the attitude of the staff during those years.

• An April 1, 1969, entry in John Skelton's daily journal during a field trip with J.H. Barks to large Missouri springs was at least semi-enlightening concerning Barks, currently (2000) Missouri's District Chief: "The new man (Barks) has picked up our field procedures very well, though he did originally point his current meter downstream to measure velocity. He is a bit windy, but I like him." You just never know, do you?

• One of the more interesting characters in the District during the period was Frankie Franco, a technician who assisted in construction activities and the District water-quality laboratory. He was, undeniably, the strongest person District personnel had ever seen, but unfortunately he was not always reliable. Franco once had to be bailed out of a Hermann jail on a Saturday by a disgruntled Mel Janson and John Skelton after he drove a government vehicle "under the influence," and he insisted that he was unfairly jailed. Janson and Skelton begged to differ, and District Chief (and World War II veteran) Tony Homyk blistered Frankie's ears with a classic lecture, then gave him a second chance. Sadly, some years later Frankie would die under tragic circumstances after transferring to the New Mexico District.

• In an attempt to broaden their capabilities, Franco and Liesman were sent to a bridge site to run levels to a gage. Upon returning to the office, they were informed that the levels incorrectly showed the streambed to be at a higher elevation than the bridge. One of them quickly blamed the other for the error stating, "I told you the instrument had to be set up at exactly the same place it was before." Frankie and Foots never learned to run levels, but they were an outstanding construction team.

An era of sandals, long hair, and beards (not to mention extraordinary technical knowledge) dawned as Jeffrey L. Imes arrived in the District in late 1979, following extensive geophysical work in the Middle East and elsewhere. Imes and others who would follow in the 1980's ushered in technological advances and computer expertise that would make the District a Division leader in practical applications of hydrologic theory, especially in ground-water hydrology. Truly, the best was yet to come.

MONTANA

by Robert Gale McMurtrey

At the beginning of the period, the Water Resources programs of the U.S. Geological Survey (USGS) in Montana were under the jurisdiction of a Surface Water Branch and a Ground Water Branch. The Quality of Water Branch did not maintain an office in Montana. The headquarters of the Surface Water Branch was in Helena, Mont., with a Field Headquarters office in Fort Peck and Subdistrict Offices in Billings and Kalispell. George M. Pike was Acting District Engineer; Kenneth L.Tangen was Technician-in-Charge at Fort Peck; Allen Sollid was Engineer-in-Charge at Billings; and Lynn J. Hull was Engineer-in-Charge at Kalispell. The Ground Water Branch headquarters was in Billings, Mont., with a Field Headquarters office in Missoula. Charles W. Lane was the District Geologist and Richard L. Konizeski was Geologist-in-Charge at Missoula. On July 1, 1966, the two branches were merged into the Montana District with headquarters in Helena. Charles W. Lane, District Geologist for the Ground Water Branch, was transferred from Billings to Helena and appointed District Chief. George M. Pike, Acting District Engineer for the Surface Water Branch was appointed Assistant District Chief.

ORGANIZATION AND PERSONNEL

The District organizational structure consisted of the administrative office in Helena, Subdistrict Offices in Helena, Billings, and Kalispell, and a Field Headquarters in Fort Peck. The duties of the administrative office were delegated to an Administrative Services Section, a Hydrologic Records Section, an International Waters Section, and an Investigations and Reports Section.

Charles W. Lane was District Chief until March 1969, when he transferred to the Kansas District. George M. Pike was appointed District Chief, and Robert G. McMurtrey was appointed Assistant District Chief. Both continued in those positions to the end of the period.

Donald W. Woodall served as Administrative Services Officer from 1966 until his retirement in 1976, at which time Mark S. Gerl was appointed to the position. He continued through the rest of the period. Others who worked in the section for at least part of the period were: Doris J. Brazill, Betty Dean, Patricia Harris, Marilyn Harrison, Margaret Lee, Michelle F. Johnston, and Luanne P. Romasko.

Grant W. Buswell was Chief of the Hydrologic Records Section from 1966 to 1972. L. Grady Moore was Chief from then until mid-1979, when Ronald R. Shields was appointed Chief. Others in the section at some time during the period were Fern C. Aagard, Eugene R. Beesly, Fred C. Boner, Tordis Brosten, Connie Buckner, Merry E. Burch, Richard L. Clements, Jack M. Creach, Judith Dahl, Jay H. Diamond, Rodger Ferreira, Colin J. Fetsch, Jerry L. Finn, Leonard R. Frost, John F. Guipre, Linda Hoskins-Kokoruda, Reider K. Ilvedson, Marjory Jacobsen, Marion L. Kasman, Ronald J. King, Michael H. Mahlman, Joyce I. Marsh, Patrick W. McKinley, Evonne Molyneaux, Michael O'Conner, Clay A. Olsen, Waite R. Osterkamp, Marian D. Piatte, Paul R. Rafferty, Pauline M. Raw, John D. Roda, Wauna L. Story, Gary A. Upshaw, Pamela Wallery, Melvin K. White, and Joseph F. Williamson. Chemical quality of water in the Hydrologic Records Section was under the direction of J. Roger Knapton from 1968 to the end of the period.

Robert G. McMurtrey was in charge of the Investigations and Reports Section until 1969, at which time Donald L. Coffin was appointed. He led the section until he transferred to Denver in 1977. Joe A. Moreland served as Chief of the section through the rest of the period. Others working in the section for part of all of the period were Arnold J. Boettcher, Alex Brietkrietz, Kent A. Dodge, Julianne Fliegner, Arthur W. Gosling, William R. Hotchkiss, James A. Hull, Kurt C. Jenewein, Melvin V. Johnson, Robert B. Leonard, Gary W. Levings, Neal A. McClymonds, George A. Murgel, Robert J. Omang, Charles Parrett, Thomas E. Reed, Robert S. Roberts, Andrew Skerda, Steven G. Slagle, Donna K. Vincent, and Kathleen R. Wilke.

Walter A. Blenkarn was in charge of the International Section from 1966 until his retirement in 1976. Claude O. Geiger was appointed at that time and continued in the position until the end of the period. The District Chief and the International Section worked closely with their counterparts in Canada on matters pertaining to division of the waters of the St. Mary and Milk Rivers between Canada and the United States. They also cooperated on other international problems along the Montana-Canada border. Others in the section during the period were Orrin J. Folsom, Dave R. Johnson, and Francis M. O'Neill.

Fred C. Boner served as Chief of the Helena Subdistrict from 1966 to 1970. He was followed by Barney Granstra (1970 to 1972) and Ron Shields (1972 to 1979). Others who worked in the Subdistrict were Bruce Bochy, C. Lee Chambers, Richard O. Clausen, Jay H. Diamond, James E. Elliott, Warren H. Erskin, Del P. Gariepy, Eugene O. Lovely, Stephen V. Lynn, Michael Manger, Norwood B. Melcher, Norman A. Midtlying, Dennis W. Morford, Leslie R. Murray, and R. Dale Schuler.

The Billings Subdistrict had two Chiefs during the period. Charles H. Carstens served from 1966 to 1974 and Rickard D. Hutchinson from 1974 to 1979. Others working in the Subdistrict were Sheldon D. Ayers, Bruce M. Bochy, Lawrence E. Carey, Betty G. Cowger, Estevan DeLeon, Terry P. Erwin, Richard D. Feltis, Colin J. Fetsch, James L. Fischer, Thomas I. Follinglo, Douglas E. Gibbs, Norman D. Haffield, Valerie M. Herren, William B. Hopkins, James L. Huber, Katherine S. Kraus, Roger W. Lee, Barney D. Lewis, David W. Litke, Patrick W. McKinley, Lawrence Merritt, William R. Miller, Wilard J. Page, Marian D. Piatte, Thomas E. Reed, Ronald P. Rioux, Robert S. Roberts, B. Paul Schmitt, Truman L. Sheldon, Steven E. Slagle, Gail Smothers, David O. Sparks, Jeffrey D. Stoner, Steven A. Strauz, O. James Taylor, D. June Thompson, James D. Tkach, Wayne R. Tomlinson, Melvin K. White, and Michael E. Young.

The Kalispell Subdistrict also had only two Chiefs during the period. Lynn Hull served as Chief for all except 1 year, and Edward J. Blank served for 1979. The others who worked in the Subdistrict were Randall T. Cronk, Joseph W. Lalley, Shirley K. Nicholson, Dean R. Sirvcek, and Raymond J. Weinberg.

The Fort Peck Field Headquarters was under the general supervision of the Helena Subdistrict Chief. Kenneth LeRoy Tangen was in charge locally from 1966 to 1978 and Nick Melcher from 1978 to 1979. Others who worked in the Fort Peck office were Randall T. Cronk, John T. French, Thomas I. Follinglo, Kenneth G. Nieskens, Clifford A. Ramsbacher, and Virginia Redstone.

The Missoula Field Headquarters was operated only until September 1966. At that time, Richard L. Konizeski resigned to teach at the University of Montana, and Alex Brietkrietz transferred to Helena.

FUNDING AND COOPERATION

Funding for the District came from other Federal agencies (OFA), the Federal-State Cooperative Program, the Federal Program, and Federal Power Commission (FPC) Licensees (Montana Power Company and Washington Water Power). Except for 2 years (1967 and 1972), funding gradually increased from $625,200 in 1966 to $3,657,700 in 1979 (see table). In 1972, the OFA program was reduced by more than $550,000 but was partly offset by a large increase in the program for coal hydrology and inflationary increases in other programs. This made it possible to maintain personnel by shifting from OFA programs to the total hydrology program.

Cooperating Agencies

The Montana Water Resources and Conservation Board was the principal cooperator for the streamflow program. The Montana Highway Commission supported a crest-stage gage program for small-area peak-flow determinations. The Montana Bureau of Mines and Geology (MBM&G) was the principal cooperator for the ground-water program. This included major ground-water studies of selected areas throughout the State and measurements of water levels in a statewide observation-well network.

Other Federal Agencies

The Department of State, through the Waterways Treaty Program, supported the collection of streamflow and water-quality data pertinent to the division of boundary waters between Canada and the United States. The U.S. Army Corps of Engineers funded some streamflow-gaging stations needed for reservoir operation. The Bureau of Reclamation funded stations necessary for water control through their dams. Other agencies that funded special information requests at various times through the period were: U.S. Forest Service, Bureau of Indian Affairs, Public Health Service, National Park Service, U.S. Fish and Wildlife Service, Bureau of Land Management, U.S. Environmental Protection Agency, and the General Services Administration.

HYDROLOGIC DATA PROGRAMS

Surface Water

The collection, processing and publication of surface-water data were the largest parts of the District program during the period. Although the number of gaging stations decreased from 238 in 1966 to 199 in 1970, funding for the total surface-water program increased. This was a period of readjustment of costs

Funding, in thousands of dollars, Montana District

Source	1966	1967	1968	1969	1970	1971	1972	1973
OFA	333.4	326.7	524.5	511.8	648.1	698.5	145.7	221.0
Coop	254.7	249.4	138.5	161.8	175.5	217.3	233.3	320.6
			115.0	120.1	145.1	180.2	193.3	277.6
Fed	19.6	28.6	34.1	44.3	51.3	44.2	217.7	241.1
FPC	17.5	16.2	16.4	19.7	20.0	25.0	24.4	29.9
Total	625.2	620.9	828.5	857.7	1,040.0	1,165.2	814.4	1,090.2

Source	1974	1975	1976	July 1976– Sept. 1976	1977	1978	1979
OFA	445.4	508.4	1,160.7	278.6	944.7	1,232.5	1,233.2
Coop	259.8	318.6	277.1	75.5	681.7	339.6	372.8
	214.8	292.1	269.1	69.7	673.9	326.5	364.3
Fed	241.5	288.7	366.1	180.5	963.5	1,371.8	1,642.7
FPC	27.5	30.3	35.0	12.0	36.1	48.7	44.7
Total	1,189.0	1,438.1	2,108.0	616.3	3,299.9	3,319.1	3,657.7

for operating stations. Some stations had been continued even though funding had been dropped and inflationary increases had been much greater than funding increases. With the agreement of cooperators, least-needed stations were discontinued, others were changed to partial-record stations, and funding for the remaining stations was increased to reflect actual operating costs. The number of stations increased from 199 in 1970 to 226 in 1979. The increase was mainly due to funding from the Federal Coal Hydrology Program. Surface-water records for Montana were published in Water-Supply Papers by the Water Resources Division through 1970. After 1970, the records were published in the "Annual Water Resources Data for Montana" series, which is on file in the Montana District office in Helena.

Quality of Water

Most of the water-quality data collection in Montana was being done by the Wyoming District at the beginning of the period. Some water samples were being collected by Montana personnel for analysis in the Lincoln, Nebr., Worland, Wyo., or Portland, Oreg., laboratories. However, in July of 1967, personnel from the Montana District took over operation of the water-quality stations in the State. The program increased quite rapidly from 1966 to 1969 and then increased rapidly again from 1974 to the end of the period when the Bureau of Land Management coal hydrology program funded projects in the coal areas of Montana. By the end of the period, funding for quality of water data collection and interpretation was more than that for ground water.

During the period, water quality was determined at 238 stations. Only 30 of those had 10 or more years of record, and 10 of them were not in operation at the end of the period. Twelve of the stations had 15 or more years of record. Two of them were discontinued before the end of the period. There were five stations with 20 or more years of record and two with more than 30 years of record. The network of stations operated throughout Montana changed from year to year as a result of completion of objectives, changes in data required, and(or) changes in funding. Most stations operated during the period were part of short-term investigations and were active for only a few years.

Special Studies

Observation of stream temperatures are made at approximately monthly intervals at most streamflow stations. A compilation of those temperatures for the period of record was made by Fern C. Aagaard and published by the Montana Fish and Game Department in 1969.

Two suspended-sediment load studies started during the previous period were completed. The Little Prickly Peak Creek study was finished in 1967 and the Blue Water Creek study in 1970. A 1-year study of the sediment load in Muddy Creek near Vaughn was made in 1972. All samples from these studies were processed at the sediment laboratory in Worland, Wyo., as were all sediment samples collected for the Coal Hydrology Program.

In 1972, an intensive water-quality study was started in connection with Lake Coocanusa in western Montana and continued to the end of the period. Sampling was done by personnel in the Kalispell Subdistrict, under the direction of Roger Knapton. Samples were collected from the Kootenai River inflow in Canada, at stations in the lake, on streams entering the lake in Montana, and on the river downstream from the lake.

During the period, samples were taken at streamflow stations on the Beaverhead River above and below Clark Canyon Reservoir, and on other streams entering the reservoir, to monitor the effect of the reservoir on stream quality.

In 1974, collection of water-quality data was begun at several stations in eastern Montana for the Coal Hydrology Program. The number and type of stations operated each year increased to the end of the period. However, as site-specific projects were completed during the period, those stations were discontinued and others were started.

The quality of water data for Montana were published in Water-Supply Papers by the Water Resources Division through 1970. For the remainder of the period, the data were published in the "Annual Water Resources Data for Montana" series.

Ground Water

Long-term water-level measurements were continued during the entire period to determine if any changes in annual or year-to-year fluctuations had occurred due to changes in climatic conditions and(or) human activities such as large-scale withdrawals of water for irrigation, industrial use, city water supply, and so forth. Water levels were measured in 82 wells at the beginning of the period. Twenty of those were national network stations. At the end of the period, 222 wells were being measured. Of those, 23 were national network stations. Most of the large increase in number of wells measured was due to starting the Coal Hydrology Program in 1974. Ground-water-level data for those Montana sites included in the national network of observation wells were published in Water-Supply Papers through 1974. For the rest of the period, those data were published in the "Annual Water Resources Data for Montana" series. Data for the other statewide observation wells were published in the Montana Bureau of Mines and Geology bulletin series.

In addition to the statewide network of observation wells, project observation wells were established in connection with many of the areal studies of geology and water resources. Water levels periodically measured in those wells were published in project reports or in data reports for the project. The data reports were published as Montana Bureau of Mines and Geology bulletins. The project reports were published by the USGS or by the State of Montana.

Special Investigations

A program to investigate the magnitude and frequency of floods from small drainage areas in Montana was started in 1955 with funding from the Montana Highway Commission. Originally, 45 crest-stage gage stations were established. The program was expanded to 152 stations in 1959 and to 216 stations in 1963. In 1966, 214 stations were operative. From 1968 to 1970, 199 stations were operated and from 1970 through 1973, 193 stations were operated. In 1973, the program was re-evaluated. The evaluation indicated that about 100 new stations were needed to provide adequate areal coverage of the State, 62 existing stations should be continued for long-term record, and all other stations should be discontinued upon collection of 15 years of record. By September of 1977, 156 stations had been discontinued, and by 1979 the program was continuing with 191 crest-stage gages in operation. Melvin V. Johnson was in charge of the project until his retirement in 1976, at which time Robert J. Omang assumed the responsibility. Others involved in the program were Charles Parrett and James A. Hull. Periodic reports on the program were published by the USGS as Open-File Reports, which are on file in the District Office at Helena.

During this period, studies of the quantity and quality of ground water were made throughout the State. These were mainly funded by the USGS-Coop Program in conjunction with the Montana Bureau of Mines and Geology. Among these were a study of the water resources of the Upper Blackfoot River Valley in west-central Montana by Donald L. Coffin and Kathleen R. Wilke (Montana Department of Natural Resources and Conservation, 1971). Coffin and Wilke also completed an appraisal of the quality of ground water in the Helena Valley (USGS Water-Resources Investigations Report 32–73, 1973), and Wilke also reported on a study of ground-water levels and chemical quality of ground water in Lincoln (USGS Open-File Map 76–333). Coffin, Thomas E. Reed, and Sheldon D. Ayers made a followup study of water-level changes in wells along the west side of the Cedar Creek Anticline in southeastern Montana. The original study was done by O. James Taylor during a previous period. The study was made to define changes in water levels in wells caused by ground-water withdrawals for use in a water-flood project to enhance oil recovery from an underlying petroleum reservoir (USGS Water-Resources Investigations Report 77–93). William R. Miller made a preliminary evaluation of water in carbonate rocks of the Madison Group in southeastern Montana (USGS Water-Supply Paper 2043). Frank Swenson, William R. Miller, Hugh Hudson, and Visher mapped the configuration and thickness, potentiometric surface, and water quality in the Madison Group of the Powder River Basin in Wyoming and Montana (USGS Miscellaneous Investigations Map I–847–C). Barney D. Lewis prepared a paper for presentation at the 30th annual meeting of the Rocky Mountain Section of the Geological Society of America on "The Geology of the Northern Powder River Basin, Southeastern Montana." For the same meeting, Roger W. Lee prepared a paper on "The Geochemistry of Shallow Ground Water in the Northern Powder River Basin, Southeastern Montana." Arnold S. Boettcher and Haralick wrote a paper "The Use of Thermal-Infrared Imagery in Ground Water Investigations in Montana" for the Eleventh International Symposium on Remote Sensing (Environmental Research Institute of Michigan, 1979). A report was prepared by Robert B. Leonard and Janzer on their research into the natural radioactivity in geothermal waters at Alhambra Hot

Springs and nearby areas in Jefferson County (USGS Journal of Research, v. 6, no. 4).

The water resources of the Clark Fork Basin upstream from St. Regis were investigated by Arnold J. Boettcher and Arthur W. Gosling (MBM&G bulletin 104); the geology and water resources of the northern part of the Judith River Basin were reported on by Richard D. Feltis (MBM&G bulletin 101); Boettcher and Wilke investigated the ground-water resources in the Libby area in northwestern Montana (MBM&G bulletin 106); Roger Knapton made an evaluation and correlation of the water-quality data for the North Fork Flathead River in northwestern Montana (USGS Water-Resources Investigations Report 78–111); Barney Lewis, Stephen Custer, and William R. Miller reported on the development of a saline seep in the Hailstone Basin of northern Stillwater County (USGS Water-Resources Investigations Report 79–107); and Richard Feltis investigated the water resources of shallow aquifers in the Upper Poplar River Basin of northeastern Montana (USGS Water-Resources Investigations Report 79–51).

During the period, several studies were completed and reported on for the Coal Hydrology Program. Among these was a study by Knapton and Patrick W. McKinley on the water quality of selected streams in the coal area of southeastern Montana (USGS Water-Resources Investigations Report 77–80); a map prepared by Barney Lewis and Robert S. Roberts of the geology and water-yielding characteristics of rocks in the northern Powder River Basin of southeastern Montana (MSGS Miscellaneous Investigations Map I–847–D); Patrick McKinley reported on the water quality for some selected streams in the coal area of east-central Montana (USGS Water-Resources Investigations Report 78–142); Steven E. Slagle and James R. Stimson compiled hydrologic data from the northern Powder River Basin of southeastern Montana (USGS Water-Resources Investigations Report 79–1332); and William R. Miller reported on the water resources of the Central Powder River area of southeastern Montana (MBM&G bulletin 108). A report on the ground water of the Fort Union coal region of eastern Montana was prepared jointly by the Montana District and the Montana Bureau of Mines and Geology (MBM&G Special Publication 80). There were many other studies of the quantity and quality of surface and ground water in progress at the end of the period.

In addition to the studies mentioned above, many small site-specific studies were made at the request of various cooperating agencies. They covered various aspects of ground water, surface water, and quality of water throughout the State. They were reported in open-file or administrative reports on file in the Montana District Office in Helena.

NEBRASKA

By Richard A. Engberg

INTRODUCTION

The Nebraska District of the Water Resources Division (WRD) was organized in 1966 by combining three Branch districts: Surface Water, Ground Water, and Water Quality. Kenneth A. MacKichan from the USGS office in Ocala, Fla., was named District Chief. The District and Lincoln Subdistrict Offices were located in Nebraska Hall on the University of Nebraska campus at 901 N. 17th Street, Lincoln, in the same location as the former Surface Water and Ground Water Districts. A water quality and sediment laboratory was located at 225 N. Cotner Street in east Lincoln, and other water-quality personnel from the former Water Quality District also were housed at the Cotner location.

The Lincoln Subdistrict Office moved from Nebraska Hall to the Cotner building in 1967. Other Subdistrict Offices were located in Ord (north-central Nebraska) and Cambridge (southwest Nebraska). The USGS stationed one hydrologist in the Nebraska Department of Water Resources office at Bridgeport.

The water-quality laboratory was closed in 1971, with the advent of the WRD Central Laboratories System. In 1975, the Cotner and Nebraska Hall offices were closed, and all WRD personnel at Lincoln moved into the just-constructed Robert V. Denney Federal Building in downtown Lincoln at 100 Centennial Mall North.

ORGANIZATION, MANAGEMENT, AND PERSONNEL

Kenneth A. MacKichan served as District Chief from 1966 until his retirement in 1979. Other management personnel in 1966 were Floyd Le Fever, former Chief of the Surface Water Branch who served as Assistant District Chief and Hydrologic Data Chief, and Charles F. Keech, former Chief of the Ground Water Branch who served as Hydrologic Studies Chief. Le Fever retired in 1968 and was succeeded as Assistant District Chief by Keech and as Hydrologic Data Chief by Lester R. Petri, a position he held through 1979. Keech retired in 1975 and was succeeded in 1976 by Joe Downey as Assistant District Chief and Hydrologic Studies Chief. Downey held the position for 2 years until his transfer to Denver. The position was vacant through 1979. Arlene Summers served as Secretary to the District Chief during 1966–1979. Herman Brice was on the District Chief's staff from 1966 to 1971.

Throughout the period 1966–79, individuals were designated as discipline specialists for surface water (SW), ground water (GW), and water quality (QW). These individuals were senior or mid-level scientists who, by virtue of academic and professional background, were considered to be the District "experts" in their respective disciplines. Discipline specialists during the period were: SW–Floyd Le Fever, 1966–68, Gordon Jamison, 1969–1978, Glenn Engel, 1979; GW–Charles Keech, 1966–69, Mike Ellis, 1970–79; QW–Lester Petri, 1969–74, Richard A. Engberg, 1975–79.

Support Services

Jim McLaughlin headed the District Administrative Services Section in 1966. Lucille Stephens took over the section in 1967. Following Lucille's retirement in 1973, Agnes Watson headed the section as Administrative Officer through 1979. Others who worked for various periods in the section were Dorothy Hald, Nancy Cidlik, Jane Green, and Rebecca Colberg.

Esther Gushard headed a combined Records Processing and Computer Section in 1966. This section entered all field data on punch cards and was responsible for editorial review of all interpretive and data reports that were produced by the District. Esther retired in 1974. At that time, the section was reorganized; responsibility for editorial review of interpretive reports was transferred to the Hydrologic Studies Section. The reorganized Computer Section was headed successively by Roger Booker and Don Schild through 1979. Bunny Loerch was in the section from 1966 to 1979, Neil Stuthmann from 1967 to 1974, and Jan Beard from 1975 to 1979. Others who worked in the Computer Section for varying periods during 1966–79 were Audrey Flick, Marilyn Lovelace, Carol Spielmann, Marilyn Scott, Fern Adams, Willadeen Bridges, and Chris Rolff. The District acquired a Data 100 computer in 1975, ushering in a new era of processing hydrologic data and interpretive work, including ground-water model development.

Sanford C. (Sandy) Downs headed the District Laboratory, which from 1966 to 1971 analyzed all water-quality samples collected from Nebraska, South Dakota, North Dakota, Montana, Wyoming, Minnesota, and part of Kansas. Also under the Laboratory Chief's supervision was a sediment laboratory that analyzed sediment samples from Nebraska, South Dakota, and North Dakota as well as some other States. The chemistry laboratory was staffed by 4–7 chemists and technicians including Gerry Gordon, Richard Engberg, Tim Renschler, Jack Craven, and Lloyd Blackburn. Four to six part-time student employees also were on the laboratory staff, performing analyses and support duties. Upon closure of the laboratory in 1971, all staff except Richard Engberg and Lloyd Blackburn transferred to other locations. The sediment laboratory operated through the entire period of 1966–79. Physical Science Technicians Bennie L. Day followed by Carol G. Hoy and supplemented by student employees, performed analyses and managed the sediment laboratory.

Lincoln Subdistrict Office

The Lincoln Subdistrict Office collected all surface-water data in approximately the eastern one-third of Nebraska during 1966–79, and all water-quality and ground-water data from 1975 to 1979. Jack Anderson was in charge of the office from 1966 to 1972, and Glenn Engel from 1973 to 1979. Hydrologic Technicians in the office during part or all of the period included Maynard Kubicek, Dick Harmon, Lloyd Blackburn, Paul Hemphill, Eugene K. Steele, Jr., Stephen Hull, Bob Swanson, and James Marburger. Judy Boohar joined the office in 1975, and Josephine Eyen was with the office from 1966 to 1972. Dick Harmon also served the District Office in charge of scientific property and vehicle acquisition.

Cambridge Subdistrict Office

The Subdistrict Office at Cambridge collected all surface-water data for southwest Nebraska during 1966–79 and water-quality and ground-water data from 1975 to 1979. During 1966–79, Bob Liggett was in charge of the office, and Loyd Thompson and Marjorie Gilbert were the staff.

Ord Subdistrict Office

The Subdistrict Office in Ord collected all surface-water data for north-central Nebraska during 1966–79 and water-quality and ground-water data for the same area from 1975 to 1979. Gordon Jamison was in charge of the office from 1966 to 1971, and Dean Stephens was in charge from 1972 to 1979. Hydrologic technicians in the office during part of the period were John Wagner, Ken Calver, and Ron Drudik. Alice Woitalewicz, succeeded by Lou Ann Quinn, served as secretary during 1966–79.

Bridgeport Office

Joel Schuetz was a USGS employee stationed in the Nebraska Department of Water Resources office in Bridgeport during 1966–71. Joel participated in surface-water and sediment-data collection. The USGS Bridgeport office was closed upon Joel's transfer from the District.

FUNDING

Funding for District Programs increased steadily from 1966 to 1979, mostly in response to the high inflation in the 1970's. The overall growth of the District Program was modest. Funding sources included the Federal-State Cooperative Program (Coop) of the USGS, direct Federal funding (Federal), and funding transferred from other Federal agencies (OFA). The Coop Program funding shown in the following table includes both Federal matching funds and the cash part of cooperating agencies' contributions. In reality, a large part of the cooperator match during the period, specifically from the two largest State cooperating agencies, was direct or "in kind" services. Federal funding was directly appropriated to the USGS for the collection of basic records (CBR), for networks such as the National Surface Water Quality Accounting Network (NASQAN) and the Hydrologic Benchmark Program, and for interpretive studies under new programs such as the Regional Aquifer-System Analysis (RASA) studies. OFA funding was for data collection and interpretive studies in support of programmatic activities. The U.S. Army Corps of Engineers funded surface-water stations in eastern Nebraska, and the Bureau of Reclamation and the Missouri River Basin (MRB) program funded observation wells and stream-gaging and water-quality stations in central and western Nebraska. The U.S. Environmental Protection Agency funded water-quality stations on the Missouri River. The Federal Emergency Management Agency (FEMA) funded preparation of flood insurance studies for several communities in Nebraska. The National Weather Service shared equipment and funded several gaging stations in eastern Nebraska. The total of these funding sources shown in the table constituted the overall District budget for the period.

Nebraska District funding summary - Fiscal years 1966–79

Fiscal year	Coop	Federal	Other Federal funding	Total
1966	$2,217,408	$37,450	$308,403	$567,261
1967	309,895	39,800	242,370	592,065
1968	345,000	43,245	241,692	629,937
1969	3,977,940	531624	235,979	687,543
1970	418,400	71,311	2,617,006	750,717
1971	484,700	66,515	250,839	802,054
1972	546,348	210,956	81,409	838,713
1973	585,300	222,627	203,476	1,011,403
1974	689,082	212,482	237,882	1,139,446
1975	722,979	256,440	186,769	1,166,188
1976	966,255	334,295	203,186	1,503,736
1977	948,065	2,957,701	1,931,069	1,436,835
1978	1,049,484	591,445	155,015	1,795,944
1979	1,130,259	667,490	148,065	1,945,814

COOPERATING AGENCIES

The principal cooperator for the surface-water records program was in the Nebraska Department of Water Resources (NDWR). During the period of 1966–79, the NDWR provided in-kind services rather than cash to the Coop Program. NDWR hydrographers were responsible for all data collection in western Nebraska following the closure of the USGS Bridgeport office in 1971. NDWR hydrographers worked with USGS personnel in the other three Subdistricts, sharing office space at both Cambridge and Ord. The NDWR also cooperated with indirect measurements of high flow at ungaged sites.

The principal cooperator on the ground-water data and interpretive programs was the Conservation and Survey Division of the University of Nebraska

(CSD). The CSD also provided services rather than cash for the collection of water-level data and for participation in county ground-water studies and some water-quality studies. During 1966–75, when the USGS District Office was located in Nebraska Hall, CSD was located in adjacent offices and provided the space for USGS as part of the Coop Program.

The USGS began a water-quality cooperative program in 1972 with the Nebraska Natural Resources Commission (NNRC). Sites principally in eastern Nebraska along the Missouri River and in the Salt Creek Basin comprised the early water network. The NNRC furnished funding and some in-kind services to USGS.

The Nebraska Department of Roads was a cooperator during part of the reporting period, providing support for crest-stage and partial-record surface-water stations.

The Nebraska Legislature in 1973 established 25 Natural Districts (NRD's) covering the entire State. These districts had taxing authority and were responsible for natural resources in their areas. During 1973–79, the WRD established Coop Programs with several NRD's including the Central Platte, Upper Republican, Twin Platte-Middle Republican, Big Blue, Lower Platte South, Lower Platte North, and Elkhorn NRD's. Data-collection and interpretive studies were carried out under these programs.

SUMMARY OF PROGRAMS

The two principal operating sections in the Nebraska District during 1966–79 were the Hydrologic Surveillance Section and the Hydrologic Studies Section. The Surveillance Section collected, processed, and published water records in an annual report series. The Studies Section performed interpretive areal and modeling investigations.

Hydrologic Surveillance Programs

From 1966–74, data for the surface-water, ground-water, and water-quality disciplines generally were collected independently of each of each other. In 1975, the Subdistrict Offices, which until that time collected only surface-water data, integrated collection of all data into their responsibilities.

Surface-Water Records

Records of daily river stage and water discharge were collected at 154 gaging stations across Nebraska in 1966. A few gaging stations were discontinued and a few were started, and the number of gages remained stable during 1966–79. In 1979, records were collected at 155 stations. Partial records on high flow were collected at 144 sites in 1966, but this dropped to 58 sites in 1979 as a result of program reductions. During the period, a Hydrologic Benchmark Station to monitor hydrologic responses to an area unimpacted by humans was established at the Dismal River near Thedford. Emil Beckmann was responsible for the crest-stage gage program, indirect measurements, and other surface-water studies until his retirement in 1976. Hydrologic technicians Jack Anderson and Eugene Steele took over these functions for the rest of the period.

Gordon J. Jamison was responsible for three major projects in the 1970's. He led the effort to prepare flood-prone area maps for all areas in Nebraska having 7.5-minute topographic map coverage. In the early 1970's, Jamison conducted a comprehensive evaluation of the stream-gaging program and was able to prioritize the stream-gaging network based on availability of long-term records. For the next several years, funding decisions for gaging-station support were based on this analysis. Finally, Jamison, assisted by Glenn Engel, delineated drainage areas on all topographic maps of the State and determined river mileage of all perennial streams in the State.

Personnel from all Subdistrict Offices and the District Office participated in numerous time-of-travel studies during the period. The first, in 1968, was on the Missouri River. Rhodamine–WT dye was injected at a Nebraska City site, and samples were collected at all major bridges downstream to the Nebraska-Kansas border. Numerous other time-of-travel studies were carried out in the Elkhorn River, the Big Blue River system, Salt Creek, and in other basins statewide.

Major flood events occurred in several years during the period. Rainfall of 12–14 inches in central Nebraska was responsible for record flooding in the lower Loup and Platte River Basins in 1966 and in 1967. Major flooding occurred in both the Big and Little Blue River Basin and in the Nemaha River Basin in 1967 and 1974. Personnel from all Field Offices and from the District Office were called upon to measure flood peaks and to assist with indirect measurements at ungaged sites.

Ground-Water Records

The District maintained a large network of water-level observation wells during 1966–79. The Hydrologic Surveillance staff obtained water-level measurements at varying frequencies (monthly, semi-annually, and annually) in 1,493 wells in 1966. By 1979, the network had grown to 2,130 wells. Rapid development of irrigation in large areas of Nebraska increased the demand for records of water levels in wells. In areas irrigated by diverted surface water, water levels tend to rise. In areas irrigated by pumpage of ground water, water levels tend to decline. Although large, the number of water levels measured by District personnel represented only part of this effort in Nebraska. With the establishment of the NRD's in Nebraska in 1973, Hydrologic Surveillance personnel during 1973–79, assisted personnel in most NRD's to set up ground-water-level monitoring networks in their Districts. Eugene Steele managed well networks in the Big Blue River Basin. Jim Nelson was responsible for water-level measurements from the Statewide ground-water well network until his retirement in 1968. Following Nelson's retirement, responsibilities were distributed throughout the District until they were assumed by the Subdistrict Offices in 1975. Michael J. Ellis prepared the annual ground-water-level report in cooperation with CSD from 1966 to 1978, and Martin Johnson prepared the report in 1979.

Sediment Records

Daily records of suspended sediment were collected at 18 sites in 1966 and at 13 sites in 1979. Once-daily samples were collected and analyzed for suspended-sediment concentrations at each site, and particle-size analyses were conducted on a periodic basis on samples from each site. All analyses were done in the District sediment laboratory.

Water-Quality Records

Collection of water-quality records at surface-water sites increased greatly during 1966–79. In 1966, samples were collected for water-quality analyses at 49 sites, mostly at gaging stations. In 1979, the sites sampled totaled 104. Samples were collected at most sites on a monthly basis. The degree of sophistication of water-quality sampling increased substantially during the period. Analysis for trace constituents and pesticides became commonplace during 1966–79. In about 1971–72, sampling for biological parameters, including total and fecal coliform, fecal streptococcus, phytoplankton, and periphyton, was added to the analytical schedules at several sites. During the same period, accepted procedures for suspended-sediment sample collection were instituted for water-quality sample collection to ensure representative samples.

Collection of samples from ground water sites varied greatly during 1966–79. Several long-term ground-water sampling networks were in place in irrigation project areas during the period, but most ground-water-quality sample collection was carved out as part of short-term special projects, and these numbers varied greatly on a year-to-year basis. In 1966, ground-water-quality samples were collected from 660 wells. In 1979, samples were collected from 276 wells.

During 1966–79, some water-quality measurements were automated and collected continuously at several sites. In 1967, Jim Ficken installed the first continuous water-quality monitor on the Missouri River at Nebraska City. Constituents measured were water temperature, pH, specific conductance, and dissolved oxygen.

Water-quality samples were collected not only for Nebraska but also for North and South Dakota during 1966–68. Those individuals responsible for sample collection were Gerry Gordon, Jack Craven, Tim Renschler, Sandy Downs, and Bruce Ringen. From 1970 to 1974, Richard A. Engberg was responsible for all water-quality data collection in Nebraska.

Hydrologic Studies Programs

During the period 1966–79, several studies of the water resources of Nebraska counties were published. In 1967, C.F. Keech and P.A. Emery did a study on the availability of ground water in York County (WSP-1839-F, 1968). The use of an analog model by Phil Emery represented the first attempt in a Nebraska District report to predict water levels. C.F. Keech published studies of ground water for Adams (HA-257, 1968) and Fillmore (WSP 1839-L, 1968) Counties. L.R. Petri supplied a section on chemical quality of water for the Fillmore County report. F.B. Shaffer co-authored a study of Antelope County

(HA-316, 1969). F.B. Shaffer and R.A. Engberg co-authored a study of Pierce County in 1976 (Nebr. Water Survey Paper 41, 1976). C.F. Keech was the author of a report on Seward County, and R.A. Engberg contributed a section on the chemical quality of water (Nebr. Water Survey Paper 46, 1978).

Four studies of areas larger than counties were published during the period by E.G. Lappala and co-authors including I.T. Dugan, P.F. Hemphill, and R.E. Booker. Three reports were for areas in southwest Nebraska (OFR 76–498, 1976; WRI 78–38, 1978; and OFR 78–61, 1978) and one area was in northeast Nebraska (WRI 78–67, 1978). The studies utilized finite-difference modeling to predict future availability of ground water. Jon M. Peckenpaugh began work in 1979 on a modeling study in southwest Nebraska. Ground-water interpretive studies also were underway by William F. Lichtler (1974–79), Robert A. Pettijohn (1979), and Hsi-Hsiung Chen (1979).

F.B. Shaffer published reports on the characteristics of streamflow in Shelf Creek, Elkhorn River, and Salt Creek Basins (OFR 72–04, 1972), Loup River Basin (OFR 74–01, 1974), and the Nebraska part of the North and South Platte River Basins (OFR 76–167, 1975). Along with K.J. Braun, Shaffer prepared reports on floods in the Seward quadrangle (HA–258, 1967), the lower Loup River Basin (HA–188, 1967), and at Grand Island (HA–352, 1970). E.W. Beckmann authored a report on magnitude and frequency of floods in Nebraska (WRI 76–109, 1976). Dale Lillie (1966–68) assisted with surface-water interpretive studies.

G.V. Gordon prepared a report on the chemical effects of irrigation-return water in the North Platte River Basin in western Nebraska (Prof. Paper 550–C, 1966). K.A. MacKichan (1967) authored a report on temperature fluctuations of three Nebraska streams (Prof. Paper 575–B, 1967). L.R. Petri summarized pesticide concentrations in Nebraska streams (OFR, 1972) for the period 1968–72. In 1977, L.R. Petri and R.A. Engberg studied the movement of nitrogen into aquifers in the Central Platte Natural Resources District (OFR, 1977). R.A. Engberg studied the nitrate hazard in well water in Holt County (Nebr. Water Survey Paper 21, 1967), nitrate and orthophosphate in several Nebraska streams (Prof. Paper 750–C, 1971), and selenium in Nebraska ground water and streams (Nebr. Water Survey Paper 35, 1973). Engberg and co-author Tim Renschler reported on phosphorus and nitrogen in Salt Creek in Lincoln (Prof. Paper 750–C, 1971). Engberg and a non-USGS co-author prepared a ground-water-quality atlas of Nebraska in (UNL-CSD Resource Atlas 3, 1978). Water-quality investigations were carried out by L. Rodney Larson (1966–68) and James Ficken (1966–68).

E.K. Steele, Jr., published reports on water-use for irrigation in Hamilton and York Counties (Nebr. Water Survey Papers 27 and 30, 1971), Clay County (Nebr. Water Survey Paper 32, 1972), and Seward County (OFR 73-08, 1973).

C.F. Keech and Ray Bentall prepared a report on the Sandhills region of Nebraska (UNL-CSD Resources Report 4, 1971). Ray Bentall led a team of authors who produced an interdisciplinary report on the hydrology of the Elkhorn River Basin (UNL-CSD Resources Atlas 1, 1971). K.A. MacKichan, N.G. Stuthmann, and Ray Bentall used channel slope and discharge to determine reaeration coefficients for the Elkhorn River in Nebraska (Prof. Paper 700–C, 1970).

Mildred Malhoit was the secretary and reports person from 1966 to 1977, and Jean McKinney served in the same position during 1978–79. Jack Dugan worked on soil projects in 1977–79. Paul Bartz and Dave Schwartz were Hydrologic Technicians in the Studies Section in 1979. Ray Bentall was in charge of reports until his retirement in 1974.

OTHER ACTIVITIES

For many years prior to the reporting period, the old Surface Water District conducted an annual conference jointly with the Nebraska Department of Water Resources. This meeting called the "North Platte Conference," named for the city in Nebraska where it was held, also was attended by members of the Regional Staff who enjoyed both the technical presentations and the conviviality. After organization of the District Office, the conferences continued to be held. In 1970, they were switched to an every-other-year frequency, and personnel whose disciplines were ground water and water quality were invited to attend, much to the chagrin of some of the surface-water purists. In the mid-1970's the conferences were expanded to include all major State cooperators, and in 1978, came the last straw. The organizing committee moved the conference to Kearney, a city located in central Nebraska. Even with the changes, this conference remained the cornerstone for information exchange and sociability between representatives of the hydrologic community of Nebraska.

EPILOGUE

The period of 1966–79 was a time of transition in the WRD history of Nebraska. The beginning of the period was a shakedown for the new District structure. As time progressed, the lines between the disciplines blurred and in 1975 ceased to exist as the Subdistrict Offices finally assumed total control of all hydrologic data collection. Together with this, new cooperators, primarily in the field of water quality, began working with the District. Loss of the District Laboratory in 1971 was highly traumatic as several long-term employees were required to take their talents elsewhere.

Even with the changes mentioned above, much of the period was spent maintaining a status quo. District organization was unchanged, the two principal cooperators remained the same, and the programs were changed little from the beginning of the period. A reduction in the crest-stage gage program in the middle 1970's was offset by the addition of water-quality cooperators. Hydrologic studies moved from the classic county studies to basin model studies and water-quality studies, but the number of studies remained fairly constant. The overall increase in District funding was largely the result of the large inflation of salaries and prices during the period.

As the period drew to a close, the number of District employees was roughly the same as that at the beginning of the period.

NEW MEXICO

By John P. Borland, Glenn A. Hearne, John S. McLean, and Roy R. Cruz

ORGANIZATION AND MANAGEMENT

When the reorganization of the Water Resources Division began in January of 1966, there were three Branch Districts with offices in nine locations throughout New Mexico. William E. Hale returned from Denver to be the new District Chief. Wilbur L. Heckler, formerly the District Engineer of the Surface Water Branch, was designated the Assistant District Chief. Upon his retirement in 1969, he was replaced by Ernest D. Cobb, who transferred to Puerto Rico in 1974. Cobb was replaced by Pat L. Soule as Assistant District Chief. Kim Ong continued as Chief of Chemical Quality Laboratory with Jack D. Dewey supervising the Sediment Laboratory operation. The combined number of staff members from the three branches totaled approximately 90. This is the same number of staff members working in the District as of 1979. With the reorganization came the designations of the scope of work that was being done by the staff. Francis C. Koopman was responsible for supervising the investigation or project activities in the District regardless of discipline. James B. Cooper was in charge of the reports and drafting section for the District, and Elsie F. Sanchez continued as Chief of the Administrative Section. L.P. (Bud) Denis, who was serving as Assistant Chief for the Surface Water Branch, was designated Data Chief. All of the Albuquerque offices continued to be located in the Geology Building on the University of New Mexico campus.

In 1976, the District Offices relocated to the Western Bank Building at 505 Marquette NW in downtown Albuquerque. Prior to the District moving downtown, the Albuquerque Subdistrict Office relocated to 3540 B Pan American Freeway in northeast Albuquerque.

Albuquerque Subdistrict

The Albuquerque Subdistrict continued to be located with the District offices until the spring of 1976 when it relocated to a site along I-25 North in northeast Albuquerque. At the time of the reorganization, Fred K. Fields was Hydrologist-in-Charge of the office. Fields transferred to Puerto Rico in August of 1967. John P. (Pat) Borland, who had transferred from Santa Fe in March of 1967, was named Acting and later Hydrologist-in-Charge of the office. Staff members during the period included Allan J. Asquith (until 1970), who transferred to the California District; Joe G. Cordova (1967–70) retired; Larry J. Kuck (until 1970) transferred to the Idaho District; Luis C. Madrid transferred from Texas in 1970; David Ortiz transferred from the sediment laboratory in 1970; Tino S. Quintana; Jim C. Schafer transferred from Santa Fe in 1970; Phil C. Teeters; and Linda V. Beal was both secretary and data entry clerk to the Subdistrict. Secretarial support also was provided during the period by Rosemary S. Ames, Anita M. Garcia, and part-time students.

During the entire period the Albuquerque Subdistrict was responsible for monitoring streamflow, water quality, sediment, and ground-water levels at selected sites in the western half of New Mexico and on the Rio Grande from Cochiti Dam to below Elephant Butte Dam. This included supervision of the Field Headquarters located in Durango, Colo., and San Antonio and Silver City, N. Mex. When the Subdistrict moved to its new location in 1976, it also received responsibility for supervision of the contractor hired by WRD to collect data for the coal hydrology studies in northwestern New Mexico. At that time four hydrologists who were conducting coal hydrology studies were reassigned to the Subdistrict; the four were Jack D. Dewey, Kim Ong, Forest P. Lyford, and Peter F. Frenzel. Henry J. Hejl transferred from Kansas in 1977 and also was a project chief of studies in the coal hydrology area. John J. Rote (transferred from Florida 1977), and Edward D. Villanueva provided technician support to the project and also was assigned to the Subdistrict.

Roswell Subdistrict/Field Headquarters

At the time of the reorganization, George E. Maddox was Hydrologist-in-Charge of the Roswell office, but he transferred and was replaced by George E. (Ed) Welder, who transferred from Wyoming in 1968. Terry J. Perkins, who had been in Carlsbad, N. Mex., and had transferred to Wyoming, also returned to the Roswell office but transferred to Santa Fe in 1970. Jim D. Hudson and Rosemary S. Ames transferred to Albuquerque after Maddox transferred. Forest P. Lyford was hired to assist on the Pecos River studies and later transferred to Albuquerque in 1973. Howard E. Lobley and Jerry D. Stevens both transferred to Albuquerque in 1971. Ronald L. Rogers transferred from Carlsbad to Roswell in 1970. When George E. Welder transferred to Albuquerque in 1975, the office designation was changed from Subdistrict to Field Headquarters. The remaining staff member was Ronald L. Rogers. The office conducted hydrologic studies and collected streamflow, water-quality, sediment, and ground-water data in the upper reaches of the Pecos River and provided supervision to the Carlsbad Field Headquarters until Welder's transfer in 1975.

Santa Fe Subdistrict

William K. (Bill) Dein was Hydrologist-in-Charge of the Subdistrict during the entire period. The office had a mixture of staff members with some assigned to the Subdistrict and others considered to be District staff members, but located in Santa Fe. This was a result of both the District and a Subdistrict Office for the previous Surface Water Branch being located in Santa Fe. Moving these staff members to Albuquerque was not considered necessary. Those staff members assigned to the Subdistrict were E.E. Cerny (until 1969, retired); R.L. McCracken, transferred to Silver City in 1971; J.C. Schafer, transferred to Albuquerque 1970; J.P. (Pat) Borland, transferred to Albuquerque 1967; B.R. Tribble; M.F. Ortiz; T.J. Perkins, transferred from Roswell, 1970; R.P. Thomas and L.A. Waite, transferred to Carlsbad 1978; and L.J. Kuck, transferred from Carlsbad 1977. The Santa Fe Subdistrict was responsible for all hydrologic data collection in north and northeastern New Mexico and supervised the Field Headquarters that were located in Las Vegas and Tucumcari, N. Mex.

District staff members located in Santa Fe were R.E. Cook (until 1969, retired), W.D. Purtymun (until 1970, resigned); A.G. (Pete) Scott (transferred to Reston in 1976); L.J. Reiland (until 1979, retired); J.L. Kunkler; R.W. Clement (transferred to Albuquerque, 1973, and to Kansas, 1978); E.L. Hogue (until 1976, retired); R.R. White (transferred from Las Cruces, 1978); and Pedro Gonzales.

Carlsbad Field Headquarters

Edward R. Cox was the Hydrologist-in-Charge of the Field Headquarters at the time of the reorganization and later transferred to Wyoming in 1966. C.C. Cranston became Supervisory Hydrologic Technician in 1972, then transferred to Pascoe, Wash., in 1977. L.A. Waite became Supervisory Hydrologist of the office in 1978. John S. Havens transferred to Oklahoma in 1970. Other staff members were W.I. Garner (until 1977, retired). R.L. Rogers transferred to Roswell in 1970; R.K. DeWeese, Jr., and L.J. Kuck transferred from Idaho in 1974 and later to Santa Fe in 1977.

The Carlsbad Field Headquarters had the responsibility for hydrologic data collection in the lower Pecos River Basin in New Mexico and acted as Secretary to the Pecos River Commission.

Durango Field Headquarters

Orville McCoy was the Hydrologic Technician at this Field Headquarters during the entire period. He was responsible for all hydrologic data collection in the San Juan River Basin of northwest New Mexico.

Las Vegas Field Headquarters

Dale A. Reynolds was the Hydrologic Technician at this Field Headquarters until he retired in 1974. This Field Headquarters was responsible for hydrologic data collection on the upper Canadian, Gallinas, and Mora Rivers. Data collection for this area was assumed by the Santa Fe Subdistrict.

San Antonio/Socorro Field Headquarters

At the time of the reorganization, Lorenzo B. Baca and Transcito Díaz were the Hydrologic Technicians working in this area—Baca for the Surface Water Branch and Díaz for Water Quality Branch. Both continued to work in the area until they retired—Baca in 1969 and Díaz in 1975. Emilio Pargas was hired as Hydrologic Technician in the area in 1970. The Field Headquarters was responsible for streamflow, water-quality, and sediment data collection in the Middle Rio Grande from Bernardo to San Marcial. In this reach of the Rio Grande, gaging stations were measured weekly and sediment samples were collected on a daily basis at selected gaging stations.

Silver City Field Headquarters

Thurman E. Yates was Hydrologic Technician at the Field Headquarters at the time of the reorganization. He retired in 1971 and R.L. McCracken transferred from Santa Fe to assume responsibility for hydrologic data collection in the Gila and San Francisco River Basins of southwest New Mexico.

Tucumcari Field Headquarters

Ralph K. DeWeese was Hydrologic Technician at the Field Headquarters until he retired in 1973. Hydrologic data collection for the Canadian River, which had been the responsibility of the Field Headquarters, was assumed by the Santa Fe Subdistrict.

Las Cruces Field Headquarters

A new Field Headquarters was established in Las Cruces in 1971. Clyde A. Wilson transferred to New Mexico from Texas to conduct a hydrologic investigation in the lower Rio Grande Basin. Other staff members were William R. Bauersfeld, a student at New Mexico State University (until 1974), Robert R. White (transferred to Santa Fe in 1978), and Gary G. Roybal (transferred to Albuquerque, 1977). This office, in addition to work on the lower Rio Grande, assumed work that was being conducted at White Sands Missile Range. This work previously had been done by District staff members from Albuquerque.

HYDROLOGIC DATA COLLECTION

The streamflow, water-quality, sediment, and water-level programs remained fairly constant during the period 1966–74. But in 1975, as with other Western States, the programs all expanded to meet the needs of the energy-related activities taking place in northwestern New Mexico.

Streamflow Stations

The number of continuous-record stations operated in New Mexico in 1966 was about 215. Most of the stations lost were associated with baseline data needs that had been obtained for the Bureau of Reclamation San Juan-Chama Diversion Project and the Forest Service's runoff study in the Santa Fe National Forest.

As a result of a court settlement involving Arizona and California, an extensive program was started in southwestern New Mexico in cooperation with the New Mexico Interstate Stream Commission to determine the amount of water being used for irrigation from both surface- and ground-water sources. This project resulted in the establishment of 40 seasonal surface-water stations and the installation of over 100 meters to measure ground-water pumping for irrigation.

During the period, 1966–79, major floods produced peaks of record on the lower Pecos River and in southwestern New Mexico on the Gila and San Francisco Rivers. The peaks that occurred on the Pecos River during August of 1966 helped to convince Congress to provide funding for the construction of Brantley Dam north of Carlsbad.

The lack of all types of hydrologic data in northwestern New Mexico to meet the needs of the energy industry resulted in the addition of 20 new gaging stations. The gaging stations were established primarily on ephemeral streams to try to determine the runoff characteristics of the area. In addition to the new gaging stations, crest-stage gages were constructed, and a small drainage basin (AH-SHI-SLE-PAH Wash, 8.2 square miles) was instrumented with automatic samplers and numerous rain gages around the perimeter and at other locations in the basin to measure rainfall and determine the runoff produced along with sediment concentrations. Kim Ong, Jack Dewey, and Henry R. Hejl all worked on the Coal Hydrology Program and the AH-SHI-SLE-PAH Wash study.

The Water Resources Division contracted with a private consulting firm from Helena, Mont., (Morrison-Mairle) to help operate the gaging station and collect water-quality and sediment samples at the new gaging stations that were established to meet the hydrologic data needs of the energy industry in New Mexico and Utah. A Field Headquarters was established in Farmington, N. Mex., to serve northwestern New Mexico and southwestern Utah. Quality assurance and control for the contractor were provided by the Albuquerque Subdistrict Office.

Water-Quality Stations

The water-quality program grew steadily during the period and experienced a sharp upturn about 1968 when environmental concerns became a national issue. The District has always had a cooperative program with the Office of the State Engineer, but with the addition of the national programs—hydrologic benchmark, national stream-quality accounting network (NASQAN), pesticide, radiochemical, tritium, and the surveillance networks—the water-quality program expanded rapidly. In addition to all of the new programs coming on line after 1968, the Coal Hydrology Program also provided rapid expansion starting in about 1975.

These changes are reflected in the number of gaging stations where water-quality samples were collected (about 57 in 1966 and about 130 in 1979). These numbers do not include the miscellaneous samples collected from wells (143 in 1979).

Kim Ong was Supervisory Chemist of the District Laboratory following the reorganization to WRD and became the District's Water-Quality Specialist when the Central Laboratory was opened in 1971. He later worked on the water-quality component of the Coal Hydrology Program in addition to his specialist duties. Richard L. Lepp assumed responsibility for the day-to-day operation of the Laboratory following Kim Ong's designation as Water-Quality Specialist.

When the Central Laboratories started processing samples in 1971, the New Mexico District started sending the majority of their samples to those laboratories. Later, the only analyses being done at the District laboratory were special requests or quality-assurance check analyses.

Sediment Stations

At the time of the reorganization, there were approximately 35 gaging stations at which sediment samples were being collected. Of these, continuous record of sediment loads was being collected at 21 gaging stations. In contrast to 1979, sediment samples were being collected at 45 gaging stations, but only 15 of these gaging stations were collecting continuous record of sediment loads.

The New Mexico District's Sediment Laboratory provided concentration, size, and bed-material analyses for all samples collected in New Mexico plus accepting work from other Districts.

Extensive research was done in the District regarding sediment transport at the gaging station, Rio Grande near Bernalillo, and transport of heavy metals at the gaging station, Rio Grande Conveyance Channel near Bernardo. In addition to these sites, research involving sediment transport into the Rio Grande also was done on the Rio Puerco. Most of the research was done through the efforts of James K. Culbertson and Cloyd H. Scott in New Mexico, assisted by Jack D. Dewey, Vernon W. Norman, and Bruce M. Delaney.

Flood Investigations

In 1966, Owen J. Larimer was Project Chief of the Highway Program, started in 1952 by Hugh H. Hudson in cooperation with the New Mexico State Highway Department and the Federal Bureau of Public Roads. As with other nationwide highway programs, it included a statewide network of approximately 148 crest-stage gages, evaluation of hydraulics of flows at bridge sites, and indirect measurements of extreme high flows such as the 1966 flood in the Pecos River Basin. A.G. "Pete" Scott became Project Chief after Larimer transferred to South Dakota in 1968.

Scott, with assistance from R.W. Clement (until 1973) and J.L. Kunkler, ran the highway program until his transfer in 1976 to Headquarters in Reston, Va.

R.P. Thomas, who along with Clement had been working on the Flood-Prone Area Maps, became Project Chief for the program.

During the period when Scott was Project Chief, he produced three reports that were used extensively by the New Mexico State Highway Department to determine flood runoff at ungaged sites. He also started a small drainage-area study that related rainfall in small drainage areas to runoff produced. The study started with 11 rainfall/runoff sites and had a maximum number of 42 sites in 1971.

R.P. Thomas and R.W. Clement produced extensive flood-prone area maps for the cities of Grants/Milan, Belen, Bosque Farms, and Farmington, along with delineating flood-prone areas on topographic maps for all of the major towns and villages in New Mexico. The following reports were produced by Scott and others during the period:

Preliminary Flood-Frequency Relations and Summary of Maximum Discharge in New Mexico, Open-File Report (1971).

Flood Discharges of Streams in New Mexico as Related to Channel Geometry, Open-File Report (1976); Investigation and Analysis of Floods from Small Drainage Areas in New Mexico, Open-File Report (1974).

Flood of July 17, 1972, in Gallup, New Mexico, Open-File Report (1973).

Ground-Water Data Program

The observation-well program was conducted primarily in cooperation with New Mexico Office of the State Engineer/Interstate Stream Commission. Other cooperators included White Sands Missile Range (Department of Defense) and the New Mexico Highway Department. The statewide network grew from about 1,500 wells in 1966 to more than 5,000 by 1979. The program included well inventories, periodic water-level measurement, geophysical logging of wells, and aerial photography used for determination of irrigated acreage and water use. Reports published during the period included:

Annual "Ground-Water Levels in New Mexico" (1966–79) by Fred Busch and Jim Hudson.

Annual "Water-Resources Review, White Sands Missile Range" (1966–79) by Fred Busch and Roy Cruz.

Annual "Ground-Water Depletion, in Feet, Allowed in Part of Curry County, Central and Northern Lea County, Portales Valley and Lea County, New Mexico, by U.S. Internal Revenue Service for Calendar Year" (1966–79) by Jim Hudson.

"A Compilation of Hydrologic Data Before and During Highway Construction in Parts of Tijeras Canyon, New Mexico, 1972–1978," by Jim Hudson.

INTERPRETIVE STUDIES

From 1966 to 1979, the District published more than 90 reports on the hydrology of New Mexico. A major issue of the period was the allocation of the limited water resources among Indian and non-Indian landowners. The New Mexico State Engineer's Office (SEO) sought to adjudicate water rights among water users in the Pojoaque River Basin, northwest of Santa Fe. The U.S. Bureau of Indian Affairs (BIA) entered into the litigation to establish water rights for the four Indian pueblos in the basin: Nambe, Tesuque, Pojoaque, and San Ildefonso. The Pojoaque River Basin is within the Espanola Basin, one of several interconnected structural basins that form the Rio Grande depression. The BIA sought to quantify water rights for the pueblos on the basis of quantity of water of suitable quality that could be economically withdrawn from the Tesuque Formation, which underlies the central part of the Espanola Basin, including most of the Pojoaque River Basin. The SEO was especially interested in the effect of withdrawals on flow in the Rio Grande.

A WRD project to simulate effects of withdrawals on ground-water levels and flow of the Rio Grande presented programmatic and technical challenges to management and staff of the New Mexico District. Programmatic challenges arose because the adjudication pitted two of the District's principal cooperators, SEO and BIA, against each other. At one time during the adjudication, William E. Hale, District Chief since 1966, was required to appear in court and convince the presiding judge he should not be held in contempt of court. Publication of one of the resulting reports—Open-File Report 80–421—as "prepared in cooperation with the U.S. Bureau of Indian Affairs and the New Mexico State Engineer's Office" indicates the strength of the District's relationship with cooperators.

Technical challenges included working with an aquifer composed of interbedded layers of varied permeability, dipping about 5–10 degrees from the horizontal; lack of software and hardware adequate to simulate this complex system; and lack of reliable data describing aquifer characteristics. C.V. Theis (Office of the Chief Hydrologist, collocated with the District office) analyzed the anisotropy that results from dipping interbedded layers of varied permeability and demonstrated the significance of the resulting anisotropy on the horizontal and vertical components of ground-water flow. Al Clebsch and others later published Theis' results after his death as part of WSP–2415.

Representing anisotropy using available computer code for ground-water flow models required orienting the x- and y-axes along the bedding plane and the z-axis orthogonal to the beds. Orienting the x- and y-axes at an angle to the horizontal resulted in a model requiring storage exceeding the physical limits of any available computer. Doug Posson, Glenn Hearne, Jim Tracy (WRD, Reston, Va.), and Peter Frenzel cooperatively developed and documented computer code to allow the economical processing of extremely developed and documented computer code to allow the economical processing of extremely large grids, essentially unconstrained by the physical limits of a computer's memory (Open-File Report 80–421). The BIA installed wells and piezometers at four sites in Espanola Basin. At each site, Jim Hudson and Roy Cruz recorded geophysical logs; Frank Koopman, Jim Basler, and Glenn Hearne conducted aquifer tests. Hearne estimated aquifer characteristics at one site by using the computer code to simulate water-level data from multiple piezometers open to selected beds near a pumping well (WSP 2206), demonstrating the ability to accurately represent this complex aquifer. Using a model of Espanola Basin, Hearne concluded that—after 50 years of withdrawals presented by BIA to quantify Indian water rights—about 10–20 percent of withdrawals are captured from the Rio Grande or tributaries to the Rio Grande (WSP 2205). In addition to publishing the results of the model studies, Hearne testified in court concerning those publications.

Another interesting and highly visible study started in 1968. Visitors to Carlsbad Caverns in the late 1960's reported to National Park Service rangers that the cave seemed much drier, and the water levels in pools were lower than on previous visits. Francis Koopman of the New Mexico District then (in 1968) began a study of the microclimate in the cave to determine possible causes of the drying. Instruments for measuring temperature, humidity, and carbon dioxide content of the cave atmosphere were installed and supplemented with measurements of evaporation rates and air flow when John McLean took over as Project Chief in early 1969. The main cause of the drying was found to be uncontrolled air flow up the 750-foot elevator shaft. This "chimney effect" was responsible for venting an estimated 83,000 gallons of water per year from the cave. The open-file report "The Microclimate in Carlsbad Caverns, New Mexico," published in 1971, resulted in revolving doors and airlock doors being added at the bottom of the elevator shafts. The effects of this and other mitigating measures were evaluated in a followup study, and the results showing relative effects of airflow and heat added by the cave lighting system were published in another open-file report in 1976 entitled "Factors Altering the Microclimate in Carlsbad Caverns, New Mexico."

The Hueco Bolson aquifer was modeled by W.R. Meyer, and the model was used to simulate the effects of ground-water pumping in the El Paso area. The Hueco Bolson provides a substantial part of the municipal and industrial water supply of the El Paso area of Texas, Mexico, and New Mexico. The model was used to test a proposed plan to increase pumping from 1973 to 1991 and showed that water-level declines would increase.

Kelly and Hearne used a digital simulation model and a conceptual model to estimate water-level declines and water-quality changes through 1996 at the White Sands Missile Range and suggested areas offering the greatest potential for development of additional water supplies. Another study of a site by Mercer and Orr that is very visible today (1999) is the Waste Isolation Pilot Plan (WIPP). They reported on the geohydrology of the proposed WIPP in southeast New Mexico. After more than 20 years, the WIPP site is now open and has begun receiving radioactive waste.

These are but a few of the many studies (most of them ground water) that were conducted during the 1966-79 period. Ground water was and continues to be the principal source of water for New Mexico's growing needs.

NORTH DAKOTA

By Douglas G. Emerson and LaRue Baker-Odenbach

ORGANIZATION AND MANAGEMENT

Reorganization—A New District

In 1966, North Dakota operations were handled by two Branch District offices. Both the Surface-Water Branch and the Ground-Water Branch were headquartered in Bismarck. Harlan M. Erskine was the District Engineer and Delbert W. Brown was the District Geologist. The Surface Water Branch had Subdistrict Offices in Grand Forks, N. Dak. (Charles E. Cornelius, Engineering Technician-in-Charge), Pierre, S. Dak. (John E. Wagar, Engineer-in-Charge), and Rapid City, S. Dak. (Leonard B. Yarger, Engineer-in-Charge), and Field Headquarters in Dickinson, N. Dak. (John R. Little, Engineer-in-Charge), and in Yankton, S. Dak. (Donald J. Pangburn, Engineering Technician). The Ground Water Branch had a Subdistrict Office in Grand Forks, N. Dak. (Quentin F. Paulson, Geologist-in-Charge) and a Field Headquarters in Fargo, N. Dak. (Robert L. Klausing, Geologist). The Water-Quality program was conducted out of Lincoln, Nebr., by the Regional Engineer. Administrative services for the offices were provided by Gordon M. Holtan and LaRue A. Baker and were located in Bismarck.

By January 1967, the Branch Districts were merged into a single Water Resources Division District that was headquartered in Bismarck. The surface-water offices in South Dakota became part of the newly developed South Dakota District. The first District Chief was Harlan M. Erskine. James L. Hatchett became the first Assistant District Chief and Mildred M. Schneider became the Administrative Assistant.

Bismarck District Office

The Bismarck office was on the third floor of the New Federal Building, Third Street and Rosser Avenue in downtown Bismarck, until August 1978, when a new building was completed especially for the District Office at 821 East Interstate Avenue.

In 1969, Jelmer B. Shjeflo became Chief of the Basic Data and Operations Section and Orlo A. Crosby became the Engineer-in-Charge of the Hydrologic Studies Section. In early 1970, the District Chief, Harlan M. Erskine, died. Later that year, Robert C. Williams transferred from Cheyenne, Wyo., to become the second District Chief of North Dakota. Quentin F. Paulson become the second Assistant District Chief when James L. Hatchett transferred to the Planning Section at USGS National Headquarters in Washington, D.C.

In 1973, a Subdistrict Office consisting of the surface-water data personnel was established in Bismarck with Jelmer B. Shjeflo as the Supervisory Hydraulic Engineer. Others in the office were David B. Hanson, Morris S. Brostrom, Leonard Bachmeier, and James D. Heidt. Shjeflo retired in 1974 and William E. Harkness, who transferred from the Grand Forks Subdistrict Office in August 1973, became the Supervisory Hydraulic Engineer.

Robert C. Williams, the District Chief, died March 20, 1974, after a courageous battle with cancer. Quentin F. Paulson was the Acting District Chief until October 1974 when Walter R. Scott, who was the Assistant District Chief in the New York District Office, transferred to Bismarck as the third District Chief. Scott retired in 1978 and Leo Grady Moore, Chief of the Hydrologic Records Section in Helena, Mont., transferred to Bismarck to become the District's fourth chief.

The following employees were on the rolls in the Bismarck District Office in 1966: Harlan M. Erskine, James L. Hatchett, Delbert W. Brown, Jelmer B. Shjeflo, Charles E. Schoppenhorst, Orlo A. Crosby, William E. Harkness, Morris S. Brostrom, Roger A. Pewe, John R. Eastman, Leonard Bachmeier, James D. Heidt, Gordon M. Holtan, LaRue A. Baker, Marjorie C. Kocon, Wayne A. Pettyjohn, Clarence A. Armstrong, Frank J. Buturla, Jr., Philip G. Randich, Luverne L. Albright, James D. Wald, Jeannette E. Wagner, and Marjorie C. Pokladnik.

Throughout the period the role of women in the District's program increased. The first female hydrologist, Anne H. Harrington, joined the Hydrologic Studies Section in 1979. About that same time, Beryl A. Binde was hired as a hydrologic technician for the Hydrologic Records and Information Section. Mildred M. Schneider progressed from the Administrative Assistant GS–5 to Administrative Officer, GS–9. Marjorie C. Pokladnik also joined the Professional Series as a Technical Publications Editor. In 1979, 26 percent of the District employees were women. Although most were concentrated in the clerical positions, their responsibilities and grades had increased considerably.

The following employees were on the rolls in the Bismarck District Office in 1979: L. Grady Moore, Quentin F. Paulson, Mildred M. Schneider, LaRue A. Baker, Sharon G. Anheluk, Ione K. Leet, Russell E. Harkness, Norman D. Haffield, Daniel J. Ackerman, David B. Hanson, Joseph A. Smath, Morris S. Brostrom, James D. Heidt, Robert W. Gauger, Michael J. Voigt, Jeannette E. Wagner, Dale R. Bast, Katherine L. Cox, Gilbert L. Berg, Beryl A. Binde, Orlo A. Crosby, Clarence A. Armstrong, Raymond D. Butler, Mack G. Croft, Michael R. Burkart, William F. Horak, Jr., Robert L. Klausing, Philip G. Randich, Douglas G. Emerson, G. Eldon Ghering, Jr., Mark E. Crawley, Kenneth F. Brinster, Anne H. Harrington, Marjorie C. Pokladnik, Luverne L. Albright, Carolyn S. Helgesen, Steven W. Norbeck, Cathy R. Martin, Ronald L. Kuzniar, Rosanne R. Heiser, and Geraldine B. Wald.

Grand Forks Subdistrict Office

At the beginning of the period, the Surface Water and Ground Water Branches were located at the Federal Building, 102 N. 4th Street in Grand Forks, N. Dak. The surface-water section consisted of three engineering technicians and was headed by Charles E. Cornelius. The ground-water section was headed by Quentin F. Paulson, Geologist-in-Charge, and had six employees who were associated with five ongoing ground-water investigations in eastern North Dakota. Quentin F. Paulson also provided the supervision of the Fargo Field Headquarters.

In August 1966, Paulson transferred to Bismarck, and the two sections were combined into a Subdistrict Office headed by Hans M. Jensen. Jensen transferred to the Subdistrict Office in Mineola, N.Y., and in 1968, Richard D. Hutchinson transferred from Waukesha, Wis., to the office as the Hydrologist-in-Charge. By 1970, most ground-water employees were transferred to the Bismarck office. Personnel in the office besides Richard D. Hutchinson were William E. Harkness, Joe S. Downey, Oren O. Holmen, Wayne R. Westensee, and various seasonal and When Actually Employed (WAE) persons.

In August of 1972, William E. Harkness, who was the Hydraulic Engineer-in-Charge of the surface-water data section, transferred to the Bismarck District Office, and John R. Little transferred from the Dickinson Field Headquarters to the Grand Forks Subdistrict Office to replace Harkness. By 1975, all the ground-water projects were managed by the Bismarck District Office—Downey had transferred to Bismarck District Office and Hutchinson had transferred to Subdistrict Office in Billings, Mont. When John R. Little transferred to the Colorado District in July 1975, the office was downgraded to a Field Headquarters and Oren O. Holmen became the Hydrologist-in-Charge.

Dickinson Field Headquarters

The Dickinson Field Headquarters was in the Masonic Temple Building at 42 Sims Street and was staffed by John (Jack) R. Little, who was the Engineer-in-Charge, and by Anton Mack, Douglas L. Ellenbecker, and Richard Beard, who were engineering technicians. Richard Beard transferred to Pierre, S. Dak., and Anton Mack retired in 1969. George J. Klug was hired as Mack's replacement. In August of 1972, Jack transferred to the Grand Forks Subdistrict Office and Roger A. Pewe transferred from the Bismarck District Office to assume leadership of the Dickinson Field Headquarters.

In January 1977 the office moved from Sims Street to 669 12th Street West. This allowed the consolidation of the office and storage space. The office functioned with an engineer-in-charge and two technicians until Kelvin L. Boespflug was hired in August 1978 to assist with the energy projects.

The office was responsible for the stream-gaging activities in western North Dakota and the stage gages on the Missouri River near Williston, N. Dak.

Fargo Field Headquarters

Robert L. Klausing, Geologist, was the lone employee of the Fargo Field Headquarters except for an occasional seasonal employee. The Fargo Field Headquarters was established in 1963 on the North Dakota State University campus for the duration of the Cass County ground-water study because of driving distances from Grand Forks. The office was closed in 1967 and Robert L. Klausing transferred to the Bismarck District Office.

Energy Boom—A Bigger District

Large increases in staff and budget began in 1975 as the North Dakota District became a major participant in the Division's Coal Hydrology Program. Most of the increase in energy-related work was in cooperation with the Bureau of Land Management. The growth continued through this reporting period (1979). In 1977, the growth was enhanced when the District participated in one of the Division's first Regional Aquifer-System Analysis (RASA) projects—Northern Great Plains. The number of employees was growing rapidly for the small District. This increase caused space shortage and was one of the main reasons for moving to a new building in August of 1978. The Bismarck District Office had grown from 22 permanent employees in 1966 to 41 employees in 1979.

Funding

The District budget continued to increase during this period. The District started with a budget of $605,300 in 1966. The budget figures that are available are listed in the table below. The Coop funding increased from $435,200 in 1966 to $925,800 in 1979. Funding from OFA increased significantly because of the energy boom that started in 1975.

HYDROLOGIC DATA PROGRAMS

Between 1966 and 1976, the hydrologic data network had minor changes and the data program remained fairly stable. Starting in 1977, the data network had major expansions as part of the energy-related programs. Clerical support for the preparation and processing of the annual data report was provided by Marjorie C. Kocon through 1973 and by Jeannette E. Wagner thereafter.

Surface-Water Stations

The streamflow-gaging station network continued to increase from about 6 gaging stations in 1928 to about 119 gaging stations in 1966. Between 1966 and 1976, the streamflow-gaging station program was fairly stable and the number of gaging stations only varied from 116 to 124. From 1976 to 1979, the program experienced a rapid increase in the number of gaging stations due to the energy-related programs. The number of gaging stations peaked in 1979 with about 146 stations.

Ground-Water Observation Wells

The ground-water observation-well program was substantially increasing. By 1966 some of the county ground-water studies had been completed. As these county studies were completed, many observation wells that were measured during the study were added to the observation-well program. The measurement frequency varied; a few wells had recorders, a few more wells were measured monthly, many wells were measured quarterly, and most of the wells were measured annually.

Water-Quality and Sediment Stations

In 1966, water-quality samples were collected at 20 sites in cooperation with the U.S. Department of the Interior for the Irrigation Network or were collected at the request of the U.S. State Department. Field parameters were also measured at 20 sites. By 1979, the collection of water samples started to expand; samples were collected at 154 sites, and field parameters were measured at 166 sites. Cooperators also expanded and included U.S. Department of the Interior, U.S. State Department, Federal Water Quality Administration, International Joint Commission, and North Dakota State Water Commission. Sediment

North Dakota District funds, fiscal years 1966–79

[In thousands of dollars; N/A, not available]

Fund source	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Coop	435.2	444.9	497.4	501.5	N/A	625.4	599.0	667.3	667.3	763.3	786.0	762.0	787.1	925.8
OFA	148.0	157.9	151.1	174.4	N/A	177.1	153.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fed	22.1	23.1	25.9	43.3	38.4	39.5	133.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	605.3	625.9	674.4	719.2	N/A	842.0	886.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A

collection also expanded during this period. In 1966, sediment samples were collected at 4 sites, and by 1979, sediment samples were collected at 76 sites.

Other Data Activities

Greater than normal precipitation during the fall, followed by large snowfall in December, January, and February, created conditions conducive to flooding in April 1969. Maximum stages and discharges exceeded previous floods in the Souris River Basin and in the James and Wild Rice Rivers. Peak flows at many sites exceeded the 25-year recurrence-interval discharge. Flooding was especially severe in Minot, where flow in the Souris River peaked on April 16 at 6,020 cubic feet per second. Most of the personnel in the District, including projects, were busy making flood measurements.

Torrential rains during late June and early July 1975 caused severe flooding mainly along the lower reaches of the Sheyenne and Maple Rivers and their tributaries in North Dakota, and in the Buffalo and Wild Rice Rivers in Minnesota. The Red River of the North from the Fargo-Moorhead area to the Halstad, Minn., area also was severely flooded. Parts of LaMoure, Barnes, Ransom, Cass, and Richland Counties received rainfall exceeding 10 inches. Several District crews ran about 15 indirect measurements to help quantify the flood. A summary flood report was prepared by K.L. Lindskov of the Minnesota District.

One of the most noteworthy floods in the Red River Basin occurred during April 1979. The peak discharge of 82,000 cubic feet per second on April 23 at Grand Forks had a recurrence interval greater than 50 years; that discharge was exceeded only during the flood of 1897. High flows occurred in other parts of the State and kept crews busy making measurements during spring breakup.

HYDROLOGIC INVESTIGATIONS PROGRAMS

The long-term cooperative programs continued through 1979 even after energy-related projects were started in 1975. As the hydrologic investigations programs expanded, more hydrologists and hydrologic technicians were hired. The publications staff also expanded from two in 1966 to four at the end of the reporting period.

Ground-Water Investigations

In North Dakota, numerous isolated investigations had been made in different parts of the State, mostly in small areas surrounding villages and small towns. The investigations generally were localized and problem-solving in scope. Although the investigations provided a needed and valuable service, they did not provide the kind of broad-coverage information needed to systematically evaluate the State's ground-water resources and potential for future development.

Consequently, a team of local, State, and Federal officials was formed in the early 1960's for the purpose of developing a statewide ground-water-resources evaluation program. The county was chosen as the unit of study because of the availability of a financing mechanism, even though it was recognized that a more naturally formed unit such as a drainage basin may have been preferable.

It was decided that the program would be a cooperative one—financed from county, State and Federal sources. It was the decision of county officials and residents to decide after a presentation to them whether they wished to embark on a county study. Funds by the county were usually raised by a property mill levy to support one-fourth of the overall cost. This in turn was matched by the North Dakota State Water Commission and North Dakota State Geological Survey, and the total would be matched by the USGS.

Each county study was considered a project and was done under the overall supervision of a USGS hydrologist. In some cases, where two small counties were contiguous, the studies were completed as a single project. The work was completed in several phases, each resulting in a separate report. Early in each study, the North Dakota Geological Survey compiled a map of the surface geology. This served as a basis for studying the ground-water hydrology and to design a test drilling program. An inventory of existing ground-water sources (wells and springs) was made, and these data, along with water-level data, chemical-quality analyses, aquifer tests (pumping tests), and test-hole logs, were published in a basic-data report. After synthesizing and analyzing all of the collected water facts in the project area, the USGS prepared a report describing and evaluating the major aquifers that were identified and delineated. The projects usually required 4 years for completion at an overall cost of several hundred thousand dollars, depending on the size and complexity of the study area.

The county ground-water studies formed the basis for the sound development of the State's ground-water resources for whatever purpose, ranging from a single-family domestic well to large-scale irrigation or municipal developments. One of the major but unforeseen benefits of the program was the formation of rural water cooperatives or districts. As knowledge of the extent and productivity of the State's ground-water resources became available, it became obvious that these resources could supply water-delivery systems in rural areas much the same as in municipalities located along rivers and streams. Almost all entities used water from major aquifers identified and delineated in the course of the County Ground Water Studies Program.

The period from 1966 through 1979 was definitely the time for county ground-water studies. Of the 53 counties in North Dakota, 2 counties (Kidder and Stutsman Counties) were completed before 1966 and 1 (Towner County) was started in 1980. County ground-water studies that were completed or started during the period are identified with a project number in parentheses. Adams County (ND058), Barnes County (ND029), Benson County (ND049), Billings County (ND069), Bottineau County (ND081), Bowman County (ND058), Burke County (ND041), Burleigh County (ND028), Cass County (ND030), Cavalier County (ND054), Dickey County (ND067), Divide County (ND032), Dunn County (ND059), Eddy County (ND033), Emmons County (ND60), Foster County (ND033), Golden Valley County (ND069), Grand Forks County (ND037), Grant County (ND061), Griggs County (ND057), Hettinger County (ND046), LaMoure County (ND067), Logan County (ND080), McHenry County (ND073), McIntosh County (ND074), McKenzie County (ND086), McLean County (ND044), Mercer County (ND045), Morton County (ND063), Mountrail County (ND041), Nelson County (ND048), Oliver County (ND045), Pembina County (ND054), Pierce County (ND049), Ramsey County (ND066), Ranson County (ND068), Renville County (ND034), Richland County (ND031), Rolette County (ND081), Sargent County (ND068), Sheridan County (ND073), Sioux County (ND061), Slope County (ND069), Stark County (ND046), Steele County (ND057), Traill County (ND039), Walsh County (ND048), Ward County (ND034), Wells County (ND038), and Williams County (ND035).

The project "Effects of Proposed Kindred Reservoir on the Ground-Water Environment in the Sheyenne Delta Deposits, Southeastern North Dakota" (ND062) started a new era for the Survey and the District. The objectives of the study were to predict the changes in ground-water levels and ground-water discharge resulting from construction of a dam and reservoir on the Sheyenne River using a digital computer model. The concern was the effect the impoundment might have on the ground-water levels and natural discharge in the surrounding areas, which were underlain by highly permeable deposits of sand and gravel. Computer models were in a relatively infant state in the early 1970's and this project was somewhat of a pioneering venture. J.S. Downey designed and operated the model using an IBM 360 computer at the University of North Dakota. Q.F. Paulson provided the geologic and hydrologic input. Other early ground-water studies included "Hydrology of the Madison Group and Associated Rocks in the Williston Basin, North Dakota" (ND078) and "Evaluation of Hydrologic Effects of Withdrawal on the West Fargo Aquifer" (ND088).

Flood Investigations

The long-term program of investigations of flood characteristics of North Dakota streams started in 1954 in cooperation with the North Dakota Department of Transportation. The project "Magnitude and Frequency of Floods on Small Streams—North Dakota" (ND010) was directed by Orlo A. Crosby through 1973 when the program ended. The project consisted of a network of crest-stage gages and determination of basin characteristics. Several reports were published, including "Magnitude and Frequency of Foods in Small Drainage Basins in North Dakota." From 1964 through 1975, Orlo also directed a project studying the effect of basin characteristics on magnitude of floodflows. Three separate areas across the State with adjoining basins of different shapes were heavily instrumented for rainfall and runoff data. A flood-hazard mapping project (ND065) defined flood profiles and flood boundaries. The project was started in 1968 and was completed in 1979.

Energy Resources Investigations

Triggered by the Arab oil embargo, an extensive number of energy-related investigations began in 1974 in the Fort Union Coal Region of North Dakota. Major funding was provided by Bureau of Land Management's Energy Minerals Rehabilitation, Inventory, and Analysis (EMRIA) program. The first energy-related project (ND070) was "Hydrologic Changes Due to Lignite Mining in North Dakota," which was conducted by William F. Horak. The objectives were to define basic geologic and hydrologic information for strippable lignite deposits. Numerous other energy projects were conducted through 1979. "Availability of Ground Water from the Cretaceous and Tertiary Aquifers of the Fort Union Coal Region" (ND071) compiled existing data for the four-State area on the Tertiary rocks and aquifers overlying the Pierre Shale. "Hydrologic Effects of Strip Mining in the Gascoyne Area, Bowman County, North Dakota" (ND075) determined and evaluated hydrologic effects of expanded strip mining in the Gascoyne area. "Hydrologic Evaluation of Mining and Reclamation, Horse Nose Butte, Dunn County, North Dakota" (ND076) defined premining conditions in about 5 square miles in eastern Dunn County. "Hydrologic Evaluation of Mining and Reclamation, Beulah Trench Area, Mercer County, West-Central North Dakota" (ND077) determined premining hydrologic and geochemical conditions with which to compare changes with mining and to predict effects of the stresses imposed by mining.

In 1977, the Survey conducted its first project in which the Survey had field work provided by a private contractor (Morrison Mairle). The objectives of the project "Water Monitoring West Central Coal Region, North Dakota" (ND095) were to determine the characteristics of the regional water-resources system and to detect and document changes in the system. The contractor operated 16 surface-water and water-quality stations and measured and sampled 52 ground-water wells. Premining hydrologic and geochemical regimes were defined for the Wibaux-Beach lignite deposits (ND082) and for the Rattlesnake Butte area (ND085). A very comprehensive surface-water study (ND087) of the Antelope Creek area and the Wibaux-Beach Deposit area developed and calibrated snowmelt and rainfall-runoff models for watersheds in these areas. By 1979, the District was in the middle of energy-related studies that would continue for several more years.

OTHER ITEMS OF INTEREST

February 23–24, 1977, the North Dakota and Minnesota Districts held a joint District Conference in Minneapolis. All employees of the North Dakota District traveled by bus to Minneapolis, Minn., to attend the meeting held at the Normandy Hotel. The Minnesota District was a part of the Northeastern Region and North Dakota part of the Central Region. The purpose of the conference was to exchange information between the Districts and Regions and to share ideas and experiences. A second joint District Conference was held with the Montana District December 6 and 7, 1978, in Billings, Mont. National, Regional, and State representatives participated along with individuals from both Districts.

The District adopted FLEXITIME on October 1, 1976. It allowed employees to start work any time from 6:30 a.m. to 9:00 a.m. and to end their day from 3:30 to 6:00 p.m. A core time was 9:00 a.m. to 3:30 p.m. when all employees were required to be at work or on leave.

Computers Come to the District

Prior to 1974, computer analyses were accomplished by taking or mailing computer cards to either the University of North Dakota in Grand Forks, N. Dak., or to the USGS in Denver, Colo. The District acquired its first computer, an IBM 2780 terminal, in January 1974. Data were keypunched onto cards and transmitted to the Amdahl mainframe by telephone for processing into the WATSTORE (National Water Data Storage and Retrieval System) data bases. The IBM 2780 was replaced in 1978 with Datapoint terminals. Data processing was handled in much the same way except floppy diskettes could be used for data storage.

Northern Association of Scenic States

The Northern Association of Scenic States (NOASS) was the brainchild of Montana's District Chief, George Pike. Early correspondence between George Pike and John Powell, District Chief of South Dakota, indicated that the association was fashioned after the Association of Southern States (ASS). The ASS had the following characteristics: (1) no formal by-laws, (2) membership consisted only of District Chiefs of member States, (3) meetings were held twice a year and never at a District Office, (4) no agenda—anything was open for discussion, (5) Regional

Hydrologists did not attend except by formal invitation, and (6) field trips were taken as part of one meeting each year. NOASS developed a set of by-laws that consisted of the following: (1) organization name would be Northern Association of Scenic States (NOASS), (2) its purpose was to promote a better understanding among Districts, discussion of mutual problems, correlation of interstate projects, and exchange of ideas for more efficient and less expensive means of operation, (3) membership would consist of District Chiefs and Assistant District Chiefs from Montana, North Dakota, South Dakota, and Wyoming, (4) officers would be the chairman and a secretary who would serve for 1 year, (5) two meetings would be held each year, (6) meetings would be informal with District Chiefs submitting discussion items, and (7) host State would pay for meeting rooms. The first NOASS meeting was held at the Tip-Top Motel in Rapid City, S. Dak., in September 1970. Later, meetings sometimes included people from Headquarters or Central Region. The Association met 19 times. The NOASS was to meet for the twentieth time July 1990 in North Dakota, but the four District Chiefs and the Regional Hydrologist decided to indefinitely suspend participation in NOASS by the active Survey members.

OKLAHOMA

by Willard B. Mills and John Havens

In Oklahoma, Branch Districts were merged into a Division (WRD) District in 1967. Previously, water-resources investigations were conducted separately by Surface Water (SW), headed by Alex A. Fischback; Ground Water (GW), headed by James H. Irwin; and Quality of Water (QW), headed by Richard P. Orth.

District Headquarters for SW operations was in the Federal Court House Building at 200 NW 4th Street, in Oklahoma City. Ground Water Headquarters was located at the University of Oklahoma campus in Norman, and QW was located in the warehouse at 2800 South Eastern in Oklahoma City. In 1973, QW officially moved to the basement of the Old Post Office Building at 215 NW Third Street.

After the merger, the District moved to the second floor of the Federal Court House Building at 200 NW 4th Street, where SW was located. The QW trucks and miscellaneous equipment were kept in a warehouse at 2800 South Eastern. In 1974, the WRD moved across the alley to the Old Post Office. Personnel occupied the sixth floor, part of the eighth, and part of the basement. WRD continued to keep miscellaneous equipment at the warehouse, but most of the trucks were in a garage in the new Federal (Murrah) Building at 200 NW Fifth Street.

ORGANIZATION AND PERSONNEL

After reorganization in July 1967, John W. O'Dell served as District Chief. Alex A. Fischback moved to Denver, Colo. When O'Dell retired in May 1971, James H. Irwin*, Assistant District Chief, was made District Chief and remained District Chief until his retirement some years after 1979. Three assistants served under Irwin: Leo L. Laine (1967–72), Vernon B. Sauer (1972–75), and Ronald L. Hanson (1975 past 1979). [Asterisk (*) designates those who were present during the entire reporting period.]

An Administrative Services Section was set up to process financial accounts, payroll, travel vouchers, supply orders, and personnel action. Mary (Todd) Barker was hired in 1973 as an administrative clerk; she continued to head the section past 1979.

All GW discipline operations were carried on from the District Office in Norman, Okla., until their move to the Federal Court House Building. Melvin V. Marcher*, (GW Chief), Donald L. Hart, Jr., Robert B. Morton*, Robert E. Davis, and Robert L. Goemaat* formed the core of the GW personnel and were present from 1970 through 1979.

Leo L. Laine (SW Chief), Charles W. Sullivan (1967–71), who worked mostly with crest-stage gages, and Willard B. Mills (SW and QW Chief, 1972 to past 1979) spent most of their professional careers collecting and reporting on SW data. Several technicians earned the "old-timer award," and served from 1970 through 1979: DeRoy L. Bergman*, Robert K. Corley*, Derryl K. White, Darrell M. Walters, Robert W. Chadd, Tony E. Coffee, Lionel D. Mize*, and Dale V. Mitchell*.

The QW Section was headed by Richard P. Orth (1967–71) and Joanne Kurklin* (under Mills) through 1979. The QW discipline worked with SW and GW to meet the project needs of both disciplines as well as their own requirements.

The Special Studies Section (formed in 1973 under Mills' direction) was headed by Wilbert O.

Thomas, Jr., (1973–76) and Thomas L. Huntzinger (1976 through and beyond 1979). The main thrust of the section was the delineation of flood-prone area maps for many areas of the State. They also made several topical studies in the SW and QW disciplines.

In 1975–76, the District was reorganized into the Administrative Services Section, Areal Investigations and Research Section, and Hydrologic Surveillance, Research, and Analysis Section.

Surface Water personnel in Field Headquarters in Pryor collected and processed water data primarily from the Neosho River Basin in the northeastern part of the State. Beginning in 1976, field personnel in Woodward collected and processed data from the northwestern part of the State. Other Field Offices in Guymon and Elk City were open for shorter periods and generally were project-specific.

COOPERATING AGENCIES

The Oklahoma Water Resources Board (OWRB) was the prime State cooperator for SW activities. Frank Rabb was director for 1966 through 1967, Forrest Nelson from 1967 through 1976, and James Barnett served as acting director from 1976 through and beyond 1979. The Oklahoma Geological Survey (OGS), under the direction of Charles J. Mankin, was the principal State cooperator for GW activities. Quality of Water data were collected in support of both GW and SW projects funded by these cooperators.

Other entities that cooperated with the USGS from 1966 through 1979 were Oklahoma Department of Highways (now called Oklahoma Department of Transportation); Oklahoma Department of Health; Environmental Heath Services; Oklahoma Pollution Control Coordinating Board; Department of Pollution Control; Grand River Dam Authority; Central Oklahoma Master Conservancy District; Lugert-Altus Irrigation District; Ross Reservoir Master Conservancy District; Oklahoma Gas and Electric Company; and the cities of Ada, Altus, Claremore, Edmond, Guthrie, Lawton, Oklahoma City, Sapulpa, Shawnee, and Tulsa.

Federal support for District operations came from the Department of the Interior—Bureau of Reclamation and Bureau of Land Management; Soil Conservation Service; U.S. Army Corps of Engineers; Federal Water Quality Administration (later the USEPA); Federal Emergency Management Agency; Science and Education Administration; Water and Power Resources Service; and National Weather Service (NWS). In addition to the matching funds supplied by State and local agencies, the Geological Survey provided full support for selected streamflow stations and GW observation wells, for an in-depth analysis of the stream-gaging program, and for outlining flood-prone areas on topographic maps as part of a nationwide Federal program for managing flood losses. The greatest support from other Federal agencies came from the Corps of Engineers. Because of the many reservoirs in the State, the Corps had a vital interest in streamflow quantity, quality, and sediment load. The Bureau of Reclamation had some reservoirs in the State and was interested in building more. The Soil Conservation Service funded collection of water-quality and surface-water data for several small watersheds in the State. The USEPA provided funding for the collection of water-quality data. The Federal Emergency Management Agency (FEMA) provided funding for the preparation of flood-insurance studies for a number of communities in the State. The National Oceanic and Atmospheric Administration (NOAA) provided support in the form of services or use of their facilities.

SUMMARY OF PROGRAMS

Surface-water and water-quality personnel devoted much of their time to the collection, processing, and publication of water records. The conversion from analog to digital recorders was completed during this period, and the application of computer technology in the processing of records became standard procedure. A significant number of gaging stations, primarily those supported by the Corps, were equipped with devices that could be interrogated to supply real-time data. By the end of the period, all of the water records (both SW and QW) collected were being stored in the Survey's National Water Data Storage and Retrieval System (WATSTORE).

Surface-Water Records

Records of daily river stage and discharge were collected at 142 stations in 1966 and at 140 stations in 1979. Records of daily water levels were collected at 15 lakes and reservoirs in 1966 and at 26 in 1979. High-flow and low-flow partial records were obtained at 129 sites in 1966 and 42 sites in 1979. A Hydrologic

Benchmark Station was established on the Washita River near Durwood, as part of a nationwide network to monitor hydrologic response to purely natural forces.

Ground-Water Records

In 1979, water levels were measured at 76 project wells and at 48 observation, and physical and chemical-quality data were obtained at 76 and 48 wells, respectively.

Water-Quality Records

In 1966, water-quality records were collected at 21 stations, and monthly records were obtained at 12 others. In 1979, there were 135 stations (57 daily, 42 miscellaneous, 1 monthly or more, and the remainder less than monthly). Data on physical, chemical, radiochemical, and biological quality were obtained at these sites daily. Toward the end of the period, some stations were incorporated into the Survey's National Stream Quality Accounting Network (NASQAN) to detect nationwide trends in water quality.

Geologic and Hydrologic Studies

Studies relating to the geology and GW resources of specific areas always had been, and continued to be, a principal element in GW operations. Following the reorganization of the District, Division-oriented interdisciplinary studies became more common.

Reports published during this period by the Oklahoma District are listed in:

Havens, J.S., 1993, Bibliography of Oklahoma Hydrology—Reports Prepared by the U.S. Geological Survey and Principal Cooperating Agencies, 1901–93: U.S. Geological Survey Open-File Report 93–448, 61 p.

River-Basin Studies

In cooperation with the U.S. Army Corps of Engineers, Robert B. Morton and S.W. Fader, of the Kansas WRD District, studied ground-water resources and movement in river basins lying along the Arkansas River in eastern Oklahoma and Kansas. The reports cover the Verdigris River Basin (OFR 75–365), the Middle Arkansas River Basin (OFR 75–367), and Grand (Neosho) River Basin (OFR 75–366).

Special Surface-Water Studies

In addition to the flood-prone area maps, the Special Studies Section, headed by Wilbert O. Thomas, Jr., and later by Thomas L. Huntzinger, published studies applicable to Oklahoma streams of low-flow characteristics (Huntzinger, OFR 78–414), high-flow frequencies (Huntzinger, OFR 78–161), application of hydraulic and hydrologic data in urban storm-water management (Huntzinger, OFR 78–414), flood characteristics (Sauer, WRI 52–73), estimation of flood frequency in urban areas (Sauer, WRI 23–74), estimation of flood depths (Thomas, WRI 2–76), and estimation of flood discharges (Thomas and Corley, WRI 77–54). The reports by Vernon B. Sauer, Assistant District Chief, and by Thomas and Corley are still in demand [1997].

The High Plains (Ogallala) Aquifer

The Oklahoma Panhandle, one of the richest farming areas of the State, is irrigated exclusively from the High Plains (Ogallala) aquifer. Because of inferred and perceived water-level declines, extensive studies of this area were begun in the early 1970's, in cooperation with the Oklahoma Water Resources Board and the Oklahoma Geological Survey. A Field Office was established in Guymon in about 1967 as a center of the activities, with David L. Sapik, Robert L. Goemaat, and Charles R. Haddock assigned to the office. Previous USGS Panhandle-county studies by Schoff, Mogg, and Reed were published by the Oklahoma Geological Survey. Studies from the 1966–79 period included hydrologic atlases of the three Panhandle counties: Beaver County (HA–450, Morton and Goemaat), Cimarron County (HA–373, Sapik and Goemaat), and Texas County (HA–250, Wood and Hart). Geohydrology of the Panhandle was discussed in WRI 25–75 (Hart, Hoffman, and Goemaat). Annual water-level measurements made in about 375 wells in the Panhandle were published yearly.

Much of this work was preliminary to the High Plains Regional Aquifer-System Analysis, which began in 1978 with compilation of data from the Oklahoma section of the High Plains (Ogallala) aquifer by John S. Havens for input to the regional model.

Other Aquifer Studies

The Garber-Wellington (central Oklahoma) aquifer underlies Oklahoma City and Edmond and supplies drinking water to many other individuals and municipalities in central Oklahoma. Jerry L. Carr began a preliminary study in 1974, in cooperation with the Bureau of Reclamation. The area underlying the projected location of a reservoir on Cottonwood Creek in southwestern Logan County was studied to determine if an in-depth study of the aquifer was warranted. The reservoir would be used conjunctively with the aquifer to supply the water needs of the area.

The Vamoosa-Ada aquifer, which crops out in a north-south band in east-central Oklahoma, was studied by Joseph J. D'Lugosz, beginning in about 1974. The Vamoosa-Ada reportedly contains sufficient water of quality suitable for municipal, domestic, and stock use. High bromide concentrations in parts of the aquifer may infer pollution from petroleum production.

The Antlers aquifer, which crops out in an area of about 1,860 square miles lying along the Texas-Oklahoma State line in southeastern Oklahoma, was studied, in cooperation with the Oklahoma Geological Survey, to determine its suitability for municipal supply. The study began in 1974. Water use is small because of abundant surface-water supplies, but the aquifer would supply sufficient water of generally suitable quality for municipal use. The OGS published the report on the Antlers aquifer by Donald L. Hart, Jr., and Robert E. Davis, as OGS Circular 81.

The Arbuckle-Simpson aquifer crops out in an area of 500 square miles in the Arbuckle Mountains of south-central Oklahoma. A study by Roy W. Fairchild, Ronald L. Hanson, and Robert E. Davis, in cooperation with OGS, determined that base flow of streams flowing from the area is maintained generally by spring flow; chemical quality of water from the aquifer is hard but suitable for most uses. The report was published in 1990 by the OGS as Circular 91.

Chemical Quality of Ground Water

A study begun in 1976 in cooperation with OGS determined that the quality of water in abandoned zinc and lead mines in the Picher Field, northeastern Oklahoma and southeastern Kansas, was unsuitable for most uses without treatment. The report, published as OGS Circular 82 in 1980 by Stephen J. Playton, Robert E. Davis, and Roger G. McClaflin, also warned that rising water levels in the abandoned mines might endanger potable water supplies.

Hydrologic Atlases

Of a projected series of nine hydrologic atlases covering the main body of the State, exclusive of the Panhandle, six were completed from 1966 through 1979. Each of these map reports, prepared in cooperation with and published by the OGS, covered an area of $1^\circ \times 2^\circ$ and consisted of four maps showing geology, ground-water hydrology, water quality in wells, and miscellaneous information, including flood frequency, rural water districts, and precipitation. These maps, which present useful information in an easily read format, have continued to be "best sellers" since their publication.

Coal Hydrology Studies

Hydrologic studies in areas of eastern Oklahoma that were under consideration for strip mining of coal began in 1976. These studies were made in cooperation with the Bureau of Land Management. Initial hydrologic reconnaissance studies of four areas in eastern Oklahoma were made: Blocker, Stigler, Rock Island, and Red Oak. These studies included water-level measurements, compilation of geologic maps from existing sources, and ground-water-quality sampling and analysis. Existing water-level and ground-water-quality data from the files of the WRD were compiled and published by Havens and Bergman (OFR's 76–889, 76–890, and 78–357). Final reports on the four areas were published in the next reporting period.

Late in this reporting period, work was begun on two coal-area reports, Areas 40 and 41. Melvin V. Marcher was the principal author, and contributions were made by other members of the Oklahoma District staff.

Modeling Studies

Three digital modeling studies were begun during this period. In 1974, a cooperative study by Robert B. Morton (OFR 79–565) with OWRB was begun to determine ground-water reserves and projected effects of withdrawals on the Ogallala aquifer underlying Texas County. In 1978, Robert E. Davis and Scott C. Christenson, in cooperation with the OWRB, began modeling the alluvium and terrace deposits of the North Canadian River from the eastern edge of the Oklahoma Panhandle to Canton Reservoir. The report, which gives a quantitative description of the aquifer, was published in1981 as OFR 81–483. In 1979, Joe E. Reed, in cooperation with the Corps of Engineers, modeled the effects of chloride-control structures on the movement of salt into the Great Salt Plains Lake. Upward-moving Permian brine contributes about 2,000 tons per day of salt load to the outflow from the lake. The report was published in 1982 as WRIR 80–120.

SUMMARY

The era from 1966 to 1979 was a period of great change for the Oklahoma District. Emphasis was shifted from county-type reports to site-specific, problem-specific, and areal studies. In particular, the 6 years from 1974 through 1979 were a time of great growth in the number of projects with a concomitant increase in personnel. Many of the new projects were related to coal hydrology, on both the State and Federal level. About 18 new projects were initiated from 1975 through 1979, and the staff increased from about 40 in 1973 to about 50 in 1979, with a high of 54 in 1976. This era also marked a shift to the extensive use of digital models for the definition of hydrologic problems.

SOUTH DAKOTA

by E.F. LeRoux

Organization and Management

In July 1966, the South Dakota District began functioning on a Division basis. Previously, the Surface Water Branch operations in South Dakota had been administered and supervised by the Bismarck, N. Dak., District; the Water Quality Branch functions were handled by the Branch Regional office in Lincoln, Nebr.; and Ground Water Branch operations were handled by the Huron, S. Dak., office.

Reorganization—A New District

With the establishment of South Dakota as a Water Resources Division District, Huron was designated as the District Office. J.E. Powell, who had been Ground Water Branch District Engineer in Huron, was named District Chief, and E.F. LeRoux, recently from the Washington, D.C., Headquarters, was named Assistant District Chief. Margaret Bloomberg was assigned as Administrative Officer. N.C. Koch came from the South Carolina District to oversee the District's ground-water studies, and O.J. Larimer moved from the New Mexico District to assume responsibility for the surface-water and water-quality aspects of the program. Offices in Rapid City and Pierre, which had been doing only surface-water and water-quality work, were designated as Subdistrict Offices with plans to move some of the ground water work to them. L.B. Yarger was named Engineer-in-Charge of the Rapid City office, and J.E. Wagar was Engineer-in-Charge of the Pierre office. Wagar was replaced by R.E. West in Pierre in 1967. A small Field Headquarters continued at Yankton under the direction of E.B. Hoffman. This office was maintained primarily to make almost daily flow measurements below Gavins Point Dam on the Missouri River. In 1967, at the request of the State Geologist, this office was moved to the University of South Dakota campus in Vermillion. Responsibilities were increased to include several ground-water projects, and Jack Kume was moved from Huron as Hydrologist-in-Charge of the Subdistrict Office; H.L. Dixson directed the surface-water program. D.W. Heyd was assigned responsibility for the Pierre office operation in 1973, following the death of R.E. West. In 1976, the District Office was reorganized into an Administrative Services Section headed by Margaret A. Bloomberg, a Hydrologic Surveillance and Analysis Section under O.J. Larimer, and a Hydrologic Interpretation and Evaluation Section with N.C. Koch in charge. In Rapid City, J.H. Eade replaced L.B. Yarger upon his retirement in 1977. Eade transferred out of the District and was replaced by H.L. Case in 1978. J.E. Powell retired as District Chief in 1978 and was replaced by Richard E. Fidler, who transferred from the Pueblo, Colo., office.

Funding and Principal Programs

Much of the water-resources program during this period was a cooperative effort in which the planning and financial support were shared with State and local governments and other Federal agencies. Primary participants in the program were the South Dakota Department of Natural Resources Development—Water Rights Commission and Geological Survey, South Dakota Department of Highways, several Conservancy Subdistricts, and municipalities. Federal agencies involved included U.S. Army Corps of Engineers, Bureau of Reclamation, and the U.S. Environmental Protection Agency.

In 1966, the total program funding for the South Dakota District was slightly over $366,000. Federal-State Cooperative (Coop) Program funds supported about 50 percent of the District program. The other principal sources of funding were from other Federal agencies (OFA)—about 45 percent of the program. A relatively small amount of money from the Survey's Federal (Fed) program was used to service Federal Interagency River Basin Commission gaging stations and benchmark stations and to prepare a surface-water network evaluation.

By 1973, the picture had changed substantially. The total District program funds had more than doubled. The Federal program had increased nearly twentyfold and accounted for 30 percent of the program, while funds from other Federal agencies remained essentially unchanged. The increase in Federal funding was in support of the District's participation in the High Plains Regional Aquifer-System Analysis, the regional study of the hydrology of aquifers in the Northern Great Plains, and the Madison Limestone project.

From 1973 to 1979 the District program continued to prosper. The total program more than doubled—from $760,000 in 1973 to $1,530,000 in 1979. The Cooperative Program now accounted for 45 percent of District funds, with Federal funds 41 percent, and funds from other Federal agencies at 14 percent.

South Dakota District funds, fiscal year 1973–79

(In thousands of dollars. From USGS Management System)

Fund source	1973	1974	1975	1976	1977	1978	1979
Coop	370.5	407.1	461.1	473.5	513.7	617.8	682.2
OFA	160.8	159.8	144.2	161.7	200.2	210.5	218.7
Fed	228.5	184.0	186.8	249.5	299.3	400.1	633.7
Total	759.8	750.9	792.1	884.7	1,013.2	1,228.4	1,534.6

About 60 percent of the District program in 1966 was data collection and compilation. There were about 120 gaging stations, 230 ground-water observation wells, and 20 surface-water-quality sites. By 1979, this had increased to more than 200 gaging and partial-record stations and more than 400 ground-water observation wells. Water-quality data were obtained at about 35 surface-water sites and 30 ground-water sites.

In addition to the surface-water-data program, a study to analyze flood hydrographs from small drainage basins was begun by L.D. Becker in 1967. Basin and streamflow characteristics were determined for 80 representative basins in South Dakota. These data, combined with long-term precipitation records and calibration of a rainfall-runoff model, were used to estimate the magnitude and frequency of floods that might be expected from small drainage basins in the State (WRI 35–74 and WRI 80–80). These reports and the techniques developed by Becker have been used extensively by the South Dakota Department of Highways in the design of highway culverts and bridges throughout the State. They also have been useful in land-use planning, in mapping flood-prone areas, and in establishing rates for flood insurance.

The county water-resources studies in cooperation with the South Dakota State Geological Survey were the backbone of the District ground-water program for many years. The studies began in 1959 and were continuing through 1979. The objective was to provide reliable and useful hydrologic data for each county east of the Missouri River. During 1966–79, reports on the water resources of 18 eastern South Dakota counties were published in conjunction with the South Dakota Geological Survey. Other significant areal studies during 1966–79 included a study of the aquifers in the Madison Limestone and participation in regional studies of the High Plains and Northern Great Plains aquifers. With predictions of annual withdrawals exceeding 100,000 acre-feet per year from the Madison Group in western South Dakota, there was concern that the aquifers might be incapable of supporting a sustained yield of that magnitude. The Madison Limestone project, conducted by L.W. Howells, was designed to delineate the water resources of the Madison Group and associated formations and to study the surface- and ground-water relationships in the outcrop areas. The objective was to predict the probable results of removal of large amounts of water from the Madison.

The High Plains Regional Aquifer-System Analysis and the Hydrology of Aquifers in the Northern Great Plains, under the supervision of H.L. Case in South Dakota, were parts of regional aquifer projects of the Water Resources Division. Both were initiated in response to predictions of increased water demand for irrigation, industrial development, and expansion of coal mining and power generation. These investigations began in 1975 and continued past 1979.

Undoubtedly the most significant hydrologic event during 1966–79 was the Black Hills-Rapid City Flood of June 9–10, 1972. A group of thunderstorms over the eastern Black Hills in western South Dakota resulted in record rainfall and stream discharge. Near Nemo, northwest of Rapid City, nearly 15 inches of rain fell in about 6 hours. More than 10 inches of rain fell over a 60-square-mile area, resulting in floods that were the highest ever recorded in South Dakota. At least 237 people died, and more than 3,000 people were injured. Total damage was estimated to have exceeded $160 million. The Water Resources Division mobilized surface-water personnel from around the Nation to collect and analyze the flood data. M.S. Petersen of the Denver Regional office was assigned overall responsibility, while O.J. Larimer and L.D. Becker handled the local operations. A landmark Professional Paper (PP 877) by Peterson and D.B. Kelly in cooperation with the National Weather Service gave a graphic description of the flood and an analysis of the data collected.

TEXAS

By Ernest T. Baker, Jr.

The Texas District was one year into its reorganization as a WRD District by 1966. Prior to 1965, the Texas District carried out its water-related work as separate branches—Ground Water Branch, Surface Water Branch, and Quality of Water Branch. Trigg Twichell, formerly District Engineer of the Surface Water Branch in Texas, became District Chief.

Also by 1966, the headquarters of the water-resources operations in Texas were one year into their new location in a new Federal Building at 300 East Eighth Street in downtown Austin. This location was just one block away from the Survey's previous location in the Vaughn Building at 807 Brazos Street. The USGS WRD occupied the entire sixth floor of the Federal Building and had additional office space on the eighth floor, first floor, and basement. The USGS Geologic Division also had an office on the eighth floor. Also, President Lyndon B. Johnson had the west one-half of the ninth (top) floor for his Austin office. When the President was in town, helicopters from Bergstrom AFB and from the LBJ Ranch would land on the roof, and there would be the usual influx of Secret Service agents. WRD personnel occasionally would glimpse the President, his family, and Secret Service agents on the elevators.

Organization and Personnel

Trigg Twichell occupied an office at the northwest corner of the sixth floor. His principal assistants in that year were close by. Charles H. Hembree, who previously served as District Geologist of the Quality of Water Branch prior to 1965, was named Assistant District Chief. Allen G. Winslow (GW), Clarence R. Gilbert (SW), Leon S. Hughes (QW), Edward R. Leggat (GW), and William H. Goines (SW) functioned as Supervisory Hydrologists and staff assistants.

There were five Subdistrict Offices in 1966—Houston with 19 employees; San Antonio, with 16 employees; Fort Worth, with 14 employees; Wichita Falls, with 9 employees; and San Angelo, with 7 employees. Robert E. Smith, Arthur E. Hulme, John H. Montgomery, John O. Joerns, and Richard U. Grozier were Engineers-in-Charge, respectively. These titles were changed by 1967 to Hydrologists-in-Charge, and by 1970, to Subdistrict Chiefs.

Field Headquarters in 1966 were located in El Paso (Marvin E. Davis and John D. Gordon, Jr.), Crockett (George R. Tarver), Katy (Clyde A. Wilson), McAllen (Oscar C. Dale), and Mount Pleasant (Matthew E. [Matt] Broom). A Permian Basin Project office, reporting to the Area Hydrologist (Regional Hydrologist in 1967) in Denver, was located in Austin and staffed by Peter R. (Pete) Stevens and William F. (Bill) Hardt as Research Hydrologists. Also reporting to the Area Hydrologist in Denver were the Stream Morphology Project office, headed by Robert K. Fahnestock and located in Austin, and the Evaporation Methods Project office, headed by Alfredo Gonzalez and located in Laredo. Also reporting to the Regional Hydrologist in Denver, by 1968, were Victor B. Jaeggli, who first headed a Project office in Corpus Christi, and Tinco E.A. van Hylckama, who headed a Project Office in Lubbock. During 1966, there were about 155 employees in the Texas District, of which about 90 were in the District Office in Austin.

As the first District Chief of the WRD in Texas, Trigg Twichell was an effective manager. His life was dedicated to the USGS, and as a native Texan, he built up the Texas District program significantly during his tenure. His position as District Chief, unfortunately, lasted only 5 years when, at the age of 70, he had to retire in April 1971. Twichell was succeeded by Ivan D. (Dale) Yost, also a native Texan and Assistant Regional Hydrologist of the old Mid-Continent Region in St. Louis, Mo. Dale Yost became District Chief in 1971 and served in that capacity for the next 9 years before retiring in Austin in 1980.

Overall management of GW, SW, and QW operations during 1966–79 throughout the Texas District was assigned to specialists in their respective disciplines. For ground water, this was carried out by Al Winslow who, in addition to these duties, became Assistant District Chief in 1968 upon the departure of Chuck Hembree. Principal assistants in GW in the ensuing years were Ed Leggat, Ernest T. (Ernie) Baker, Jr., and Sergio Garza. Surface-water operations were under the general management of Clarence Gilbert with additional supervision from the Austin office by Billy Goines, Leo G. (Gordon) Steams, and Willard B. Mills. Water-quality operations were under the overall management of Leon Hughes who, after his retirement in 1977, was succeeded by Jack Rawson, with laboratory supervision being handled principally by Heberto B. (Herb) Mendieta and by Clarence T. Welborn. Additional water-quality assistance by 1979 was provided by Marvin W. (Sam) Flugrath, Freeman L. Andrews, Wanda J. Shelby, Alton J. Dupuy, Emma M. McPherson, Helen J. Connell Davidson, Dale L. Pate, Jeffrey L. Strause, Searcy M. Jacobs, Eleanor S. Chitwood, Eugene Burse, and Fay VanZandt. Edward A. (Ed) Adey, III, managed many of the fiscal affairs, especially in the District's Cooperative (Coop) Program, from 1969 to 1977.

Major organization of functions within the Austin office were in place by 1966. A Projects Section was managed by Al Winslow, with technical assistance by Ed Leggat, James F. (Jim) Blakey (who became Regional Hydrologist, Central Region, in 1986), Jack Rawson, Donald K. (Don) Leifeste, Clarence Gilbert, and Roger C. Baker. A Basic Data Section was headed by Billy Goines. The Hydrologic Studies section was headed by Gordon Stearns. The Reports and Technical Information Section, which processed 67 reports in 1966, was managed by Ernie Baker. The library, which housed 15,000 volumes, was run by Charlotte D. (Rusty) Friebele, who was succeeded in 1977 by Rosemarie Tovar Jean. The Administrative Services Section was headed by James R. (Jim) McLaughlin with assistance by Raymond M. Slaughter, Ena B. Shaw, Iris M. Jackson, and Bonnie R. Kamenar. Secretarial services were provided by Evelyn M. Ogden, Leio J. Krueger, Mary L. Bauer, Frances S. Price, Eleanor S. Chitwood, with later assistance by Ruth S. Young, Pamela Jo (Pam) McGlamery, Karen S. Steele, Mary E. Davis, Frances S. (Fran) Heintze Ellis, Mary A. Christianson, and Evangeline R. (Vangie) Carrillo. Sylvester Pleasant, Jr., and Homer H. McGrand handled many of the shop duties.

In succeeding years, additional reorganization slowly evolved throughout the Texas District. There were several personnel changes, mainly at management levels and especially in Subdistrict Chiefs, from 1966 to 1979.

San Angelo Subdistrict

With the transfer of Dick Grozier to Colorado in 1968, Ernest S. Denison became Subdistrict Chief of the San Angelo Subdistrict. He was succeeded by Robert J. Snipes in 1976, and Robert Snipes was succeeded by James H. (Jim) Eade in 1979. Principal assistance over the years was provided by Joe M. Alexander, Henry R. (Bob) Hejl, Jr., Virgil L. Spires, Jimmy N. Lee, Clyde Wilson, Harold W. Albert, Wallace R. Carnes, and William H. Martin. Additional technical assistance was provided by the following staff with at least 2 years of service: Ernest Prochazka, James B. Schiller, Jimmy G. Pond, Jesse J. Woodward, Lawanna M. Kiser, Henry Jacques, Jr., Lloyd D. Swaringin, Orlan R. Coleman, Loma Hoffman, Freddie L. Stroman, and Iris Jackson. There were 10 employees in the San Angelo Subdistrict Office in 1979.

San Antonio Subdistrict

The San Antonio Subdistrict office saw several changes in key personnel. In 1966, there were 14 employees, among which were Sergio Garza, who started his career in the District Office in Austin; Marshall E. Jennings, who early in his career worked in the Wichita Falls Subdistrict; Paul B. Rohne, Jr., Richard D. (Dick) Reeves, Paul L. Rettman, Ira G. Rathbun, William E. (Bill) Reeves, Ronnie D. Steger, John A. Tomlinson, Olga Hernandez Munoz, Oliver J. Barton, Robert Saenz, and Randall S. Stark. By 1969, Sergio Garza and Marshall Jennings, former staff assistants to the Subdistrict Chief, Ed Hulme, had transferred to Albuquerque and Washington, D.C., respectively. By 1974, Robert W. (Bob) Maclay, Celso Puente, Dick Reeves, Joe Alexander, and Theodore A. (Ted) Small, who came to the District from the International Boundary and Water Commission, were principal members of the investigative staff. After the retirement of Ed Hulme in 1974, William H. (Bill) Kastner became Subdistrict Chief, and he was succeeded in 1979 by Dick Grozier, who returned to Texas from the Colorado District. The latter half of the 1960's and beyond saw the addition of the following personnel with at least 2 years of service: Lynn Harmsen, Richard L. (Rick) Goss, Roberto Perez, John F. Stanford, Jr., Kenneth C. (Ken) Grimm, Jeffrey L. (Jeff) Strause, Dale L. Pate, Walter G. Hines, Larry F. Land, John Tomlinson, Dan R. Reddy, Walter Rast, Jr., Victor Gonzales, Ronnie A. Rappmund, Margarita Fernandez Davis, Francis A. Wessels, James C. Wisecarver, William C. (Bill) Billings, Bill Reeves, Gregory B. O'Neill, and Mary M. Wolfe. The San Antonio office had 19 employees in 1979.

Houston Subdistrict

In the Houston Subdistrict Office, which was formally organized in functional units beginning in 1978, Bob Smith remained Subdistrict Chief through 1979 with Robert K. (Bob) Gabrysch as principal assistant. Betty R. Miles functioned as administrative clerk. Emil G. Kaminski, Rick Goss, and Florietta Gillis formed the Hydrologic Surveillance and Analysis unit. Fred Liscum ran the Urban and Data Network unit, assisted in 1978 and 1979 by Donald E. (Don) Ferguson, Carl A. Heinrich, Chester J. Phillips, Stanley (Mick) Baldys, III, James S. (Jim) Hutchison, Joseph P. (Pat) Bruchmiller, Jay F. Wiegel, Mary C. Kegg, Lee B. Goldstein, Michael B. Bowman, and Laura S. Walther, each with at least 2 years of service. Karl W. Ratzlaff and Walter R. (Walt) Meyer headed the Hydrologic Systems unit during 1978–79, with a staff of 10 including Stephen J. (Steve) Halasz, William M. (Bill) Sandeen, Charles W. (Bill) Bonnet, William B. Lind, Clarence E. (Ed) Ranzau, Roy S. Sonenshein, Laura S. Coplin, and Ivy R. Atherton. James C. (Jim) Fisher, Ira Rathbun, and Samuel O. Skinner were key personnel in the Bays and Estuaries Project office during 1978–79. Edna M. Paul, Cervando S. Ramirez, and Alberta G. Swanson made up the Water Quality Service unit during 1978–79. Important additional positions in the Houston office through the years were filled by the following personnel with at least 2 years service: Robert B. (Bob) Anders, Steven L. (Steve) Johnson, Jerry E. Carr, Donald G. Jorgensen, Carole L. Loskot, Dan Reddy, John B. Wesselman, Robert H. Dolman, Wellborn L. Naftel, Fred L. Tyler, John A. Watson, Freddie J. Farrier, Catherine J.H. Eiby, Barney P. Popkin, Gene D. McAdoo, Daniel C. (Dan) Hahl, Guadalupe Ramos, Leonard L. Lamar, Patricia L.B. (Pat) Reinhardt, Jesse M. Barrera, Laura A. Hensley, Alberta Swanson, Sherwood B. Browning, Addis M. (Buddy) Miller, III, Herbert D. King, Jr., Erwin S. Asselstine, Ken Grimm, and Jesse J. Goodwin. In 1979, there were 34 employees in the Houston Subdistrict office, including the Rockport Field Office, where Gail D. Driver was motorboat operator for the Bays and Estuaries Project.

Fort Worth Subdistrict

The Fort Worth Subdistrict office was led by John Montgomery until his retirement in 1974. Through the years, Ralph H. Ollman, George R. Dempster, Jr., Robert L. Allen, Fred Liscum, and Bernard C. (Bernie) Massey were surface-water specialists; Sam Flugrath and James T. Howard were water-quality specialists; and Gerald L. (Jerry) Thompson was ground-water specialist. After John Montgomery, Ector E. (Gene) Gann became Subdistrict Chief, with Ralph Ollman, Billie B. Hampton, Dennis R. Myers, and Raymond M. Slade, Jr., as principal assistants. Additional assistance was provided by the following staff members who had at least 2 years of service: Willard J. Gibbons, Walter A. Lear, Thomas H. Hays, Erich E. Lotto, Jr., Charles M. Wood, J.M. Taylor, Clyde T. Schoultz, H. Sue Butler, T. Roy Hastings, Jack D. Benton, F. Altina Pillers, Leslie E. Andrus, C.P. Armstrong, Robert M. Eastwood, Robert D. Hull, Donald R. Tapley, Douglas L. Haynes, Charles A. Beaver, and Judith H. Donohue. There were 14 employees in 1979.

Wichita Falls Subdistrict

The Wichita Falls Subdistrict Office continued to be managed by Jack Joerns through 1979. Charles C. (Chuck) Kidwell, as principal assistant during 1975–79, was preceded by assistance from Virgil Spiers, Jimmy Lee, James W. Board, Marion L. (Spike) Maderak, James T. (Jim) Smith, and Raymond

Slade. Additional assistance in the office was provided by the following personnel with at least 2 years service: Gordon H. Martin, Willie F. Hastings, William Martin, Doris F. Tipps, Dick Reeves, Elizardo Lucero, and Bertha D. Nesbitt. There were seven employees in 1979, counting the Pampa Field Headquarters headed by Gene McAdoo and assisted by Wilda J. McGahen.

The Texas District's Sixth Subdistrict (Austin)

The Austin Subdistrict was established in 1974 with Spike Maderak at the helm. There were seven employees that year. Ernie Baker succeeded Spike as Subdistrict Chief at the close of 1979, with 11 employees, of which Raymond Slade, Wallace D. Robbins, and James K. (Ken) VanZandt (lead hydrologic technician) were principal assistants. Additional assistance through the years was provided by Milton M. Miller, who was a professional rodeo clown, John Gordon, Raymond M. Mitchell, Buddy Miller, William R. (Bill) Roddy, Michael E. (Mike) Dorsey, Steve Halasz, Eugene E. Wehmeyer, Kenneth L. Choffel, George D. (Dan) McElhany, Mark S. Brown, and Niki V. Talley Philip.

Texas District, Austin Office

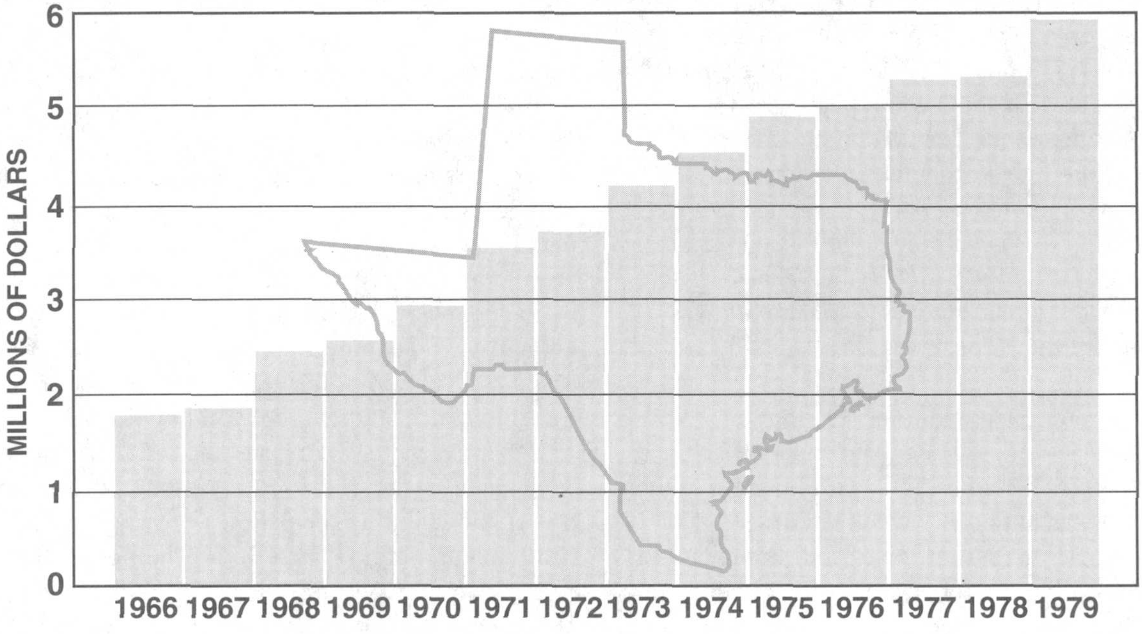
In the years following 1966, additional reorganization and staffing evolved at the District Office level in Austin. In 1975, the Hydrologic Systems Investigations and Research section was established with Ed Leggat as Chief and a staff of 11. By 1978–79, Larry Land was Chief, and the section was staffed by Sergio Garza, Ernie Baker, Jerry Carr, Elmer E. Schroeder, Austin A. Bricker, III, James D. (Jim) Bohn, and Mary Bauer. Also up and running during 1975–79 was the Hydrologic Surveillance, Research, and Analysis section with Clarence Gilbert as Chief, assisted by Bernie Massey and Frances Price. The Hydrologic Surveillance and Analysis unit, under Gordon Stearns and later, by 1979, under Bernie Massey, generally supervised the collection and final analysis of surface-water records with a staff consisting of James N. (Jim) Sansom, Walter Lear, Bill Reeves, and Fran Heintze Ellis. A rather large unit—Water Quality—was managed by Leon Hughes, who was succeeded by Jack Rawson in 1977. The unit consisted of 15 employees in 1979, including Frank C. Wells, who transferred from Louisiana and became Assistant District Chief, Texas District, in 1993, and long-time employees such as Herb Mendieta, Clarence Welborn, Wanda Shelby, Emma McPherson, Freeman Andrews, Sam Flugrath, Helen Connell Davidson, Searcy Jacobs, Eleanor Chitwood, who served ably as a professional secretary, Eugene Burse, Jeff Strause, Dale Pate, and Fay VanZandt. Prior to 1979, important key personnel with at least 2 years of service in water quality included Jim Blakey, Richard O. (Rich) Hawkinson, who became District Chief, Texas District, in 1991, Kidd M. Waddell, Douglas B. (Doug) Manigold, Bill Roddy, Willard Gibbons, Edna Paul, Bill Billings, Myra Lansford, Harvey L. Kunze, Guadalupe Ramos, Isaac L. Crawford, Lloyd S. Woodruff, Jean A. Schulze, Alton Dupuy, Claudia C. Wallace, Marilyn J. Harper, Louis R. Aran, Kathryn J. Calhoun, Pat W. Skinner, Alvin M. Pickard, Helen S. Rinehart, Niki V. Talley Philip, Vonny M. Franklin, Henry R. Mitchell, and Joyce M. Coleman Stewart. The Construction, Instrumentation, and Map unit was headed by Pat Skinner and included long-time employees Fred A. Hubbard, who specialized in surveying, Milton Miller (who specialized in construction in addition to mapping and instrumentation duties), Felipe H. (Phil) Tovar, who specialized in surveying, Sylvester Pleasant, Neal A. Bothmer, Patrick K. (Pat) Holland, and Harold P. (Paul) Shanahan. In the late 1960's to mid-1970's, technical assistance in the Scientific Publications section included Walter H. (Herb) Alexander, Leio Krueger, Ena Shaw, who came to the District from NASA in Houston, Pam McGlamery, Lorene (Mrs. G) Griffin (a vari-type operator who was State funded), Vangie Carrillo, Freddie Stroman, Ruth Young, Mary L. Cartwright, Alicia A. Mitchell Ranzau, who came from the U.S. Selective Service System, Gail J. Sladek, who came to the District from the U.S. Air Force in Wiesbaden, Germany, Karen S. Steele, Clarence R. (Buster) Follett, Rosemarie Tovar Jean, Joyce Coleman Stewart, Lois A. Rogers, Mary L. Jordan, and Joyce R. Lawson. By 1979, the Scientific Publications Section, headed by James Ray Wall, had eight employees, including H.D. (Doug) Buckner, Bobby D. Jones, Donald L. Leslie, Alicia A. Mitchell Ranzau, Stanley H. Crenwelge, Gail J. Sladek, and John P. (Pat) Maguire. The Computer Operations was headed by Freddie Stroman with assistance from Vangie Carrillo, Karen Steele, and Joyce Coleman Stewart. By 1979, the Survey's library, which had grown significantly since 1966, was being managed by

Rosemarie Tovar Jean. The Administrative Services section, with six employees, had Elizabeth S. (Liz) Deavers as Administrative Officer, a position she took in 1975. Her assistants from 1975 to 1979 were Jacquelyn M. (Jackie) Thrash Kendrick, Mary Davis, Catherine Eiby, Carolyn V. Norton, Mary Christianson, and Vickie L. Self Labutis. Important additional personnel through the years, most of whom left the Austin office prior to reorganization into official functional units in 1975 included Stanley P. (Stan) Sauer, who became Regional Hydrologist, Northeastern Region, in 1982, Paul Rohne, Henry P. (Carr) Pritchett, James G. (Jerry) Cronin, Brian N. Myers, Donald E. (Don) White, George H. Shafer, Gerald K. Schultz, Jim Fisher, Henry G. Krauss, John Watson, Douglas M. Sayre, James H. Patman, Gary E. Largent, John Stanford, Leonard E. Hough, Pat Reinhardt, Terry L. Slade, James N. (Jim) Bates, Virginia J. Howard, Alice O. Townsend, James H. Duke, Jr., Bertran T. Bader, III, Barry W. Ellis, Carl J. Fleese, John P. Legendre, Matthew Mullone, and Mark A. Sorelle.

Space requirements do not permit mentioning all of the employees in the Texas District. Employees totaled 148 at the beginning of 1966, rose to a maximum of 212 in 1971, and settled at 152 by the end of 1979.

Cooperating Agencies

The principal cooperator in the Texas District was the Texas Water Development Board (TWDB) and its successor agency in September 1977, the Texas Department of Water Resources (TDWR). These State agencies led the list of cooperators in terms of dollars and scope of work that were directed toward multidisciplinary studies and data-collection activities including ground water, surface water, and quality of water. Numerous other organizations assisted in collecting data under cooperative agreements with the USGS and assisted in the form of funds or services, much of which were rendered through the TWDB or TDWR. These other organizations included other Federal agencies (OFA's), river and water authorities, water supply and improvement districts, flood-control districts, conservation and reclamation districts, power-control districts, counties, cities, river-compact commissions, and non-governmental entities, such as electric utilities, chemical companies, and agricultural associations. The total number of these cooperating organizations gradually increased through the ensuing years from 67 organizations in 1966 to 77 in 1979.



TEXAS DISTRICT FUNDING, 1966-79

Program Activities

The Texas District water-resources program maintained a mix of data-collection and interpretive studies. Data collection was extensive throughout the State and involved all three disciplines. This continuous collection of data, in turn, required the necessary data processing and eventual publication of the data in various types of reports. There were numerous studies of an interpretive nature constantly being processed during the period, particularly in ground water, but with an important complement of surface water and water quality.

Data Collection

A large part of the Texas District budget went for data collection associated with continuing surface-water, water-quality, and ground-water programs. These programs generally varied in intensity and scope through the years. In 1966, the Texas District operated 406 streamflow, 58 reservoir-content, 6 stage, 89 low-flow partial-record, 150 crest-stage partial-record, 4 miscellaneous, 78 chemical-quality, and 10 sediment stations on streams and reservoirs for a total of 801 stations in the surface-water network. Also in 1966, the Texas District ground-water programs were monitoring water levels, chemical quality, and land subsidence in 1,094 observation wells in the Houston District, Galveston County, San Antonio area, El Paso area, and Trans-Pecos area. The number of observation wells peaked the following year (1967) at 1,538, with the addition of the Orange County area. The year 1972 was a peak year for the number of stations in just the continuous-record streamflow-station network with 576. The total surface-water data-collection program in 1972, including quality of surface water, had 1,262 stations. At the close of the period in 1979, the Texas District continuous-record streamflow-station network was down 6 percent from its peak year in 1972 and stood at 544.

With regard to expenditures relating to data-collection activities, aside from data collection as a part of interpretive studies, the overall budget of the Texas District was noticeably weighted toward data collection in the early part of the period. For example, in 1966, $1.2 million, or 69 percent, of the total Texas District budget was allocated to various functions associated with data collection. Of this amount, about $0.75 million, or about 60 percent, was spent on streamflow-gaging station operation and maintenance including construction, with the remainder of the data-collection budget, roughly $0.45 million, about equally divided between data-collection activities related to ground-water and water-quality functions. Four years later, by 1970, expenditures for data-collection activities were down to 60 percent of the total Texas District budget—a drop of almost 10 percent since 1966.

Interpretive Studies

Interpretive studies in the Texas District were numerous and varied. All three disciplines had their share of these studies. The scope also varied, which affected the length of the projects.

Interest in interpretive studies including research was gaining in importance. Expenditures in 1966 for interpretive studies in the Texas District totaled roughly $0.55 million. Of this amount, 52 percent was expended on ground-water-related studies, 43 percent on surface-water-related studies, and 5 percent on water-quality-related studies. By 1970, expenditures for interpretive studies totaled about $1.2 million. Of this amount, 47 percent was expended on ground-water-related studies, 41 percent on surface-water-related studies, and 12 percent on water-quality-related studies. The big percentage increase in water-quality-related studies was attributable to the Texas bays and estuaries water-quality program.

County ground-water appraisal studies, usually of a 14- to 24-month duration, were well underway by 1966. That year saw 30 counties throughout Texas being investigated thoroughly so as to provide the refined data and interpretation required for proper planning of the development of Texas ground-water resources. The resulting reports were used extensively by the people in each area. Many of the Texas District geologists and engineers in the Projects Section were assigned to carry out these county ground-water investigations. Such studies were winding down by the late 1960's and early 1970's, and they were essentially terminated by the mid-1970's. Among the principal investigators during the period were George Tarver, Ernie Baker, Sergio Garza, Jerry Thompson, Bob Anders, Archie T. Long, Gene McAdoo, Herb Alexander, George Shafer, Matt Broom, Buster Follett, Clyde Wilson, Bill Sandeen, Don White, James Patman, John Wesselman, Barney Popkin, Jerry

Cronin, Jim Smith, Spike Maderak, Brian Myers, Ted Small, Dick Reeves, and Bill Bonnet. The resulting reports were printed by the State cooperator, the TWDB and its successor in name, the TDWR, and usually bore the title "Ground-Water Resources of (county name), Texas."

Continuing from its start-up in 1962 was the series of lake surveys across Texas. From an inauspicious beginning of having to fabricate fathometers, the lake surveys became a highly important continuing program of the Texas District. Under the guidance of Herb Mendieta, these surveys were initially carried out using a 12-foot boat with a 25-horsepower Wizard outboard motor.

Lakes in the Brazos River Basin were emphasized initially, with work being done on Possum Kingdom Reservoir, Whitney Lake, and Belton Lake. This was expanded to include Canyon Lake, Hubbard Creek Reservoir, Lake Arlington, Lake Conroe, Lake Corpus Christi, Lake Granbury, Lake Meredith, Lake O' the Pines, Lewisville Lake, Livingston Reservoir, Sam Rayburn Reservoir, Somerville Lake, Town Lake, Wright Patman Lake, Benbrook Lake, Proctor Lake, Lake Limestone, E.V. Spence Reservoir, and International Falcon Reservoir. Onsite measurements were made of specific conductance, dissolved oxygen, temperature, and pH, and samples were collected for laboratory analysis. From this were determined the areal and seasonal variations and patterns of stratification of temperature, dissolved oxygen, nutrients, and selected inorganic constituents. The resulting reports were released as USGS open-file reports, and some were published by the TWDB. Titles of the reports were usually "Water-Quality Records for Selected Reservoirs in Texas, (date)" or "Quality of Water in (lake or reservoir)."

An extraordinary happening took place in an early lake survey of Possum Kingdom Reservoir and was experienced by Herb Mendieta and Jim Blakey. While sounding the bottom of the lake with a weighted line (at a precise point where the lake was normally 19 feet deep), the bottom was detected at 60 feet. Detailed maps of the pre-impoundment area showed the existence of a dug well at an old farmhouse. What had happened was the sounding line had actually bottomed out in the dug well, which was 41 feet deep.

Interpretive studies continued yearly in the Houston-Galveston area, San Antonio area, El Paso area, and Orange County area. For these areas of heavy pumping, the studies were designed to keep abreast of the pumping effects and were planned to meet specific objectives. Numerous personnel in the Houston and San Antonio Subdistrict Offices and in the El Paso Office spent years studying virtually all aspects of the ground-water hydrology of these areas.

An understanding of land-surface subsidence in the Houston-Galveston area was advanced significantly, and computer models were developed to predict subsidence and water-level declines. This came about through the work of Bob Gabrysch and other investigators such as Donald Jorgensen, Walt Meyer, and Jerry Carr. Karl Ratzlaff, Ernie Baker, and Sergio Garza, using this knowledge, mapped and predicted subsidence for specific areas in the Coastal Plain of Texas in the 1970's. Analog and digital computer models for the El Paso area were developed by Ed Leggat, Marvin Davis, and Walt Meyer in the mid-1960's and mid-1970's. Resulting reports were numerous and titles varied.

San Antonio personnel continued to appraise quantitatively the hydrology of the Edwards aquifer. Through 1966–79, recharge-discharge effects, as well as the hydrogeologic framework of the aquifer accompanied by much test drilling, were studied by scientists including Bob Maclay, Dick Reeves, Ted Small, Celso Puente, Sergio Garza, Paul Rettman, Frederick J. (Joe) Pearson, Jr., and Bill Roddy. Resulting reports were numerous and titles varied.

In the El Paso area, studies were centered around the completion of computer models of the Hueco Bolson and Lower Mesilla Valley. Boundaries of the fresh and saline water and sources of saline water as contamination continually were being investigated by investigators such as Marvin Davis in 1966, Walt Meyer, Joseph S. (Joe) Gates, Jim Smith, and John Gordon, in the late 1960's and early 1970's, and Don White in the mid- to late 1970's.

Other Interpretive Studies

Other important interpretive studies were carried out during 1966–79, many of which were outside of the large metropolitan areas. All of these studies addressed major hydrologic concerns. Resulting reports were numerous and titles varied.

A 3-year ground-water study to demonstrate the depletion of the Ogallala aquifer on the High Plains began in 1965 and was completed in 1967. Jerry Cronin was the chief investigator. USGS Hydrologic Investigations Atlas HA–330 was the resulting report.

A multiyear study of the water resources of Big Bend National Park, with the National Park Service as cooperator, was started in 1966. It eventually led to drilling important water-supply wells in the 1970's. The study was done under the direction of Ed Leggat. Administrative reports to the National Park Service detailed the findings of the studies.

Hydrologic studies of numerous small watersheds, including effects of Soil Conservation Service floodwater-retarding structures, which started in the 1950's, continued into the late 1970's. This ambitious program studied 12 areas in 4 major river basins. Scientists involved in these studies included Stan Sauer, Frank W. Kennon, Clarence Gilbert, Rich Hawkinson, Clarence Welborn, Ed Leggat, Chuck Kidwell, Willard Mills, Brian Myers, Jimmy Lee, Jim Sansom, Bernie Massey, Wallace Robbins, and Elmer Schroeder. The resulting publications, usually open-file or basic-data reports, but occasionally a TWDB report, generally bore the title, "Hydrologic Studies of Small Watersheds, (name of stream, river basin, and date)" and "Annual Compilation and Analysis of Hydrologic Data for (name of stream, river basin, and date)."

Urban hydrology was studied intensively in seven metropolitan areas—Austin, Houston, Dallas, Dallas County, Fort Worth, San Antonio, and Bryan. These studies, some of which started as early as 1954 and as late as 1969, lasted for many years. Principal investigators included Bernie Massey, Bob Smith, Steve Johnson, Larry Land, Wallace Robbins, Phil Tovar, George Dempster, Don Ferguson, and Billie Hampton. Resulting reports were openfiled and usually had the title, "Hydrologic Data for Urban Studies in the (location and date)," "Urban Hydrology of the (location and date)," and "Annual Compilation and Analysis of Hydrologic Data for Urban Studies in the (location and date)."

There were numerous separate low-flow and water-delivery studies of streams across Texas. These studies were conducted by such scientists as Stan Sauer, Jim Blakey, Chuck Hembree, Ernie Baker, Clarence Gilbert, Sergio Garza, Pat Holland, Leon Hughes, Herb Mendieta, Spike Maderak, Don Leifeste, Willard Mills, Jack Rawson, Bob Smith, Dick Grozier, Jim Fisher, Virgil Spiers, Doug Buckner, Paul Rohne, Harvey Kunze, Gerald Schultz, Jimmy Lee, Bob Hejl, John Watson, Jerry Thompson, Harold Albert, Steve Johnson, Guadalupe Ramos, Dan Reddy, Bill Reeves, and Myra Lansford. The resulting publications usually were titled "Quantity and Quality of Low Flow in (stream studied and date)" or "Water-Delivery Study (stream studied) Quantity and Quality." These reports were initially released as USGS open-file reports. Many were printed by the State cooperator—the TWDB—in their "Report" series.

A followup to these reconnaissance investigations was a study by Jack Rawson summarizing the records of dissolved solids, chloride, and sulfate for the principal streams in Texas and the records of dissolved oxygen, biochemical oxygen demand, minor elements, and pesticides for sites on nontidal reaches of streams. This resulted in USGS WRI Report 7–74 entitled, "The Quality of Surface Waters in Texas." Reconnaissance investigations of the chemical quality of surface water of every river basin Statewide, the first one of which was begun shortly after the program started up in 1961, were completed by the early 1970's. Those studies were conducted by investigators such as Jim Blakey, Don Leifeste, Leon Hughes, Jack Rawson, Herb Mendieta, Harvey Kunze, Jimmy Lee, and Myra Lansford, The resulting reports were printed by the TWDB in the "Report" series.

A streamflow network evaluation study for Texas was one that was ranked high in national importance by the USGS. It was begun in fiscal year 1970 by Clarence Gilbert and Rich Hawkinson. These investigators defined the purposes of the current network, defined statistics of streamflow for unregulated stations, identified stations to be used in defining long-term changes in streamflow, identified environmental data on stream channels and basins, provided justification for each element of future streamflow programs, and allowed for the weeding out of less productive elements. The findings of the study were published in 1971 in a 52-page report, "A Proposed Streamflow Data Program for Texas (USGS Open-File Report 71–0120).

In fiscal year 1971, a Statewide quality-of-water systems study was initiated. Jim Blakey, Rich Hawkinson, and Timothy D. Steele (with the Systems Laboratory Group in the USGS Washington, D.C., office) were the investigators who evaluated the water-quality data-collection program throughout Texas. Twelve water-quality stations were classified by data use and station operation to determine if the data collected were satisfying data needs. The results of the study were released in a 40-page report, "An Evaluation of

Water-Quality Records for Texas Streams" (USGS Open-File Report 72–0037).

A multiyear, well-funded study was started in October 1967, in cooperation with the TWDB, to assess the quantity and quality of freshwater inflows to Texas bays and estuaries and their physical and chemical characteristics. Much of the direction and management came from the Houston office from Dan Hahl, Karl Ratzlaff, and Jim Fisher, with assistance by William B. Lind. Several boats of all sizes were part of the fleet ("Bob Smith's Navy") having such names as Skinny Dipper, Egret, Tarpon, Bluefin, Skipjack, and Pandora, and also included an all-wood J-boat (mine-sweeper type) from the Air Force on Matagorda Island, and also an air boat. The resulting reports were printed by the TWDB in their "Report" series.

In the late 1970's an effort was made by the Texas District to provide a set of standardized guidelines and quality-control procedures for the collection and preservation of samples and field analysis of the common unstable constituents or properties of samples from streams in Texas. This resulted in a comprehensive report of 152 pages by Jack Rawson entitled, "Guidelines for Collection and Field Analysis of Water-Quality Samples from Streams in Texas." The report was printed by the Texas District for internal use only.

In 1968, the Texas District established an organics (pesticides) laboratory in Austin. Key players in the establishment were Leon Hughes, Herb Mendieta, Jack Rawson, and Jim Blakey. Staffing the laboratory during its 6-year life were Doug Manigold, as Chief Chemist, assisted by Jean Schulze, Claudia Wallace, Freeman Andrews, Louis Aran, Joe Cadwell, and Nick Brezindine. The pesticides program in Texas involved monthly and quarterly analyses of a Federal network of stations on streams throughout the Western States (west of the Mississippi River). Of this network of stations, as many as 15 were in Texas. Additionally, District programs in cooperation with State cooperators provided for studies of the quantities of chlorinated hydrocarbon pesticides in water and bottom sediment in a network of surface-water stations; in drainage from rice-irrigation areas; in runoff in the Austin, Houston, and San Antonio urban areas; and in selected wells in counties where ground-water studies were in progress. Especially noteworthy during the laboratory's existence is the fact that the presence of PCB's (polychlorinated biphenyls) in water was first established by the organics laboratory after much nationwide investigative work that was spearheaded by Herb Mendieta. The organics laboratory remained in operation until 1974 when the Central Laboratory in Denver took over. The activities of the laboratory are discussed in USGS Open-File Report 74–0051 entitled, "Pesticides Data-Collection Activities of the U.S. Geological Survey in Texas," by Doug Manigold.

A program of drainage-area determinations, which began in 1961, continued during 1966–79. Much of the determinations were done by Phil Tovar and Charles S. (Scott) Carney. This program redetermined drainage areas for almost all river basins in Texas, utilizing the latest topographic maps. After the determinations were completed, the results were compiled, by river basin, in open-file reports that served to eliminate the use of conflicting values. The study on the drainage area of the Brazos River Basin was one of the last studies, and it was completed during fiscal year 1976. The report entitled "Drainage Areas of Texas Streams, Brazos River Basin" was authored by Phil Tovar and S.M. Brown.

There were other interpretive studies that provided much needed information and analysis. Some of these that took place during 1966–79 need to be mentioned. Following Hurricane Beulah, which hit south Texas in 1967 with record-breaking rainfall, a 1968 study directed by Ernie Baker documented the relation of impounded floodwater to ground water. This involved work on the famous King Ranch and other large ranches (TWDB Report 138). In 1968, a project was started to provide hydrologic information in connection with a proposed importation of surface water to the High Plains and to provide an opportunity for applied research on artificial recharge. This was led by investigators Richmond F. (Rich) Brown, Donald C. (Don) Signor, and Warren W. Wood (USGS WRI 1073, and USGS OFR 76–0730). The National Park Service in 1969 asked the Survey to appraise the water resources of the newly established Guadalupe Mountains National Park, and this study, conducted by Ed Leggat and assisted by John Gordon, continued on a part-time basis until 1977. An Administrative report to the National Park Service detailed the findings of the study. During 1969–71, Stan Sauer studied the causes of low runoff in the Concho River Basin in west-central Texas and, as a contribution to the hydrology of the United States, reported various factors in Water-Supply Paper 1999–L. During 1970–72, Ed Leggat, Jim Blakey, and Bernie Massey investigated a liquid-waste disposal site in Dallas for the city of Dallas to determine whether liquid wastes had reached the water table and, if so, to determine the dispersal patterns; this information would enable the city to develop more effective means of liquid-waste disposal (USGS OFR 72–0228). Ernie Baker, during 1971–72, directed a project to assess the influence of ground-water development, with attendant land-surface subsidence, on the proposed Palmetto Bend dam and reservoir (USGS WRIR 18–73). In 1972, Sergio Garza headed a digital-model study to predict the effects on the Trinity River alluvial system from the proposed impoundment of water behind navigational dams and locks (USGS OFR 79–1270). A project called the Rio Grande Regional Environmental Project (RGREP) started in the early 1970's to provide reliable information on the amounts and quality of fresh and slightly saline ground water east of El Paso for possible future needs of El Paso. Joe Gates, Don White, Jim Smith, and Bonnie J. Fry participated in this study (TDWR Reports 256 and 259). In the 1970's, important land-surface subsidence studies, including installation of borehole extensometers, were directed by Bob Gabrysch for critical areas of subsidence such as at Baytown, Texas City, and Seabrook (USGS WRIR 21–74, TWDB R188, and USGS WRIR's 76–31 and 76–32). Beginning in 1974, and lasting for several years, a digital-model study of the Chicot and Evangeline aquifers of the Texas Gulf Coast was done by Jerry Carr, Walt Meyer, Bill Sandeen, and Ivy R. McLane (TDWR Report 289). A project in cooperation with the Sabine River Authority and the Sabine River Compact Administration and conducted by Ernie Baker and Jack Rawson during 1971-74 investigated by means of monitoring wells the possibility of pollution of Toledo Bend Reservoir from septic tanks at fishing camps and housing developments (USGS OFR 79–0010). The mapping of flood-prone areas outlining the 100-year floods was done statewide under the general direction of Jim Bohn as part of a nationwide Federal program and resulted in 658 topographic quadrangles being mapped through 1976. Time-of-travel studies, beginning in 1972 and continuing for several years on the Sabine and Trinity Rivers, were done by investigators Willard Mills, Ralph Ollman, Dennis Myers, and Raymond Slade to provide data for a hydrologic model of the river systems (USGS OFR 72–0257, 75–0558, and 76–0683). A multiyear study, directed by Ernie Baker during 1976–79, resulted in a digital model of the Miocene aquifers in southeast Texas (TWDB R295) and a report describing the stratigraphic framework of the Coastal Plain of Texas (TDWR R236). Intensive, well-funded hydrologic-research studies of the Edwards aquifer, beginning in 1970 and continuing through 1979, involved scientists Bob Maclay, Ted Small, Celso Puente, Paul Rettman, Joe Pearson, and others. These studies advanced knowledge of the Edwards aquifer significantly (USGS OFR 74–0362, 75–0298, 76–0393, 76–0627, and USGS WRIR 78–10).

Reports

The extensive scope of the Texas District's water-resources programs resulted in the production of a steady stream of reports, both basic data and interpretive. This, of course, required that the District devote considerable time and manpower to processing the reports. Consequently, the publications unit was kept continually busy.

During the period 1966–79, the Texas District produced and processed a total of 502 reports. This included 5 Professional Papers, 41 Water-Supply Papers, 18 Water-Resources Investigations Reports, 3 Hydrologic Investigations Atlases, 226 Open-File Reports, 33 annual Water-Data Reports, and 176 reports that were published by the Texas Water Development Board, and its successor in name, the Texas Department of Water Resources. This total body of reports does not include numerous brochures, newsletters, quarterly Information Bulletins, lists of publications, journal articles, and annual summaries of fiscal activities. All of these demanded careful review, following standardized USGS review guidelines.

Summary

Looking back at the period 1966–79, one sees the Texas District growing to fulfill the needs and concerns regarding water statewide. This was in partial response to the growth in Texas population, which expanded 34 percent in this period to 14.2 million. The increases in the District operation budget tell the story (see funding graph). In order to carry out the Texas District program in 1966, District expenditures totaled $1.8 million with 144 employees on the roll at the beginning of the year. By 1968, which saw employees increasing to 187, the budget stood at $2.5 million, which was divided as 59 percent surface water, 24 percent water quality, and 17 percent ground water. Two years later in 1970, the budget was up to

$3 million with the number of employees peaking at 212. Nine years later at the end of the period in 1979, $5.8 million was required to operate the water-resources program in Texas—a program that required the services of 152 employees.

UTAH

By James W. Hood and Joseph S. Gates, and reviewed by Ted Arnow and Kidd M. Waddell

During 1966–79, reorganization of the Water Resources Division in Utah achieved what the National Headquarters expected and more. The reorganization allowed professional and support personnel to grow into better-trained individuals with wider work horizons by broadening both perspectives and experience. Rapid changes in data handling and technical equipment improved job performance and published reports, the end product of the Division. Typists traded typewriters for word processors. Data handling and accounting were computerized, and even at the beginning of the period, illustrators had traded drafting pens and linen for scribing equipment.

The Utah District was reorganized in 1965. The change was announced to the District on July 1 by Milton T. Wilson, District Engineer for the Surface Water Branch, who was designated the new WRD District Chief. Prior to reorganization, Utah had separate District offices for the three independent branches, a Quality of Water Branch laboratory, which served not only Utah but several adjacent States. At the beginning of the period, the offices of the three operating branches were on the eighth floor of the Federal Building at State and First South Streets in downtown Salt Lake City. A preexisting Upper Colorado River Regional project office and several other non-WRD USGS offices also were on the eighth floor.

Despite some rearrangement of space, the WRD District office remained in the Federal Building until November 1979. At that time, all Geological Survey personnel, with the exception of the Public Information Office, were moved to larger quarters in the "Administration Building," at the corner of 1700 South and Redwood Road in the industrial area of southwestern Salt Lake City. This building was the remaining vestige of a World War II Remington Arms ammunition plant. Prior to the move, parts of the building housed the District laboratory, later the WRD Central Laboratory, and also WRD storage and shop space. For many, the old building was painfully archaic although it had been refurbished with new partitions, lowered ceilings, and new carpet. Its principal advantage was abundant employee parking.

The last 6 months of 1965 saw changes in operations, but reorganization was not really completed until December 1965–January 1966. Milt Wilson retired in December 1965 and Ted Arnow, former District Geologist for the Ground Water Branch, was designated District Chief.

Organization and Management

On January 3, 1966, Ted Arnow issued a memorandum to all personnel specifying the "new order." George L. Whitaker, formerly Assistant District Engineer of the Surface Water Branch office, was designated as Assistant District Chief, and R. Hal Langford, formerly District Chemist of the Quality of Water Branch office in Utah, was designated Chemist-in-Charge of all quality-of-water work in Utah and parts of Colorado and Wyoming. Before the reorganization was completed, however, Langford transferred to the National Headquarters to a management position in the new Office of Water Data Coordination. WRD District activities were reassigned to three sections. This tripartite arrangement continued with some modification to 1979.

The Data Section was placed under James C. Mundorff, but the name "Data Section" was changed to the "Hydrologic Surveillance (HS) Section" in 1977. Most of the personnel in the HS Section had been in the Surface Water Branch. Several former Ground Water Branch employees whose duties included maintenance of the observation-well network were moved into the HS Section. At reorganization, the HS Section included Subdistrict Offices at Salt Lake City, headed by Harold W. Chase, and at Vernal, headed by Dayl J. Webb. Field Headquarters were at Cedar City, Green River, Monticello, Richfield, and St. George. An office in Logan, headed by Wallace N. Jibson, collected data largely for the Bear River Compact and reported directly to the Regional Hydrologist. The Logan office was assigned to the HS Section in 1968, although Jibson reported directly to the District Chief. In 1967 the Field Headquarters in Cedar City, Green River, and Monticello were closed; the office in St. George operated until 1971. The Richfield Field Headquarters was designated a Subdistrict, headed by Louis J. Bjorklund, in 1967 and conducted interpretive projects as well as collecting data. In 1971, the Richfield Subdistrict was moved to Cedar City and headed by G. Woodard Sandberg. The Cedar City and Logan Subdistricts conducted some interpretive projects during 1968–79. The Vernal Subdistrict Office operated through the period and was involved in both data collection and interpretive projects, mostly related to oil-shale hydrology in the Uinta Basin, during about 1975–78. Glenn C. Anderson headed that office after 1976. In 1979, most of the personnel involved in interpretive work were moved from Vernal to the District Office. The Salt Lake City Subdistrict was staffed by 9 to 14 people and operated during 1966–79. It was headed by Reinhart T. Kowallis from 1972 to 1976 and George E. Pyper from 1976 to 1979. A Field Headquarters was established in Moab in 1967, headed by George A. Birdwell, and operated during the rest of the period.

The Investigations Section was placed under the supervision of James W. Hood. Several members of the HS and Support Sections also worked part-time on Investigations Section projects.

The Support Section was supervised by the Assistant District Chief, George Whitaker. The section included the Administrative Services Unit, the District laboratory under Alonzo H. Handy, III (doing much of the work that had continued from the Quality of Water Branch office), and a Reports Processing Unit. The Administrative Services Unit was headed by Reid S. Lawrence as Administrative Officer during 1966–72, Ferne T. Graves during 1972–76, and David L. Hansen during 1976–79. The District laboratory was supervised by Glenn E. Johnson during 1971–76 and by Gerald G. Plantz during 1976–79. The Reports Processing Unit was placed under the supervision of the Investigations Section, and in 1979 a Publications Section was created under the supervision of Donald Price.

At the beginning of the period, an office in Salt Lake City, headed by W. Vaughn Iorns and reporting directly to the Regional Hydrologist, was conducting a study of the Upper Colorado River Basin. By 1967, this study was essentially completed and its personnel were absorbed by the District. In 1971 a pilot laboratory for the Central Laboratories System was created in Salt Lake City and headed by Russell L. McAvoy. This new unit incorporated much of the District laboratory, and several District personnel moved into it. At the same time, a small District field unit was created. The Central Laboratory unit moved to Denver in 1976.

Personnel

Changes in supervisory personnel of the District were relatively few. Ted Arnow and Jim Mundorff remained in their positions throughout the 1966–79 period. Assistant District Chief George Whitaker retired in 1970 and was replaced by Russell W. Cruff. In 1971, Jim Hood withdrew as Chief of the Investigations Section and returned to full-time technical work. He was replaced by Jerry C. Stephens, who transferred to Utah in 1972. In 1977, Jerry Stephens transferred and was replaced by Joseph S. Gates, who had worked in the Ground Water Branch Office in Utah during 1958–64.

Overall, the number of personnel changed little from the beginning to the end of the 1966–79 period. Although total personnel increased from 65 in 1966 (55 permanent and 10 non-permanent) to 80 in 1979 (72 permanent, including 19 part-time permanent, and 8 non-permanent), essentially 12 of the increase of 15 was absorption of personnel from the Logan Office and the Upper Colorado River basin project office. In 1974, however, the number of District personnel was down to 56 (47 permanent and 9 non-permanent). The District budget almost doubled from 1974 to 1976 because of a large increase in energy-related programs, and the personnel count went from 56 to 70 (58 permanent and 12 non-permanent).

In 1966, permanent staff was composed of 11 engineers, 5 chemists/soil scientists, 5 geologists, 26 technicians/technical aids/cartographic-technicians, and 8 administrators/clerks/typist-stenos. In 1979, permanent personnel was composed of 27 hydrologists (11 engineers, 12 geologists, and 4 chemists/soil scientists/biologists), 1 computer programmer, 32 technicians, and 12 administrators, clerks, secretary-typist-stenos, and editors. In 1966, 14 employees were in management, administration, and support functions, about 38 in data-collection activities (including water-quality sampling and analysis), and about 13 in hydrologic investigations. In 1979, about 20 employees were in management, administration, and support functions, about 32 in data-collection activities, and about 28 in hydrologic investigations. The large relative increase in employees in hydrologic investigations was mostly a result of increases in energy-related investigations.

Funding

Table 1 presents data for funding sources for FY's 1966 and 1972–79. Data are not available for FY's 1967–71. Table 2 presents data for funding by program type for FY's 1972–79. Total District funding for FY 1966 was $763,000. By FY 1972, total District funding was about $1,117,000—an increase of about 46 percent over FY 1966, which is an average growth of about 6.5 percent per year, indicating moderate growth in funding.

District funding increased at a low to moderate rate from FY 1972 through FY 1974; but from FY 1974 to FY 1976, District funding doubled. Funding returned to a low to moderate rate of increase from FY 1976 to FY 1979, a total of 13 percent over those 3 years. As shown in table 2, the large increase in funding after FY 1974 was in energy-related data-collection and interpretive studies, primarily involving oil-shale and coal hydrology, with a small program in geothermal energy. In 1976, funding for energy-related data collection and studies was at least 39 percent larger than the entire District budget in FY 1966.

From FY 1978 to FY 1979, Federal funding for investigation of hydrology in the oil-shale area of the Uinta Basin dropped from $685,000 to $257,000, thus creating a potentially serious financial problem for the District. Fortunately, funding for monitoring and investigations in coal-resource areas of eastern and southern Utah, largely from the Bureau of Land Management, increased by about $380,000, which, along with funding increases in other programs, resulted in a slight increase in the overall District budget from FY 1978 to FY 1979.

Changes in Technology

The period 1966 to 1979 saw changes in technology that Water Resources Division employees of years past would have considered with amazement. Of greatest immediate impact, overall, was the computerization of data files. Prior to the advent of the computer, hydrologists and technicians alike spent hours laboriously tabulating data by hand. Later, the same data were tediously typed and retyped by publications personnel. After computerization of data files,

Table 1. Utah District funds by source, fiscal years 1972–79 (in thousands of dollars)

Fund source	1966	1972	1973	1974	1975	1976	1977	1978	1979
Cooperative Program	622.8	890.1	923.0	937.7	1,226.6	1,161.5	1,025.2	1,295.6	1,410.0
Federal program	71.2	135.2	180.0	163.2	428.6	824.3	953.5	1,023.7	654.3
Other Federal agencies	68.2	90.1	89.2	113.0	235.3	428.7	379.7	370.6	654.2
Federal Power Commission	1.0	1.6	1.6	1.7	1.7	2.7	1.8	2.1	2.2
Total	763.2	1,117.0	1,193.8	1,215.6	1,892.2	2,417.2	2,360.2	2,692.0	2,720.7

Source: From tables prepared by the District Chief for the annual program review in the spring of each year. Funds listed in the table are as of about 2/3 of the way through the fiscal year and may not be exactly the same as the final figure.

Table 2. Utah District funds by program type, fiscal years 1972–79 (in thousands of dollars)

Program type	1972	1973	1974	1975	1976	1977	1978	1979
Data collection	658.4	654.5	698.1	1,163.6 (at least 387 energy-related)	1,140.0 (at least 296 energy-related)	1,017.0 (at least 19 energy-related)	1,272.1 (at least 20 energy-related)	1,549.2 (at least 95 energy-related)
Interpretive studies								
Non-energy	458.6	539.3	517.5	423.0	515.0	520.7	505.5	464.1
Energy	0	0	0	305.6	762.2	822.5	914.4	707.4
Total	1,117.0	1,193.8	1,215.6	1,892.2	2,417.2	2,360.2	2,692.0	2,720.7

Source: From tables prepared by the District Chief to track District funding through each fiscal year (commonly including the final income and expenditure figures for the preceding fiscal year).

the computer could be used to print tables that were very nearly camera-ready for publication.

Complementing the computer-storage techniques were the means of data acquisition. In 1966, the Division was graduating from the manual analysis of analog-recorder charts to machine-read punch tape. By 1979, gaging-station equipment and techniques were approaching the capability of providing real-time data through satellite telemetry.

Water-quality analysis likewise was changing from the old routine of a bench chemist needing a week to analyze a set of 10 to 20 water samples to rapid analysis of many samples through the use of automated colorimetric analyses with direct input to the computer files. New instrumentation and procedures permitted quick analysis for concentrations of many more elements and radicals than bench techniques normally allowed.

In ground-water investigations, the professional could not be replaced by automation of thought, but the professional was given better tools. In 1964, computerization of ground-water records was started with relatively simple forms on punch cards. At first, these were processed in the National Center, and later at Denver. Retrieval of data was done through the computer link at the District laboratory or by mailing printouts from the computer centers. With the establishment of WATSTORE, computer processing accelerated, and the Utah District obtained its own terminal facilities. Computerized ground-water-data files not only made tabulation of records easy, but they allowed for computer-plotted contour maps and other analytical aids.

A development in technology that added much to the quality of the Utah District's analysis of project data was the development of methods for modeling the hydrologic system. The first was an analog model utilizing resistance-paper representation of aquifers, followed by analysis using an analog model consisting of a resistor-capacitor network. Later, WRD developed programs for digital analysis of ground-water flow and storage using the computer. The earliest use of ground-water system modeling in Utah appears to be a resistor-capacitor analog model of the Salt Lake Valley ground-water system, prepared by Reed W. Mower during about 1964–68. Mower later constructed the District's first digital model of a ground-water system, that of Beaver Valley, during 1973–76. Terence W. Danielson and James W. Hood did some conceptual modeling of a consolidated-rock aquifer in the Dirty Devil River Basin of eastern Utah during 1975–78.

Programs

Programs and project work were affected minimally by the 1965–66 reorganization, although new projects tended to be multidisciplinary in design. Federal and State data networks were continued, although they were reevaluated and refined. The water-quality network was expanded. Federal funding of investigations expanded in response to the energy "crisis" of the mid-1970's.

In FY 1966, the Federal-State Cooperative Program provided 82 percent of the operating funds for the Utah District. The principal cooperators were in what is now the Utah Department of Natural Resources. The Office of the Utah State Engineer (now the Division of Water Rights), the Utah Water and Power Board (now the Division of Water Resources), and the Utah Geological and Mineralogical Survey (now the Utah Geological Survey) provided the bulk of cooperative funds and also provided State publication of many of the District's reports of investigation. In FY 1966, the cooperative program with the Utah State Engineer included both data collection and hydrologic investigations and provided more than half the District's funding. The Utah Department of Highways also provided cooperative funds. Other local cooperators, such as Salt Lake County, funneled most of their funds through the State Engineer, thus adding to the total cooperative funds.

During the first two-thirds of the 1966–79 period, FY's 1967–74, about 80 percent of the District program consisted of cooperative studies with State and local agencies. More than half the program was related to surface water, mostly data collection. During the latter one-third of the 1966–79 period, fiscal years 1975–79, the District program was expanded by energy-related hydrologic investigations and data collection under the Federal and "Other Federal Agency" programs (see tables 1 and 2). The Cooperative Program, although larger than during the first two-thirds of the period, was only about one-half the total program. At least half the program still consisted of surface-water data collection.

Table 3 shows the number of data-collection sites in FY 1967, in FY 1974 before energy-related work began, and in FY 1979 when the District was involved in energy studies and data collection. More

Table 3. Data-collection sites in the Utah District, fiscal years 1967, 1974, and 1979

Type of site	FY 1967	FY 1974	FY 1979
Surface-water data			
Streamflow stations	233	222	248
Reservoirs	19	16	18
Lake-stage stations	2	3	3
Stream-stage stations	1	1	--
Ground-water data			
Water-level observations			
Annual measurements	--	1,090	1,030
Semiannual measurements[1]	1,000	760	720
Continuous data by recorder	42	33	33
Springs—continuous stage/discharge data by recorder	--	1	4
Quality-of-Water Data			
Surface-water sites			
Water-quality analyses	[2]21	[3]27	32
Specific-conductance measurements	--	145	140
Sediment-size analyses	10	9	32
Ground-water sites			
Water-quality observation wells	?	113	315
Springs	?	3	3

[1]Generally included in the number of wells measured annually.
[2]20 sites in Utah and 1 in Arizona.
[3]26 sites in Utah and 1 in Arizona.
Source: "Water Resources Studies in Utah"—annual summaries of progress by the U.S. Geological Survey.

surface-water-flow and quality, sediment, and ground-water-quality data were collected in FY 1979.

A District project that was overseen by the Investigations Section but substantially conducted by the Hydrologic Surveillance Section (much of the data were collected by R. Glenn Butler and Larry R. Herbert of the HS Section) was the District's annual assessment of ground-water conditions in Utah. This project, begun in 1964, consisted of compilation of data on water levels in observation wells, discharge from wells, quality of water from wells, and number of wells constructed, and preparation of an annual report summarizing the data in water-level hydrographs, water-level-change maps, discharge graphs, and tables of discharge and well construction. The reports included a minimum of interpretation, mainly discussion of the general correlation between water-level changes and changes in discharge and precipitation, and were published within a few months of the measurement of water levels in the spring of each year. The reports were recognized throughout the WRD as a model for monitoring and assessing ground-water conditions.

Another project substantially conducted by the HS Section was the continuing compilation of water-use data in Utah. This project, conducted in cooperation with the Utah Division of Water Rights (the Division actually did most of the work), was begun by Russell W. Cruff in FY 1978.

Hydrologic Investigations

During 1966–79, the District's program of hydrologic investigations continued to include the major elements from 1957–66. These were (1) detailed studies of basins of western Utah from which large amounts of ground water were withdrawn from unconsolidated deposits for irrigation and public supply, (2) reconnaissance of basins of western Utah where ground water was little developed, (3) studies of Great Salt Lake, (4) studies that interpreted surface-water data to characterize runoff, extend records, describe flooding, or do other special analyses, and (5) studies of quality of water in river basins, surface reservoirs, and ground-water reservoirs. After 1966, hydrologic investigations tended to be multidisciplinary when possible, with personnel trained in ground water, surface water, and water quality involved.

(1) Studies of developed ground-water basins included a multidisciplinary study of the Salt Lake Valley, which was the most detailed ground-water study ever done by the District. This study, directed by W. Vaughn Iorns, succeeded by Alan G. Hely, was done during fiscal years 1964–70 and brought up-to-date two previous studies of the Salt Lake Valley by the District. Iorns and Hely did the surface-water part of the study, Reed W. Mower the ground-water part, C. Albert Horr the quality-of-water part, and Ted Arnow the geologic interpretations. Other studies of developed ground-water basins, mostly in western Utah, were done in Sanpete Valley by Gerald B. Robinson, in Southern Utah Valley by Robert M. Cordova, in the Heber-Kamas-Park City area by Claud H. Baker, in Cache Valley by Louis J. Bjorklund and Laurence J. McGreevy, in the East Shore area (from Bountiful to Willard at the east shore of Great Salt Lake) by Edward L. Bolke and Kidd M. Waddell (the third study done in the East Shore area by the District), in Curlew Valley by Claud H. Baker, in the lower Bear River Basin by Louis J. Bjorklund and Laurence J. McGreevy, in the Milford area by Reed W. Mower and Robert M. Cordova (the second specific study of the Milford area by the District), in the Parowan-Cedar City drainage basin by Louis J. Bjorklund, Carlton T. Sumsion, and G. Woodward Sandberg (the second specific study of the basin by the District), in Beaver Valley by Reed W. Mower (which included the District's first digital ground-water flow model), in the Beryl-Enterprise area by Reed W. Mower (the second study and the first that included a digital model in this area by the District), and in Tooele Valley by Allan C. Razem and Judy I. Steiger (the third study and first model of Tooele Valley by the District).

(2) The reconnaissances of water resources, chiefly ground water, in the arid and little-developed basins of western Utah continued from the preceding period. This series of studies was patterned after the basin reconnaissances done in the Nevada District by Thomas E. Eakin and others. These studies involved less than 2 months of fieldwork and were completed in one fiscal year. James W. Hood began these reconnaissances in Utah in 1964 and continued them until 1972. Others involved were Don Price, Edward L. Bolke, Kidd M. Waddell, Jerry C. Stephens, and Carlton T. Sumsion. Basins that were studied included Deep Creek, Sink, Grouse Creek, Curlew, Park, Hansel, Blue Creek, Pilot, Wah Wah, Pine, and Tule Valleys, the Promontory Mountains area, the Dugway Valley-Government Creek area, and Fish Springs Flat. Summary reports, including evaluations of the northern and southern Great Salt Lake Desert, were prepared for basins in northwestern Utah by Jerry C. Stephens and basins in west-central Utah by Joseph S. Gates and Stacie A. Kruer. Other reconnaissances by the District during 1966–79 included those of the upper Fremont River Valley by Louis J. Bjorklund, the southern Uinta Basin by Don Price and Louise L. Miller, and the central Weber River area by Joseph S. Gates and Judy I. Steiger.

(3) The District's studies of Great Salt Lake continued during 1966–79. These included studies of the chemistry of the lake by Daniel C. Hahl and Robert J. Madison, of effects of restricted circulation on brine concentrations by Waddell and Edward L. Bolke (which featured the initial digital modeling of the hydrology and water quality of the lake), of surface-water inflow to the lake by James C. Mundorff and George E. Pyper, and of effects of diking on the water and salt balance of the lake by Kidd M. Waddell and Fred K. Fields (which featured an overall digital lake model).

(4) Surface-water-related studies during 1966–79 included extension of streamflow records by J. Kenneth Reid and George E. Pyper, of magnitude and frequency of floods by Elmer Butler and Pyper, of mean annual runoff in ungaged areas by Butler, of cloudburst floods by Butler, of the magnitude and frequency of floods by Fields and Pyper, and of runoff in the Duchesne River Basin by Russell W. Cruff and Leon J. Jensen. In addition, in FY 1974 Cruff began a series of canal-loss studies. These consisted of 2-year studies to determine seepage from a set of canals, commonly in an area where the District was conducting a ground-water study and needed these data to estimate that part of recharge.

(5) Studies of water quality in river basins, surface reservoirs, and ground-water reservoirs during 1966–79 included studies of water quality and sediment in the Sevier River Basin by Daniel C. Hahl and in the Bear River Basin by Kidd M. Waddell. Studies of the water quality of Flaming Gorge Reservoir were done by Hahl, Robert J. Madison, Waddell, and Edward L. Bolke. In FY 1970, James C. Mundorff began a series of reconnaissances of water quality and sediment of major river basins. Kendall R. Thompson assisted on these studies at the end of the period. These

studies included the Price River, Utah Lake, Duchesne River, Dirty Devil River, and San Rafael River Basins. Mundorff also prepared compilations of data on major thermal and non-thermal springs of Utah.

During the early 1970's concern was expressed by racers using the Bonneville Salt Flats on the Utah-Nevada border that the area and thickness of the salt crust of the Salt Flats was decreasing. In response to this concern, a detailed study of the hydrology of the Salt Flats was conducted by Gregory C. Lines during FY's 1976–77.

The Utah District also began, in FY's 1968–69, detailed studies of ground water in eastern and southern Utah, where consolidated-rock aquifers are significant or the major sources of water. These include a study of Spanish Valley (Moab area) by Carlton T. Sumsion, a study of the central Virgin River Basin by Robert M. Cordova, and a multidisciplinary study of the northern Uinta Basin by James W. Hood and Fred K. Fields. Then in FY 1974 the District began a series of studies in southeastern and southern Utah that focused on ground water in the Navajo Sandstone, the major consolidated-rock aquifer in that area. The first was a study of the Navajo Sandstone in the central Virgin River Basin by Robert M. Cordova, followed by studies of the Navajo Sandstone in the lower Dirty Devil River Basin by Hood and Terence W. Danielson, in the upper Virgin River and Kanab Creek Basins area by Cordova, and in the northern San Rafael Swell area by Hood and Dennis J. Patterson.

In the last one-third of the 1966–79 period, concerns about energy led to a national effort to evaluate energy resources, including the hydrology of energy-resource areas. In FY 1975 the Utah District began studies and collection of data related to the hydrology of energy-resource areas. Initially, this mostly involved oil shale in eastern Utah but soon included coal and geothermal resources. The largest effort was a federally funded study of the oil-shale area of the southeastern Uinta Basin, headed by Fred K. Fields, who was succeeded at the end of FY 1977 by Kenneth L. Lindskov. Walter F. Holmes, Briant A. Kimball, Daniel W. Finn, John E. Tooley, Scott Waltemeyer, and others also were assigned to the study. The oil-shale study consisted of surface- and ground-water hydrology (including digital models of selected aquifers) and quality of water; it also included such topics as geochemical reactions between water and geologic formations, including those that are oil-shale bearing; the area's vegetative cover; and stream morphology.

Hydrology of the coal-resource areas of eastern and southern Utah was a growing part of the District's program starting in FY 1975. The first study was a coal-strip-mining reclamation site at Alton in Kane County by G. Woodard Sandberg. This was followed by collection of hydrologic data in the Book Cliffs and Wasatch Plateau coal areas by Carlton T. Sumsion, hydrology of the central Wasatch Plateau area by Lines (succeeded by Michael J. Graham) and John E. Tooley, hydrology of the Ferron Sandstone and effects of proposed strip mining in Castle Valley by Lines and Daniel J. Morrissey (which included a digital model of ground water in the Ferron Sandstone), water resources of underground coal-resource areas in the Huntington and Cottonwood Creek drainages by Terence W. Danielson and John R. Butler, water-resources monitoring in the central Utah coal region by Gerald G. Plantz and Lines, and the hydrology of the Price River Basin by Kidd M. Waddell and Jeanette E. Dodge.

Another national energy interest was to evaluate geothermal energy. A study of geothermal resources in western Utah was conducted by F. Eugene Rush during FY's 1976–77.

Energy-related investigations and data collection provided funding to the District which enabled some increase in staff and improvement in equipment and technology. Resulting reports and data were useful to managers and others who needed to assess the impacts of energy development on water resources. The energy-related work, however, diverted experienced personnel and resources from the Federal-State Cooperative Program and production of cooperative reports, which probably are more widely used than the reports of energy-related studies. The shorter term energy-related program probably had some negative effect on the longer term Cooperative Program in Utah.

Publications

The period 1966–79 saw a surge in the number and timeliness of publications issued by the Utah District. Strong impetus for timely publication was provided by the National Center, the Regional Office, and most certainly the District Chief. The availability of data was much more timely. For example, the spring round of annual water-level measurements in observation wells was summarized in map form within weeks of the completion of measurements and released soon afterwards to the open file. Most of the District's hydrologic investigations under the Federal-State Cooperative Program were published in the Utah Department of Natural Resources Technical Publication series. From about 1940 to 1966, a 27-year period, the District's program contributed 18 reports to this series. From 1967 to 1979, a 13-year period, the District's program contributed about 58 reports, about a sevenfold increase in report production.

The quality of reporting was improved both in content and format; better methods were used to improve the utility of the reports to the user and report appearance. High standards were set for colleague and editorial review. The resultant reports were a far cry from the local mimeographed reports of past decades.

Those who wish to see the publication output of the Utah District can find those reports and maps listed in the USDI "List of U.S. Geological Reports and Maps for Utah," as of August 1988. A more comprehensive list of Federal and State reports is to be found in "Bibliography of U.S. Geological Survey Water-Resources Reports for Utah," Utah Department of Natural Resources Information Bulletin 29, 1993. This bibliography is available from the Utah District Office or from the Utah Department of Natural Resources, both in Salt Lake City.

Vignette

The writers and their colleagues would like to pay tribute to an individual whose treatment and performance emphasized both WRD's accommodation of its valued employees and the value of dedicated handicapped persons.

Don Price is a native of Utah, a graduate of the University of Utah, who served in the Ground Water Branch, Utah District Office, during 1956–59. He later transferred to Oregon where his sight began failing, mainly his center vision. The Oregon District asked that Don be accepted in an open slot in the Utah District so he could be near his family, and the transfer was made in 1966.

Although Don could not do field work alone (he could not drive), he turned out a steady flow of reports of local, areal, and regional importance until his retirement in 1987. His continuation in technical and report-review work was done in a competent and professional way, despite his using only peripheral vision, and he supervised the District's Publication section during much of the 1980's. After a vigorous life of college athletics and of field work for GWB, Don's acceptance of his later limitations is all the more remarkable. The consideration shown to Don and his response demonstrated the strong "family feeling" among long-time employees of WRD.

WYOMING

By James F. Wilson, Jr., including information provided by Edward R. Cox, and reviewed by Fred C. Boner, Marvin A. Crist, Robert L. Cushman, Pamela B. Daddow, Stanley A. Druse, William R. Glass, Barney D. Lewis, Philip B. McCollam, James G. Rankl, Samuel J. Rucker, IV, Kenneth L. Wahl, and Sam W. West.

ORGANIZATION AND MANAGEMENT

As the period 1966–79 began, there were three Branch Districts in Wyoming. Thomas F. Hanly was District Engineer of the Quality of Water District headquartered in Worland, with one-man Field Headquarters in Riverton (Charles F. Obert) and Laramie (Thomas J. Spedding). Ground Water and Surface Water Districts were headquartered in Cheyenne, with Ellis D. Gordon, District Geologist (GW), and Leon A. Wiard, District Engineer (SW). Kenneth B. Rennick was Engineer-in-Charge of the Casper Subdistrict (SW), and Lawrence D. Becker, the Riverton Subdistrict (SW). Technicians-in-Charge of Field Headquarters (SW) were Terry J. Perkins in Cheyenne, who replaced James G. Rickher (transferred to Puerto Rico early in 1966) and Philip B. McCollam in Lovell. Helen M. (Lee) Clark provided administrative services in Cheyenne.

In 1966 the Quality of Water District headquarters, water-quality laboratory, and sediment laboratory were located at 1214 Bighorn Avenue in Worland. The Surface Water and Ground Water District Headquarters occupied the second floor of the old Blue Cross building at 215 East Eighth Avenue, near the Cheyenne municipal airport.

Reorganization, 1967

The Branch Districts were merged into one District headquartered in Cheyenne in February 1967, with Wiard as the first District Chief. Hanly was named Engineer-in-Charge of the redesignated Worland Subdistrict, and Gordon joined the Central

Region staff in Denver. Robert L. Cushman was the first Assistant District Chief and first Investigations Section Chief, transferring from Egypt as the Middle East War began. Robert C. Williams transferred back to Wyoming from Oregon to be the first Data (Surveillance) Section Chief. Jack R. Carter, Assistant District Engineer (SW) and Chief of the Hydraulics Section, transferred to Kansas. James F. Wilson, Jr., transferred from Division Headquarters to be in charge of the Hydraulics Section. Rennick moved to Cheyenne to be the office engineer for surface-water records. Helen Clark continued to provide administrative services.

District Headquarters, 1968–79

Cushman was appointed to be the second District Chief when Wiard retired in 1968. Williams added the Assistant District Chief hat to his Data Section Chief hat. Rennick transferred to the Central Region office in Denver, and Keith G. Polinoski, a senior technician, assumed the duties of office engineer. Wilson was appointed Chief of the reorganized Investigations Section, which was combined with the Hydraulics Section. After Williams was appointed North Dakota District Chief in 1970, Fred C. Boner transferred from Montana to be Data Section Chief, and Wilson was appointed Assistant District Chief, a position he held for the remainder of the reporting period.

Samuel W. West, the third District Chief, moved from Denver in December 1973, after Cushman had retired in June. James R. Marie, from the Indiana District, was Investigations Section Chief from June 1975 to the end of the period. For the first time, the Assistant District Chief was not also a section chief.

In April 1979 the fourth District Chief, William W. Dudley, Jr., transferred from Denver. West had retired in December 1978. Ernest S. Denison, from the New England District, became the new Data Section Chief in May 1979, replacing Boner, who transferred to Arizona.

In June 1973 the staff moved temporarily to a converted drugstore on the corner of Warren and Eighth Avenues. By 1975 the District was leasing space in three additional buildings nearby. In December of 1976, most of the staff moved back to the old Blue Cross building, but 6 months later the office was relocated downtown to the J.C. O'Mahoney Federal Center on Capitol Avenue. The water-quality laboratory was moved to the old Federal Building, a block west of the O'Mahoney Building, in May 1979.

Field Offices, 1967–79

Worland Subdistrict—Arvo R. Gustafson was named Hydrologist-in-Charge after Hanly retired in 1969. Stanley A. Druse, from Cheyenne, replaced Gustafson in 1971. Harold B. Fabricius was appointed Technician-in-Charge in 1977, when Druse moved back to Cheyenne. The Worland office and sediment laboratory remained at 1214 Bighorn Avenue throughout the period. The water-quality laboratory, however, was moved to Cheyenne in 1971 after the Division's Central Laboratory opened in Salt Lake City.

Casper Subdistrict—Gerald W. Armentrout, Jr., replaced Rennick in 1967. William R. Glass was appointed Hydrologist-in-Charge in 1975, when Armentrout was reassigned to the Investigations Section. The office was relocated from South Jackson Street to the Federal Building on "B" Street in 1970, and to North Lincoln Street in 1976.

Riverton Subdistrict/Field Headquarters—In 1967 Delmer J. O'Connell replaced Becker, who transferred to South Dakota. Bruce C. Ringen, from Nebraska, became Hydrologist-in-Charge in 1969 when O'Connell moved to Cheyenne. O'Connell returned in 1971, and Ringen moved to Cheyenne to direct the observation-well program. When O'Connell moved to Green River in 1976, Charles F. Obert was named Technician-in-Charge, and the office designation was changed to Field Headquarters. During 1966–79 the office was located on South Federal Boulevard.

Cheyenne Field Headquarters/Field Unit—In 1967 Perkins transferred to New Mexico, and Polinoski transferred from Nebraska to be Technician-in-Charge. McCollam replaced Polinoski in 1968. Donald J. Pangburn transferred from Minnesota in 1974 to replace McCollam, who transferred to Worland. The office was redesignated as a Field Unit in about 1976.

Lovell Field Headquarters—McCollam had moved to Riverton in 1966 but returned as Technician-in-Charge in August 1967. Gary D. Robinson, Engineer-in-Charge for about a year, transferred to Kansas. A year later, when monitoring inflow to Bighorn Lake no longer was needed, the office was closed. McCollam moved to Cheyenne.

Laramie Field Headquarters—This office provided part-time liaison with the State Laboratory at the

University of Wyoming. The office was closed in 1970, but the State laboratory continued to analyze water-quality samples collected in cooperation with State agencies, under the Direct Services provisions of the cooperative program with the Wyoming Department of Agriculture.

Green River Field Headquarters—The office was opened on West Flaming Gorge Way in November 1976, in response to the large increase in data collection in the Green River Basin. O'Connell was Hydrologist-in-Charge, moving from Riverton. McCollam—by now an expert at moving—had transferred from Worland a month early and operated out of his home until office space could be leased. In 1978 the office was relocated to East 5th Street South.

Buffalo Field Headquarters—The office was opened on North Main Street in June 1977 in response to the large increase in data collection in the Powder River Basin. Polinoski moved fromCheyenne to be Technician-in-Charge.

Funding and Personnel

Annual funding remained fairly steady until 1975 (see table). During 1967–79 the Federal-State Cooperative (Coop) Program accounted for about 60–70 percent of the annual basic (non-energy) program funding. Even after 1975, increases in the basic programs mainly were inflationary. New sources of funding in 1975 included the Federal Program (Fed) Coal Hydrology and Oil-Shale Hydrology programs and Madison Limestone Study, and energy-related work in cooperation with the Bureau of Land Management and the U.S. Environmental Protection Agency. The Coop Program included energy-related funds during 1975 ($194,400) and 1976 ($75,600). In 1977 Wyoming was included in two of the Division's first Regional Aquifer-System Analysis (RASA) projects: Northern Great Plains and High Plains. By 1979, energy and RASA funding accounted for about 58 percent of the total budget.

The combined staffs totaled about 54 people in 1966, but by 1974 the reorganized District had decreased to 39. By 1979 the staff had increased to 74 and for the first time included specialists in geochemistry, geophysics, and aquatic biology.

Donna W. Brownell, Physical Science Aid, Worland, was the only woman in a technical series in 1966, but the role of women in the District soon would change. Beginning in 1967 with Cora E. (Brusaw) Louie in Casper, many women in clerical positions were trained and converted to hydrologic clerks or aids. In 1974 Kathy D. Peter joined the District as its first woman hydrologist; she later would be the first woman District Chief (Oklahoma), and Pamela B. (Freudenthal) Daddow was the first woman hydrologic technician hired for interpretive studies; she later qualified as the District's second woman hydrologist.

Other technical staff in Cheyenne were Charles F. Avery, Wilbur C. Ballance, D. Steven Barker, William B. Borchert, John F. Busby, David L. Butler, Darrell D. Carlson, Dannie L. Collins, Maurice E. ("Spade") Cooley, Edward R. Cox, Gordon S. Craig, Jr., Milo D. Cress, Marvin A. Crist, Thad W. Custis, Richard L. Daddow, Lewis L. DeLong, Druse, John H. Dumeyer, Morris J. Engelke, Philip L. Fitzwater, Kent C. Glover, Arvo R. Gustafson, William J. Head, Warren G. Hodson, Dwight T. Hoxie, Craig L. Joy, Thomas N. Keefer, Hugh I. Kennedy, Kevin T. Kilty, James E. Kircher, Richard W. Knottek, L. Rodney Larson, Leslie W. ("Lee") Lenfest, Jr., Gregory C.

Wyoming District funds, fiscal years 1967–79

[In thousands of dollars. Transition quarter of 1976 not included. --, no data]

Fund source	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Coop	--	--	496.6	516.9	533.7	561.6	573.8	658.7	832.7	714.9	782.9	743.9	801.1
OFA	--	--	71.4	90.8	87.0	97.0	151.6	109.6	272.9	587.7	462.2	537.4	478.1
Fed	--	--	149.0	186.2	178.9	157.3	173.0	162.3	422.1	742.4	1,164.2	1,407.9	1,412.7
Total	--	--	717.0	793.9	799.6	815.9	898.4	930.6	1,527.7	2,045.0	2,409.3	2,689.2	2,691.9

Source: District program documents and personal notes of J.F. Wilson, Jr.

Lines, Hugh W. Lowham, Marlin E. Lowry, Laurence J. McGreevy, Alan E. Myers, O'Connell, Waite R. Osterkamp, Richard H. Pearl, David A. Peterson, Polinoski, David W. Pollock, Jess O. Ragsdale, James G. Rankl, Ringen, Samuel J. Rucker IV, Joel R. Schuetz, Betty J. Tucker, Theodore J. Vore, Kenneth L. Wahl, David J. Wangsness, George E. Welder, Harold A. Whitcomb, and Everett A. Zimmerman.

Staff for report processing in 1966 consisted of Janet M. Johnson, who prepared the annual data reports, and Ruth V. Foresman, who prepared manuscripts for District authors. Sharon L. Green replaced Johnson in 1973. Warren Hodson was District Reports Specialist from about 1968 to 1978, when he transferred to Florida. Edward Cox replaced Hodson in 1978. The District's first illustrator, Lynn F. Cunningham, was hired in 1970.

Other clerical staff who served in Cheyenne during the period were L. Kay Bedlan, Frances E. Birchell, Valerie K. Cook, Marjorie E. Gookin, Rebecca L. Greene, Elnora E. Johnson, Cora Louie, Marjorie A. Stanczyk, Irene Vigil, Janet D. Walgren, and Deborah K. Wells.

Others who served in the field offices during the period were:

Worland—David E. Barge, Marguerite E. Barnett, Brownell, Craig M. Hansen, Sharon L. Huhnke, Kennedy, James P. Kyner, Larson, Lowham, James L. Lynch, McCollam, Raymond L. Muench, Robert W. Paris, Ronald C. Reichenbaugh, Rucker, Myron L. Smalley, John R. Tilstra, and James M. Swan.

Casper—Cora Louie, Custis, Thomas J. Leman, Lenfest, Michael J. McCoy, Bruce C. Pedersen, Ragsdale, Leonard L. Reed, and Karen R. Watson.

Riverton—Robert C. Baumann, J. David Blanchet, Laura K. Bohmert, Borchert, James M. Burton, Mark D. Clark, Terry L. Collins, Custis, Sandy Digiovanni, Donald D. Englert, Glass, Judy K. Jeter, Gerry Lebing, Leman, James L. Lynch, McCollam, Eris C. McConnell, John R. Nunn, Michael T. O'Grady, Gary D. Robinson, Marvin D. Stevens, Dennis E. Whitehead, and Varnard L. Wintermote.

Cheyenne—Gregory J. Bundros, Terry L. Collins, Russel G. Houser, Stanley M. Howard, Mark A. Lyverse, Rankl, Stevens, Earle W. Stewart, and Wahl.

Lovell—Englert and Lynch.

Green River—Mark D. Clark, Gookin, Thomas A. Herrett, Gerry Lebing, Mary K. Tucker, and Thomas F. Werth.

Buffalo—Clinton D. Nagel, Pedersen, and Jane M. Peterson.

The District acquired its first computer in 1975—a Data 100, replaced with a Datapoint in 1978. Janet Walgren was the District's first computer operator. Kent Glover and Dwight Hoxie also provided computer assistance to the staff for the remainder of the period.

Principal Programs

All reports of investigations released during the period are listed in Open-File Report 93–413, "Water-Resources Activities of the U.S. Geological Survey in Wyoming, October 1991 through September 1993," p. 27–42.

Hydrologic Data Collection

There were changes in the networks during 1966–74, but in 1975 major expansions began for energy-resources investigations. Regulatory agencies, mining companies, and others needed the data to help characterize the hydrology of areas of potential energy-resource development, or to establish predevelopment baseline conditions.

Streamflow Stations

Ken Wahl evaluated the gaging-station network and identified certain stations that could be discontinued after 20 years of operation (1970 open-file report). Implementation began in 1971. Many water-management stations in cooperation with the Wyoming State Engineer (WSE) were converted to seasonal operation (no winter record collected), and operation of most of the seasonal stations was assumed by WSE for direct-services credit.

The number of continuous-record stations decreased from about 200 in 1966 to about 150 in 1971. By 1977 there were 200 again, in response to the WRD and Bureau of Land Management (BLM) coal and oil-shale programs. Also, 150 to 200 partial-record crest-stage and flood-hydrograph stations were operated in cooperation with the Wyoming Highway Department.

New technology was applied to data collection. The use of helicopters to visit high-altitude stations during winter became standard practice. During 1967–68 Rankl used dye-dilution discharge measurements to verify the stage-discharge ratings for two gaging stations on the western edge of the Snowy Range, thus encouraging further use of the technique. Satellite transmission of data from Wyoming stations began in 1975, in cooperation with the National Weather Service.

During 1975–76, 38 stations (32 new) were operated in pairs to measure streamflow changes across outcrops of the Madison Limestone in the Powder River Basin in anticipation of development of industrial water supplies from the Madison. The WSE and the Old West Regional Commission were cooperators. The South Dakota District operated a few stations in the Black Hills. Some stations were continued in cooperation with the WSE, but only five remained by 1979.

The District participated in a 5-year WRD experiment to contract out construction and operation of streamflow and water-quality stations in energy-resources areas, beginning in 1977. Several were destroyed by severe flooding in 1978, but the contractor quickly replaced them. Carlson and Craig were the Wyoming coauthors of Professional Paper 1244 (1984), produced jointly with the Montana District and the National Weather Service, documenting the 1978 floods in the Powder River Basin. Stanley A. Druse used data from the floods to verify stage-discharge ratings previously derived indirectly for three of the stations (WSP 2199, 1982).

Water-Quality Stations

A combined total of about 63 daily and monthly water-quality stations on streams were in operation in 1966. Most had been started the year before in cooperation with the Wyoming Department of Agriculture (WDA). Worland personnel also operated most of the stations in Montana until July 1967, when the Montana District assumed operation. Sampling programs were begun in 1969 in cooperation with the Federal Water Pollution Control Administration (now the U.S. Environmental Protection Agency) and in 1973, in cooperation with the Wyoming Department of Environmental Quality (DEQ), a new State agency. By 1974 there were about 85 stations and by 1979, about 150. Butler began a Statewide pesticide-sampling network in 1977 in cooperation with WDA.

In 1969 Rucker transferred from Worland to direct the water-quality-data program from Cheyenne. The laboratory remained in Worland, with Larson overseeing the work. When the Central Laboratory opened in Salt Lake City in 1970, Larson transferred there. The downgraded Worland laboratory was relocated to Cheyenne in March 1971. Stewart assisted Rucker until DeLong transferred from Denver in 1972. Schuetz transferred from Iowa in 1974 and replaced Rucker as Chief in 1976. The District continued to use the State Laboratory in Laramie for salinity analyses of samples from streams and wells under State Coop Programs. The WDA received direct-services credit for this work.

DeLong statistically analyzed data for the Green River Basin as part of the energy-resources investigation of that area (WRIR 77–103). Rucker and DeLong later analyzed data for the rest of the State, in cooperation with WDA and the Wyoming Conservation Commission (WRIR 82–4003).

Sediment stations

About 20 daily sediment stations were being operated in 1967. Two daily stations operated in cooperation with the WSE were replaced with 20 monthly stations in 1972 because of increasing costs and increasing difficulty in hiring and retaining local observers.

The number of stations increased from about 37 in 1975 to about 120 in 1977, mainly for the Coal Hydrology Program in cooperation with BLM. Most of the new stations were in the Green River Basin; automatic pumping samplers were installed at a few. Two stations in the Powder River Basin were equipped with continuous samplers, and special sediment-suspending weirs designed by Frederick A. Kilpatrick, Surface Water Branch. By 1979 the network had stabilized at 75 stations.

Directed by Fabricius, the sediment laboratory in Worland provided all concentration, size, and bed-material analyses for Wyoming, and for a few years, for the Montana and North Dakota Districts as well. During the peak year, 1978, the laboratory processed more than 28,000 sample bottles, making more than 17,000 concentration analyses, 890 sand-silt sieve analyses, and 600 size analyses.

Ground-Water Observation Wells

The observation-well program was conducted primarily in cooperation with the WSE. Water-level measurements for the Department's Missouri River Basin (MRB) Program were discontinued in 1969. The statewide network varied from 181 wells in 1971 to more than 300 in 1979, when about 1,200 water-level measurements were made. Ringen completed the first statewide compilation of records of ground-water levels (Wyoming Water Planning Program Report No. 13, 1973). Annual reports on water levels in the municipal well fields near Cheyenne were discontinued in 1974, but the monitoring program in cooperation with the City of Cheyenne continued.

District personnel assisted in site selection, drilling, and testing of two test wells more than 4,000 feet deep: one in Crook County in 1976 for the Madison Limestone Study, and one in Sheridan County in 1979 for the Northern Great Plains RASA. The sites were selected where additional information was needed about the deep aquifers. Custis handled the logistics for both wells and for additional wells in Montana.

Interpretive Studies

Long-term programs in cooperation with the State Engineer, the Highway Department, and the National Park Service (NPS) continued. Because of the emphasis of the coal and oil-shale hydrology programs in the Green and Powder River Basins, ground-water investigations in cooperation with the State Engineer after 1975 focused on other areas.

Dye tracing was used in several investigations. Lowham measured time of travel in the Wind/Bighorn River in 1971, the Green River and selected tributaries during 1975–77, and the Little Snake River during 1976–77. Armentrout and Larson measured time of travel in the North Platte River downstream from Casper in 1978. Cox traced effluent from a wastewater lagoon through adjacent alluvium in Yellowstone National Park during 1975–76. Dye tests also were made in several losing streams in karst terrane along the east flank of the Bighorn Mountains. Details of dye tracing during the period are given in WRIR 96–4122, "Use of Dye Tracing in Water-Resources Investigations in Wyoming, 1967–94."

Cooperative Ground-Water Investigations

Cox, Hodson, Lines, Lowry, Welder, and Whitcomb were senior authors of a Statewide series of Hydrologic Investigations Atlases (HA) that describe the water resources of major structural basins or other large areas. The studies were done in cooperation with the WSE. Published between 1966 and 1976, the atlases have been used extensively by government agencies, consulting firms, and the general public interested in regional-scale hydrologic information.

Studies of the geology and ground-water resources of counties, started during the 1950's in cooperation with the WSE, continued: Johnson County by Whitcomb and others (WSP 1806, 1966); Sheridan County by Lowry and T. Ray Cummings (WSP 1807, 1966); Laramie County by Lowry and Crist (WSP 1834, 1967); and Natrona County by Crist and Lowry (WSP 1897, 1972). McGreevey and others conducted a similar study of the Wind River Indian Reservation for the MRB program (WSP 1576–I, 1969).

Crist evaluated the source and movement of selenium in water in the Kendrick Reclamation Project area near Casper (WSP 2023, 1974). The work was done in cooperation with the WSE, the City of Casper, the Wyoming Game and Fish Commission, and the Wyoming Department of Health.

Deep aquifers were evaluated in several studies in cooperation with the WSE. In 1971 Lowry began a study of the Fox Hills Sandstone, and Hodson studied the Madison Limestone, both formations in northeastern Wyoming. The Madison findings were combined with those from studies by the Montana District and by Central Region staff (I–847–C, 1974). In 1974 Cooley began an investigation of the deep Paleozoic aquifers on the west flank of the Bighorn Mountains.

By the mid-1970's, digital modeling of ground-water flow was being applied in studies of the availability of ground water for irrigation and of long-term hydrologic effects of pumpage. The WSE and Wyoming Department of Economic Planning and Development were cooperators. Crist applied the first model in a study of the North Platte River valley near the town of Torrington (WRIR 3–75). Digital flow models also were used by Lines for the Dwyer area, Crist for the Lusk area, Hoxie for the Wheatland area, and Borchert for the Sweetwater River Basin. Hoxie's work included an evaluation of effects of ground-water withdrawals for the Laramie River Power Station, in cooperation with the Rural Electrification Administration. Studies started before 1979 and completed later were by Crist, Laramie County; Glover, Bates Creek alluvium near Casper; and Borchert, LaGrange area.

Flood Investigations

In 1967 Druse and Wahl were directing the Highway Program, started in 1958 in cooperation with the WHD. It included operation of a statewide crest-stage gage network, evaluation of hydraulics of flows at bridge sites, and miscellaneous measurements of unusual floods. Lowham, who was Project Chief during 1972–76, used the data in an analysis of statewide flood frequency (WRIR 76–112). For the next 12 years Lowham's report was used extensively in highway design, as well as for planning development of energy minerals in Wyoming. Craig was Project Chief after 1976.

Craig and Rankl completed a study of flood-volume frequency and hydrograph shape on small ephemeral streams, started in 1964 (WSP 2056, 1978). The WHD and the U.S. Bureau of Public Roads were cooperators. David R. Dawdy (WRD, Fort Collins, Colo.) assisted Craig and Rankl in modifying Dawdy's rainfall-runoff model for semiarid areas. The results were adapted by the WHD for use in culvert design and by DEQ for use in new surface-mine permits. Rankl later used the data in other investigations of infiltration/runoff processes in ephemeral-stream basins.

District staff also delineated flood-prone areas on approximately 180 topographic quadrangles for the Federal Insurance Administration (FIA). The FIA used the maps to implement a Congressionally mandated emergency flood-insurance program.

Investigations in National Parks

Cox investigated water problems at selected sites in Yellowstone National Park, beginning in 1966, and in Grand Teton National Park, beginning in 1967. Both studies, in cooperation with the NPS, were expanded later to describe the water resources of the parks. The NPS needed the information for planning water supplies at new visitor facilities. During 1968–69, Cox also evaluated the usefulness of remote sensing for hydrologic studies in Yellowstone, in cooperation with the National Aeronautics and Space Administration (NASA). Thermal-infrared imagery and other data were obtained from overflights of selected sites by NASA and WRD aircraft.

Cox began an investigation in 1974 of movement of wastewater effluent percolating from sewage-disposal lagoons in Yellowstone and Grand Teton National Parks, in cooperation with the NPS. A preliminary evaluation for Grand Teton National Park was completed in 1977. The studies in both parks continued past 1979.

Glass, Rankl, and Thomas N. Keefer (National Research Program) used a flood-routing model to prepare maps of areas inundated by floods caused by hypothetical ruptures of Jackson Lake Dam, in cooperation with the NPS (WRIR 76–77). The NPS used the information in an assessment of possible effects of a large earthquake on the Teton Fault in Grand Teton National Park.

Federal Energy-Resources Programs

In 1975 District Chief Sam West appointed interdisciplinary teams to examine regional and local hydrologic processes and problems associated with the pending massive increase in development of energy resources. Lowry led the Powder River Basin team, and Lowham, the Green River Basin team. Kathy Peter was chief of a coal-hydrology study of the Hanna Basin in south-central Wyoming. These studies were funded by the Survey's Coal-Hydrology or Oil-Shale Hydrology Programs and(or) the BLM's Energy Minerals Rehabilitation, Inventory, and Analysis (EMRIA) program. The studies continued into the 1980's.

Studies of Regional Aquifers

Beginning in 1975, the District participated in the regionally coordinated Madison Limestone Study and, in 1978, the RASA projects for the Northern Great Plains and High Plains. Hodson was initial Project Chief for the Wyoming part of the Madison Limestone Study; Hoxie for the Northern Great Plains RASA; and Avery for the High Plains RASA. These three investigations continued past 1979.

Vignettes

In January 1971 Hugh Lowham and Raymond Muench survived a fierce blizzard during a streamgaging trip in the Bighorn Mountains. After 8 hours in a snow cave, they found their snowmobiles inoperable. They started to snowshoe out but were forced to find shelter in a cabin. Lowham's feet were frostbitten, so Muench left to get help. After walking for hours in the dark, Muench became disoriented, but found another cabin. He walked out the next morning and brought help back to Lowham. A month later Muench narrowly escaped serious injury when a car crashed through the front window of the Worland office. The two unattended children in the car were not injured.

The first-ever Wyoming District conference was held at the Hitching Post in Cheyenne during April 1974. Newly appointed Chief Hydrologist Joseph S. Cragwall, Jr., and Regional Hydrologist Alfred Clebsch, Jr., attended. Subsequent conferences were held in Cheyenne in 1976 and 1978.

District Chief Sam West had just sat down for lunch at the Cheyenne airport on July 2, 1975, when the roof fell down. He looked up when he heard a crack, recognized what was happening, and made it to the door just in time. Many customers were injured, some seriously.

The entire staff of the Cheyenne office hosted a highly successful open house on March 2, 1979, in celebration of the Survey's 100th birthday. Nearly 500 people attended. One elementary school science teacher made a separate trip with each of her classes to see the exhibits and demonstrations.

On July 16, 1979, a very destructive tornado crossed northern Cheyenne. A District employee, Janet Walgren, and a cooperator, State Ground Water Geologist Richard G. Stockdale, lost their homes. The home of another District employee, Betty Tucker, was heavily damaged.

WESTERN REGION

by William H. Robinson

Regional Office

At the start of this period, this Region was called the Pacific Coast Region. It had jurisdiction over the Water Resources Division activities in Alaska, California, Hawaii, Idaho, Nevada, Oregon, and Washington. In 1972, the Water Resources Division regions were redefined. The Pacific Coast Region became the Western Region, and Arizona was reassigned to it from the former Rocky Mountain Region. The Western Region is an area of wide geographic distribution ranging from polar Point Barrow in the north to tropical Samoa in the south and from eastern Idaho in the east to the island of Guam and the Trust Territories in the west. Climatic conditions are every bit as varying.

Ever since the Water Resources Division Regions were defined in the 1950's, the headquarters of the Western Region (Pacific Coast Area) has been located at the Geological Survey Center in Menlo Park, Calif. Headquarters of the other USGS western regions also were located there. The Center is a campuslike area and a pleasant place to work.

The professional staff at the Western Region Headquarters averaged about 11 for this period (1966–79), with the supporting staff ranging from 5 to 10. Other personnel, exclusive of District personnel, on research and other projects assigned to the Regional Hydrologist ranged from 38 professional employees and 14 others in 1966 to 62 professionals and 18 others in 1978.

By 1966, the Water Resources Division essentially had completed its reorganization from Branch to Division line-of-authority, and the Pacific Coast Regional staff and most of the District staffs were reorganized by this time. The remaining District staffs were reorganized shortly afterward. It took some time for the Region and the Districts to accommodate themselves to this new organization. This was a somewhat traumatic time; but by and large, everyone recognized the benefits of the new organization. Generally, the reorganization went amazingly well. The staff specialists from each Regional Office and their corresponding specialists in the Districts soon established a close rapport. Increased travel by the Regional staff was necessitated to improve project design, implementation, and reporting.

New technical developments had a profound effect on the work of the Districts. For instance, the digital recorder coupled with computer computation of streamflow records permitted considerable savings of personnel costs and more current computation of records. The advent of computer modeling enabled analysis of streamflow in a manner not previously possible. Increased consultation by Regional staff and other specialists was necessary to adopt these and other developments to District programs.

Broadening demands for information on the quality of water resources had an increasing impact on the programs of the Water Resources Division. One of the results of this broadening of programs was the broadening of the expertise required. Biologists, botanists, limnologists, and so forth, were added to the traditional geologists, engineers, and chemists of the professional staffs of both the Districts and the Regions.

The advent of the environmental impact statements also affected the work of the Districts and the Region. They were flooded with requests to review statements for the hydrologic effect of a proposed action. This was particularly true before government agencies and private consultants became more experienced in preparing these statements. It was estimated at one time that this activity alone took at least 1 person-year effort on the part of the Regional staff.

Each year, there was a steady increase in cooperative offerings of funds to the Districts by State and local governments. Federal matching funds did not keep pace with these offerings. This created a troublesome problem of matching limited Federal funds with proposed cooperative offerings to achieve a program that would maximize the Division's goals. The solution reached included annual oral and written presentations by the District staffs to a probing Regional staff. This was followed by an evaluation of each project by the Regional staff. It worked quite successfully.

Throughout the period 1966 through 1979, the personnel situation was complicated by personnel ceilings and hiring freezes. This was especially handicapping, for it was a time of expanding programs. The allocation of personnel and the assignment of key personnel caused friction between the Districts and the Region and between Regions.

An undesirable side effect of the continuing personnel ceiling was the hiring of part-time employees. These part-time employees did not count in the employee ceilings. A growing number of part-time employees, mostly in the lower grades, created a serious morale problem throughout the Region. They worked side by side with full-time employees, but they did not receive the normal benefits such as annual leave, sick leave, holiday credit, retirement, and so forth. This inequitable situation still existed at the end of the period.

The discovery of oil in Prudoe Bay, Alaska, had a significant effect on all Divisions of the Geological Survey. The Survey was directed by the Under Secretary of the Department of the Interior, William Pecora, to furnish maximum assistance to the planners of the Trans-Alaska Pipeline (TAPS). It was a major interdivision effort with Pecora, himself, sometimes taking an active role in planning sessions. In the Water Resources Division, the Alaska District furnished information for the environmental impact statement for TAPS and also information on the hydrologic hazards along the proposed routes. Personnel from the Regional research sector gathered information on the movement of polar ice in Beaufort Sea and for several summers maintained camps on the polar ice.

At the southern end of the pipeline, there was concern that a catastrophic retreat of the huge Columbia Glacier would release an excessive number of icebergs into Prince William Sound and into the straits leading to Valdez, the southern terminus of the pipeline. This could be an unacceptable hazard to the tankers operating out of Valdez. Mark Meier of the Regional Research staff headed a multiyear study of the glacier for the potential of such a retreat.

In another part of the Region, harvesting of redwood timber in the vicinity of the newly created Redwood National Park in northern California raised fears of possible damage to a part of that park. There was considerable political interest in the problem. Richard Janda of the Regional Research staff made an intensive study of the effects of logging on the movement of sediment in that rugged and unstable terrain.

Farther south, there was concern over the quality of water in San Francisco Bay. Over the past several decades, the floodwaters of the principal tributaries had been increasingly controlled, and consequently, these floods were no longer available to flush out the bay. It was believed that this lack of flushing was one of the contributing factors in the deteriorating quality of the bay. John Conomos, of the Regional Research staff, headed a study on how inflow from the Sacramento Delta influenced currents, movement of sediments, and nutrients. This study was continuing at the close of the period.

The energy shortage of the early 1970's created intense interest in the development of geothermal energy. The Geological Survey was involved heavily in gathering and analyzing information on that resource. Most of this work was an interdivisional effort in the western part of the country by the Water

Resources and Geologic Divisions. Several research projects were established in the Western Region, and a coordinator for the Water Resources Division's geothermal program was located there.

Late in the 1970's, a program was originated in the Willamette River Basin in Oregon under the direction of David Rickert. This was a pilot program studying nonpoint pollution and its influence on the quality of the stream. This study called for new techniques and concepts and was in full swing at the close of the period.

Space and time do not permit coverage of all or even most of the activities of the Western Region during this interesting period. The items briefly discussed above are those that were relevant to the time period or were unique to this diverse Region.

DISTRICTS

ALASKA

by Harry Hulsing

This is the law of the Yukon, and ever
she makes it plain: Send not your foolish
and feeble; send me your strong
and your sane"
"The Law of the Yukon" by Robert Service

INTRODUCTION AND BACKGROUND

The 1960's and 1970's were momentous years for Alaska. With its treasure trove of natural resources, gold, copper, minerals, coal, forests, fish, water, and wildlife, all in a setting of stupendous mountains, vast silent valleys and unparalleled scenery, Alaska proved also to have vast quantities of oil for our energy-short Nation. A chronology of events that occurred in the 1960's and 1970's will show that Alaska finally shed its image of a "land of ice and snow" and its derisive appellation of "Seward's Folly." The chronology also shows events and forces that shaped the USGS programs.

Statehood

Alaska achieved statehood on January 7, 1959, when President Eisenhower signed the Statehood Act. To WRD and the whole USGS, this provided the necessary local mechanisms for cooperatively funded projects. Cooperative (Coop) funding in WRD went from $134,500 in 1966 to $738,000 in 1979. Coop programs were developed with Federal agencies such as the U.S. Army Corps of Engineers, U.S. Department of Agriculture (Forest Service), U.S. Environmental Protection Agency, U.S. Air Force, and Alaska Power Administration; State agencies such as the Alaska Departments of Natural Resources (Division of Geological and Geophysical Surveys), Environmental Conservation, Fish and Game, and Highways; the Alaska Power Authority and Alaska State Pipeline Coordinators Office; municipal agencies such as Municipality of Anchorage, Fairbanks-North Star Borough, City and Borough of Juneau, Kenai Peninsula Borough, and Matanuska-Susitna Borough.

Earthquake

On March 27, 1964 (Good Friday), one of the largest earthquakes of all time struck south-central Alaska. This event reverberated throughout the USGS; it greatly increased the workload and attracted programs and projects for many years.

Fairbanks Flood

On August 15, 1967, the city of Fairbanks and its flood plain were inundated by the largest flood since the city's founding in 1902. According to the Corps of Engineers, the 1967 flood was 6.8 feet above flood stage and 3.6 feet higher than the previous highest flood, which occurred in August 1930. Funding from the Corps of Engineers resulted in WRD installing a network of flood-warning gaging stations, and a spate of special hydrologic projects were augmented.

Oil Discovery

The search for oil in Alaska began in 1836–37, when the Hudson Bay Company reported oil seeps along the Canadian Arctic shore. In 1886, a U.S. Navy exploration expedition found oil on the upper Colville River. Over the years, many more reports of oil north of the Brooks Range were made. President Harding, by Executive Order on February 27, 1923, created the Naval Petroleum Reserve #4 (NPR), an area of 37,000 square miles. Wildcat drilling on the NPR and other northern Alaska sites continued throughout the 1940's and 1950's, and on January 16, 1968, an announcement was made by Atlantic Richfield (ARCO) that a substantial flow of gas had been found. In March

1968, ARCO announced a "major find," and the great Alaska oil rush was underway. Development of the huge 9.6-billion-barrel Prudhoe Bay oil field now took over Alaska's destiny. The demands of the developers, environmentalists, local, State, and Federal governments for detailed maps, geologic and soil data, and hydrologic information swamped the USGS. For WRD, basic data projects were greatly expanded, and a new project on the hydrologic environment of the Trans-Alaska Pipeline System (TAPS) in Alaska was created.

Alaska Native Claims Settlement Act

The passage of the Alaska Native Claims Settlement Act of 1971 (ANCSA), while overshadowed by the Prudhoe Bay oil development, will probably in the long run have a greater effect on Alaska's future than oil. ANCSA is an extremely complex bit of legislation. It extinguished all Native claims based on aboriginal rights and in exchange granted the Natives legal title to 40 million acres of land. In addition, Alaska Natives, with one-quarter or more Alaska Indian, Eskimo, or Aleut blood, received compensation amounting to $962.5 million. Twelve Regional Native Corporations were established. The act also authorized the Secretary of the Interior to withdraw up to 80 million acres of land in Alaska for possible inclusion into national parks or forests, wildlife refuges, or wild and scenic rivers. The act created a 10-member Joint Federal-State Land Use Planning Commission that was to recommend how to implement the act. With no precedents to guide them, the Federal and State agencies responsible for implementation of ANSCA were faced with an almost insurmountable task.

The demands for geologic, mineral, topographic, and hydrologic data swept the USGS into the maelstrom. During the late 1960's and all of the 1970's, countless hours were spent by USGS experts in meetings, seminars, hearings, or on committees all relating to ANSCA. WRD's basic-data programs were woefully inadequate to meet the challenge. Federal money for WRD programs more than doubled between 1966 and 1973 from $326,200 to $773,000, but most of that went to TAPS projects. From 1973 to 1977, Federal monies did increase to nearly $1 million, but again most of that increase went to the following projects: TAPS, land-use planning, coal hydrology, and Arctic hydrology.

Oil Lease Sale and Pipeline

On September 10, 1969, the State of Alaska conducted a lease sale at which oil companies bid on the right to develop some 179 tracts of land at Prudhoe Bay. Bids totaling $900,220,590 were received, and thereby Alaska, as an equal partner, joined that exclusive club of "oil rich" States like Texas, Louisiana, and California. The next big problem was how to get that oil from the barren Arctic north slope of Alaska to the "lower 48" States. The principal oil companies of the lease sale—ARCO, British Petroleum, and Humble Oil—applied in June 1969 to the Department of the Interior to construct a 48-inch hot-oil (160°) pipeline across 800 miles of public land—some of it permanently frozen—to tidewater at Valdez.

Thus, the stage was set in which three epic forces would meet head-on in Alaska:

1. The destiny of Alaska Natives
2. The ever more compelling validity of the environmental movement
3. The Nation's urgent need for Alaska's oil

The whole idea of hot Prudhoe Bay oil, the pipeline, permafrost, the Valdez terminal, and the huge tankers was so fraught with environmental disaster as to boggle the mind of any ardent environmentalist. Yet, nothing could occur without a Native claim settlement act. So the validity and provisions of the Alaska Native Claims Settlement Act of 1971, the regulations and power of the U.S. Environmental Protection Agency (USEPA) (created December 2, 1970), and the developers of one of the world's largest oil fields would be tested not just on their engineering skills but also on their environmental values and concerns of the Native people in the barren Arctic and the valleys and mountains of Alaska. It was ironic that USEPA's first real test of its Environmental Impact Statement (EIS) requirement would be on the largest private construction project ever undertaken in the United States. In addition, information was very limited regarding the basically uninhabited area of terrain that was, in large part, permanently frozen. Even though a draft EIS was released in January 1971 and a nine-volume final EIS was released on March 2, 1972, the pipeline project was so controversial that the U.S. Congress took over the issue, bypassed USEPA, and authorized the construction. President Nixon signed the authorization into law on November 16, 1973. The years 1974, 1975, and 1976 were boom construction years beyond description for Alaska. On July 28, 1977, the first oil arrived at the Valdez terminal. More than 9 years after discovery of the Prudhoe Bay oil field and the expenditure of some $8 billion, Alaska entered the oil business.

Capital Move

With the $900 million oil-lease sale money sitting in the State's bank account, activists in the State brought up a long-simmering issue. How about moving the capital from the inaccessible, albeit stunningly spectacular, city of Juneau setting, to the State's population and economic center—the Anchorage area. Although previous initiatives in the 1960's had failed, the 1974 move proposal was approved. A Capital Site Committee was created, and the battle was joined. The capital move generated a great deal of heat, controversy, and antagonism. It also generated a lot of work (but no money) for the USGS. Of three choices, in November 1976, Alaskan voters selected the Willow site, about 70 miles north of Anchorage. So now the reality of just what this move might cost had to be faced. When the voters heard the figure of $2.5 billion total cost and a $900+ million bond issue, they decisively rejected the whole idea in the November 1978 general election.

DISTRICT ORGANIZATION AND OPERATION

In the early fall of 1964, Warren Hastings, Regional Hydrologist for the Western Region, and Harry Hulsing, Flood Specialist for the Western Region, visited the Juneau, Palmer, and Anchorage offices of WRD. The purpose of the visit was twofold: first, to introduce Harry as the soon-to-be WRD District Chief for Alaska, and second, to discuss and explain to everyone the Divisionwide concept for programs, organization, and funding. Hulsing completed his move to Anchorage in early December 1964, and the Alaska District Office at 218 E Street, the odd-shaped, gray and red Skyline Building in Anchorage became a reality. The ground-water group, headquartered in the Cordova Building in Anchorage, immediately moved into the Skyline Building, and Peggy Hayes of that group became District Administrative Officer.

The former Juneau surface-water office became a Subdistrict Office, with Vern Berwick in charge. The Anchorage Subdistrict Office, with Joe Childers in charge, was established in January 1965, also in the Skyline Building, as the operations group for western Alaska. During 1965 and 1966, the surface-water and quality-of-water (QW) offices and laboratories in Palmer shifted to Anchorage as personnel and space adjustments were made. A new office, shop, QW, and sediment laboratory building with direct access to Merrill Airfield were completed in 1967 at 1209 Orca Street in Anchorage. After a second story was added in 1972, the Anchorage Subdistrict Office moved in, with Dennis Stewart in charge. Burdge Irelan was the head of the QW/Sediment laboratory by this time. In 1966, a Field Office was opened in Fairbanks with Jim Meckel in charge. With the advent of Prudhoe Bay oil discovery and the Trans-Alaska Pipeline (TAPS), this office had to be beefed up, and in 1974, it became a Subdistrict Office.

Organizations such as the WRD Districts are created to accomplish a predescribed mission, or as a dictionary puts it, "a number of individuals systematically united for same end or work." During this WRD history period, the Alaska District was blessed with an outstanding group of people. Key personnel not mentioned elsewhere in this history are: Associate Chiefs Don Morris (1965–74) and Rich Brown (1974–79); Bob Lamke, Surface Water Specialist; Bob Madison, QW Specialist; and Pat Still, Hydrologist. The contributions and skills of the "support and staff" people are exemplified by Bob Gilmore, cartographic technician; Denvy Saxowsky, mathematician; Dick Snyder, hydrologic technician; Ernie Chase, drill operator; Helen Robson, clerk-typist; and Betty McIntire, head of the Administrative Division in Alaska and her staff. Of particular pride, five of Alaska's best moved on to become District Chiefs in other States: Bill Barnwell, Wisconsin; Bill Boning, Texas; Dennis Stewart, Indiana; Vernon Norman, Wisconsin; and Gary Anderson, Virginia. In addition, Jack Weeks eventually became the Regional Research Hydrologist,

Summary of pertinent statistics, 1966–79

Year	Alaska population	Funding (approximate) Federal, Coop, other Federal agencies	Funding (approximate) Gross	District personnel (average)
1966	270,000	$720,000	$800,000	45
1970	303,000	1,100,000	1,300,000	60
1975	350,000	1,670,000	2,200,000	65
1979	390,000	2,400,000	3,200,000	75

Central Region, and Chet Zenone became the Staff Hydrologist for Reports in Reston.

The total District staff increased from about 45 in 1966 to about 75 in 1979, but a notable change in composition of the technical and professional staff evolved. In 1966, one woman professional and no women technicians were on the staff. By 1979, there were 10 women technicians and 6 women professionals (1 GS–12, 2 GS–11's, 3 GS–9's).

The District's funding increased from about $800,000 in 1966 to more than $3.2 million in 1979, and there was a significant change in how funds were used. During the mid-1960's, more than 90 percent of the funds were expended on basic-data programs and about 10 percent on projects; by 1977, this ratio was 50 percent basic data and 50 percent projects. This shift in program funding was significant because it reflected the change from the former separate Branch (SW, GW, QW) philosophy to the multidisciplinary approach of a District organization.

Alaska is a large, sparsely inhabited piece of real estate (586,000 square miles)—one-fifth the size of the entire "lower 48." A map of Alaska superimposed on a map of the "lower 48" would reach from Florida to California and from Minnesota to Mexico (same scale). The most northern, eastern, and western points of the United States are all in Alaska. The flip side of these size statistics is the population figures. Using 1970 census data, the population per square mile for Alaska was about 0.5 person, for the United States as a whole it was about 57 persons, and for the large State of Texas, it was about 43 persons. Considering that more than half of Alaska's population resides within a 50-mile radius of Anchorage, the empty stillness of the "Great Land" has an aura all its own.

The combination of immense area, few people, rugged terrain, few roads, harsh Arctic weather, and very poor communications made field work a challenging, albeit exhilarating experience. Safety was a major concern: always "leave tracks" (detailed itinerary) and never travel alone. Float planes, river boats, helicopters, 4-wheel drives, and backpacking were the order of the day. Field work ranged from Barrow to Ketchikan, from the Aleutian Islands to Prudhoe Bay. Field work throughout Alaska continued to be done as in earlier days (described in the 1957–66 WRD History, v. VI, Alaska segment) except that the Juneau Subdistrict gradually phased out use of its 75-foot motor vessel for field work as helicopters became available throughout that area.

BASIC-DATA COLLECTION

The conversion of Alaska WRD from separate and independent branches (SW, QW, GW, Sediment) into one integrated unit was most difficult in the basic-data program. This was because the skills and techniques of each branch required special training and different discipline backgrounds. Hence, the conversion process entailed a great deal of cross training, particularly in field procedures, for all personnel. The brunt of this retraining fell onto the Chiefs of the Subdistricts, because this is where all the basic data were collected and analyzed and where most of the project work was accomplished.

Key players were: *Juneau*—Vern Berwick (Chief), Bill Boning, Gary Balding, and Millard Hiner; *Anchorage*—Dennis Stewart (Chief, 1967–73), Ray George (Chief, 1973–79), Larry Leveen, Jack Weeks, Will Ballance, Gary Anderson, Jack McKechnie, and Jack Hale (streamgager par excellence, raconteur, and occasional fisherman); *Fairbanks*—Jim Meckel (Chief 1966–77), Bruce Parks (became Chief in 1977), Bob Burrows, and Gordon Nelson.

During these years of turmoil and frantic activity, data-collection activities abounded at a continually fluctuating rate. Water year 1977 was one of the busiest years of this period: discharge records were collected at 112 gaging stations, stage-only records at 4 stations, water-quality records at 60 stations, and water levels at 25 observation wells. Data also were collected at 18 low-flow, 91 crest-stage, and 19 water-quality partial-record stations. In addition, miscellaneous measurements of discharge, lake stage, or water quality were made at many other sites.

Nineteen statewide water-resources data reports were prepared during this period. The reports were published annually in Water-Supply Papers through 1976. In 1972, a series of "Water-Data Reports" was started that merged all water-resources data.

HYDROLOGIC INVESTIGATIONS

During this 1966–79 history period, the District averaged about 16 hydrologic investigation projects per year. Some highly specialized projects lasted for only 1 or 2 years—for example, the Amchitka Nuclear Test project—and others, such as the Anchorage project, never seemed to end. About 120 reports were generated during this time; they are all cataloged in the report "Location Maps and List of U.S. Geological Survey Reports on Water Resources in Alaska, 1950–1990," by Elisabeth F. Snyder, U.S. Geological Survey Open-File Report 91–60. A brief description of project activity in Alaska for this history period follows:

Statewide—About 10 reports dealing with water availability, quality, use, and flood characteristics were prepared by various authors including Gary Balding, Al Feulner, Joe Childers, Bob Lamke, and Chet Zenone.

Southeast Region—This area encompasses the panhandle. Eight reports were published, including two by George McCoy on limnological investigations on six lakes; reconnaissance of water resources in the Haines/Port Chilkoot area by James McConaghy; water-resources data for Skagway by Gary Balding; water resources and surficial geology of the Mendenhall Valley by Bill Barnwell and Bill Boning; and two reports on the water resources of the City and Borough of Juneau by James McConaghy.

South-Central Region—More than half of Alaska's population lives in this region, which encompasses the Anchorage Bowl, Cook Inlet area, Matanuska-Susitna Borough, Kenai Peninsula, Copper River, Valdez, and Kodiak Island. About 35 reports were published for this area. A few of the multifaceted reports are those on water for Anchorage by Bill Barnwell, Ray George, Larry Dearborn, Jack Weeks, and Chet Zenone; hydrology for land-use planning by Larry Dearborn and Bill Barnwell; geology and ground water for land-use planning in the Eagle River-Chugiak area by Chet Zenone, and Hank Schmoll and Ernest Dobrovolny of the Geologic Division; surface-water records of Cook Inlet by Dave Scully, Larry Leveen, and Ray George; water resources of the Cordova area by George McCoy and Geoffrey Freethey; artificial recharge experiments in the Ship Creek alluvial fan, Anchorage, by Gary Anderson; water-quality and geohydrologic data at two sanitary landfill sites near Anchorage by Chet Zenone and Don Donaldson; water resources of the Kenai-Soldotna area by Gary Anderson and Stan Jones; and water resources and surficial geology of the Homer area by Roger Waller, Al Feulner, and Don Morris.

East-Central Region—This area includes the Brooks Range on the north, the Alaska Range on the south, the upper Yukon River, the Tanana River, and the Fairbanks-North Star Borough. Thirteen reports were published including several on the floods of August 1967 by Joe Childers, Jim Meckel, and Gary Anderson; several reports on arsenic, nitrate, iron, and hardness in ground water, Fairbanks area, by Paula Johnson, Dorothy Wilcox and others; biological quality of the Chena and Little Chena Rivers in vicinity of Chena lakes flood project near Fairbanks by George McCoy; hydrologic information for land-use planning, Fairbanks vicinity, by Gordon Nelson; hydrologic reconnaissance of the Tanana River Basin by Gary Anderson; and several reports on sediment transport in the Tanana River near Fairbanks by Bob Burrows, Bruce Parks, and Bill Emmett.

Arctic Slope Region—This region encompasses all of the area north of the Brooks Range. It includes the 37,000-square-mile National Petroleum Reserve, the Prudhoe Bay oil fields, and the Arctic National Wildlife Refuge. This area of more than 88,000 square miles, which is larger than 40 of the lower 48 States, is all north of the Arctic Circle. About a dozen reports were prepared for this region, including hydrologic reconnaissances of western Arctic Alaska and of streams and springs in the eastern Brooks Range by Joe Childers; surface-water investigations at Barrow by Stan Jones; the effect of a fuel-oil spill on benthic invertebrates and water quality on the Alaskan Arctic Slope by Jon Nauman and Don Kernodle; and reconnaissance snow surveys of the National Petroleum Reserve in Alaska by Charlie Sloan and others.

West-Southwest Region—This sparsely settled, roadless area includes the Seward Peninsula, lower Yukon River, Bristol Bay, Aleutian Islands, Nome, and Kotzebue. Six reports were prepared including hydrologic reconnaissance of the Noatak River by Joe Childers and Don Kernodle; water-resources reconnaissance of the Kwiguk (Emmonak) area by Al Feulner; water-resources reconnaissance of the Golovin area by Jack Weeks; and water-resources reconnaissance of St. George Island and the Pribilof Islands, by Gary Anderson.

Trans-Alaska Pipeline System (TAPS)—This 800-mile-long, 48-inch-diameter hot-oil pipeline from Prudhoe Bay on the Arctic Slope to tidewater at Valdez traverses a corridor of Alaska for which basically no hydrologic data existed. This hydrologic-investigations project began in 1971, peaked during the construction years of 1973–74, and ended in 1979. The project expended over $1,500,000 of TAPS reimbursable funds and generated 16 technical reports, including water resources along the TAPS route by Joe Childers; the hydraulic geometry of some streams by Bill Emmett; icings along the TAPS route by Charlie Sloan; surveys of channel erosion and floods along the TAPS route by Joe Childers; and field-water-quality and aquatic organisms information from selected sites along the proposed TAPS corridor by Jon Nauman.

Glaciology—Glaciology projects in Alaska were under the direction and funding of the glaciology office in Tacoma, Wash., headed by Mark Meier. Two glaciologists, Larry Mayo and Dennis Trabant, were headquartered in the WRD Subdistrict Office in Fairbanks. They played significant roles in projects and reports such as glacier-dammed lakes and outburst floods in Alaska by Austin Post and Larry Mayo; Columbia Glacier stake location, mass balance, glacier surface altitude, and ice radar—1978 measurement year by Larry Mayo; and studies of combined ice and water balances of Gulkana and Wolverine Glaciers by Larry Mayo and others.

ARIZONA

by Alberto Condes

DISTRICT ORGANIZATION AND MANAGEMENT

In 1966, the Arizona District was headed by Horace Babcock, District Chief, and James Ligner, Assistant District Chief. Ed Davidson, Byron Aldridge, and Les Kister were the District ground-water, surface-water, and water-quality specialists, respectively. There were five Subdistrict Offices. Angelo Dalcerro was the Chief in Yuma, Jay Gillespie in Flagstaff, Fred Anderson in Tucson, Rufus Musgrove in Phoenix, and Milton Edington in Safford. Charles Pynchon was the District Administrative Assistant, Ed Hodges and Tom Davey provided quality control for surface-water data collection and analysis, Natalie White coordinated ground-water data publications, George Smith headed the District drafting department, and Carol Hicks was the chief reports editor. There were Field Headquarters in Blythe, Grand Canyon, Kingman, Lees Ferry, and Show Low manned by Sam Jones, Bill Burnett, Craig Bentley, Jack Blee, and Max Peterson, respectively.

Dave Click replaced Ligner as Assistant District Chief in 1970 and served in that position until 1973; Dave Camp assumed the duties as Assistant District Chief in 1974. Bert Thomsen replaced Musgrove in Phoenix in the fall of 1966 and remained in the position until 1977; Bob Laney was Acting Chief from then until he was replaced by Paul Rhone in 1978. In Flagstaff, Ed McGavock replaced Gillespie as Subdistrict Chief in 1968; Tom Anderson followed in 1975, and then Terry Thompson in 1977. The Tucson Subdistrict Chief position was rotated among the professionals in the District Office after Fred Anderson retired. Stuart Brown, Rod Roeske, Al Condes, Maurice Cooley, and Bob Laney each served in the position. In 1973, Clark Benson became the Tucson Subdistrict Chief and remained in the job until 1977, when Larry Mann took his place. Pynchon retired as Administrative Officer in 1969; Troy Petty served as Administrative Assistant for a short period, and then in 1970, Lucella Siberts became the Arizona District Administrative Officer.

OTHER WRD ACTIVITY IN ARIZONA

During the 1966–79 period, there was extensive Water Resources Division activity in Arizona peripheral to or outside of the Arizona District program. In the late 1960's and early 1970's, Tom Maddock, Jr., and John Ferris, attached to the Office of the Division Chief, were instructors for the University of Arizona's hydrology program; Russ Brown and Herb Skibitzke headed a large research effort in Phoenix; Gene Patten headed the Division ground-water analog unit in Phoenix; Richard Culler headed a large phreatophyte study on the Gila River upstream from Coolidge Dam; and Charlie McDonald headed a group in Yuma defining the hydrology of the Lower Colorado River.

HYDROLOGIC INVESTIGATIONS

The Arizona District conducted a large number of hydrologic investigations during this reporting period which were of critical importance to the State, its economy, and its residents. Following is a discussion of some of those projects:

- On the Black Mesa, a study was conducted to determine the impact of pumping—for coal development—on the surrounding area. A model was developed to predict the effects of the pumping and also used to determine where observation wells should be placed for future monitoring. Ed McGavock was the Project Chief, and Gary Levings worked on the project.

• A study of the hydrology of the Hualapai and Sacramento valleys in the Kingman area was conducted by Jay Gillespie and Craig Bentley.

• The Arizona District performed a series of reconnaissance-type ground-water investigations across the State in cooperation with the State Land Department. These studies inventoried ground-water levels and pumpage in the study areas to define ground-water conditions. Studies of this type included the following:

Douglas Basin by Natalie White and Dallas Childers; Paradise Valley by Fred Arteaga, Natalie White, Maurice Cooley, and A. Suthheimer; Waterman Wash area by Ed Denis; Gila Bend basin by Ron Stulik and Otto Moosburner; McMullen Valley by Phil Briggs; Ranegras Plain by Phil Briggs; Harquahala Plain by Ed Denis; Lower Hassayampa area by Ron Stulik; and Quartzite area by Dave Wilkens.

• One very significant research and development study was conducted early in this period by Herb Schumann in cooperation with the National Aeronautics and Space Administration. This was the test and development of a surface-water platform to utilize satellite telemetry to monitor water levels on a real-time basis. Schumann set up a test site on the Verde River at Camp Verde and showed that satellite telemetry had an application in water-resources data collection.

• The Arizona District undertook a study of the water resources of the Tucson Basin in cooperation with Federal and local agencies. The study was headed by Ed Davidson. As part of this study, Davidson analyzed the ground-water hydrogeology of the Tucson Basin; Al Condes, surface-water hydrology; Bob Laney, water quality; Durl Burkham, surface-water infiltration; and Tom Anderson developed an analog hydrologic model of the Tucson Basin. These studies were published in a series of Water-Supply Papers.

• A study of the water resources of southern Coconino County was conducted by a team consisting of Ed McGavock, Tom Anderson, Otto Moosburner, and Larry Mann. The ground-water hydrogeology and the surface-water characteristics were defined.

• A study of the eastern part of the Salt River Valley was conducted by Bob Laney, largely to evaluate the subsurface geologic framework as part of a hydrogeologic assessment of the area.

• A hydrogeologic investigation of the lower Tonto Creek Basin was conducted by Herb Schumann and Bert Thomsen.

• A study to monitor the effects of vegetation manipulation on the surface runoff on Sycamore Creek was conducted by Win Hjalmarson.

• A land-subsidence study along the Salt-Gila Rivers aqueduct was conducted in cooperation with the Bureau of Reclamation with Bob Laney as the Project Chief. The study determined the amount of land subsidence and where earth fissures were likely to form.

• A study of floods and mudslides that occurred in the Grand Canyon was conducted by Byron Aldridge and Maurice Cooley.

• A study of southern Apache County was conducted by Larry Mann; information from the study was used to locate a well field for powerplant development.

• A study of the Tucson-Phoenix urban corridor whose objective was to provide usable hydrologic information in consultation with potential users of the data was conducted with Ed Davidson as Project Chief. The project was part of a national program that addressed selected urban areas across the country.

•A statewide project to define and map flood plains along the waterways was conducted with Byron Aldridge and Win Hjalmarson providing guidance.

• A study to collect and interpret flood data in Maricopa County was conducted with Leonard Werho as the Project Chief.

- A study of southern Navajo County was conducted with Larry Mann as the Project Chief.

- The District Special Studies Section, with Byron Aldridge as the Chief, and staffed at different times during the period by Joanne Garrett, Marshall Moss, Al Condes, Otto Moosburner, and Rod Roeske, conducted a statewide study of floods from small drainage areas to provide information for the design of bridges and culverts.

HYDROLOGIC DATA COLLECTION

The Arizona District operated an extensive network of data-collection stations. In 1973, the Arizona District operated 260 continuous-record discharge stations and 175 peak-flow stations; 55 surface-water-quality stations, of which 22 were in the area between Imperial Dam and the southerly international boundary; and water levels were measured in 884 wells.

During this period, the computation of digital tape surface-water records became more efficient. At the beginning of the period, digital tapes were mailed to Denver and electronically processed to the Washington, D.C., mainframe for discharge computation. Many station records, where monthly figures were required immediately after the end of the month, were computed manually because of the long turnaround time for the digital tape processing. A computer terminal was installed in Flagstaff that could communicate directly with the Washington, D.C., mainframe computer, and all the District digital tapes were processed through Flagstaff. In the early 1970's, the District purchased a computer terminal in Tucson, and all the digital tapes then were processed through the District Office to the mainframe computer. High priority was given to the monthly records, and the duplicate manual computation was no longer required. Colleen Babcock was an integral factor in the success of this effort.

A large number of District personnel participated in the collection and analysis of hydrologic data in each office. Among these were Angelo Dalcerro, Bill Dorries, Rudy Westphal, Curtis Webb, Bill Roberts, and Dave Kresch in Yuma; Dick Trenck, Sam Jones, and Chuck English in Tucson; Gene Buell, Frank Brewsaugh, Larry Neff, and Elvoid Gillespie in Flagstaff; Leonard Werho, Ron Stulik, Reino Rukkila, Vince Higginbotham, Bobby Wallace, Fred Arteaga, Ed Denis, Max Peterson, and Ruth Bellinoff in Phoenix. Ed Hodges, Natalie White, Tom Davey, and Chuck Cox provided the technical support for the data programs in the District Office.

LOWER COLORADO RIVER

The Supreme Court Decree of 1964, Arizona v. California, specified how water of the Lower Colorado River would be allocated to Arizona, California, and Nevada. The decree required the Secretary of the Interior to determine the consumptive use of Colorado River water—diversion minus return—for each State. The decree also charged the Secretary with annually publishing a report on the consumptive use. The Secretary's responsibilities to the Decree were assumed by the U.S. Geological Survey (USGS) and the Bureau of Reclamation (BOR). It was agreed that the USGS would collect and analyze the data required and the BOR would format and publish the annual data report. The USGS also would publish a provisional monthly report on the diversions and returns of Colorado River water.

Special problems were encountered in trying to determine consumptive use—return flows were generally in backwater, and it was difficult to establish a stage-discharge relationship; pumpage from the flood plain was not metered and had to be estimated based on pump ratings, power records, or irrigated crop surveys; all surface- and ground-water diversions from, and returns to, the Colorado River had to be instrumented and measured; and ground-water return flows for which the States demanded credit had to be quantified. Additionally, coordination had to be maintained with the U.S. International Boundary and Water Commission (IBWC) on the delivery of water to Mexico as required by the Treaty between the two countries.

In the summer of 1966, David Click was selected to head the USGS Yuma, Ariz., office and to take the lead in implementing the data-collection requirements of the Supreme Court Decree. Click was assisted in Yuma by Angelo Dalcerro, Bill Dorries, Rudy Westphal, and Ann Gordon; and in Blythe, Calif., by Jim Watkins, George Scarborough, and Frank Brewsaugh. Click coordinated the work with the Bureau of Reclamation and instrumented the major diversions and returns from Hoover Dam to the international boundary with Mexico during the period 1966 to 1970. Water-quality issues became important during this time period, and water-quality staff were added to the Subdistrict.

In December 1970, Alberto Condes replaced David Click as Subdistrict Chief in Yuma, when Click moved to Tucson to assume the duties of Assistant District Chief. Water quality became very critical in the Lower Colorado River when the United States agreed that it had a moral obligation to deliver Colorado River water to Mexico that was similar in quality to that arriving at Imperial Dam. An extensive water-quality data-collection program was established from Hoover Dam to the southernmost international boundary to evaluate the quality of the water in the Colorado River as it flowed southward toward Mexico, and the quality of the irrigation return flows that affected the quality of the water in the Colorado River. Meetings on water-quality problems were frequent with the IBWC and the BOR. The USGS established a water-quality laboratory that performed analyses for the USGS, IBWC, and the BOR. Daily analysis was made of split water samples collected at the northerly international boundary by the USGS laboratory and the Mexican laboratory located in Mexicali. Colorado River and return-flow water samples also were analyzed to provide the BOR with operational information. The Yuma water-quality laboratory was operated by Ethel Linville and, for a period, by Jack Welborne. Frequent consultation and technical direction on water-quality procedures were provided by Les Kister and Don Culbertson, USGS Arizona District and Western Region water-quality specialists, respectively.

The States of California and Arizona requested that they be given credit for ground water returning to the Colorado River. A committee was set up with representation from the States of California, Arizona, and Nevada, the BOR, and the USGS to monitor the implementation of the project. The USGS took the lead in quantifying the ground-water flow to the river, and in 1969, Omar Loeltz was made the Project Chief. Loeltz addressed the problem by establishing cross sections at 1-mile intervals perpendicular to the Colorado River. Twelve wells were installed in each cross section, 6 on each side of the river. A cluster of three wells was installed 100 feet from the river, and a second cluster was installed 600 feet from the river. The wells were installed at three different depths. The wells were used along with a river-water-surface measuring gage to develop a flow net at each cross section. The BOR, under the direction of Wayne Moffet, drilled and installed the casing for all the wells. Dave Wilkens assisted Loeltz on the project. Wells for cross sections were drilled and instrumented in the Yuma area, the Parker area, and the Blythe area from 1968 to 1975. Instrumentation to have the water levels from six wells on each bank punch on one recorder was developed by George Smoot and the Instrumentation group.

Between 1970 and 1975, Dave Clay, Curtis Webb, Bill Roberts, and Dave Kresch were added to the Yuma Subdistrict staff.

In 1973, flow was released into the Gila River from Painted Rock Dam near Gila Bend, Ariz. This caused problems in the delivery of water to Mexico because the normally dry Gila River flowed through the Welton-Mohawk Irrigation Project, raising ground-water levels in saline drainage wells, which had to be pumped through the Main Outlet Drain into the Colorado River.

A report of daily flow values in the Lower Colorado River was published the tenth of each month; this USGS report included data on releases from all reservoirs on the Lower Colorado River, all surface-water diversions from the Colorado River, and all returns to the Colorado River. Use of digital computer-based computations was developed to expedite the report processing.

In June of 1975, Robert Livesay replaced Al Condes as Subdistrict Chief in Yuma, when Condes moved to Reston, Va., to assume duties as the WRD Contracts Coordinator.

CALIFORNIA

by Loren E. Young

Acknowledgments and thanks to Gilbert Bertoldi, Lee Peterson, and John Wark for their helpful review comments.

ORGANIZATION AND PERSONNEL

Headquarters for the new Division-level District established in 1965 remained at Menlo Park throughout the 1966 to 1979 period. District Chiefs during that time were Walter Hofmann, 1966; R. Stanley Lord, 1967–71; Lee R. Peterson, 1972–77; and Richard M. Bloyd, 1978–79. Except for some research studies and some Districtwide projects supervised from the District Headquarters Office, the work was supervised and conducted from three geographically oriented Subdistrict Headquarters and their supporting Field Offices:

1. *Sacramento Subdistrict*. From the Oregon border south to the Tehachapi Mountains, except for coastal drainage, with Field Headquarters at Redding and Merced throughout the period, at Visalia 1969–76, and at Tahoe City 1971–79.
2. *Garden Grove Subdistrict until 1975 when it moved to Laguna Niguel*. From the Tehachapi Mountains south to the Mexican border and Sierra Nevada drainage to the east, with Field Headquarters at Santa Barbara throughout the period and at Escondido 1966–75.
3. *Menlo Park Subdistrict*. Coastal drainage from the Oregon border south to the San Luis Obispo area, with Field Headquarters at Eureka, Santa Rosa, and Salinas throughout the period.

During the period, the following served as Subdistrict Chiefs for varying periods of time:

Sacramento: Robert C. Averett, Willard W. Dean, and E. Jerre McClelland.
Garden Grove/Laguna Niguel: David H. Appel, James L. Cook, Lee C. Dutcher, Darwin Knochenmus, and Raymond E. Miller.
Menlo Park Subdistrict: Charles W. Boning and Loren E. Young.

By 1966, the reorganization of the California WRD Branches into a WRD District had progressed successfully but was still evolving in some aspects. Developing the management and support techniques for such a large and varied technical program was difficult. Assistant District Chief and technical discipline specialist positions were established to provide the needed guidance in developing and conducting the multidiscipline technical program. Administrative support was another area that required some expansion with Administrative Assistant positions eventually being established in each of the three Subdistricts.

During the ensuing 1966 to 1979 period, Districtwide staff remained above 200, reaching a peak of about 225 in 1973 before dropping back close to 200 in 1979. Because of hiring restrictions on full-time positions in place during the late 1960's, part-time positions in the District more than tripled, increasing from about 15 in 1966 to nearly 50 in 1979. This was not the most desirable situation for the District nor for the employees. District operation was less efficient at times, and the part-time employees did not receive the same benefits as full-time employees.

Increased emphasis on the environment and concern for the deteriorating quality of the Nation's water resources led to a change in the educational background of many new hires during the period. Utilizing the new Civil Service occupational category, "Hydrologist," a myriad of new disciplines were accepted into WRD; prior to 1966, engineers, geologists, and chemists made up the bulk of new hires. Among these new hires were biologists, zoologists, ecologists, meteorologists, oceanographers, physical geographers, and mathematicians. The California District was a leader in accepting these disciplines.

Added responsibilities for review, preparation, and publication of data and interpretive reports necessitated enhancement of these capabilities at both the District and Subdistrict levels. The fact that more than 750 reports on the water resources of California were produced during the 13-year period is testimony to the success of this effort.

The California District, with its large Subdistricts, served as a training ground for future Division managers. This was particularly true of the Garden Grove/Laguna Niguel Subdistrict, from which three of the five Subdistrict Chiefs went on to be District Chiefs, and one, James L. Cook, became a Regional Hydrologist. By 1985, more than 30 of the people who worked in the District during the 1966–79 period had moved on to District Chief or higher level management positions in the Division—one, James F. Daniel, to the Headquarters position of Assistant Chief Hydrologist, and one, Robert C. Averett, to Associate Chief Hydrologist, the number two position in the Division.

With nearly 300 different people on the District staff at one time or another during the 13-year period, space limitations prevent giving appropriate credit to all those who deserve it. There is, however, one hydrologist whose efforts during this period must be mentioned. Saul E. Rantz, senior District surface-water hydrologist, continued as he had before 1966 to make major contributions in the field of surface-water hydrology. Rantz's efforts in research, as well as interpretive aspects of surface-water hydrology, are documented in some 40 reports and papers published during the period. As testimony to his international recognition, he was engaged as consultant to the World Meteorological Organization and UNESCO on the preparation of manuals on hydrometeorology and flood-flow computation. His last work, published after retirement, is WSP 2175, a two-volume modern version of the original streamgager's manual, Water-Supply Paper 888.

FUNDING AND COOPERATORS

During the 1966–79 period, District funding increased from about $2.2 to $13.0 million. However, after considering inflation, this amounted to approximately a doubling of the funding available for program rather than a sixfold increase. Funds available for new or expanded programs were further reduced because nonsalary costs increased at a rate greater than inflation. In particular, the expanded use of computers during the period was a factor in the increased cost of work. Computers provided for more and faster data manipulations but did not seem to decrease the personnel required to do a given job, and computer hardware, software, and training costs mounted.

Percentage of program, 1973 and 1979

Funding source	Percentage of program	
	1973	1979
Federal-State Cooperative (Coop)	75	45
Federal	7	43
Other Federal agencies (OFA)	14	10
Other sources	4	2

Makeup of the District program funding support remained somewhat the same during the early years of the period, but a significant increase in Federal funding occurred in the latter part. The following source of funds comparison illustrates the significant changes:

Although actual Cooperative (Coop) Program funds increased during the period, inflationary adjustment did not allow for much increase in technical program. The California Department of Water Resources (DWR) continued to be the major cooperator in the District Coop Program, but more than 70 other State, county, city, and local agencies made significant contributions to the program.

Several large new Federal projects and data programs provided for a large increase in Federal funding and program content. Among these were the National Stream Quality Accounting Network (NASQAN), Hydrologic Benchmark Network (HBN), Central Valley Regional Aquifer-System Analysis (CVRASA), Federal program for managing flood losses, and the Redwood National Park Program discussed herein.

Although the OFA program became a smaller percentage of the District program, there was a sizable increase in funds. The concern with erosion and sedimentation in Redwood National Park led to a large new project funded by the National Park Service (NPS) and by the Geological Survey's Federal Program. This project, conducted from the Regional Office, had a large input from the District, particularly in data-collection activities. Beginning in 1970, the Department of Housing and Urban Development (HUD) funded the San Francisco Bay Region Environment and Resources Planning Study (SFBRS). This was a large Divisionwide project, led by the Geologic Division, to which California District personnel had considerable input. Other increases of note were the flood insurance studies funded by the Federal Emergency Management Agency (FEMA) and a program of water-resources investigations on Indian lands funded by the Bureau of Indian Affairs (BIA) and by some Indian Tribes. Ten other Federal agencies provided varying amounts of funding to the District program.

HYDROLOGIC DATA

Hydrologic data collection continued to be a major part of the District program throughout the period, representing more than half the District funding. Surface-water data collection, which had been increasing prior to 1966, leveled off and actually decreased somewhat in the late 1970's, while interest in water-quality data was increasing with a resultant increase in funding. The NASQAN program, which began in 1973, was a large part of the increased water-quality activity. Ground-water data collection remained at about the same level until 1977, when a large new Federal-State Cooperative Program for collecting ground-water pumpage data was initiated.

Prior to 1966, several watersheds in California were selected as sites in the Federal HBN program for collecting long-term baseline hydrologic data under as near pristine conditions as possible. These data would then be available for comparison with similar data from other less pristine watersheds. The 1961 press release announcing this nationwide program listed Elder Creek near Banscomb, Calif., as the first site to be established. It is interesting to note that data collection did not actually begin at this site in north-coastal California until 1967 because of continual problems in obtaining permission for access from the property owner.

Surface-Water Data

There were about 900 continuous-record stations in operation in California in 1966 and about 720 in 1979. This reduction was due in large part to limited funds in the Federal-State Cooperative Program and increased interest in funding water-quality data collection. With completion of crest-stage flood-data collection for the Floods From Small Drainage Areas program, the number of crest-stage gages decreased significantly in the mid-1970's. Other types of surface-water data collection, such as lake levels and contents, remained about the same.

Installation of digital recorders at streamflow stations was essentially completed during the period, increasing from about 30 percent of the stations in 1966 to nearly 100 percent in 1979. Also, automation of streamflow-record computation through use of digital computers continued to evolve. Field Offices were provided with computers and trained in the art of automated record computation. This placed significantly more responsibility on the Field Office Chiefs, most of whom were hydrologic technicians. They and their staffs proved equal to the task and performed very well.

Ground-Water Data

In 1966, ground-water-level data were collected routinely at the more than 1,000 sites of the statewide observation-well network and published in the annual basic-data reports. By 1979, this number had been reduced significantly to less than 500 due to funding restrictions in the Federal-State Cooperative Program and the shifting of effort to interpretive studies, including modeling of ground-water basins. The need for more and better ground-water pumpage data throughout the State resulted in development in 1977 of a large cooperative program with the California Department of Water Resources for collecting and publishing pumpage data in special reports. As in the past, much additional ground-water data were collected as a part of site-specific studies and made available through special reports.

Water-Quality Data

Concern with water pollution and the establishment of water-quality standards by the State of California during the period resulted in significant increases in water-quality data collection. The federally funded NASQAN program, begun in 1973, was a major effort to further document the pollution problem in the Nation's surface waters. Because of the technical complexities of this data collection, a major training program was developed by senior District and Subdistrict staff to train Field Office personnel. As they had with the streamflow automation complexities, the Field Office personnel performed exceptionally well in learning and conducting these new data-collection activities.

Sediment transport by California streams continued to be a major concern throughout the period; thus, data-collection activities continued at a high level. Most of these activities were on coastal streams draining the highly erodible coastal mountains. Periodic or daily sediment data were collected at more than 100 sites during the period.

Establishment of Redwood National Park in the highly erodible mountainous area of north-coastal California led to development of a large project to investigate erosion and sedimentation in the park. The project leader was headquartered in the Western Region Office, but California District personnel were heavily involved in the data collection and some interpretive studies.

About 150 topical, areal, and site studies were active at some time during the period, many of which involved the use of some new technique or instrumentation. Some were designed as research projects to develop and test new techniques or instruments. Because of the continuing importance of ground water on the California water scene, about two-thirds of the studies involved some aspect of ground water. The remainder involved various aspects of surface-water quantity and quality. In addition to Federal Program funds, many Federal, State, and local agencies assisted in funding of these programs. Water-resource appraisal studies were conducted in National Parks and on Military and Indian Reservations at the request of the responsible Federal agencies.

Several large multidiscipline hydrologic studies were conducted during the period. One of the largest was the SFBRS mentioned previously. This project, begun in 1970, was designed to study the physical environment and resources of the San Francisco Bay Region and their significance for improved urban and regional planning. Water-resources aspects included such elements as availability and quality of water resources, channel erosion and sediment deposition, water hazards including flooding and pollution, drainage design criteria, and planning and management considerations. During the ensuing years, many useful products were generated from this project.

In anticipation of future development of desert areas, a large study of arid land hydrology was underway. This project, in cooperation with the California Department of Water Resources, was located in the Mojave Desert area and was directed mainly at documenting the quantity and quality of available water.

Ground-Water Studies

Ground-water appraisal studies continued at about the same level during the period, but modeling of ground-water basins as a technique for basin management expanded in central and southern California. Ground-water pumpage was depleting the resource, and the models were useful in studying the feasibility of artificial recharge in combination with various pumping scenarios. During this period, development and refinement of digital computer modeling techniques facilitated completion of several significant ground-water models in the State.

Subsidence continued to be monitored and studied in some areas of California where increased use of ground water was underway or planned. Increased pumpage was causing aquifer contamination by saltwater intrusion along the coast, and by nitrates and chemicals in the agricultural areas. At the same time, runoff from urban areas also was contaminating the ground water. In order to better understand the actions of underground contaminants, some modeling studies involved collection of water-quality data along with geologic, hydrologic, and pumpage data. Adding water-quality parameters to ground-water modeling considerably increased the complexity. Consequently, while modeling techniques were being studied, water-quality-monitoring networks were established to collect data for future modeling and to monitor movement of the contaminants.

National concern about depletion and contamination of the Nation's aquifers led to funding of a long-term program of Regional Aquifer-System Analysis (RASA) to assess the Nation's major aquifers. The Central Valley RASA Project in California (1978) was one of the first to be established under this program and was designed to run for several years and bring together a wealth of ground-water information for the Central Valley. This was one of the largest projects in California District history, and by 1979 it was staffed by eight full-time technical personnel.

Surface-Water Studies

Flood studies continued as a high priority item in the District surface-water program. As part of a Federal program for managing flood losses, flood-prone areas were delineated on many quadrangles throughout the State; also, site-specific flood-insurance studies funded by HUD were prepared for many communities. Many channel capacity studies to develop flood profiles were done, particularly on Central Valley rivers. Several research studies to determine floodflows during or after the flood event were also conducted. Updated flood magnitude-frequency relationships were developed and published for the State, using data from the Floods From Small Drainage Areas program to extend the relationships to the smaller streams.

Other surface-water studies conducted during the period involved modeling of runoff and tidal river discharge, flood hydrology and low-flow studies, streamflow, and thermograph network evaluation. Further development and testing of the acoustic velocity meter and optical current meter were also carried out by District personnel.

Water-Quality Studies

Starting in the late 1960's, the District began a concentrated effort to develop interpretive studies relating to the water-quality concerns of the State. Many such studies were developed and carried out in the Coop Program with State and local agencies during the ensuing period. Documenting and interpreting the effects of contaminants moving through the surface water and ground water were high priorities in this work. Several of the studies involved researching new techniques such as analyzing water samples for trace elements or isotopes of oxygen and hydrogen as a means of tracing ground-water recharge water from various sources, effects of artificially aerating large reservoirs, and use of artificial substrates in stream biological studies. Several urban hydrology studies to document and interpret how nonpoint-source pollution moves through manmade conduits and natural channels were carried out during the period.

Sediment transport and turbidity in the State's rivers, lakes, and estuaries continued to be a major concern. Several studies addressed the problem of increased erosion because of logging, construction, and forest and brush fires. Determining the effects of these activities as well as instream activities such as gravel mining on fish spawning, reservoir sedimentation, bridge construction, and beach erosion was addressed in several studies during the period. A study of the hydrologic environment of Bolinas Lagoon, an estuary just north of San Francisco Bay, included determination of the sediment budget for the estuary. This comprehensive study involved developing or modifying techniques and instruments for measuring water and sediment movement within a lagoon and on the beach adjacent to a lagoon.

Other sediment-related studies involved development of a new suspended-sediment sampler, tracking the movement of sediment by fluorescent tagging of particles, and determining the velocity required to move streambed particles of various sizes.

HAWAII

by Ben Jones and Kiyoshi Takasaki

ORGANIZATION AND PERSONNEL

The Hawaii District was integrated as a Division-level District on February 2, 1966, with Mearle "Swede" Miller as District Chief. District Headquarters and Honolulu Subdistrict Offices were in the First Insurance Building, 1100 Ward Avenue.

The Honolulu staff during early Division years included George Yamanaga, Dan Davis, George Hirashima, Ted Cardwell, Kiyoshi Takasaki, Salwyn Chinn, Reuben Lee, Stuart Hoffard, Santos Valenciano, Bob Dale, Ben Jones, Johnson Yee, Charley Ewart, Richard Nakahara, Wally Brownlie, Ken Fowler, Charles Huxel, Harold Sexton, Isao Yamashiro, Chris Vaudrey, Joan Hirai, Mae Kuboi, Rose Maruoka, Amy Watanabe, Daisy Reelitz, Louise Kabasawa, Hajime Matsuura, James Nitta, Sandra Hutchcroft, Frank Romualdo, Jack Rosenau, Akiko Tanaka, Grace Tateishi, Katherine Wong, Clayton Wyse, Ralph Yukumoto, K.Y. Chang, George Dayag, Pearl Tam, John Burt, Tamie Ishibashi, Ben Shimizu, Bob Busch, and Lindsay Swain.

Subdistrict personnel were:

Hilo, Hawaii: Otto Van der Brug, John Janssen, Isao Yamashiro, Gene Capellas, Isami Ogi, and Hideo Gushiken.

Kahului, Maui: Kenzo Takumi, George Gohara, Raymond Otsubo, Robert Sugimoto, James Kanno, and Norman Yoshioka.

Lihue, Kauai: Ken Fowler, Richard Nakahara, Noriaki Kojiri, Kenneth Konishi, and Roy Taogoshi.

Agana, Guam: Otto Van der Brug, Charles Huxel, Jose Quinata, Dave Beck, Margaret Edwards, and Lourdes Brittingham.

Camp Kue, Okinawa: Salwyn Chinn, Iwao Matsuoka, Hisashi Kanno, and Tommy Ushijima. When Okinawa was returned to Japan in 1970, the Subdistrict was discontinued and remaining staff returned to Honolulu.

Pago Pago, American Samoa: Craig Bentley moved to Samoa in 1970 and collected most of the field data and performed ground-water investigations thereafter. Water studies and data collection were accomplished from Honolulu prior to that with assistance by Falassa Tiamalu, a public works employee assigned full time to the Samoa program.

Project Office, Honolulu: A research project office operated under the Regional Hydrologist but had close ties to activities of the District. This research unit, under Akio Ogata, included Jim Cahill and Violet Ansai.

OPERATIONS

District operations centered around its people perhaps more than most Districts. About three-fourths of the employees were native to the islands where they worked. Personnel for special investigations and studies were furnished by the District and frequently by detail from the mainland.

Some of these investigations were:

1. Rainfall records on Mount Waialeale, Kauai.
2. Hydrology of basal water systems on Oahu.
3. Hydrology of floods in Moanalua Valley, Oahu.
4. Water-table mapping in Kailua, Oahu.
5. A series of water resources studies on Oahu, Maui, Molokai, Hawaii Island, and Samoa.
6. Investigation of floods in Hawaii for specific periods.
7. Magnitude and frequency of floods in Hawaii and other Pacific areas.
8. Flood-plain mapping, Oahu.
9. Investigation of low and dependable flows.

10. Water resources of Kadena-Tengan area, Okinawa.
11. Availability of water from catchment areas.
12. Storm runoff from Andersen Air Force Base on Guam.

In 1966, Dan Davis was the Chief of the Ground Water Section. On request from the U.S. Navy, he was responsible for evaluating the ground-water cooling supply at the Navy's Communication Station. It was located in the North West Cape in western Australia where wells were drilled at below sea level near the shore of the Indian Ocean for this project.

Jack Rosenau's project study was the water resources on north-central Oahu, Hawaii. Kiyoshi Takasaki's project study was water in the Kahoku area in Oahu, Hawaii.

The Hawaii Water Resources Regional Study.—One of the most significant efforts in the field of water-resources investigations in Hawaii was the Hawaii Water Resources Regional Study. This study, which was begun pursuant to the Water Resources Planning Act of 1965, was sponsored jointly by the Water Resources Council and the State of Hawaii. Planning for the study began in 1968. In 1972 and 1973, a draft plan was accepted, and funding for a planning staff was provided by the Hawaii Legislature.

The purpose of the Regional Study was to "formulate ... a comprehensive plan of action to achieve the balanced conservation, development, and use of Hawaii's water resources and related land resources ... through the year 2020." Although water plans had been drawn up for various areas of Hawaii, most of these pertained to functional planning of water systems and generally assumed that sufficient water would always be available, provided that adequate systems for delivery were created. With the population of the State approaching 1 million people, and with more and more land being converted from agriculture to urban use, it was becoming increasingly evident that water, though plentiful in much of Hawaii, was a finite resource, and that some difficult decisions were facing resource planners.

In 1973, Manabu Tagomori, a senior engineer in the State Department of Land and Natural Resources, WRD's principal State cooperator, was named study manager, and he began recruiting a staff from Federal, State, and local agencies. Ben Jones was temporarily loaned to the planning staff of the study and transferred physically to the offices of the Regional Study, which was located in the new Pacific Trade Center in downtown Honolulu. Jones would continue to work on the study through the final phases of the process, and in fact he was the last Federal member of the staff, serving as an author/editor of the Regional Plan.

In order to understand the complexity of the undertaking involved in the Regional Study, the times must be considered. The period was one of dawning national awareness of the limitations of land and water resources. But in Hawaii, which was just beginning to benefit from statehood, pressures were extremely great for development. The idea of giving equal consideration to environmental concerns was attractive for those considering the great natural beauty of Hawaii, but it was very threatening to developers, who wanted to treat the availability of these resources as a "given." Thus, it early became apparent that appraisal of water quality, as well as quantity, would be crucial to the study's success.

As the study progressed, the expertise of the USGS-WRD became more and more appreciated. At various times, WRD personnel were leaders of six of the study element teams, and WRD staff contributed to most of the technical reports. George Yamanaga, Reuben Lee, Kiyoshi Takasaki, Charles Ewart, and Johnson Yee were all active in the preparation of the technical reports needed to formulate the plan. Although those reports have never been published in a formal series, they are documents widely used by State and local planners, and they reflect considerable credit upon the WRD.

Several visible results of the Hawaii Water Resources Regional Study include enactment of a body of legislation aimed at bringing water and land development laws into better conformity with the rest of the United States, and the formation of a State Water Commission. Manabu Tagomori became Manager-Chief Engineer of the Division of Water and Land Development and a member of the Water Commission. Ben Jones became Hawaii District Chief and later was Assistant Regional Hydrologist in the Western Region.

In 1967, Davis visited Guam to review Guam's ground-water program. Davis conferred with the U.S. Air Force regarding Guam's ground-water supply at the Andersen Air Base. He also visited the U.S. Navy Communications Station at the North West Cape in western Australia to determine the cause of the heat exchanger failures by iron oxide.

Dale continued the Pearl Harbor study and made some field trips to American Samoa for the ground-water investigations. Rosenau continued the Northwest Oahu study. Takasaki studied ground water in the Wainae District on Oahu, Hawaii. Charles Huxel transferred from the Nevada District to study, with George Yamanaga, the water resources of the Lahaina District, Maui. Huxel and Kamanaga also accompanied Davis to Guam. The Surface Water Branch continued to hire staff members, Harold Seaton and Ralph Yukumoto.

In 1968, Davis continued the routine administration of the ground-water operations under the Cooperative Program in Hawaii. Dale and Takasaki continued their studies. Huxel teamed up with Yamanaga to study the water resources of the Wailuku area on Maui, Hawaii.

Personnel changes made in 1968 were:

- Thomas Ushijima transferred to Okinawa from Honolulu.
- Salwyn Chinn transferred to Honolulu from Okinawa.
- Iwao Matsuoka replaced Chinn as Okinawa Chief.
- Robert Busch transferred to California District.

In 1969, Davis continued to study the water-supply problems at the Navy Communication Station in the North West Cape in western Australia. The water-supply problems were resolved when the State Government decided to drill 12 new wells at the Navy Station. On Midway Island, Davis examined the shallow wells tapping ground water in coralline deposits to determine whether the wells could be used to supplement the rain-catchment supply. Ground-water supply was stable but needed sanitary measures if it was to be used.

In 1970, Davis continued the administration of the ground-water operations under the Cooperative Program in Hawaii. Dale continued the Pearl Harbor study and made field trips to the American Samoa for ground-water investigations. Takasaki and Yamanaga studied the water resources of central Maui, Hawaii. Rosenau transferred to the Florida District. Ben Jones transferred to Hawaii from California and started on the Moanalua project.

In 1971, Willis Burnham was named the new District Chief, replacing Mearle Miller. Burnham transferred to Honolulu from the Idaho District. Dale and Takasaki studied the effects of increasing the pumpage from the Schofield Ground Water aquifer, Oahu, Hawaii. Takasaki was teamed with Yamanaga to study the water resources of southeast Maui, Hawaii. Craig Bentley transferred to the Hawaii District from the Arizona District. He was sent to the American Samoa to initiate a comprehensive ground-water study. David Beck was hired by the Surface Water office in Guam.

In 1972, Davis was sent to the Clark Air Base in the Philippines to study the geology and ground water for the U.S. Air Force. He proposed to the Air Force that a series of test holes should be drilled to determine the possibility of developing a ground-water supply for existing wells. Davis was also in Wallace Air Station in Lingayan Gulf, in the Philippines, to examine and evaluate two wells pumping from a thin freshwater body in limestone.

Also, Dale and Takasaki continued their effort on the Schofield studies. Jones continued his study on the Moanalua. Lindsay Swain transferred from California District to study the ground water of Kawainui Swamp on Oahu, Hawaii.

The surface-water program on Okinawa was discontinued as the island reverted back to Japanese control. Iwao Matsuoka transferred to Hawaii from Okinawa and Hisashi Kanno retired.

In 1973, Davis was called to Clark Air Base in the Philippines to oversee test drilling and development of the new production wells. He was also in Japan, at the Yokota Air Base, and later in South Korea, at the Osan Air Base, to advise the base personnel regarding ground-water problems at the two bases.

Also, as Dale and Takasaki continued their Schofield studies, Takasaki began a new project on hydrologic conditions related to the subsurface disposal of wastes. Huxel transferred to Guam from Hawaii; Bentley continued the American Samoa study; Swain studied the chemical quality of ground water in Hawaii; and Burnham transferred to Menlo Park, Calif.

In 1974, Davis was sent to Truk Island, in the Trust Territories, for office and field reviews of the water-supply problems and studies. He gathered useful information for the Hawaii District Office in planning and funding the cooperative water-resource program.

Dale's assignment was to go to the Eniwetok Atoll in the Pacific Ocean to do additional field work. Takasaki studied the elements needed in the design of a ground-water-quality monitoring network in Hawaii.

Bentley continued the American Samoa ground-water study, and John Burt transferred from the California District. Burt was assigned to the Kekaha-Mana ground-water study on Kauai, Hawaii.

In 1975, Davis worked on Truk Island, Saipan, and on Tinian to collect ground-water data. Along with Burt, he visited Kauai to form plans for a ground-water study in southern Kauai. They also planned and supervised a ground-water exploration program on the Island of Moen, Truk.

For 6 months, Dale continued to work on the Eniwetok Atoll in the Pacific Ocean. Takasaki continued the underground waste study. Burt continued the Kauai ground-water study. Bentley later transferred to Jacksonville, Florida, from American Samoa. Burnham transferred from California to work on the sewage effluent wells on Maui, Hawaii.

In 1976, Davis continued the ground-water exploration and development program in the Truk area. Typhoon Pamela was approaching, so all of the work was discontinued. Winds damaged structures and vegetated areas in Moen, Truk. A landslide on Moen caused the death of 10 people. Davis gave advice and assistance in finding areas of possible additional landslides. In the same year, Dale transferred to Denver, Colo. Takasaki continued the sewage-effluent study, and Burt continued the ground-water study on Kauai.

In 1977, in cooperation with the Public Works Department of Saipan, Davis supported the drilling program. Takasaki made field trips for the ground-water investigations of the Truk area and prepared a summary appraisal of ground water in Hawaii. Burt continued the Kauai ground-water study, and Hidaka transferred to Carson City, Nev.

In 1978, Davis and the U.S. Navy's technical team visited the Navy's support facility in the Diego Garcia area in the Indian Ocean. They surveyed the ground-water supply in the atoll. A program of development was proposed in which the ground-water pumpage would be widespread over the atoll. The atoll was to be included in a system of shallow wells that would result in a minimum of seawater intrusion.

Takasaki was appointed to the Governor's Ad Hoc State Water Commission in a period of extremely low rainfall and began to study the Truk drought. Ronald Soroos was hired in Honolulu to study the ground-water status in the Pearl Harbor area. In the same year, Ben Jones was appointed District Chief.

In 1979, Davis traveled to Truk, Saipan, and Yap. He studied monitoring of test holes and the production of well drilling. He conferred with Public Works personnel on the ground-water exploration and development under the USGS–Trust Territory Cooperative Program.

Takasaki and James Kauahikaua continued their study on the Truk drought. Soroos was called to study the water resources of Kipahulu area on Maui, Hawaii. In the same year, Paul Eyre and Patricia Shade were hired in Honolulu.

STUDIES IN THE WESTERN PACIFIC

The Pacific Ocean is almost unimaginably large. For example, the distance from Washington, D.C., to Honolulu is about the same as the distance from Honolulu to Guam; a like distance separates Guam from Okinawa, where the Hawaii District maintained data-collection stations on streams and wells. Land in the vast expanses of the Pacific is extremely scarce. The islands which comprise the bulk of such lands are valuable, for both their strategic importance and their beauty. Most are low coral islands, with only a thin lens of fresh ground water floating on the underlying saltwater.

Because of the difference in density between freshwater and saltwater, a 40-foot thickness of the freshwater lens will result in elevation of the surface of the "basal water lens" to 1 foot above sea level. In the Pearl Harbor and Honolulu areas of Hawaii, clay sediments eroded from uplands have formed poorly permeable caprock, which creates artesian conditions by inhibiting leakage to the ocean. When these artesian aquifers were first tapped, the positive heads were more than 50 feet, and this pressure was actually used to power machinery such as rice mills; the flow of freshwater generally was wasted. Such waste and the leakage from lost and abandoned wells, causing rapidly declining artesian heads, was the impetus for creating the Honolulu Board of Water Supply.

On the low coral islands of the western Pacific, water is derived from seeps or shallow wells dug to the top of the freshwater lens. Pumpage from these wells must be controlled because overpumping results in the underlying saltwater moving into the well. Once this occurs, the well may remain brackish for some time. This concept of "upconing" of the saltwater is hard even for water engineers trained on the mainland to understand, as the usual concepts of a well drawing down or going dry are more easily understood. Needless to say, people with no training in hydrology have even more trouble with this idea. Two anecdotes serve to illustrate some of the special problems encountered:

In the Western Carolines, Peace Corps workers were active in the development of wells for water supply in remote villages. Usually, following the recommendations of investigators like Kiyoshi Takasaki and Dan Davis, a pipe with a sharp well screen was driven down to the freshwater lens and a hand pump was mounted on the pipe. In one area, someone had the idea of using photoelectric panels to power a small pump so that whenever a faucet was opened, water would flow. Of course, faucets were often left open and the wells became salty. This problem, as it turned out, was self-regulating because the solar panels were very popular for running radios and stereos. As the solar panels "disappeared" and hand pumps were reinstalled, the water quality recovered!

The Island of Diego Garcia in the Indian Ocean became an area of study for Hawaii District ground-water hydrologists. A vital forward base for the protection of U.S. interests in the Persian Gulf area, Diego Garcia is a low coral island, covered almost totally by air and port facilities. Although there is heavy rainfall, there is little opportunity for collecting and storing water.

Working with the U.S. Navy, Dan Davis helped design a system of shallow wells, with interconnecting galleries and piping, to allow enough water to be pumped for cleaning and servicing aircraft and at the same time to maintain the quality of water supplied to base housing and ships. This involved the installation of equipment to detect the salinity at each wellhead, and the training of personnel to understand the need for balancing pumpage from the system. This is not the usual function of USGS hydrologists but is well within the mandate to assist other government agencies. It was a great opportunity to witness some rather unique and esoteric knowledge being applied to a real-world situation.

IDAHO

by Herman A. Ray

Introduction

Idaho, along with several other States, became a Division-level District operation in 1966. Prior to that time, separate branches of Ground Water (GW) and Surface Water (SW) had for many years successfully conducted rather parallel programs of water-resources investigations throughout the entire State. Quality-of-water activities were limited to analysis of samples for ongoing ground-water studies, except for sediment work done in the late 1930's in the Boise River Basin in southwestern Idaho.

In July 1966, the GW and SW units, headed by Herb Waite and Wayne Travis, respectively, were moved from 10th and Jefferson in Boise into the New Federal Building at 550 W. Fort Street on Federal property immediately adjacent to the Veterans Hospital area. During this move, the two units were reorganized and consolidated into the new Water Resources Division concept. Willis Burnham came aboard as District Chief.

While most hydrologic data collection and investigations were conducted from the Boise Office, a Field Headquarters at Idaho Falls had long been in operation in the Upper Snake River Basin of eastern Idaho and neighboring Wyoming. Work in northern Idaho was handled by the Sandpoint Field Headquarters. Additionally, WRD had established a special project office at the Idaho National Engineering Laboratory (INEL) to conduct water-resource-related studies in support of U.S. Department of Energy nuclear power development at INEL. Known as the National Reactor Testing Station (NRTS) when started in the 1940's, the need for accompanying hydrologic studies continued through the years, and WRD activities increased manyfold during the period of years under discussion.

Throughout the arid western lands, the availability and distribution of life-giving water, so essential to agriculture, has been of paramount concern to many Western States, including Idaho. As early as 1908, USGS gaging stations were determining available flows in the Snake River Basin and certain major tributaries. The WRD office in Idaho Falls was established early on to collect hydrologic data, of course, but the primary duties of the Hydrologist-in-Charge were to provide jurisdiction over distribution of all surface water in the Upper Snake River Basin upstream from Milner, Idaho. Such unique duties were additional responsibilities that continued until March 1978, when they were relinquished to the State of Idaho authority—namely, the Idaho Department of Water Resources, a principal cooperating agency for many years.

ORGANIZATION AND PERSONNEL

The reorganization to Division-level operations began in August 1966 with the arrival of Willis Burnham as the new District Chief. The former GW unit head, Herb Waite, continued as a member of the new District Management Committee (DMC) until his retirement in October 1976, when he contracted to pursue GW studies in Pakistan. Wayne Travis also continued on the DMC and was responsible for increased surface-water activities. Sherm Decker was data-collection head and Harold McDowell was the "office engineer" doing record computations. They were assisted in many aspects of analysis and interpretation of data by senior staffers Cecil Thomas, Jim Spofford, and several well-qualified field technicians. Joyce Harper, newly hired by Burnham, started up the first Administrative Section to process financial matters, to handle the payroll, to order supplies, and to process all personnel actions. She continued as Administrative Officer until she was replaced by Merle Carte in 1971.

With Burnham leaving for Hawaii in late 1970, Hal K. Hall, his assistant, was promoted to Idaho District Chief. Fred Harder from Louisiana had arrived earlier in 1967, and as Assistant District Chief, Hydrologic Studies, continued to be responsible and in charge of the increasing scope of hydrologic investigations. In January 1971, Herman Ray arrived from California as the new Assistant District Chief, Hydrologic Data, for the statewide surface-water program. Data collection in eastern Idaho was under Art Larson in Idaho Falls and Stewart Gutenberger at the Sandpoint office. During 1970, generally, both data collection and special studies were expanding with the addition of new professionals hired to keep pace with increased activities.

In mid-1973, the Western Region approved an Associate District Chief position that was filled by Albert LaSala, transferring in from Florida. Later in the year, Joe Moreland replaced the retiring Fred Harder as Chief, Projects and Reports Section.

In June 1975, Glenda Blessing replaced Merle Carte as District Administrative Officer and remained in that position for more than a decade of considerable turbulence caused by expanding programs and numerous personnel changes in supervisory positions in the Idaho District.

Upon Hal Hall's retirement on January 3, 1976, Al LaSala became Acting District Chief until Edwin Harris arrived in April of that year to be District Chief. Ed's term ended when he retired on December 23, 1977.

Later in 1976, Al LaSala transferred to the Richland, Wash., atomic energy operation, thus returning to technical work. After completion of a 1-year study sponsored by the USGS, Ralph Norvitch returned to Boise in mid-1977 to become both Chief of Project Studies and Associate District Chief, replacing LaSala. A very short time later, Joe Moreland left Boise for a responsible position as Assistant District Chief in Helena, Mont. Norvitch continued wearing three hats until Ernest F. Hubbard arrived in June 1978.

In 1979, District activities were conducted by the Boise District Office, and by Field Headquarters at Sandpoint and Idaho Falls. A special project office related to the INEL program was headed by Jack Barraclough at a separate location in Idaho Falls. District employees numbered 71 persons, consisting of 36 full time and 35 less than full time. Total funding had increased to about $1.7 million directed toward a primary effort of carrying out hydrologic data collection and interpretive studies throughout the State.

COOPERATING AGENCIES

In conformance with the overall mission of the Water Resources Division, the Idaho District program was directed toward providing, to governmental planners and managers and to private citizens, the scientific information and technical support needed for wise use, protection, and conservation of the water resources in Idaho. Major considerations in all projects included provision of needed information and support in a cost-effective manner, continual improvement in the quality of products, and continual striving of staff scientists to keep abreast of technological advances in the field of hydrology.

Throughout this period, the Idaho District programs provided essential water data including the collection, analysis, and dissemination of hydrologic data and water-use information, areal resource appraisals, and other interpretive studies, and research projects. Much of this work was a cooperative effort in which planning and financial support were shared by State and local governments and other Federal agencies.

In Idaho, various parts of the U.S. Geological Survey program were conducted in cooperation with Butte Soil Conservation District; City of Orofino;

Idaho Department of Health and Welfare; Idaho Department of Water Resources; Idaho Transportation Department; Shoshone-Bannock Tribes of the Fort Hall Indian Reservation; Water Districts 01, 31, 33, 34, 37, 37N, and 65K; Bonneville Power Administration; Federal Energy Regulatory Commission; Bureau of Land Management; Bureau of Reclamation; U.S. Department of Agriculture (Forest Service); U.S. Department of Army (Corps of Engineers); U.S. Department of Energy; and U.S. Department of State (Waterways Treaty). Assistance in the collection of water data also was furnished by the U.S. Bureau of Indian Affairs, Oakley Canal Company, Salmon River Canal Company, Ltd., and Black Canyon and King Hill Irrigation Districts.

SUMMARY OF PROGRAM

Much of the Idaho District's program, especially in the SW discipline, was devoted to the collection, processing, and publication of water records. The conversion from analog to digital recorders was completed during the 1966–79 period, and the application of computer technology in the processing of SW and other hydrologic records became standard operating procedures. A significant number of gaging stations, primarily those supported by the Corps and the Bureau of Reclamation, were equipped with devices that could be interrogated to supply real-time data. By the end of the period, all of the water records collected were being stored in the Survey's National Water Data Storage and Retrieval System (WATSTORE).

Studies relating to the geology and GW resources of specific areas always had been, and continued to be, a principal element in GW operations. Following the reorganization of the District, Division-oriented interdisciplinary studies became more common.

Surface-Water Records

Hydrologic-data stations at more than 200 selected key locations throughout Idaho were used by the U.S. Geological Survey (USGS) to obtain records on stream discharge and stage, reservoir and lake storage, well and spring discharge, and the quality of surface and ground water. Each year, stations were added and others were discontinued; thus, the Water Resources Division had both current and historical files of hydrologic data. All data collected were stored in WATSTORE and were available on request to water planners and others involved in making decisions that affected the State's water resources. These data could be retrieved in machine-readable form or in the form of computer-printed tables or graphs, statistical analyses, and digital plots. Local assistance in the acquisition of services or products from WATSTORE was obtained from the District Chief.

Methods for estimating the magnitude and frequency of floods for selected streams were given in the water-supply paper series "Magnitude and Frequency of Floods in the United States" (W1671–1689), which included reports released in parts according to drainage basins; data for Idaho were in Parts 10, 12, and 13. The USGS also outlined flood-prone areas on topographic maps as part of a nationwide Federal program for managing flood losses.

Most of the annual precipitation in Idaho falls as snow in the cold, high mountain areas and then later gradually melts during warmer spring temperatures. In 1975, however, warmer than normal air temperatures at high elevations caused the second-highest monthly mean discharge for 63 and 64 years of record at two long-term index stations—Salmon River at Whitebird and Snake River at Heise. In northern Idaho, the Clearwater River at Spalding also had a 52-year-high monthly mean. Many other streams had flows in the excessive range from precipitation amounts of 250–300 percent above normal, thus ensuring an ample water supply for the many irrigation needs of the 1976 season.

A very unusual disaster struck southeastern Idaho on June 5, 1976, when the newly completed Teton Dam breached and failed. Being nearly filled for the first time, the dam held 251,000 acre-feet of water. In about 143 minutes, approximately 173,000 acre-feet of water drained through the breach, sending a disastrous wall of water down the upper Snake River. Nearly 30,000 valley inhabitants fled with a loss of only 10 lives, considered extremely light for such a disaster. District personnel, assisted by detailees from other States, made a slope-area survey measurement indicating that the peak discharge slightly exceeded 2.5 million cubic feet per second, or about the same as the Mississippi River's greatest known discharge.

Ground-Water Records

Throughout the 1966–79 period, an observation-well network designed to monitor changes in ground-water levels in 300–500 selected wells distributed across Idaho was maintained by WRD in cooperation with the Idaho Department of Water Resources and several other entities. The data collected were used by well owners, water users, water managers, and other interested parties. About 3 million acre-feet of water was withdrawn from ground-water reservoirs of Idaho each year to irrigate about 1 million acres. Additionally, nearly all municipal, industrial, domestic, and livestock water requirements were met from this resource. Most areas of the State where large volumes of ground water were known to exist were being developed extensively by the construction of numerous wells intended for distributing water throughout areas suitable for agriculture.

Records of ground-water levels have been published from about 1935 to the present (1999) in a continuing annual series of Water-Supply Papers. Since the beginning of work in Idaho, ground-water investigations have centered on topical and areal studies. Each of the several hundred reports of various types provided new and useful water facts and related information that has been used to allow beginning or further developments, usually agriculture-related, in a particular area or as part of a river basin. For a number of years, Idaho has ranked somewhere among the top five States for the volume of ground water used. Idaho's economy is dominated by agriculture and related businesses such as food and meat processing; feedlots and dairies; aquaculture; and farm chemical, feed, fuel, and equipment supply. Because much of the State has high mountains that were very sparsely settled, the growing population was concentrated in the lowland river valleys. These areas generally received only 8 to 12 inches of precipitation per year and required billions of gallons of surface water and ground water application to crops and pastureland. Early on, water studies were basic appraisals for small hydrologic units, followed by larger and more complex interdisciplinary efforts, which provided much additional information about water availability all over the southern part of Idaho.

During the period of the 1960's and 1970's, Idaho hydrologists investigated geothermal sources in many areas, water quality of irrigation return flows, ground-water contamination from various sources, chemical and physical data for disposal wells in the eastern Snake River Plain, isotopic and geothermal analyses of water in the Bruneau-Grandview area, mineral resources in many areas, and numerous other investigations that advanced our knowledge in water resources over the State. Unquestionably, the Water Resources Division programs contributed greatly to Idaho's continuing growth and present prosperity.

Quality-of-Water Records

In Idaho, prior to the decade of the 1960's, little need for water-quality information was foreseen. A water temperature measurement was taken with each streamflow measurement. During the 1960's, for nearly all appraisal studies throughout the State, a much greater effort began to evaluate "quality" as well as the magnitude of that particular water resource being studied. Chemical quality and a few biological aspects were determined by laboratory analysis. Early laboratory work was done by the Idaho Department of Health and Welfare and, as the need for analyses became greater, by the WRD Portland, Oreg., facility. The FWPCA (later the U.S. Environmental Protection Agency) began to provide funding to USGS to develop a national program for collecting water samples for analysis of an ever-increasing number of parameters. To adequately handle the increasing workload, numerous WRD Districts began to train or hire more qualified personnel, to add on a laboratory facility, and most important, in the planning of new projects, to give greater consideration to the value of quality-of-water information.

In October 1965, at Snake River near King Hill, Idaho, the first sample was collected to start the new WRD nationwide pesticide-monitoring program. In January 1966, a daily sediment-load station was established on the North Fork Clearwater River. The station was funded by Corps of Engineers, Walla Walla District. Using International Joint Commission of Canada–United States funding, daily sediment data collection began at Kootenai River at Port Hill, Idaho. Field data, essential to measuring suspended and bedload sediment transport, were difficult to collect on any stream. For very deep, large, fast-flowing streams in Idaho, District personnel rose to the challenge by building from original design special larger, heavier sampling equipment than was ever used before to successfully provide the data needed by the agency involved. Also during this period, the range of water-quality parameters expanded to the hundreds as greater importance was given to "quality" aspects of water-resources investigations. Data from several key Idaho stations were incorporated into the Survey's National Stream Quality Accounting Network (NASQAN), the purpose being to detect trends in water quality.

Selected Literature on Water Resources

Because the number of publications pertaining to water resources in Idaho was very large, no attempt has been made in this brief history to list any particular publication or dedicated hydrologic investigation by name. One excellent source that is available upon request is IDAHO–1982, Water-Resources Investigations of the U.S. Geological Survey. Contact the District Chief, WRD, 230 Collins Road, Boise, ID 83702, or Chief Hydrologist, USGS, 420 National Center, Reston, VA 21092, to obtain a copy. This comprehensive listing of Idaho reports will inform the reader where any of several hundred of reports may be obtained.

NEVADA

by G.F. Worts, Jr., and P.A. Glancy

INTRODUCTION

"It was the best of times, it was the worst of times....." This quote from the opening lines of "A Tale of Two Cities" (Charles Dickens, 1859) in many ways describes the activities of the Nevada District during the years 1966–79. On the one hand, the period brought to completion the series of 60 reconnaissance reports covering most of the hydrographic areas of Nevada and 11 bathymetric maps of the principal Nevada lakes and reservoirs. In addition, funding programs and District personnel increased substantially. On the other hand, the period was one in which three District Chiefs successively were in charge, several key personnel retired or were transferred, and the amount of required paperwork and documentation increased substantially.

ORGANIZATION AND PERSONNEL

The Nevada District Office has been in Carson City since its inception in 1945. During much of the time since then, Field Offices have been maintained in Las Vegas and Elko. In 1962, G.F. "Skip" Worts, Jr., was placed in charge of the first Division District Office in the Nation, with headquarters in Carson City. Lynn Harmsen was in charge of the Las Vegas office (1969–72), followed by Jerry Larson (1973–74), Herb McQueen (1975–78), and Rod Carson (1979). Leo Bohner was in charge of the Elko office (1967–75) and was succeeded by Chuck Bartholet (1976–79).

In 1974, Worts requested and was placed on WAE status, and John Monis, who was transferred from the Southeastern Region, was placed in charge. Three years later (1977), Monis was transferred to the Central Region Office in Denver and Frank Hidaka was transferred from the Hawaii District to become District Chief, Nevada.

Ed Harris, who had been Assistant District Chief for Nevada since 1962, was transferred to the New York District in 1969, and Don Moore became the Assistant District Chief until he was assigned to work in Arabia (1977). In 1977, Tim Durbin became the Assistant Chief.

Other major personnel changes included the retirement of Tom Eakin (1972) and Mary Miller, District Clerk (1974), the transfer of Bob Lamke to the Alaska District (1971) and Gene Rush to the Utah District (1975); acquisitions of Pat Glancy (1966), Steve VanDenburgh (1967), Hugh Shamberger (1969), Bob Bostic (1970), Terry Katzer and Kerry Garcia (1972), Bob Squires (1974), Otto Moosburner (1975), Freddy Arteaga, Jon Nowlin, and Dave Nichols (1976), Howard Frisbie, Don Schaefer, Dick LaCamera, Larry Smith, Doug Maurer, and Alan Welch (1978), and Russ Plume and Rita Carman (1979).

In 1976, technical sections were established in the District Office. The Hydrologic Data Section was headed by Leo Bohner with assistance by Don Clendenon, Orvil Kamm, Bob Squires, and Kerry Garcia. The Hydrologic Studies Section was headed by Jim Harrill with assistance by Freddy Arteaga, Pat Glancy, Terry Katzer, Otto Moosburner, Jon Nowlin, Carroll Schroer, and Steve VanDenburgh. The Nevada District began to use computers in 1973 when Jim Harrill incorporated this technology in his ground-water work.

Work at the Nevada Test Site, although done in Nevada, was under the general direction of the Central Region Office, with technical review and coordination with the Nevada District Office. During the period 1967–70, offices were operated at both Las Vegas and Mercury and staffed by Dick Blankennagel, Ike Winograd, Murray Barber, Jim Weir, Dick Young, Dick Johnson, and Bill Thordarson. In 1978, the Nuclear Hydrology Program was reestablished with Gene Doty in charge of the project office at Mercury, Nev.

FUNDING AND COOPERATION

The primary sources of funding for the District program continued to be the cooperative program with the Nevada Department of Conservation and Natural Resources (NDCNR), which began in 1945, with other Federal agencies, and with several other State agencies.

The total Nevada District funding for the period 1966–79 increased from about $360,000 in Fiscal Year 1966 to about $456,000 in 1973, and increased substantially, particularly after 1976, to about $2,550,000 in 1979, which is shown in thousands in the following table.

Nevada District total funds, in $1,000's

1973	1974	1975	1976	1977	1978	1979
456	530	605	850	1,280	1,580	2,550

The principal participant in the Cooperative Program continued to be the NDCNR; however, the cooperative base and the office staff began to expand toward the end of the 1970's. Hugh Shamberger, who retired as Director of the NDCNR in 1964, was employed part-time to prepare reports on the water supply of 10 mining districts in Nevada. After Hugh's retirement from the NDCNR, Elmo DeRicco was selected as the new Director (1965–77), followed in turn by Norman Hall (1977–79) and Roland Westergard (1979–90). Most of the statewide water-resources studies, data networks, and related activities were supported by the Cooperative Program with the NDCNR.

SUMMARY OF PROGRAM

The District program included seven major categories of work, which had been established in 1960. Where pertinent, the activities in each category are summarized below.

The basic-records program included streamflow, ground water, and water quality. As of 1979, for streamflow, a total of 128 continuous-record stations were being operated compared to 108 in 1966; 13 low-flow partial-record stations were operated, and 78 crest-stage stations.

Many severe flash floods occurred during the period: 1967, at Incline Village, Lake Tahoe; 1974, at Eldorado canyon, a tributary to Lake Mohave on the Colorado River, that claimed nine lives; July 3, 1975, at Las Vegas, which killed two and is notoriously known as the "Caesar's Palace Flood" that destroyed several hundred automobiles; several others including those that damaged Reno and Genoa; and two on undeveloped drainages that were of a magnitude useful for helping define the Great Basin regional flood-envelope curve. The only major river flood during the period was on the Virgin River in southern Nevada, in late 1976. Heavy Sierra Nevada snowpacks in 1967 and 1969 caused above-normal spring runoff. A major drought occurred in 1976–77.

As of 1979, the District was measuring a statewide network of 208 observation wells. Less than half a dozen were equipped with recording gages.

Water-quality data for continuing-record stations were being collected at 27 stream sites and 1 lake site; partial-record water-quality data were collected at 71 stream sites. An interpretive water-quality study of sediment and nutrient transport to Lake Tahoe related to urban development was made during 1970–74. A major water-quality study on the Truckee and Carson Rivers began in 1978.

The reconnaissance studies, begun in 1960, were completed in 1974 with the publication of Reconnaissance Report 60. This series, plus reports on other areas of Nevada, provided estimates of recharge, discharge, runoff, perennial yield, and stored water in virtually all 250 hydrographic areas of the State. Thus, Hugh Shamberger's goal of having quantitative information available for all valleys of the State was finally realized and has since provided the means for the orderly planning and development of the State's water resources.

Las Vegas underwent rapid growth during this period, and growth has continued to the present time (2000). Several studies were completed describing water-level changes associated with ground-water development. Substantial depletion of the major aquifers occurred, which, in addition to causing large water-level declines, resulted in land subsidence of several feet.

Other major interpretive studies completed or in progress during the period included a suggested pumping rate for Eagle Valley, geohydrology of Smith Valley, effect of pumping in Hualapai Flat, effect of ground-water development on the water regimen of Paradise, Lemmon, and Cold Spring Valleys, water resources of Fish Lake and Big Smoky Valleys, evaluation of flood and debris hazards of selected areas, hydrology of the Nevada Test Site, hydrology of geothermal areas in Nevada, sediment-transport modeling of the East Fork Carson River, development of a technique to estimate the average flow of streams on the basis of channel-geometry measurements, and several statewide summary reports on interbasin ground-water flow, water-level maps, and water resources. In 1976, surface geophysics was used in a major way for the first time in a Nevada District project to delineate a major aquifer—the basalt aquifer beneath the Fallon area.

Interpretive studies of ground-water quality included assessments of urbanization effects adjacent to Topaz Lake, of contamination by sewage effluent and explosives wastes at a military ammunition depot near Hawthorne, and of water-quality degradation by percolating copper-ore milling wastes near Yerington. In addition, mercury contamination in the Carson River east of Carson City, which resulted from the processing of gold and silver ores in the 1800's, was investigated. Finally, streambank erosion, sediment transport, and solute loads in the lowermost Truckee River northeast of Reno, associated with the far-greater-than-average runoff of 1969, was documented.

OREGON

by Stanley F. Kapustka, Roy B. Sanderson, and Alvin R. Leonard

ORGANIZATION AND PERSONNEL

During 1966–79, the Oregon office located at 830 N.E. Holladay Street in Portland, Oreg., housed the three Branches of the Water Resources Division—Surface Water (SW), Water Quality (QW), and Ground Water (GW). Two project offices—the Northwest Water Resources Data Center and the Columbia River Estuary study group—were under the supervision of the Regional Hydrologist, Pacific Coast Region, later to be known as the Western Region (WR), Menlo Park, Calif. There also were two staff hydrologist positions held by Reuben R. Newcomb and Alvin R. Leonard, geologists who were involved in special studies. Both were under the supervision of the Regional Hydrologist. Leonard headed the Hydrology Subcommittee of the Willamette Interagency Task Force and was responsible for the Hydrology Volume of the Interagency Study of the Willamette River Basin. Newcomb was investigating the structure, water quality, and hydrology of the Columbia River Basalt in Washington and northeastern Oregon.

Roy B. Sanderson was District Engineer (DE), SW Branch; G. Lawrence Bodhaine was Research Hydrologist, in charge of Water Quality Branch and the Columbia River Estuary study group; and Eugene R. Hampton was Acting District Geologist, GW Branch. Albert M. Moore was in charge of the Northwest Water Resources Data Center and recently had transferred from his position as Assistant DE, SW Branch. David Hubbell was Project Chief for the Columbia River Estuary Study Group.

Subdistrict Offices (SDO) were located in Portland with Robert Williams serving as Engineer-in-Charge; in Eugene with John L. Ebling, Engineer-in-Charge; in LaGrande with Frank Cleaver, Engineer-in-Charge; and in Medford with Albert B. Harris, Engineer-in-Charge. Each of these offices was staffed with two to four technical persons with principal expertise in the surface-water disciplines.

In Salem, Oreg., Gordon Backe, an engineer, served as liaison officer between the District Office and our chief State cooperator, Chris Wheeler, Oregon State Engineer. Backe's office was adjacent to and furnished by the State Engineer.

The decision to combine the Branch offices into WRD Districts nationwide was made in 1965, and in early September 1966, Oregon was selected to join the ranks of Washington and California in the Western Region—two of the States where that consolidation already had taken place.

Stanley F. Kapustka was selected as District Chief, WRD, in Portland. He left his position as Assistant District Chief for Statewide Programs, WRD, Menlo Park, Calif., and arrived in Portland on September 4, 1966. Kapustka began the task of consolidating the Branch Offices and personnel in an orderly fashion with maximum cooperation from the incumbents—in particular, that of R.B. Sanderson—and with minimum disruption to the ongoing program.

R.B. "Buzz" Sanderson was named Assistant District Chief of the new WRD District. David D. Harris was selected to head the Hydrologic Investigations Section. Rufus W. Childreth was assigned the duties of officer in charge of District construction, property management, and acquisition.

The SDO's and liaison office were left intact, but SDO personnel, mostly through training, became competent in water-quality and ground-water disciplines. In early 1967, Frank Cleaver was transferred to the Portland District Office and placed in charge of the unit responsible for the review and publication of basic hydrologic data. His former position was filled by Donald H. Giles, Engineering Technician-in-Charge of the LaGrande SDO.

Alvin R. Leonard, having completed his task on the Hydrology Volume for the Interagency Study, Willamette River Basin, was assigned to the District Office as Staff Hydrologist, GW, in mid-1967, and G. Larry Bodhaine was assigned initially to the staff of the Regional Hydrologist, WR, and transferred to that office in mid-1967. Reuben R. Newcomb retired in late 1967, having distinguished himself as a prolific author of an exceptional number of authoritative reports on ground-water hydrology in the Pacific Northwest. His specialty was the Columbia River Basalt aquifer system.

In 1968, Larry L. Hubbard was named Engineer-in-Charge of the Portland SDO following Robert Williams' transfer to Montana. Albert M. Moore, Project Chief in charge of the NW Water Resources Data Center, retired in 1969, and was replaced by Nicholas A. Kallio from the District Office. During the same year, John L. Ebling was transferred to Colorado from the Eugene SDO and was replaced by William H. Higbee, Engineer-in-Charge.

In 1972, Larry L. Hubbard was reassigned from the Portland SDO to the District Office to head the Hydrologic Data Section. His former position was filled by David J. Lystrom, Supervisory Hydrologist in charge of the Portland SDO.

A project office was established in Portland in 1973 to study water quality in the Willamette River. David A. Rickert, Research Chemist, was named Project Chief. Walter G. Hines and Stuart W. McKenzie, hydraulic engineers, completed the project staff. In 1973, Albert B. Harris retired from his position as Engineer-in-Charge of the Medford SDO. He was replaced by Richard L. Kraus, Supervisory Hydrologic Engineer, who transferred to Medford from the Portland SDO. Also in 1973, Roy B. Sanderson, Associate District Chief, retired after 35 years of dedicated and exemplary service. His position was filled by Dennis K. Stewart, who transferred to Portland from the Alaska District. During the same year, 1973, Gordon Backe of the Salem liaison office and Rufus W. Childreth of the Portland District retired. Their positions were filled by David L. Weiss, hydrologist, and Howard L. Bjork, hydrologic technician, respectively.

In 1975, three new positions were established in the Portland District: Assistant District Chief, Hydrologic Investigations; Assistant District Chief, Hydrologic Data; and Administrative Assistant. David D. Harris, Larry L. Hubbard, and Gary E. Enloe, respectively, were assigned to those positions.

During 1975, Donald H. Giles retired from his position in LaGrande and was replaced by Wilmer D. Eicher, Supervisory Hydrologic Technician, whose assignment was changed from the Eugene SDO to the LaGrande SDO.

In 1976, Administrative Officer Gary E. Enloe transferred to the Western Region Office, Menlo Park, Calif. His position was filled by Camilla D. Alexander. Stuart McKenzie was reassigned from the Project Office to the District; David J. Lystrom transferred to Reston, Va. His position as Chief of the Portland SDO was filled by Gary L. Gallino, Engineer.

In 1977, Associate District Chief Dennis K. Stewart was promoted to District Chief, WRD, Indianapolis, Ind. His position in Portland was filled by Garald G. Parker, Jr., who transferred from the Washington WRD Office.

Nicholas A. Kallio, Project Chief, Northwest Water Resources Data Center, retired in 1978. His position was filled by Clyde W. Alexander, Hydrologist, who was reassigned to the Data Center from the Eugene SDO.

SUMMARY OF PROGRAMS

During the period 1966–79, the Oregon WRD continued to inventory Oregon's water resources by operating a network of streamflow-measuring stations, a network of observation wells where ground-water levels were measured, and a network of water-quality-sampling sites. Streamflow and reservoir stations operated during the period included 89 long-term hydrologic stations, 33 short-term hydrologic stations, 235 water-management stations, and 148 crest-stage stations.

Streamflow data were published at 5-year intervals in the Water-Supply Paper series "Surface Water Supplies of the United States." Records for Oregon are in Part 10 "The Great Basin," Part 11 "Pacific Slope Basins in California," Part 13 "Snake River Basin," and Part 14 "Pacific Slope Basins in Oregon and Lower Columbia River Basin."

Water-level measurements in a statewide network of observation wells, intended to give early warning of any serious depletion of ground-water storage as well as to provide background information for future water-resources investigations, were made at approximately 831 wells as follows:

Continuous measurements	1
Monthly or more often	29
4 to 6 times annually	801

Measurements from selected wells in Oregon were published by the U.S. Geological Survey (USGS) at 5-year intervals in the Water-Supply Paper series, "Ground Water Levels in the United States: Northwestern States."

A network of water-quality sampling sites was maintained to furnish information for specific areal studies and to monitor the water quality of certain streams. At the beginning of the period, chemical data were collected at 19 sites, sediment transport data at 22 sites, and water temperature data at 73 sites. Quality of water data were published in the Water-Supply Paper series, "Quality of Surface Waters of the United States." Data for Oregon are in volumes numbered Parts 9–14.

The Portland WRD laboratory provided analytical services to other Federal agencies on request. The staff of trained chemists and technicians, using state-of-the-art equipment, was capable of performing complete chemical and sediment analyses of major constituents in water. Close liaison with other USGS laboratories was maintained so that analytical capabilities not available in Portland could be furnished by other sources. As an integral part of water chemistry, the staff was trained to do interpretation, planning, and execution of water-quality-oriented areal investigations.

In 1972, a regional water-quality laboratory was established in Salt Lake City, Utah, and all laboratory functions in the Western Region were transferred to that facility. David A. Curtiss, Chemist-in-Charge of the Portland laboratory, was reassigned to the staff of the District Chief as a water-quality specialist. His duties included the critical review of reports prior to publication. The remaining laboratory and staff served to perform partial analyses and interpretations in support of areal investigations.

HYDROLOGIC INVESTIGATIONS

During 1966–79, the many projects in Oregon involved all aspects of hydrology from original research to developing the acoustic velocity meter (AVM) and research on river quality assessment to descriptions of water availability, flood hazards, and water-quality characteristics. Many of these projects were problem-oriented—that is, directed toward providing data and assessments to help cooperators identify and deal with practical water problems. Included were water availability studies for the National Park Service for Crater Lake (Frank and Harris, 1969) and Oregon Caves (Oster and Hampton, 1967) areas; surface-water availability in the Tualatin River Basin for Washington County (Swift, 1972); and numerous ground-water studies in cooperation with the State Engineer and local agencies. Also included were flood profile studies in the Umpqua River Basin with the help of the cooperator, Douglas County, to identify flood-prone areas. A water-quality study in the Bear Creek Basin (Wittenberg and McKenzie, 1980) helped Jackson County to identify and locate sources of pollution and make plans to alleviate the pollution. Other projects dealt with lake water budgets (Hubbard, 1970); water temperatures (Moore, 1968); and sediment transport (Onions, 1969).

Together, these numerous projects represent more than 80 analytical reports, most published in various USGS report series, plus more than a score of associated data reports.

Because of the large number of projects and reports, a small number of representative studies that generally typify Water Resources Division activities in Oregon during the reporting period have been selected and are described briefly below.

Movement of Radionuclides in the Columbia River Estuary

In cooperation with the U.S. Atomic Energy Commission, comprehensive surveys of the distribution of radioactivity have been made by monitoring gross gamma radiation in the steambed throughout the estuary and by analyzing numerous surficial and core samples of bed sediments for radionuclide content and sediment characteristics. Reference: Hubbell, D.W., and Glenn, J.L., 1973, "Distribution of Radionuclides in Bottom Sediment of the Columbia River Estuary," USGS Professional Paper 43–L, U.S. Government Printing Office, Washington, D.C.

The Acoustic Streamflow-Measuring System on the Columbia River at The Dalles, Oregon

Records of discharge of the Columbia River at The Dalles, Oregon, are vital to the management of the complex multiagency water-development projects in the Columbia River Basin. Slack water and erratic dam releases produced a need to develop a new technique and acquire innovative instrumentation for the computation of discharge under variable backwater conditions. Also, a system was needed to provide highly accurate "real time" data.

Those needs were met by the installation of an acoustic streamflow-measuring system in the river channel at The Dalles, Oregon. The acoustic velocity meter (AVM) is a device that has been extensively researched by the USGS and others and represents a significant advance in stream-gaging technology. The AVM on the Columbia Riber at The Dalles, Oregon, was the first installation of such equipment in a large river channel and was completed in April 1969.

The system has been in continuous satisfactory operation since that time and is being used at this writing (1994). Reference: Smith, Winchell, Hubbard, Larry L., and Laenen, Antonius, 1971, "The Acoustic Stream-Measuring System on the Columbia River at The Dalles, Oregon," USGS Open-File Report.

Lake and Reservoir Inventories

Beginning in 1971, lakes and reservoirs larger than 5 acres were inventoried in 13 counties in Oregon. Six reports covering the 13 counties were published. The reports provide information on the location, size, elevation, water quality, and recreational use of each water body. Areal photographs of most of the lake/reservoir studies are included, as are bathymetric charts. The areal photographs were produced exclusively by District personnel. Aircraft used in this entire effort was flown by the District Chief, and the photographs were taken by John Friday for the first report and for subsequent reports by the individual authors. The studies were made in cooperation with Oregon State Water Resources Department and Douglas County Department of Water Resources. The studies were initiated at the suggestion of R.B. Sanderson. The project proved to be one of our most popular efforts, and requests for copies of the reports have exhausted the inventory. Reference: Sanderson, R.B., Shulters, M.V., Curtiss, D.A. 1973, "Lakes of Oregon, Volume 1, Clatsop, Columbia, and Tillamook Counties," USGS Open-File Report; Shulters, M.V., 1974, Volume 2, Benton, Lincoln, and Polk Counties; Shulters, M.V., 1975, Volume 3, Hood River, Multnomah, Washington, and Yamhill Counties; Shulters, M.V., 1976, Volume 4, Clackamas County; Rinella, Joseph F., 1977, Volume 5, Marion County; Rinella, Joseph F., 1979, Volume 6, Douglas County.

Areal Ground-Water Studies

Studies of the occurrence, quality, availability, and volume of ground water were done for more than 20 areas in Oregon in cooperation with the State Engineer and other agencies. Results of these studies were published as Water-Supply Papers, State Engineer Reports, Hydrologic Atlases, Water-Resources Investigations, and USGS Open-File Reports.

Ground-water studies ranged in complexity from reconnaissance-type, reported in map form or open-file reports (Frank, 1979, WRI–79–8; Robison, 1972, HA–421) to analyses of ground-water sources and volume of water available for development (Price, 1967, WSP 1847; Helm and Leonard, 1976, State GW Report 24).

Most of the ground-water studies included geologic maps, utilizing available published maps that were supplemented with field observations where necessary. Also included were maps of ground-water levels, where feasible, and data on depths and yields of wells, chemical quality of the water, and seasonal fluctuations of water levels. Many included estimates of ground-water storage capacity, use, and annual replenishment. Ground-water studies during 1966–79 were for areas in the Willamette Valley, where the bulk of Oregon's population is concentrated, and areas in eastern Oregon, the coast, and the southwestern part of the State. The principal use of ground water in both the Willamette Valley and eastern Oregon is for irrigation.

Ground Water in the Harrisburg-Halsey Area

The 350-square-mile Harrisburg-Halsey area, in the southern Willamette Valley, is principally an alluvial area but includes small areas of the bordering Cascade and Coastal Ranges. The main aquifers (sand and gravel in the alluvial deposits) are estimated to have a storage capacity of about 800,000 acre-feet above a depth of 100 feet. These aquifers are recharged largely from direct precipitation. In 1974, the average decline in ground-water levels from winter to summer was about 10 feet. This represented a change in ground-water storage of about 170,000 acre-feet, of which about 8.5 percent was pumped from wells. Additional large quantities of ground water could be developed from the alluvial aquifers for irrigation, domestic, and industrial uses. The cooperator was the State Engineer. Reference: Frank, 1976, WSP 2040.

Hydrology of Dune Aquifers near Coos Bay

The 20-square-mile project area is a 10-mile-long strip of coastal sand dunes in Coos County. The objective of the project, in cooperation with the Coos Bay-North Bend Water Board, was to determine the effect of pumping 4 million gallons per day (MGD) from an 18-well municipal field and analyzing the effects of expanding the well field. Detailed tests were made on the wells while noting the effects of pumping on ground-water levels and on water levels in nearby dune lakes. Both sets of water levels were lowered by pumping.

A two-layer analog model of the aquifer and lake system was built to analyze effects from projected ground-water development. Analysis indicated that expanding pumpage to 30 MGD would result in excessive lowering of lake levels and might result in seawater intrusion into the aquifer in the well-field area. Reference: Robison, 1973: Open-File Report.

Cooperating Agencies

Most of Oregon's work was under Cooperative (Coop) Programs—arrangements and agreements whereby the cost of the work and, sometimes, part of the effort were shared jointly by the Survey and another agency. The principal Coop Program was with the Oregon State Engineer, a partnership that has continued since 1905. The Survey also had Coop Programs with the following:

State

Oregon Department of Fish and Wildlife
Oregon State Highway Division
Oregon Water Resources Department

City, County, or other Agency

City of Corvallis
City of Lakeside
City of McMinnville
Confederated Tribes of Umatilla Indian Reservation of Oregon
City of Medford
City of Portland
Columbia Region Association of Governments
Confederated Tribes of the Warm Springs Indian Reservation
Coos County
Coos Bay-North Bend Water Board
Burnt River Irrigation District
Douglas County
Eugene Water and Electric Board
Lane County
Multnomah County
Rogue Valley Council of Governments

Federal agencies that provided full financial support for Oregon water-resources programs

Bonneville Power Administration
Bureau of Land Management
Bureau of Reclamation
Corps of Engineers
Fish and Wildlife Service
National Park Service
National Weather Service
Soil Conservation Service
U.S. Environmental Protection Agency
U.S. Forest Service

In addition, financial support for certain hydrologic data work was provided by the following Federal Power Commission licensees: Clark and Cowlitz Public Utility District (Washington), Idaho Power Company, Pacific Power and Light Company, and Portland General Electric Company.

During the period 1966–79, the Oregon District program was carried out by a staff of about 60 professional, technical, and support personnel (39, 48, and 13 percent, respectively). Program funds increased from about $800,000 in 1966 to about $2.4 million in

1979, an increase of nearly 200 percent. The increase was due largely to the shift in emphasis of the program from the collection of basic data to the pursuit of projects dealing with water-resources problems including occurrence, quantity, quality, depletion, recharge, and contamination and related interpretations and solutions.

WASHINGTON

by Leslie B. Laird, Charles R. Collier, and Philip J. Carpenter

ORGANIZATION AND PERSONNEL

In 1966, the Washington District was 18 months old, having been established in June 1964 as part of the WRD reorganization. Subdistrict Offices were maintained in Tacoma and Spokane and a Field Headquarters was located in Pasco. Three District Chiefs served the District from 1966 to 1979. Leslie B. Laird, the first Washington WRD District Chief, served from 1966 to 1975, when he accepted the position of Southeastern Regional Hydrologist. John E. McCall became the District Chief in 1975, having transferred from Trenton, N.J., and served in that position until he retired in 1976. Charles R. Collier became District Chief in 1977, after transferring from St. Paul, Minn., and retired from the position in 1979. Eleanor M. Smith held the position of District Administrative Assistant during the entire period.

When originally established, the District program consisted of about 80 percent hydrologic data collection and 20 percent hydrologic studies (mostly ground water). By 1966, the interpretive studies had grown to about 40 percent and continued to grow until it became between 65 and 70 percent of the total District effort in 1975. The increase in interpretive studies reflected both growth in the total District program and the redirection of a sizable part of the Cooperative (Coop) Program from hydrologic data collection.

Beginning in 1976, the District realized the need to establish discrete sections to direct the activities of the ever-increasing number of interpretive studies. Charles H. Swift, III, was assigned Chief, Special Hydrologic Studies, and Kenneth L. Walters was assigned Chief, General Hydrologic Studies. In 1978, John L. Klein accepted the position of Chief, Environmental Quality Section.

The Tacoma Subdistrict was responsible for hydrologic data operations in all of Washington west of the Cascades. The District Office was responsible for conducting surface-water, ground-water, and water-quality interpretive investigations statewide. The Spokane Subdistrict Office was located in the Spokane Federal Building and was responsible for hydrologic data activities in the northern one-half of the State east of the Cascades. Hydrologic data activities for the southern one-half of the State east of the Cascades were conducted from the Pasco Field Office.

Throughout the first half of the period (1966–72), a concerted effort was made to build the professional staff of the District in both investigative and hydrologic data-collection programs. In 1966, professional personnel totaled 35, with 51 technical support and administrative personnel (numbers do not include WAE's). Employment of professionals reached a maximum of 52 in 1972, while support and administrative personnel declined to 31.

The District Coop Program underwent a noticeable reduction in 1971–72. After a new director was appointed to head the Washington State Department of Water Resources, the principal cooperator, State funding for the WRD Coop Program, was cut severely. This produced a budget crunch for the District, and 11 people were removed from the rolls over the next 2 years—6 transfers, 3 retirements, 1 resignation, and 1 termination. However, the impact on the State's water-management programs was severe, and the State technical personnel managed to get almost all of the cuts restored in 1973.

Senior personnel who served in the District from 1966 to 1979 are as follows:

District Chief:
• Leslie B. Laird, 1966–75
- transferred from Portland, Oreg., 1964 (District Chemist)
- transferred to Southeast Regional Office, Atlanta, Ga. (Regional Hydrologist)
• John E. McCall, 1975–76
- transferred from Trenton, N.J. (District Chief)
- retired
• Charles R. Collier, 1977–79
- transferred from St. Paul, Minn. (District Chief)
• Philip J. Carpenter
- served as Acting District Chief in 1975 and 1976–77

Assistant District Chief - Operations and Associate District Chief:
• Robert J. Throckmorton, 1966

- retired
• Earl G. Bailey, 1966–69
- retired
• Frank T. Hidaka, 1969–73
- transferred to Honolulu, Hawaii (District Chief)
• Philip J. Carpenter, 1974–79
-transferred from Indianapolis, Ind. (Chief, Surveillance Section)
Assistant District Chief - Projects and Reports (Project Coordinator):
• Arthur A. Garrett, 1966–70
- retired
• Bruce L. Foxworthy, 1970–72
-transferred to Field Headquarters Tacoma (Tacoma Urban Area Project)
• Robert D. MacNish, 1972–78
- transferred to Tucson, Ariz. (District Chief)
• William Meyer, 1978–79
- transferred from Indianapolis, Ind. (Chief, Hydrologic Studies)
Assistant District Chief - Program and Plans:
• Walter R. Scott, 1966–74
- transferred to Bismarck, N. Dak. (District Chief)
• Edwin H. McGavock, 1974–76
- transferred from Flagstaff, Ariz. (Subdistrict Chief)
- reassigned Assistant District Chief - Programs and Support (1976)
Chief, Special Hydrologic Studies:
• Charles H. Swift, III, 1976–79
Chief, General Hydrologic Studies:

• Kenneth L. Walters, 1976–79
Chief, Environmental Quality Section:
• John L. Klein, 1978–79
District Administrative Assistant:
• Eleanor M. Smith, 1966–79
Chief, Tacoma Subdistrict Office:
• Earl G. Bailey, 1966
• Bruce L. Foxworthy, 1967–70
- transferred from Mineola, N.Y. (Subdistrict Chief)
• John E. Cummans, 1970–78
• William Wiggins, 1979
- transferred from Juneau, Alaska
Chief, Spokane Subdistrict Office:
• John Savini, 1966-1977
• Edmund Nassar - Acting Chief, 1977–79

Chief, Pasco Field Headquarters:

• Philip R. Boucher, 1966–79

Other key personnel during the 14 years included: David H. Appel, Gilbert C. Bortleson, Norman P. Dion, Brian Drost, Marvin O. Fretwell, William L. Haushild, Oliver Hettick, Tom Higgins, Edwin C. Kennison, Robert J. Longfield, Dee Molenaar, Edmund A. Prych, Donald Richardson, Arthur Seldahl, James A. Skrivan, and John R. Williams.

COOPERATING AGENCIES

The major State and local cooperating agencies during 1966–79 were (in general order of program magnitude):

• Washington State Department of Ecology (Division of Water Resources until 1972)
• Municipality of Metropolitan Seattle
• Tacoma Division of Public Utilities
• Indian Tribes (see below)
• Washington State Department of Fisheries
• Seattle Department of Lighting
• Washington State Highway Department
• Washington Department of Game

The major Federal agencies cooperating with the WRD in Washington were the: U.S. Army Corps of Engineers, National Park Service, U.S. Forest Service, and the Department of Housing and Urban Development.

Eleven different Indian tribes were involved in Coop programs with the District—the largest with the Yakima Indian Nation. These tribal programs varied from complex ground-water modeling studies to simple appraisals of water resources of the reservation area. The U.S. Bureau of Indian Affairs provided some coordination for most of these programs.

PROJECTS

The following is a listing of some of the major projects undertaken in the Washington District during 1966–79; the project chief is listed in parentheses.

1964–66: Water Quality of Grays Harbor, Washington (Joseph Beverage)

Impact of paper mill, municipal, and upstream waste discharges to the Chehalis River on the chemical and biological quality of water in Grays Harbor.

Seawater Encroachment (Ken Walters)

Degree of seawater encroachment into ground-water aquifers along the ocean, Puget Sound, and Strait of Juan de Fuca.

1967: Columbia River Basin Ground Water-Project (James Luzier)

Study of ground-water use and development in part of the Columbia basin irrigation project using steady and transient State digital computer models of the system. The Washington District was the second District in the country to develop such models. The models were used very successfully by the Washington State Department of Ecology as a predictive management tool.

Real-Time Hydrologic Data System (Leslie Laird 1967–70; Charles Swift, III, 1970–79)

A unique radio relay system was developed for reporting hydrologic data from 20 sites to a computer in the District Office, where it was recorded on magnetic tape and teletype printout. At the same time, the data were transmitted by hard line to two cooperator's offices. The data were used for hydroelectric power scheduling, flood control, low-flow control, pollution control monitoring, and fisheries management purposes. This was the only system of its type within the WRD, preceding the satellite relay of data by more than 10 years.

1969: Hydrology and the Natural Environment - Puget Sound and Adjacent Waters (Leslie Laird)

This report was a major chapter in the volume Puget Sound and Adjacent Waters—a Federal and State interagency study (Type II) prepared for the U.S. Water Resources Commission.

Effects of Streamflow on Salmon Migration and Propagation (Michael Collings 1969–73; Charles H. Swift, III, 1973–76)

This far-reaching research study identified a specific relationship between streamflow volumes and the spawning and rearing conditions in a stream. The relationships developed allowed for the establishment of flows for the benefit of salmon and provided the basis for the assignment of water rights under Washington law. This methodology later was adopted by the U.S. Fish and Wildlife Service and the Province of British Columbia.

Lakes of Washington (Gilbert Bortleson, 1969–76)

Little information was available for the more than 8,000 lakes in the State. This study concentrated on the relationships between lake level, eutrophication, inflow, outflow, and shoreline use. About 30 lakes were studied each year. A lake classification system was developed. A second study phase included a reconnaissance of about 400 lakes per year to determine trophic conditions and cultural environment.

Water Resources of the Yakima Indian Reservation (Robert MacNish, 1970–73)

The study of 2,000 square miles of the reservation included the development of digital computer models of the ground water in one basin and the study in others dealing with water logging of land, timber harvesting, and expanding areas of irrigation.

Water Resources of the Walla Walla River Basin (Robert D. MacNish, 1973–75)

This basin had long been considered short of water during the irrigation season. However, digital computer models of the basalt and alluvial aquifers showed that a large quantity of ground water was available—more than enough to meet irrigation needs.

Ground Water Supply of the Pullman, Washington - Moscow, Idaho Area (Rene' Barker, 1975–78)

These two towns drew their water supply from basalt aquifers in which the water level had been steadily declining. A digital computer model of the system provided the cities several water-use alternatives.

Hydrologic Data Collection

In 1966, about 380 stage-discharge stream-gaging stations were operated together with about 70 gages on lakes and reservoirs. Sixty daily/monthly and periodic surface-water-quality sampling stations and 20+ ground-water observation wells were operated. Reemphasis on interpretive studies, as well as the National Surface Water Branch Stream Gaging Analysis, led to the gradual reduction of hydrologic data collection over the next several years. In 1971, 294 stage/discharge gaging stations were operated together with 57 lake and reservoir stations. Surface-water-quality sampling stations had increased to 225 sites—109 chemical and biological, 113 water teand 20+ ground-water observation wellsmperature, and 3 suspended-sediment load and concentration. However, most of the chemical and biological sampling was on a limited periodic basis associated with the study of "The Lakes of Washington," and the total expenditure for the water-quality part of the data program was less than that programmed annually during the 1960's.

In the early 1970's, the network of ground-water observation wells was expanded to 173 sites to establish trends in ground-water levels and to provide data for future digital modeling. In 1977, surface-water gaging sites totaled 270 daily stage and discharge stations, 43 lake and reservoir gages, and more than 90 sampling sites for chemical and biological quality and physical data. The data networks were maintained at about this level through 1979.

One rather unique part of hydrologic data collection undertaken by the Washington District was snow surveys. Twenty to 30 snow courses were sampled monthly, usually from January through April. The data on water content and depth of the snow (sometimes 30 feet) were used to predict spring runoff for hydroelectric power generation, irrigation, and public water supply. Access to almost all snow courses was by helicopter. Each winter brought its set of "experiences" with helicopter landings and takeoffs; fortunately, District personnel were involved in only two crashes. Both crashes resulted in no serious injuries.

WASHINGTON DISTRICT QUALITY OF WATER LABORATORY

Sparse historical documentation is available concerning the operating history of the Washington District laboratory in Tacoma. Events have been reconstructed as closely as possible from the memories of persons involved.

Eugene Welch was the first laboratory manager and from May 1964 until mid-1965 and was the sole staff of the small operation. In August 1965, Norman F. Leibbrand transferred to Tacoma from Portland to set up a production laboratory, which started full operation in 1966. Although he was the Laboratory Chief, Norm had little to say about what went into or on in the laboratory. Les Laird, the District Chief, was himself a chemist with extensive laboratory experience gained in Columbus, Ohio, and Portland, Oreg. The new Tacoma laboratory was his "baby."

In addition to Norm, the District hired Lynn E. Hofman, a 1965 analytical chemistry graduate from the University of Washington. A year later, the District hired Marvin O. Fretwell, a 1966 analytical chemistry graduate, also from the University of Washington. Within 6 weeks Marvin was drafted into the Army, but he returned to USGS and the laboratory 2 years later. The District hired Sherman R. Ellis in 1967 or 1968 to replace Marv, for a total chemist workforce of three. The laboratory usually also had one or two laboratory technicians and a bottle washer.

When Marv returned from military duty in 1968, Sherm moved over to the Tacoma Field Office. In 1969, Lynn married, resigned from USGS, and followed her new husband to Israel. The number of chemists in the laboratory remained at two for several years thereafter.

In June 1971 Norm transferred to South Dakota District, and in July 1971 Marv became the new laboratory chief. Marv hired James E. Ebbert as the second laboratory chemist in 1973. In 1975 Marv hired Sandra S. Embrey, a biologist. Marv became the District Quality of Water Specialist in June 1975, and that same month Jim Ebbert assumed the position of Laboratory Chief and held that position until September 1978. Sandy Embrey served a short interim term as Laboratory Chief in 1978.

Prior to 1964 the existing Ground Water Branch laboratory in Tacoma did specific conductance, chloride, and hardness analyses and little else. The first year of the Washington District laboratory operation (1964) was not much different, as it served simply as a small project-support facility to provide specific analyses for Coop projects. Analytical capabilities in 1964 were limited to determination of chlorophyll, plankton, specific conductance, chloride, and suspended-sediment concentration. Instrumentation consisted of a Bechman model B spectrophotometer, a Leads and Northrup galvanometer/conductance meter, and the necessary analytical balances, bottles, crucibles, ovens, and so forth, for sediment concentration determination.

From 1965, the major objective of the laboratory was to provide an inventory of the physical and chemical quality of the surface water of the State and, to a lesser degree, the ground water. A secondary purpose was to meet the ever-increasing service demands of special water-quality projects and national water-quality programs such as NASQAN, NWQSS, HBN, and ground-water programs.

OTHER MAJOR ORGANIZATIONAL UNITS

Centralization Of Water-Quality Laboratories

By Jim Biesecker, Herman Feltz, Saundra Duncan, Don Leifeste, and Doug Manigold

In 1970, WRD maintained 21 chemical laboratories, 19 at locations within the conterminous United States and one each in Alaska and Puerto Rico. There was a consistent increase in laboratory workload, both in the number of samples analyzed and in the number of parameters measured. Water-quality basic-data activities of WRD were increasing in number. A long-range objective of the Division was to provide comprehensive and rapid analytical services at the lowest cost commensurate with quality control.

The laboratory workload was equivalent to nearly 37,000 standard chemical analyses. A staff study of operational laboratory costs showed that unit costs decreased as the number of samples analyzed increased. Expensive analytical equipment could not be efficiently or fully utilized with the relatively small workload in existing individual laboratories. For example, the analytical capability of the 19 atomic absorption spectrophotometers in the laboratories far exceeded total requirements of the workload. Costs for analytical services were variable from laboratory to laboratory. The study showed that the existing WRD laboratory system could be modified to provide centralized service at a lower cost with fewer people. The study noted that centralization of routine analytical services was a feasible method to improve the existing laboratory system. The staff recommended testing the centralization concept by setting up an automated laboratory at an existing facility to perform standard chemical analyses for several Districts. Testing the concept would be a short-range objective and would include debugging the proposed system before any large expenditures of money, time, and personnel were made.

During the February 11–12, 1970, Water Resources Division Meeting, a Task Group was established to prepare guidelines concerning centralization of WRD's water-quality laboratories. The Task Group consisted of F.C. Ames, D.M. Culbertson, and H.R. Feltz, who were designated by Regional Hydrologists; M.W. Skougstad of the Methods Development Unit; and W.H. Durum and J.E. Biesecker of the Quality of Water Branch. The Task Group, according to Biesecker, considered both long-range and short-range objectives.The Task Group met on March 3, 1970, to prepare guidelines and considered the following alternatives for the Division's water-quality laboratory activities:

1. Continue present operations of District chemical laboratories and upgrade analytical capabilities through addition of modern instrumentation consistent with demands of local programs.
2. Consolidate and automate laboratory operations to serve large geographic areas, encompassing several WRD Districts, reducing costs and personnel and improving quality control.
3. Contract all or part of needed analytical services to other Federal agencies, State facilities, commercial laboratories, or combinations thereof. This alternative was felt to be the least desirable because of the difficulty of ensuring quality control of data and because the Survey's image in the scientific community and perhaps with cooperators could suffer by relinquishing control of essential basic data.

After the Task Group's report was completed, Regional Hydrologists were asked to assess possible locations and District configurations for the pilot laboratory. During the pilot, concepts would be tested, techniques observed, and costs compared for standard chemical analyses processed in an automated production-line laboratory with costs of a similar workload in the conventional District laboratories. Regional Hydrologists' recommendations were made by June 8, 1970.

In the fall of 1970, Russell L. McAvoy was selected as the Laboratory Chief to head the pilot program to study the feasibility of a Central Laboratories System. Space was available in Salt Lake City, and the laboratory there was staffed with personnel from WRD District laboratories in the Western United States. District laboratories were closed, allowing personnel to move to Salt Lake City. This did not please anyone who had to move, nor did it please the District Offices, who had to close their laboratory operations. There also were a number of new hires from the Salt Lake City area. A bit of mistrust and animosity developed between Districts and the Central Laboratories which took a very long time to overcome.

The pilot laboratory departed from the traditional WRD way of analyzing samples where one analyst analyzed each water sample for all major constituents. The new system had one analyst analyzing one constituent from a number of water samples, which enabled more efficient use of personnel and equipment. Few District laboratories had the capability of analyzing for minor constituents, and if they did, it was by time-consuming methods of classical chemistry. The pilot laboratory began to perform such analyses routinely with instrumentation.

Because samples had to be shipped from their collection site to the laboratory, sometimes taking a few days, techniques were developed to preserve the constituents in the sample as they were in situ. This was probably what raised the consciousness of WRD about the need for samples to be treated in special ways to ensure that constituents were not altered during shipment and storage. It also led to collection of a number of samples from the site, each treated in a different way to preserve a particular constituent or suite of constituents. Analytical techniques were rapidly evolving during this period. Atomic absorption spectrophotometry was in its infancy, and automated colorimetric analyzers were just beginning to be used in laboratories.

A much more intensive quality-control program for analytical work was being developed throughout the WRD. Quality-control programs were becoming more standardized from District to District as well as among the water-analysis laboratories. Coordination with other Federal agencies performing water analyses also was in its infancy.

In January of 1971, Harry Doyle began to develop programs needed to manage data produced from a Central Laboratory. Prior to the conceptualization of the Central Laboratories System, each analyst performed all calculations and quality-control checks on each sample. In the Central Laboratory, each analyst measured only one constituent per sample; thus, it was no longer possible to handle quality control in the traditional way. Harry developed the computer software for tracking samples (log-in), quality control, data entry, and laboratory finances, including billing.

On October 12, 1972, Hendricks announced the Division's commitment to the Central Laboratories concept and his intention to proceed with its implementation as rapidly as possible (WRD Memorandum 73.6). A general schedule was developed by the Quality of Water Branch and reviewed by the Regional Hydrologists. The implementation plan provided that:

1. Three large-scale, highly automated laboratories, located in Atlanta, Denver, and a northeastern site to be selected, would provide the bulk of the water-quality analytical services required by the Division, including District and project needs. The Atlanta laboratory was scheduled to be established early in FY 1974 and the Denver and northeastern laboratories sometime in FY's 1974 and 1975. The Albany, N.Y., laboratory would be incorporated into the Central Laboratories System on July 1, 1973, and would provide analytical services to Northeastern Region Districts until such time as the permanent laboratory in the Northeast was established.
2. During this period, all existing District laboratories would be phased down to Field Service Unit status, most within the first year, and all equipment not required for Field Service Unit operation or not owned by cooperators would be transferred to the Central Laboratories System. Districts without laboratories would continue to receive analytical services from the laboratory currently providing that service until the laboratory was phased down. At that time, analytical services would be provided by the Central Laboratories.
3. The Central Laboratories would function as a unified system. An Analytical Services Coordinator at WRD Headquarters would provide administrative and technical guidance on pricing, adjustment in service areas and workloads, methodology, quality control, and technical support considerations. The Coordinator was assigned to the Office of the Assistant Chief Hydrologist for Research and Technical Coordination to interface with the Assistant Chief Hydrologist for Operations, the Chief of the Quality of Water Branch, and the Regional Hydrologists.
4. Initially, biological analyses would be provided only by the Atlanta Laboratory. Pesticide analyses would be available in Atlanta and in Austin, Texas. Denver would be the only laboratory offering radiochemical, emission spectrographic, and neutron-activation analyses; these specialized services would continue to be available from special units in Denver until the Central Laboratory was established.
5. Each District would establish one (or more) water-quality Field Service Unit(s) capable of making critical-time-sensitive chemical measurements

and microbiological analyses required by the District program. Only determinations that could not be made satisfactorily by a Central Laboratory would be performed at the District level. Each Field Service Unit would be responsible for obtaining standard solutions for use in calibration of field instruments, maintaining bulk supplies of sampling and shipping containers, and obtaining sample preservatives and any other chemicals. Quality control in the Field Service Units would be by the District Chief, working through the Regional Water Quality Specialist and using the quality-control services of the Central Laboratories System.

The Chief Hydrologist noted the difficulty with centralizing the laboratories. Districts did not want to relinquish control over their laboratories. Objections were raised on many issues, including the need to transport samples to the centralized laboratories. Hendricks said, however, that with this centralization, WRD "broke new ground in the Federal government."

On May 1, 1973, WRD Memorandum 73.174 announced that, as one of the first steps in implementing the Central Laboratories System, the Hydrobiological Laboratory would be relocated from St. Louis to Atlanta, Ga., and its staffing would be brought to full complement. This change was effective June 1, 1973. The St. Louis laboratory continued to receive biological samples for processing and analysis until this time.

McAvoy was appointed Analytical Services Coordinator during the first steps in implementation of the Central Laboratories System. He retained his position as Chief of the Salt Lake City Central Laboratory and concurrently carried out his coordination function.

During the summer of 1973, activity was begun to convert 20,000 square feet of vacant industrial space in the Atlanta suburb of Doraville into the Atlanta Central Laboratory. Management staff of Donald K. Leifeste, Gene Bednar, and Alonzo Handy were onsite soon thereafter to receive laboratory furniture and equipment from the phased-out District laboratories. Professional and technical personnel from Alaska, Arkansas, Florida, Georgia, Louisiana, Missouri, New York, Ohio, Pennsylvania, Utah, and Washington, D.C., transferred to Doraville to round out the core laboratory staff.

In January 1974, the Atlanta laboratory was providing inorganic and organic analytical services to most of the WRD Districts east of the Mississippi River, biological analytical services and quality control for all WRD Districts, and project consultation concerning biology and organic compounds to all interested WRD offices.

In late 1973, W. Arthur Beetem was named Analytical Services Coordinator. Among his responsibilities was the task of finding a suitable site for the Denver Central Laboratory, as the Denver-area facility was called. Beetem, along with Leroy Schroder, R.L. McAvoy, and others in the Denver area, continued to work with the General Services Administration for an off-site leased building specifically designed for the laboratory. The original target for moving into the new laboratory was the summer of 1974, but because of delays in contracting work, the date was changed to the summer of 1976.

In the summer of 1974, the functions of the pesticide residue laboratory in Austin, Texas, were moved to Denver into an old building that had originally been used to load ammunition for the Remington Arms plant, for which the Federal Center was built during World War II. One advantage of moving into an old munitions-producing area was the reinforced bunkers, which could be used for storage of large quantities of flammable solvents used in the organic analyses. Doug Manigold was in charge of the laboratory.

The WRD had begun organic analyses of natural streamwater in the early 1960's in Sacramento and Menlo Park, Calif., under William Lamar and Eugene Brown. Don Goerlitz and Leroy M. Law later joined the group in Menlo Park. Originally, Goerlitz' project was the study of naturally occurring organic compounds generated by decomposing leaves, parking lot runoff, leachates from landfills, and runoff from feedlots and zoos; however, the project was changed to developing methods for analyzing streamwater for chlorinated hydrocarbon pesticides after the book "Silent Spring" by Rachel Carson and other controversial environmental writings began to appear in the scientific literature and popular press. Rapid developments in gas-liquid chromatography allowed detection limits for the persistent chlorinated hydrocarbon compounds in use at the time to be lowered to hundredths of a microgram per liter.

The production laboratory for the pesticide laboratory began operation in Sacramento but was transferred to Texas when a great deal of interest was generated by concerns about the effects of pesticide residues in streams on the fishing industry along the

Texas gulf coast. A fairly extensive network was funded in Texas, and that network, along with the national network of sampling sites, provided the funding for the operation in Texas for 7 years. Delivery of large quantities of flammable solvents to the basement of the Federal Building caused some consternation to the Federal Protective Service, and later to the Secret Service, when President Johnson was expected to visit his office on the top floor of the building. During the transfer of the Texas laboratory to Denver, the entire organic analytical services of the Division were handled by the Atlanta Central Laboratory and the Washington, D.C., laboratory.

In June 1976, construction of the National Water Quality Laboratory (NWQL) in Arvada, Colo., was completed. The new 49,000-square-foot building housed 150 persons and brought together five water-quality analytical and research laboratories that previously were scattered around the Denver area. In addition to the Central Laboratory, the NWQL consolidated other laboratories devoted to methods development, quality assurance, and basic and applied research.

Initial research and development on potential use of scanning electron microscopic technology, mass-spectroscopy gas chromatography, and argon-plasma-emission spectrophotometry were conducted in 1974–76, and the two latter systems became accepted technology in the Central Laboratories System.

During FY 1976, about 114,000 analyses were made by the Central Laboratories System. In 1977 the Albany laboratory was closed, and all services were supplied nationwide from the Denver and Atlanta facilities. More than 170,000 analyses of physical, chemical, and biological characteristics of water were made. Analytical results were transmitted directly from the laboratories by way of computer terminals to more than 50 WRD Field Offices and to the central computer in Reston.

In 1978, the Central Laboratories System added nearly 150 new analyses to its catalog of analytical services. Water analyses had become more complex as a result of the Clean Water Act of 1977 and the Safe Drinking Water Act of 1977. The greatest increase in demand was the need for determination of trace elements and organic compounds identified under the Clean Water Act as toxic pollutants. New analytical services to meet these demands included multilevel analyses to provide data at the detection levels required for specific applications. For example, trace elements were analyzed by graphite furnace atomic-absorption spectroscopy when data were needed at the submicrogram level; techniques such as flame-emission spectroscopy were used at lower cost when less sensitivity was required. The addition of a new instrument, the inductively coupled argon-plasma-emission spectrophotometer (ICP), made simultaneous multi-element analysis for inorganic constituents possible. In less than 1 minute, this computer-controlled technique provided a simultaneous analysis of 26 elements.

During 1978, the Central Water Quality Laboratories made over 500,000 analyses of the physical, chemical, and biological properties of approximately 100,000 water samples. This was a fourfold increase in the demand for water-quality work over the preceding 5 years. The variety of constituents measured also increased markedly. Standardized methods to measure dozens of additional substances were adopted in 1978. The methods focused on constituents classified under recent legal actions as "primary pollutants" such as chloroform and dicholoromethane. Also in 1978, WRD published two new instruction manuals: One manual, "Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples," included methods used by the Survey to collect, preserve, and analyze water samples for their biological and microbiological properties. It discussed biological sampling and sampling statistics and described in detail more than 45 individual methods of analysis, including those for all major groups of aquatic organisms.The second manual, "Methods for Determination of Radioactive Substances in Water and Fluvial Sediments," described 17 methods for the determination of radioactivity, natural and manmade radioactive isotopes, and radiocarbon ages.

Hydrologic Studies Related to Nuclear Explosions and Nevada Nuclear Waste Storage Investigations

By William W. Dudley, Jr.

AEC Hydrology Projects in 1966

By July 1966, the AEC Hydrology Projects, under the direction of Samuel W. West in Denver, had consolidated the USGS hydrologic support to the U.S.

Atomic Energy Commission's (AEC's) testing of nuclear weapons at the Nevada Test Site (NTS) and greatly expanded the scope of its program by incorporating W. Arthur Beetem's Radionuclides project in Denver. Supervision and administrative support to the AEC Hydrology Projects were provided by the Rocky Mountain Area, redesignated as the Rocky Mountain Region in 1967. The Chief of Geologic Division's Special Projects Branch (SPB), William S. Twenhofel, exercised USGS programmatic coordination and official interactions with the AEC for the nuclear-explosions programs.

The Radionuclides project brought into AEC Hydrology Projects its studies at several AEC experiment sites that were not at NTS. It had previously provided geochemical and instrumentation support to the Mississippi District, which was assisting AEC in seismic detection of coupled and decoupled nuclear explosions (Vela Uniform Program, Project Dribble) at Tatum Dome, and radiochemical monitoring and reporting remained as continuing obligations. In cooperation with other Districts, it also was supporting Plowshare Program (peaceful uses of nuclear explosives) projects that had been conducted or were planned to stimulate fossil-fuel development in New Mexico (projects Gnome and Gasbuggy), Colorado (projects Rulison and Rio Blanco), Utah (project WOSCO) and Wyoming (project Wagon Wheel). Beetem's staff included Hans C. Claassen, David B. Grove, Billy P. Robinson, Samuel J. Rucker, Darrell A. Baldwin, Robert L. Emerson, Jerry D. Larson, Webb A. Tarrant, Edward Villasana, Charles T. Warren, and Leonard E. Wollitz. Many in this group also had previously participated in ground-water tracer tests and deep-well testing at the NTS. Wollitz had assisted Francis C. Koopman in installing electrical transducer systems in wells to record aquifer response to Project Dribble explosions (Salmon and Sterling), and he applied similar methods to hydraulic testing, recording explosion effects, and long-term water-level monitoring at the NTS.

The staff and functions of the Las Vegas Subdistrict office were administratively reassigned in 1966 to the Rocky Mountain Area, AEC Hydrology Projects. Richard K. Blankennagel was designated in charge of the Las Vegas office, releasing Winograd, who had led the office for 8 years, to prepare the report documenting the results of almost a decade of hydrologic studies of NTS and the surrounding region. In addition to Winograd and Blankennagel, the Las Vegas staff consisted of Richard H. Johnston, Murray S. Garber, James E. Weir, Jr., and Richard A. Young. William Thordarson, who had worked with Winograd in Las Vegas since 1960, transferred to Denver. Although the field phase of hydrologic characterization of the NTS region and nuclear-test areas as planned in the late 1950's by Alfred Clebsch, Jr. and Winograd was largely completed, the task of compiling and interpreting the information fell to Winograd and Thordarson through the rest of the 1960's. (Their report was released to the open file in 1972 and published as Professional Paper 712-C in 1975. A quarter of a century later, it remains the most comprehensive description of the hydrogeology and hydrochemistry of the south-central Great Basin.) Intensive work continued on the aquifer-response and post-explosion radiochemical studies that began in 1963 at the Bilby site (Garber and Beetem), on development of the carbonate-rock tracer-testing complex in the Amargosa Desert near the NTS (Johnston, replaced by Grove in 1967), and on hydrologic testing at Pahute Mesa (Blankennagel and Weir). The numerous studies by the expanding staff resulted in a deluge of reports in preparation, and Virginia M. Buss (later Virginia Glanzman) was recruited from the Surface Water Branch to assist in the preparation, editing, and processing of reports.

As was noted in the previous volume (v. VI) of WRD History, the results of most USGS investigations at the several nuclear test sites initially were reported to the AEC in Technical Letters that received very limited distribution. In the 1970's, those that had been released to the open file were converted to USGS 474-series reports that are available from the National Technical Information Service and at selected USGS libraries. The succeeding "474" numbers, rather than the original Technical Letter numbers, are used in the present discussion. In USGS Open-File Report 92-502, Glanzman provided a comprehensive bibliography, emphasizing nuclear-explosions programs, of reports and papers authored by USGS personnel during 1957–91. A similar compilation, OFR 91–341, by Glanzman emphasizes nuclear-waste-management investigations by USGS personnel in the vicinity of the Nevada Test Site.

High-Yield Test Program

Advances in nuclear-weapons design by the mid-1960's made it feasible to arm missiles with multi-megaton warheads. However, the Bilby test, conducted in Yucca Flat in 1963 with a yield of about 200 kilotons, was felt sufficiently in Las Vegas that AEC's planned development of Pahute Mesa to accommodate tests of megaton-class devices became more urgent. The Greeley test on Pahute Mesa in 1966 indicated that explosions of one megaton, and perhaps somewhat larger, would be acceptable with respect to direct seismic effects. At the same time, AEC intensified its program to develop additional, higher-yield test areas at Hot Creek Valley in central Nevada and at Amchitka Island in the Aleutian island chain of Alaska. With participation by USGS (SPB and Beetem's QWB staff), AEC had assisted the Department of Defense in conducting the Long Shot nuclear test on Amchitka in 1965.

George A. Dinwiddie was transferred from Albuquerque to become chief of the hydrologic studies at the Central Nevada Test Area (CNTA), starting the duties in late 1966 and moving to Denver in 1967. Because the AEC Hydrology Projects could not adequately staff the rapidly expanding investigation, the AEC assembled a joint task force headed by Dinwiddie and including Isotopes, Inc. (later Teledyne Isotopes, Inc.) and the Desert Research Institute (DRI) of the University of Nevada. James W. Nelson transferred from the Nebraska District to assist in hydrologic testing, and Leroy J. Schroder joined the AEC Hydrology Projects in Beetem's Radionuclides group with his initial assignment to the CNTA study.

Wilbur C. Ballance, also from the New Mexico District, transferred in 1967 to AEC Hydrology Projects but with headquarters in Anchorage, Alaska, to oversee the hydrologic testing of the proposed nuclear test locations on Amchitka Island. Louis Gachic joined the staff in Denver to manage water-chemistry and radiochemistry laboratory support. Also joining AEC Hydrology Projects in Denver in 1967 were Edwin H. Cordes, William W. Dudley, Jr., Paul T. Voegeli, Sr., and Charles L. Washington. Cordes and Voegeli were assigned to hydrologic studies of Plowshare sites in Colorado and Wyoming. Washington joined the geochemistry group but supported field studies of all types and at all of the various locations. Dudley was assigned to the investigations of aquifer response to explosions at NTS, CNTA, and Amchitka Island, with electronics and field support principally by Wollitz. Cordes and Baldwin undertook the auxiliary task of measuring aquifer response to the planned Rulison natural-gas stimulation experiment (Plowshare Program) in western Colorado.

The first CNTA nuclear explosion, a sub-megaton seismic-calibration test code-named Faultless, was detonated in January 1968, producing a large, ironically fault-controlled subsidence area, quite different from the generally conical sinks that dotted the alluvial surface of Yucca Flat at the NTS. Evaluations of distant ground motion produced by Faultless, particularly in Salt Lake City, disqualified Hot Creek Valley from further consideration for the high-yield test program. During the 2 following years, Dinwiddie completed 10 USGS-474-series reports that documented the hydraulic testing at and around the Faultless site. He and Schroder completed a synthesis of the hydrology and hydrochemistry as well as a conceptual analysis of the areal flow system in a 1971 final report, also in the 474-series. Post-explosion monitoring of water levels and radiochemistry at the site continued through the 1970's as a joint effort of the USGS, DRI, and the U.S. Environmental Protection Agency (USEPA) and, subsequently, by USEPA alone.

Within months after the Faultless event, the sub-megaton Boxcar explosion was detonated beneath Pahute Mesa, inducing significant surface displacement on a nearby fault, apparently by release of tectonic strain. Also, AEC was notified that wells producing lithium brines in Clayton Valley, more than 100 km from Pahute Mesa, were damaged. Concern over the possibility that additional tests planned for Pahute Mesa might induce larger fault movements and cause damaging ground motion stimulated interest and increased funding for USGS tectonics studies and AEC Hydrology's aquifer response project. Three subsequent Pahute Mesa events were conducted in 1968 and 1969. Based in part on USGS observations of geologic and hydrologic effects, the high-yield (>1 megaton) Handley event was approved and was detonated in March 1970. It ruptured the surface along several kilometers of a nearby, previously unknown fault, subsequently dubbed the Handley fault. AEC Hydrology Projects' aquifer-response staff recorded large excursions of confined fluid pressure in observation wells near the Handley fault for two months afterward, revealing apparent strain events that also produced aftershocks. Ground water was judged to play a passive role, its pressure changes resulting from, rather than causing, the crustal strain. Observations at Clayton Valley indicated that surging induced in the wells by Handley ground motion did increase turbidity temporarily. However, normal pumping over sustained periods removed much larger volumes of the fine-grained valley sediment and was principally responsible for the occasional collapses around the wells.

In October 1969, the Milrow explosion, a seismic-calibration event with a yield of about one megaton, was detonated beneath Amchitka Island in the Aleutian chain. The confined ground-water pressure responses measured by AEC Hydrology staff in wells on the island were 3 to 4 times greater than had been predicted based on previous NTS experience, but the more visible surface and near-surface hydrologic effects were dramatic. High-speed photography showed water and mud geysers erupting as far as 1,300 meters from surface ground zero. Changes of stream stage at gaging stations resulted from several causes—the expulsion of shallow ground water, reduced base flow to satisfy new storage produced by bulking, tilting of stream channels, and temporary dams or restrictions caused by bank collapses. The immense cavity formed by melting and compaction at ground zero began to collapse about 36 hours after the explosion and formed a surface subsidence that contained two small lakes and captured the headwaters of a major stream. Post-explosion resampling of hydrochemical and radiochemical sites by Hydrology AEC detected no changes except at the earlier Long Shot site, where low concentrations of tritium were released when water was ejected from a postshot test hole.

The 5-megaton Cannikin event, detonated in November 1971 at a depth of 5,875 feet, was the largest underground nuclear test that the United States has conducted. The AEC Hydrology aquifer-response project, which in 1970 had been reassigned to Don Diego Gonzalez, again fielded ground-water, surface-water, and water-quality studies. Effects of Cannikin on confined ground-water pressures were somewhat greater than those predicted from Milrow results, but the effects on the land surface and drainage system again stimulated the greatest interest. The collapse of the Cannikin cavity propagated upward to produce a rectilinear subsidence that eventually filled with water to form a 30-acre lake with a maximum depth of 33 feet, one of the largest lakes on Amchitka Island. Several ponds and small lakes within about a mile of surface ground-zero were drained through new fissures or because they were tilted. For about a year, most of the flow of a major drainage basin infiltrated to fill the underground voids created by the explosion cavity and the rubble chimney that resulted from its collapse. In a paper in the Bulletin of the Seismological Society of America (v. 62, no. 6, p. 1527–1542, 1972), Gonzalez and Wollitz described the subsurface and surface hydrologic effects within the first few days after the explosion. The hydraulic recovery and distribution of radionuclides in the rubble chimney were described and analyzed by Claassen in Professional Paper 712–D, dated 1978. The Energy Research and Development Administration, which gained he nuclear-explosives functions of AEC in 1975, documented Amchitka's physical and biological environment, its human history, and the bioenvironmental effects of its use by military and nuclear-testing organizations. The large compilation (TID–26712, 1977), edited by M.L. Merritt and R.G. Fuller, included a description of the hydrologic setting and explosion effects, authored by Dudley, Ballance, and Glanzman.

Hydraulic Testing and Analyses

Beginning with the Bilby event in 1963, many of the underground explosions at NTS had sufficiently large yields that containment considerations required their burial at depths that commonly were below the water table. Questions relating to underground engineering and construction, explosion effects, and long-term radionuclide transport were posed to AEC Hydrology Projects, requiring the adaptation of hydraulic methods that were being developed by WRD, other water agencies, and academia principally for use in water-supply development.

In order to study the hydrology of Pahute Mesa, starting in 1963, Blankennagel adapted deep-well testing techniques that were then in use in the oil industry, employing a combination of down-hole geophysical techniques and hydraulic tests in intervals that were isolated by straddle packers to develop hydraulic-properties profiles. He provided an overview of these methods in *Ground Water* (v. 6, no. 4, p. 24–31, 1968) and a more detailed description in an unnumbered open-file report in 1967. The immediate application was to identify the less-permeable zones in which to excavate emplacement chambers for simulating atmospheric explosions. Quantitative estimates of interval transmissivity and storage became feasible in 1967 when H.H. Cooper, Jr., J.D. Bredehoeft, and S.S. Papadopulos published in *Water Resources Research* (v. 3, no. 1) their method for analyzing slug tests, which Blankennagel was already conducting but interpreting only by empirical methods. Dinwiddie and Dudley assisted AEC Hydrology staff in applying the analysis throughout the group's widespread weapons-testing and Plowshare study sites. Armed with hydraulic properties, Dudley (Professional Paper 700–C, p. C206–C211; Trans. of SME, v. 252, June 1972) applied in reverse the analytical methods developed by Hantush (well yield at constant drawdown) and Cooper and others (slug-test recovery) to predict inflow to mined underground openings and, later, to predict the recovery of water levels in rubble chimneys. Respectively, these analyses supported the design of dewatering systems for device-emplacement chambers and predictions of hydraulic recovery after an underground explosion, which defined the time at which water-borne radionuclides could leave the explosion site and begin to migrate in the groundwater system.

In the late 1960's, Beetem, Grove, Janzer, and Schroder continued the previously established radiochemical monitoring and carbon-14 dating of ground water at the Project Dribble site in Mississippi, at the various testing localities at the NTS, in the region around NTS, and at Plowshare sites. They also established sampling networks to document baseline water quality at the supplemental weapons-testing sites, CNTA and Amchitka Island, and sampled them repeatedly after they were expended. In order to develop greater understanding of, and a predictive capability for, radionuclide transport in the fractured regional carbonate aquifer in the NTS region, Beetem in 1961–63 had attempted to conduct tracer tests in Yucca Flat (in conjunction with Winograd) and also in the Culebra Dolomite near Carlsbad, N. Mex. The non-recirculating tests in Wells C and C–1 at Yucca Flat provided only limited information. The Carlsbad test, on the other hand, showed that it was feasible in a recirculating, imposed-gradient test to compare the transport of radionuclides such as iodine-131, strontium-90, and cesium-137 to the conservative tracer, tritium. This led Winograd and R.H. Johnston in 1964–65 to undertake selection of a site near the NTS to study the radionuclide-transport properties of the principal regional aquifer.

Johnston completed the development of the Amargosa Tracer site in the Amargosa Desert southwest of the NTS in 1966 and accepted a transfer to India in 1967. Beetem and Grove took over the final preparation of the site and planned a series of two-well non-recirculating and recirculating tracer tests, using tritium to define the flow field and dispersive properties of the fractured, carbonate-rock aquifer. The tests were conducted in the field during 1968–71. The analytical bases for interpreting the tests were published in a pair of papers in *Water Resources Research* by Grove, F.B. Sower, and Beetem (1970, v. 6, p. 1404–1410) and Grove and Beetem (1971, v. 7, p. 128–134). Grove left the project in 1969 to continue graduate studies, after which he was reassigned to the WRD National Research Program. Cordes replaced Grove as project chief of the tracer studies until he, in turn, was transferred to the Florida District in 1971. Field experiments with tritium had been completed, and attempts to gain State of Nevada approval to study transport of additional isotopes had stalled. Claassen was assigned part-time to continue negotiations with the State, analyze the data collected previously, and prepare the final report of the tritium tests. The results of the two-well recirculating tracer test in fractured carbonate rocks were published by Claassen and Cordes in *Hydrological Sciences Bulletin*, v. 20, p. 367–382 (1976). Darrell I. Leap was hired by AEC Hydrology in 1974 and was appointed project chief of the Amargosa tracer studies. With the continued lack of State approval for additional radionuclide-transport experiments, AEC's successor agency, the Energy Research and Development Administration (ERDA) terminated funding in 1975.

Plowshare Program

The AEC's program to develop peaceful applications of nuclear explosives was very active between 1960 and 1969. Experiments at the NTS were directed at construction of harbors and canals by explosive excavation of single and multiple row-type craters. The AEC Hydrology Projects did not conduct hydrologic experiments or monitoring associated with the nuclear cratering program at the NTS.

Plowshare experiments off the NTS after 1965 were designed to stimulate the production of oil or gas from low-permeability ("tight") rocks by fracturing and heating the rocks. Collapse of the initial cavity also was counted on to form a rubble chimney that would intersect a greater thickness of possibly productive strata. Explosive devices were emplaced sufficiently deep that bulking of the rubble would satisfy the original cavity volume before chimney growth closely approached the surface. Gnome and Gasbuggy were detonated in New Mexico prior to 1966. At that time, Beetem's QWB group was involved in postshot monitoring as well as the tracer experiments discussed above. By 1967, when Beetem's group administratively joined AEC Hydrology Projects under Sam West, it was participating in exploratory drilling and preshot radiochemical baseline sampling that was occurring in two locations in Colorado and in Utah and Wyoming. Cordes and Voegeli, who joined AEC Hydrology Yucca Flat in 1967, also were assigned to the Plowshare studies. Weir, Young, and Warren were detailed part-time from NTS duties to assist in hydraulic testing.

The Rulison gas-stimulation explosion occurred in 1969 in western Colorado. Postshot experiments did yield enhanced natural-gas production, but the tritium concentration was too great for the gas to be marketed. The other Plowshare sites were not used, and funding for the program declined rapidly to support only caretaker-status radiological monitoring at the expended sites. Voegeli suffered a fatal heart attack while collecting snow samples in western Colorado, and the other staff involved in Plowshare studies were transferred to NTS and Amchitka Island activities. AEC Hydrology Projects remained involved in the monitoring until the mid-1970's, when the U.S. Public Health Service (later USEPA) was assigned the responsibility for monitoring all off-NTS nuclear-explosion sites.

Refocus on NTS

From 1967 through 1971, acceleration of the high-yield test program and the culmination of the Plowshare program overshadowed the more mature and routine studies of the NTS and the surrounding region. However, a moderate level of effort was sustained at the NTS.

Before leaving for his new assignment in India, Johnston completed an open-file report, published in 1968, on the drilling, well construction, and hydraulic testing at the Amargosa tracer-test facility. Winograd and Thordarson continued compiling and interpreting data from the NTS and surrounding region, leading to an unnumbered open-file release in 1972 (including Young as third author) and publication as Professional Paper 712–C in 1975. Winograd separated from AEC Hydrology Projects in the fall of 1968 to continue graduate studies at the University of Arizona, although he remained actively involved in the completion and processing of the NTS report. Tarrant resigned from the Survey, and Young was diverted to a 2-year assignment in Korea during 1968–70. After his return to AEC Hydrology Projects in Denver, Young completed his report on development of water-supply wells at the Nuclear Rocket Development Station in southwestern NTS, published as Water-Supply Paper 1938 in 1972.

Blankennagel and Weir conducted hydraulic tests in exploratory holes at planned explosion sites on Pahute Mesa and compiled and interpreted data that they had collected since 1964. (Their Professional Paper 712–B on the geohydrology of eastern Pahute Mesa was published in 1973.) They were transferred to Denver in 1969, closing the Las Vegas office. Blankennagel was appointed Assistant Coordinator of the AEC Hydrology Projects. Warren remained in Nevada as technician-in-charge with his duty station at Mercury on the NTS. He provided field support to water-level, spring-discharge, and water-quality monitoring throughout the area, maintaining automatic radiochemical sampling systems during pumping at the Amargosa tracer site and at the Bilby postshot hole that was drilled into carbonate rocks beneath the explosion cavity in Yucca Flat.

In Denver in 1969, Grove left AEC Hydrology Projects to continue graduate studies at the Colorado School of Mines, and Gachic resigned as chemist in charge of the AEC Hydrology Laboratory. With the field phase of evaluating the potential explosion sites at Amchitka Island completed, Ballance transferred from Anchorage to Denver. In 1970, Thordarson and Robinson completed the 474-series report on the inventory of wells and springs within 100 miles of Pahute Mesa, and Robinson transferred to the New York District office. Dudley was detailed to conduct an irrigation-impact study for the Department of the Interior Desert Pupfish Task Force and, though maintaining his office with AEC Hydrology Projects, devoted most of 1970–71 to that effort. Larson transferred to the Nevada District, headquartered in Las Vegas, to participate in the pupfish investigation and continued for several years to monitor water levels in ecologically sensitive Devils Hole and spring discharges in Ash Meadows. In 1970, upon completion of graduate training at Colorado State University, Don Diego Gonzalez was assigned to the AEC Hydrology Projects, replacing Dudley on the aquifer-response program.

In 1970, Baneberry, a relatively small nuclear explosion above the water table in Yucca Flat, unexpectedly vented to the atmosphere and exposed some NTS workers to measurable radiation doses. The NTS testing program was suspended until mid-1972 while the cause was investigated and procedures were established to prevent similar events from recurring. The cause was determined to be a high-porosity saturated clay in an alteration zone along a minor fault at the Baneberry site. The AEC established a Containment Evaluation Panel (CEP) within its Nevada Operations Office in 1972 to review both natural and engineered characteristics of every future emplacement site before the event received final authorization. The Chief of the USGS Special Projects Branch, W.S. Twenhofel, was a charter member of the CEP, and AEC Hydrology staff frequently reported on hydrologic conditions through Twenhofel or directly to the panel.

The AEC terminated its contract with Teledyne Isotopes, Inc., in 1971 and asked USGS to expand the scope of the hydrologic program to include radionuclide transport predictions. The Survey declined to accept that role, at least partly because WRD was already hard-pressed to staff the demand in its own programs for the rapidly expanding field of predictive geochemical modeling. The University of Nevada's Desert Research Institute, headed by former WRD geologist George Burke Maxey, accepted the AEC's offering and hired the key staff from Teledyne Isotopes. Shortly after its inception in 1972, the CEP included regional ground-water contamination within the scope of its containment responsibilities and turned to DRI to provide the hydrologic expertise on the panel. DRI appointed Paul R. Fenske to the position.

In late 1971, Dudley returned to AEC Hydrology Projects duties and was designated project chief for hydrologic studies of the NTS. At about the same time, Sam West requested a transfer and was appointed to the interagency Westwide Water Study. Beetem was designated Acting Coordinator but soon was transferred to the Central Region staff. Blankennagel was appointed AEC Hydrology Projects Coordinator in February 1972, and Dinwiddie was appointed Assistant Coordinator. Graduate student Victor R. Baker received a part-time WAE position and assisted on the Amargosa tracer experiments and reinterpreting records of aquifer-response monitoring at the Sterling site in Mississippi, co-authoring (with Dudley and Baldwin) AEC Report VUF–1042, in which the reduction of hydrologic effects by exploding a device in a pre-existing large cavity (decoupling) was found to be much less than the reduction of seismic response.

As interest was being redirected from the supplemental, high-yield test areas and Plowshare sites back to NTS in 1971, Warren transferred to the Colorado District, leaving a vacancy at NTS. After more than a year without onsite representation and with the Long Range Hydrologic Program (described below) likely to be approved, Blankennagel found it advisable to reestablish a hydrologic staff position at NTS. Gene C. Doty transferred from AEC's Hanford Reservation in Richland, Wash. to Nevada in 1973 to provide regional and explosion-site hydrologic support. In 1974, Leap, a specialist in ground-water hydraulics, was hired and assigned to the Amargosa Tracer Site studies. Two experienced technicians in Denver also left AEC Hydrology Projects in the early 1970's, Baldwin to the WRD National Training Center in 1972 and Emerson to retirement in 1974. Wayne A. Evert was hired in 1974 to provide technical support to the close-in effects program and, after a period of training by Wollitz, moved to Mercury on the NTS. Schroder also transferred from AEC Hydrology Projects as Chemist-in-Charge of the Denver Analytical Services Unit.

Upon assignment back to hydrochemical studies of the NTS region, Claassen turned his attention to the kinetics of water-chemistry changes in tuff. Arthur F. White joined the AEC Hydrology Project in Denver in 1973 to collaborate with Claassen in this effort. Results of their research were published in 1979 by the American Chemical Society in their Symposium Series 93 (p. 447–473 and 771–793), as well as in 1980 in *Chemical Geology* (v. 28, p. 91–109) and in USGS Water-Supply Paper 1535-Q (p. Q1–Q34). White also concentrated on the effects of flow paths and evapotranspiration on the chemical evolution of water in volcanic rocks of Oasis Valley, adjacent to the NTS. His findings were reported in Professional Paper 712-E in 1979.

Close-In Effects and Source-Term Studies

At the request of Robert E. Miller, then Manager of AEC's Nevada Operations Office (NVO), AEC Hydrology Projects entered in 1972 into an alliance with DRI to develop and advocate a long-range hydrologic program to form a cohesive context for the hydrologic studies not only of USGS and DRI but also for those of other organizations conducting or proposing hydrologic work for NVO. The plan, which was delivered to NVO in February 1973, recommended a 5-year program of stable funding for the scientific staff conducting regional and site-scale studies related to radionuclide mobility. It emphasized that dozens of rubble chimneys that had been created in the past decade extended below the water table and that, based on limited measurements at the Bilby site in Yucca Flat and the Greeley site at Pahute Mea, many of these were predicted to have recovered hydraulically to the degree that outflow of water had begun, providing sources for potential radionuclide contamination in regional aquifers. The NVO Manager and the test directors for the two principal national laboratories, Lawrence Radiation Laboratory (LRL, Livermore, Calif.) and Los Alamos Scientific Laboratory (LASL, New Mexico), approved significantly increased funding for AEC Hydrology Projects to participate in the recommended close-in hydraulic-effects and radiohydrologic studies and for DRI to expand its recently acquired radionuclide-migration program. Significantly, the weapons-development budget contributed much of the large engineering, drilling, and support costs so that the ongoing studies of regional hydrology, radiological monitoring at the NTS and numerous off-NTS test areas, and other traditional tasks remained intact. The aquifer-response project, under Gonzalez with technical support by Wollitz, was redefined to have USGS responsibility for the close-in hydraulic, thermal, and radiochemical effects. The intensified effort began in mid-1973 and continued through 1978. Within that period, AEC/ERDA conducted its Accelerated High-Yield Test Program (1974–76) to alleviate the backlog of device designs that went untested during the post-Baneberry moratorium.

During 1973–76, drill-back and sampling studies were undertaken at three sites that had been expended in the 1960's, Cambric in Frenchman Flat and Nash and Bourbon in Yucca Flat. In addition, the Starwort event (1974) in Yucca Flat and the Almendro (1973) and Cheshire (1976) events at Pahute Mesa were selected for shot-time, early post-shot, and sustained hydraulic and radiochemical characterization, described as cradle-to-grave studies. A long-term (more than a decade) test of pumping-induced radionuclide migration was also initiated in 1974 at the Cambric site, ultimately demonstrating that fission products such as Sr-90 and Cs-137 can move at least sluggishly, relative to tritium, in tuffaceous alluvium for a distance of a few hundred feet.

The safety and security aspects of the drill-back operations, as well as the equipment costs and needed skills in drilling engineering, led to the transfer by 1976 of control of the postshot characterization program from the USGS-DRI alliance to LRL and LASL. The Nuclear Hydrology Program (NHP), successor to AEC Hydrology Projects, remained involved in the field operations, obtaining principally hydraulic information. NHP maintained membership by Dudley on NVO's Hydrologic Program Advisory Group, which had been formed to oversee the Long-Range Hydrologic Program.

Initial Nuclear-Waste Studies

In late 1972, USGS was requested by the AEC, Richland Operations Office, to participate in a study of potential alternative means of long-term management of high-level radioactive waste. The study was being performed for AEC by the Pacific Northwest Laboratories of Batelle Memorial Institute (BNW). Emphasis was on geologic media other than salt. The charge to USGS was to develop geohydrologic, geologic, climatic, geochemical, and geotectonic criteria for each of five terrestrial disposal or storage concepts, as well as to screen the United States for potentially favorable areas. The concepts were (1) a very deep drill hole (30,000–50,000 feet) for solid or liquid waste; (2) a matrix of multiple, shallow to moderate-depth drill holes (1,000–20,000 feet) for solid waste; (3) shallow to moderate-depth mined chambers (1,000–10,000 feet) for solid or liquid waste; (4) cavities containing separate manmade structures (1,000–10,000 feet) for solid waste; and (5) exploded cavities (2,000–20,000 feet) for liquid waste. The interdisciplinary report, prepared jointly by SPB and AEC Hydrology Projects, was released as Open-File Report 74–158, by E.B. Ekren (SPB), Dinwiddie, J.W. Mytton (SPB), Thordarson, Weir, E.N. Henrichs (SPB), and Schroder. Among the interesting observations in the report were (1) that chambers could be mined above the deep water table in many parts of the Basin and Range province in tuff, shale, or argillites; and (2) that granitic stocks at the Nevada Test Site might be suitable for matrix holes, mined chambers, and exploded cavities.

Following a request from the AEC's Albuquerque Operations Office (ALOO) in 1972, the

Office of Radiohydrology, which exercised USGS responsibilities for waste disposal (as did Geologic Division for nuclear-explosions responsibilities), turned to SPB for support in stratigraphic and structural geology of the proposed Waste Isolation Pilot Plant (WIPP) near Carlbad, N. Mex. The New Mexico District elected to retain the hydrologic investigation. Three years later, in 1975, the Utah District declined involvement in hydrologic assessment of the Paradox Basin salt anticlines, and NHP) undertook a preliminary and short-lived regional appraisal. Woodward-Clyde Consultants objected to USGS work that potentially could evolve to site-specific studies, which WCC was already conducting at other sites in the commercial high-level waste salt-repository program under contract with Battelle-Columbus (Ohio), and NHP withdrew from the Paradox Basin study.

Blankennagel transferred in May 1976 to the Madison Limestone Hydrology project. Dudley was designated Acting Coordinator of NHP initially and was appointed Coordinator in 1977. The investigations of supplemental high-yield test areas and Plowshare experiment sites were completed. The NTS studies consisted of the explosion-site hydrologic-effects investigations, hydrologic support to site selection and documentation for ERDA's planned underground explosions, and the geochemistry of ground water in NTS tuffs.

Nevada Nuclear Waste Storage Investigations

In 1976, the Nuclear Waste Terminal Storage (NWTS) Program was established within ERDA, and the earlier focus on salt deposits was broadened to other media, including thick shale and crystalline igneous and metamorphic rocks, as well as to large Federal reservations. USGS Director Vincent McKelvey wrote to ERDA in July 1976, recommending its consideration of NTS because the land was federally owned; because disposal of nuclear waste at NTS appeared to be acceptable to the State of Nevada; because of the dry climate and consequent deep water table and slow ground-water flow; because, in the event of a breach in the repository, the ground-water system would carry the waste to closed, sparsely populated basins; and because the geology of the NTS is sufficiently varied that there was a reasonable potential for finding a suitable host medium. Union Carbide's Office of Waste Isolation (OWI) in Oak Ridge, Tenn., was tasked by ERDA to assist NVO and USGS in defining an initial program in Fiscal Year 1977. SPB and NHP collaborated to develop an interdisciplinary program of regional and media-specific tasks. In June of 1977, George DeBuchananne, Chief of WRD's Office of Radiohydrology, designated Dudley as Operations Coordinator for USGS waste studies at NTS and Twenhofel as alternate. Both retained their primary responsibilities as Chiefs of NHP and SPB, respectively.

Studies of the NTS and surrounding region that were initiated in 1977 included assessments of tectonics and volcanism, monitoring of earthquake seismicity, ground-water flow modeling, ground-water geochemistry, and paleohydrology, which was intended to estimate hydrologic conditions for thousands of years into the future. Specific media and locations that were targeted for exploration on NTS by geophysics, drilling, and hydrologic testing included argillite at Syncline Ridge; granitic intrusive rocks at Climax Stock, Twinridge, Wahmonie, and Timber Mountain; and – based on its aeromagnetic anomaly – a probable granite stock beneath the Calico Hills. Reconnaissance geologic mapping and hydrologic appraisal were programmed to identify alternative sites off the NTS.

Much of the NHP staff was reassigned from projects in the dwindling nuclear-explosions program into the NTS Waste Program, which ERDA soon designated as the Nevada Nuclear Waste Storage Investigations (NNWSI). Dinwiddie, as Assistant Chief of NHP, managed the detailed planning and implementation of hydrologic studies, as well as the conduct of hydraulic tests and hydrochemical sampling in completed drill holes. Weir and Thordarson participated in the drilling and testing program. Leap was assigned the task of developing the regional flow model, assisted by Thordarson, who had extensive knowledge of the regional hydrologic data. F. Eugene Rush, Randy L. Bassett, and Richard K. Waddell were acquired by NHP to support hydrogeology and ground-water testing, hydrochemistry, and ground-water modeling. In 1978, Merrick S. Whitfield, Jr., transferred to NHP to assist in the hydrologic testing, whereas Bassett transferred to the WRD National Research Program and Glanzman transferred to SPB in Geologic Division. Doty, in addition to maintaining the traditional nuclear-explosion support to ERDA, collaborated with Winograd, then in the WRD National Research Program in Reston, to provide a regional assessment of paleohydrology, emphasizing evidence for past positions of the water table at and near the NTS.

In 1977 and early 1978, drilling and hydrologic testing were done only at Syncline Ridge, which proved to be too complex structurally to be well characterized. In late 1977, the governor of Nevada asked that ERDA suspend the off-NTS program unless NTS was found to have no suitable sites. The Department of Energy (DOE) succeeded ERDA in January 1978, and the new Assistant Secretary for Military Applications was successfully petitioned by the national laboratories' weapons-testing community to direct that the nuclear-waste search be restricted to NTS Area 25, comprising the Calico Hills and the eastern part of Yucca Mountain, as well as Jackass Flats and Skull Mountain, both of which were deemed to be unsuitable.

The first exploratory holes were drilled at the two remaining possible sites in summer and fall of 1978. The drill hole in the Calico Hills showed that the magnetic anomaly was caused by magnetite in altered argillite rather than by a granitic intrusive. The drill hole at Yucca Mountain (UE-25a #1) confirmed the expected great thickness of tuffs, including hard but brittle welded tuff and softer, less fractured, poorly permeable nonwelded tuffs. The site appeared promising, but the National Academy of Science had never considered whether tuffs might be suitable media for nuclear-waste disposal.

In late 1978, Dudley and Richard Lincoln of Sandia National Laboratory accompanied Donald L. Veith of DOE's NWTS program office to present to the NAS Board on Radioactive Waste Management a description of the geologic, hydrologic, and rock-mechanics characteristics of tuffs and the caldera environment. The NAS Board subsequently concluded that the tuffs of Yucca Mountain might prove to be suitable for waste disposal and encouraged DOE to proceed.

Geologic and hydrologic characterization of Yucca Mountain and the surrounding region resumed in earnest in 1979. Exploration was targeted to depths as great as 5,000-6,000 feet, because of the possibility that the tuffs at that depth would have sufficiently small permeabilities to allow the construction, operation, and eventual closure of a mined repository at that depth. (During the next 2 years, that proved not to be the case and, in 1982, DOE–with the strong encouragement of the USGS—designated the thick unsaturated zone at Yucca Mountain as the site proposed by NNWSI for the Nation's repository for hig[illegible] nuclear waste.)

In 1979, Dinwiddie was reassigned as Project Chief of the Northern Great Plains RASA, and Dudley was reassigned as District Chief of Wyoming. William E. Wilson was selected as Chief of NHP, and Rush was designated Assistant Chief.

Gulf Coast Hydroscience Center (GCHC), Bay St. Louis, Mississippi—1971

INTRODUCTION

The Gulf Coast Hydroscience Center (GCHC), established in 1971, is located at the National Aeronautics and Space Administration's (NASA) Mississippi Test Facility (MTF) near Bay St. Louis, Miss. Originally, NASA used the facility to test moon rockets for the space program. After the moon program, the facility was available to the scientific community for the development of environmental sciences and technology. NASA representatives contacted the USGS and other agencies to see if there was an interest in using the facility. Therefore, Hendricks sent WRD staff members to examine the facility from a research and administrative perspective. The staff felt that it was a good facility and a good opportunity for WRD. Cragwall commented that Rolland W. Carter was instrumental in working with NASA to obtain this facility for WRD's use. Carter was responsible for all the negotiations between the Survey and NASA. The Center was established under the Office of the Regional Hydrologist, Southeastern Region. WRD established the GCHC at the MTF to take advantage of office space, equipment, hydraulic research facilities, and onsite technical expertise. Vern Schneider was responsible for the hydraulic design and physical modeling, and Stanley P. Sauer transferred to Bay St. Louis from the Hydrologic Studies Section at WRD Headquarters to become the first WRD Chief in charge of the facility.

Previously, WRD had done experimentation at prominent hydraulic laboratories throughout the country that were opened in the early part of the century. WRD always had expectations for the Survey to have its own facility with flumes to study surface water in the traditional way. The GCHC was one of WRD's major initiatives for research in water resources.

The programs at the GCHC included both applied and basic research. The projects attempted to meet the specific operational needs of WRD, to advance the science of hydrology, and to strive to support the cooperative programs. The staff included both professionals and technicians.

Experimental facilities at the GCHC made the center unique among the Survey's research activities. Research facilities of principal interest to WRD at the GCHC were an indoor hydraulics laboratory, designated as the Hydroscience Laboratory Facility, an outdoor flood-plain simulation facility, designated as the Flood Plain Simulation Facility and, as part of the Hydroscience Laboratory Facility, the Instrument Research and Development Laboratory. Analog and digital computer facilities also were available at the GCHC.

Hydrologic Instrumentation Facility (HIF)

Beginning in July 1977, WRD began a series of actions and made several decisions to reorganize Division support for the development and supply of hydrologic instrumentation. These decisions were announced in WRD Memorandum 78.32, January 13, 1978.

Thomas Buchanan explained that when he was Assistant Chief Hydrologist for Operations, he found that responsibilities were split such that no one had full responsibility for the program. The program also lacked needed staff. The Administrative Division was responsible for maintaining the machine shop and equipment supply; the Assistant Chief Hydrologist for Research and Technical Coordination was responsible for instrument research; and the Assistant Chief Hydrologist for Operations was responsible for coordinating much of the activity of the program. After discussions among the senior staff, it was decided to place the entire program under the Assistant Chief Hydrologist for Operations. WRD also decided to relocate the program to the Gulf Coast Hydroscience Center (GCHC).

Early in 1978, the Administrative Division transferred to WRD the personnel and resources of the Property Maintenance Shop in Reston that were used to support WRD instrumentation and repair. During the spring of 1978, the Reston Instrumentation Group and some of the instrumentation-oriented duties of the Operations Section were transferred to the Instrument Development Laboratory at GCHC. The responsibility to develop and supply instrumentation to the Division was placed under the Assistant Chief Hydrologist for Operations. Richard W. Paulson was appointed Instrumentation Coordinator, reporting to the Assistant Chief Hydrologist for Operations.

An Instrumentation Committee was organized to help define the needs and priorities for instrumentation support within the Division. Members of the Committee represented the Ground Water, Quality of Water, and Surface Water Branches; Research; the Instrument Development Laboratory; the Automatic Data Section; the Instrumentation Coordinator; and a District Chief. The Committee reviewed the instrumentation development work which was underway and established priorities of development.

The reorganized Hydrologic Instrumentation Facility had three broad functions:

1. To maintain an inventory of hydrologic instrumentation necessary to support WRD's programs.
2. To repair, test, and maintain equipment that was returned from the field or came from vendors.
3. To evaluate commercially available products that could be used by the WRD and oversee the development of new instrumentation necessary to support Division programs. The development of new equipment would be done by contract to the private sector and by WRD personnel. This included the Satellite Data Relay Project, whose objective was to evaluate the potential role of satellite data relay technology in WRD operations.

Russ Wagner was selected as the first HIF Chief in 1978, and he and Dick Paulson, under the supervision of Tom Buchanan, fleshed out a staffing plan that was approved by the WRD senior staff. The initial HIF senior staff selected during the subsequent year consisted of Wayne Pourciau as Chief of the Technical Services Unit, Don Rapp as Chief of the Test and Evaluation Section, Bob Wall as Chief of the Repair and Calibration Section, and Sammy Wilbourne as Chief of the Field Service and Supply Section; Frank Koopman remained as Chief of the Instrumentation Development Laboratory, and Jean Curtin was the HIF Administrative Officer.

Role Of The District Administrative Officer—1977

Using the many and varied skills of the District Administrative Officer (AO) was viewed as a way to increase the effectiveness of technical capabilities in WRD, with the AO carrying out nontechnical matters. The AO's primary role was to serve as a principal staff officer with specific responsibility for administrative management functions. Specific information on the role of the Administrative Officer in WRD was disseminated on June 7, 1977, by WRD Memorandum 77.121. The AO had involvement in the following elements in each District's program:

1. Planning—assists the District Chief and staff in identification and analysis of financial, personnel, and material resources to coordinate effective use of these resources to carry out various District programs and projects.
2. Financial management—develops, adapts, and maintains the system to implement the Survey's Project Accounting program.
3. Personnel management—provides the District Chief with the specialized knowledge required to effectively initiate and process personnel matters and serves as principal communications link with specialists in the Regional Personnel Office of the Administrative Division. Facilitates accomplishments of programs such as position management, Upward Mobility, EEO, and Career Development and ensures that District personnel are aware of legislation pertinent to human rights.
4. Procurement, contracts, and agreements—assists the District Chief in negotiating contracts and organizing cooperative agreements and advises on methods of procurement, and so forth, small purchases, and GSA schedules.
5. Management analysis—conducts studies of vehicle use, space use, travel ceilings, and property management and develops recommendations. Serves as liaison officer with the Administrative Division Branches and Regional Offices on administrative management activities.
6. Office service management and supervision—supervises the Administrative Services Section and formulates overall plans to carry out the many varied administrative tasks.
7. Policy and procedural matters—keeps abreast of policies and procedures and develops internal administrative policies and procedures.

It was felt that the WRD mission could be better accomplished if the District Chief delegated administrative authority to the AO, relieving technical personnel for technical duties. The AO was considered as a member of the management team concerned with providing specialized experience and professional competence.

International Activities

by Robert M. Beall and George C. Taylor, Jr.

Introduction

One element of the Water Resources Division's basic mission is to provide "scientific and technical assistance in hydrological fields to other Federal, State, and local agencies, and to international agencies on behalf of the Department of State."[4] Within this mandate and for the parent WRD, the Office of International Hydrology (OIH):[5]

- Plans and directs WRD activities relating to foreign governments and international organizations
- Monitors foreign methodology and research for potential application to domestic programs
- Conducts international water-resources investigations
- Cooperates with and advises other Federal agencies on international matters
- Represents the United States in international water affairs
- Fosters institutional development and training programs
- Advances hydrological knowledge and methodology
- Arranges and conducts visits by foreign scientists

[4]WRD Memorandum Number 77.71, March 14, 1977.

[5] Known as the Foreign Hydrology Section until March 1967 and as the Office of International Activities (OIA) until 1974.

• Publishes findings from foreign assignments

In common with most bureaucratic entities, the conduct of these activities was constrained by internal personnel allocation policies and practices, by technical and administrative dictates of the assisted agencies (which provided the funding), and by the vagaries of national policy with regard to personnel, travel, and foreign aid emphasis.

The mid-1960's were also a period of major WRD reorganization, change in leadership style, advancement in hydrologic science and practice, and other external forces which subtly influenced the progression and pursuit of international hydrologic activities.

Personnel

The Chief of the Foreign Hydrology Section and later the OIA during the Hendricks years as Chief Hydrologist (1966–74) was George C. Taylor, Jr., a hydrogeologist with considerable overseas experience. From 1966 to 1970, George W. Edelen, a surface-water hydrologist, was Taylor's principal assistant. He was succeeded by Lawrence E. Bidwell until December 1974. Additional staff included Rebecca A. Williams, foreign participant assistant, Gary M. Bradford, cartographic technician, and Mildred M. Dunbar and Virginia M. Briggs, secretary-typists. Taylor retired in December 1974 and was succeeded by James R. Jones, also a hydrogeologist, who served as Chief throughout the Cragwall years (1975–79). During most of this period, Jones' Deputy Chief was Leopold A. Heindl, who died suddenly in October 1978. Between 1966 and 1975, Heindl had been detailed to the U.S. National Academy of Science, where he served as Executive Secretary of the U.S. National Committee for the International Hydrological Decade.

Robert M. Beall, a surface-water hydrologist, joined the OIH staff in July 1976, chiefly to provide technical backstopping of those overseas bilateral and multilateral activities outside the purview of the International Hydrological Program (successor to the IHD). He continued in this capacity through the remainder of the Cragwall years, although as a retiree from January 1979. In 1977, Lynne M. Sutphin-Price was chosen to succeed Rebecca Williams as International Training Specialist. Mildred Dunbar retired and was replaced by S. Elaine Brock. During 1979, hydrologists Della Laura and Ennio V. Giusti joined the OIH staff as did Doris C. Barry and Emily C. Jackson, replacing Briggs and Brock.

The number of Water Resources Division (WRD) employees involved in the U.S. AID-supported bilateral program reached a peak of 21 individuals on long-term (2 or more years) assignments in 1966. This number declined to 10 in 1970 and to 4 in 1974, remaining near this level through 1979. The trend reflected personnel constraints imposed on the WRD during the Hendricks and Cragwall years. The numbers, however, do not reflect the large number of individuals involved in short-term programming, consultative, technical support, and training assignments both in the bilateral program as well as in multilateral programs, notably UNESCO's International Hydrological Decade (IHD) from 1965 to 1974 and its follow-on, the International Hydrological Program (IHP) from 1975 onward. Prior to 1975, the OIA was not directly involved with U.S. participation in activities related to the UNESCO/IHD programs, nongovernmental international organizations, nor with hydrologic investigations abroad that were extensions of domestic research projects. This situation changed substantially in 1975 when the OIH was assigned broadened responsibility for the guidance of the IHP program as well as most of the other international activities mentioned previously. Collaborative activities with field programs along the international boundaries with Canada and Mexico continued to be directed by elements of the domestic WRD program.

During the mid-1960's the international programs, principally funded by U.S. AID, grew apace, reaching their zenith, according to G.C. Taylor, Jr., (1976, "Historical Review of the International Water Resources Program of the U.S. Geological Survey, 1940–70") in the year E.L. Hendricks became Chief of WRD. Taylor's review of the 1940–70 period of USGS international water programs gives an excellent summary of the many programs in existence during most of Hendricks' tenure. Only the individuals working in each country on long-term assignment are shown, along with the general nature of country programs. During 1966–79, WRD personnel were involved in assignments in 53 nations.

AFGHANISTAN

Surface-water network planning and implementation, institutional development and training, sediment studies; ground-water reconnaissance.
A.O. Westfall <6/66 – 12/68
V.J. Latkovich <6/66 – 9/69
Vincent Piro 3/67 – 7/69
Dallas Childers, Jr. 4/67 – 6/69
J.R. Jones 5/71 – 1/72, 9/72
N.E. McClymonds 5/71 – 1/72
E.A. Sammel 5/71 – 1/72

BANGLADESH (EAST PAKISTAN before 1971)

Comprehensive ground-water investigations and institutional development (terminated by civil unrest in mid-1971).
J.R. Jones 3–5/67, 8/70 – 6/71
H.M. Babcock 3–5/67
N.E. McClymonds 11/70 – 6/71
E.A. Sammel 11/70 – 6/71
H.E. Thomas 11/72 – 2/73

BRAZIL

Surface- and ground-water studies of the Northeast Region, national water-resources program elements.
W.F. Curtis 8/66 – 9/68, 8,9/69, 1–3/73
S.L. Schoff <6/66 – 9/67
W.C. Sinclair <6/66 – 11/68
G.N. Mesnier 4/67 – 2/69
C.L. Lawrence 2/67 – 7/69, 9–12/73
W.W. Evett 6/69 – 6/71, 11/71, 9/72, 11/73
D.C. Perkins 7/70 – 4/72, 7/72 – 8/74, 8–9/75
L.J. Snell 9–12/69, 2–6/70, 11/71 – 6/72

EGYPT

Technical support of ground-water investigations in the Western Desert (New Valley Project).
R.L. Cushman <6/66 – 5/67
J.S. Gates <6/66 – 5/67

ETHIOPIA

Advisory services and training in hydrology, local and regional water-supply studies, drought planning. Program review and consultation on surface-water network improvements.
J.R. Jones 2/68 – 7/70
H.E. Gill 12/70 – 6/73

INDIA

Guidance on studies of the Upper Ganges and Narmada River Basins, review of state-level plans for ground-water evaluations and institutional development in central and southern India. World Bank Foodgrains Review Mission to Assam.
P.H. Jones <66, 9 – 11/66
J.R. Jones 1/72 – 6/73
N.E. McClymonds 3/72 – 6/73
E.A. Sammel 1/72 – 6/73

Remote sensing workshop. Investigation of an irrigation and drainage projection, Rajasthan.
R.H. Johnston 10/67 – 10/68

KENYA

Coast Province program design; regional range water program proposal; interagency surveys and plans for North-Eastern Province rangeland development; hydrogeochemical study; remote sensing advisory mission; operational ground-water assessment program, North-Eastern Province.
M.J. Mundorff 12/68 – 12/70
W.V. Swarzenski 2/69 – 8/71
N.E. McClymonds 10/73 – 1/78

KOREA

Continued as Ground Water Division Chief, Han River Basin Joint Survey Team; advisor to U.S. Army Corps of Engineers well drilling activity throughout south Korea.
J.T. Callahan <6/66 – 2/71

Direction of an exploratory well-drilling program.
R.A. Young 7/68 – 2/71

MOROCCO

Initiation of analog modeling, water balance, and hydrogeologic studies.
B.J. Bermes 9/69 – 6/71

NEPAL

Continuation of surface-water institutional and operational programs. Program design and initiation of comprehensive ground-water studies of the Western

Tarai, with attendant training and organization of a Nepalese Ground Water Section; follow-up evaluations.
W.W. Evett <6/66 – 10/68
G.C. Tibbitts 3/69 – 9/74
William Ogilbee 9/69 – 8/74

NEW ZEALAND

Study of methods for sampling and analysis of geothermal field fluids; methods for computer simulation of geothermal systems.
Ivan Barnes 8/75 – 6/76
P.C. Trescott 9/77 – 3/78

NIGERIA

Planning, organization, coordination, and operation of surface- and ground-water investigational and research programs nationwide but particularly in the Chad, Sokoto, Komadugu-Yobe River Basins. National water-quality and sediment studies. Assessment of the water-resource potential of the Federal Capital Area (Abuja).
G.C. Tibbitts, Jr. <6/66 – 8/68
D.A. Phoenix <6/66 – 11/66
H.R. Anderson <6/66 – 10/66
B.E. Colson <6/66 – 11/68
C.R. Sieber <6/66 – 11/68
E.D. Lucero <6/66 – 8/67

NORWAY

Scientific exchange in field of glacier studies such as mass balance, alteration of runoff patterns, instrumentation, and field methods.
W.V. Tangborn 5–12/67

PAKISTAN

West Pakistan ground-water survey program. Enhancement of hydrologic monitoring and research programs in Salinity Control and Reclamation Project (SCARP) areas. Assessment of regional changes and trends in the water quality and flow regimen of the Indus River Basin. Evaluation of development plans in Baluchistan. Training in conjunctive ground- and surface-water management concepts for master planning.
M.J. Mundorff <6/66 – 12/66
H.A. Waite 4/68 – 5/70
P.R. Seaber 11/69 – 12/71

PHILIPPINES

Defense Department consultancies on ground-water problems or prospects.
J.T. Callahan 10/77 – 1/78
D.A. Davis 2–3/72, 12/72 – 1/73

SAUDI ARABIA

Review of Wadi Dawasir development plan; Riyadh water-supply studies; well-drilling supervision for military installations; regional aquifer studies. In June 1974, the governments of the United States and Saudi Arabia established a Joint Commission for Economic Cooperation (JECOR). One of its principal subfunctions was a working group on agriculture and water (AGWAT) involving bureaus of the U.S. Departments of the Interior and Agriculture. Within this framework, technical specialists in ground water, surface water, water quality, agrometeorology, computer programming, data storage and retrieval, and associated activities were assigned to a Riyadh Headquarters for both long and short periods to work with local Saudi Ministry counterparts. The program extended well beyond the period of Mr. Cragwall's tenure. The following were assigned from the USGS:
G.C. Tibbitts, Jr. 1–2/75, 12/77 – >11/79
D.W. Greenman 7/76 – 4/77
R.L. Wait 8/76 – 9/78
W.J. Shampine 1/77 – >11/79
D.O. Moore 5/77 – >11/79
J.F. Williams, III 4/79 – >11/79

VIETNAM

Advisory services to the military on water-supply development for bases and to the Government of South Vietnam on village water problems. Reviews of progress on various data-collection activities in the Mekong Delta region. Short missions to provide training in the use of borehole geophysical equipment and, in a team effort, to develop a national water-management plan.
G.D. DeBuchananne 9–12/66
H.G. Rodis 2–5/67
M.C. Van Lewen 2–5/67
H.R. Anderson 8/67 – 2/68, 10/68 – 4/70

YEMEN ARAB REPUBLIC

Technical assistance in the development of a national water plan and in the establishment of a Department of Hydrology. Regional ground-water studies. Surface-water network reviews and consultation.
J.R. Jones 3/74–4/75
G.C. Tibbitts, Jr. 1,2/75, 4/75–10/77

ZAMBIA

Advisor to the Department of Water Affairs on training, planning, and field operations to enhance organizational development.
L.E. Bidwell 11/68 – 12/70

MULTINATIONAL ACTIVITIES

George Taylor noted, "Comparatively, the USGS participation in water-resources activities of the United Nations and regional intergovernmental agencies ... was more extensive in terms of subject matter and geographic coverage but less intensive in terms of manpower, training and commodity inputs than in the U.S. bilateral program." Many of the activities were in the nature of lectures, demonstrations, and advisory or project evaluation assignments, and although most lasted for a matter of days, a few did involve periods of 1 month or more. Taylor's data reflect the beginning of this type of WRD participation in the late 1950's, peaking during the decade between the mid-1960's and the mid-1970's. Literally hundreds of WRD personnel were involved, either directly in the United States or abroad, or in a support capacity, mostly in the United States.

The U.S. Department of State provided some funding directly and a larger amount indirectly through their support of multilateral agencies, particularly UNESCO. WRD benefited scientifically and professionally and supported many of these activities with its own resources. These multilateral activities are reported in terms of the principal organizational sponsorship, although they often involved more than one entity.

UNITED NATIONS EDUCATION, SCIENTIFIC, AND CULTURAL ORGANIZATION (UNESCO)— The International Hydrological Decade

UNESCO was organized within the United Nations family in 1946 to enhance world peace and security through international collaboration in its titular areas. Scientific aspects of hydrology were addressed by UNESCO between 1951 and 1964 in the activities of a Committee on Arid Zone Research, certainly a worthy topic. However, to broaden the scope of UNESCO's efforts, to utilize advances in the developing science of hydrology, and to involve more nations, an International Hydrological Decade (IHD) was proposed in the early 1960's by senior USGS hydrologists R.L. Nace, W.B. Langbein, and L.B. Leopold (then Chief Hydrologist). Its purpose was to focus worldwide attention on the myriad of water problems that disturbed national and international relations and which inhibited many national development projects and prospects. The three principal objectives of the 1965–74 program decade were to strengthen the scientific base for water use and management, to stimulate and enhance education and training in hydrology, and to improve the ability of all countries to cope with their water-related problems.

International Hydrological Decade beginnings were chronicled in Volume VI of the WRD History. R.L. Nace chaired the U.S. National Committee for the International Hydrological Decade (USNC/IHD) until 1967 when he was succeeded by D.F. Peterson, Dean of the Utah State University College of Engineering. Peterson served until 1970 when Dr. H.G. Hershey, then Director of the Interior Department's Office of Water Resources Research became Chairman. Poor health forced him to resign the position late in the decade. The IHD operations in the United States were directed by the USNC/IHD and managed by its Executive Secretary, L.A. Heindl.

The IHD got underway in January 1965 after 3 years of planning and organizing effort by UNESCO's IHD Coordinating Council. Twelve working groups were established to encompass these major areas:

- World Water Balance; Nuclear Techniques in Hydrology
- Network Planning and Design; Exchange of Information
- Floods and Their Computation; Hydrological Forecasting
- Hydrological Mapping; Influence of Man on the Hydrological Cycle

- Representative and Experimental Basins; Hydrological Education

- Hydrology of Mediterranean Basin Carbonate Rocks; Standardization

The International Hydrologic Decade program enabled the United States to increase knowledge about the water cycle and water supplies throughout the world. Indirect and intangible benefits included the fact that underdeveloped countries, by participating in the program, improved their competence to deal with their own problems, thus lessening the need for U.S. assistance in the future. As part of this activity, certain benchmark hydrological sites and other stations were operated as "decade stations." Water inventory studies were made in relation to specific water problems. Other studies focused on time trends in water supply, influences of urban development, development and evolution of stream channels, and overland flow—all in accordance with recommendation of intergovernmental conferences

EDUCATION AND TRAINING OF FOREIGN PARTICIPANTS

The USGS has been active in the education and training of foreign participants in the water sciences and engineering since the early 1940's. The level of activity during the Hendricks years (1966–73) continued about the same as that during the Leopold years—that is, at an average rate of some 32 participants annually. However, during the Cragwall years (1974–79), the level of activity declined somewhat to an average of about 26 annually. During 1966–79, more than 400 scientists, engineers, and technicians were provided prearranged intern-training at USGS/WRD facilities for periods ranging from a week or two to as much as a year. Most of the training programs were scheduled by the Office of International Activities/Hydrology with the administrative assistance of the Office of International Geology (OIG) and often in collaboration with other Federal agencies or educational institutions.

Many of WRD's field offices and laboratories provided individual intern training for foreign participants, particularly during the Hendricks period, during which the hydrologic laboratory in Denver also conducted training for small groups. Later, owing to increasing demand and a perceived need for reducing the burden on the field offices, the emphasis shifted to group training at the Survey's Training Center in Denver, where multidisciplinary training was provided in general hydrology as well as in the more specialized fields of surface-water hydrology, hydrogeology, and hydrochemistry. These short courses of 2 to 3 months' duration were often a prelude to in-service field office assignments, thus continuing reliance on the field.

CHAPTER IV – HYDROLOGY AND PROFESSIONAL DEVELOPMENT

During 1966–79, WRD leadership emphasized professional development for staff members at all levels. Training programs were of particular importance, with an increase in both in-house and external training programs as well as continued use of on-the-job training. Programs in hydrology were implemented in several universities.

Hendricks and Cragwall both commented that personnel management was a major management challenge during the period. The combination of personnel ceilings and other personnel management mandates, the rapidly changing needs for water information, the increasing complexity and diversity of water problems, and the increased rate of retirement of senior personnel were some of the key factors involved. During the 1970 to 1975 period, for example, there were numerous retirements of key WRD staff. This included Hendricks, 13 of the District Chiefs, and 20 other senior staff members.

Training Programs

WRD's commitment to training was emphasized in the reorganization of the Division during 1964–66. Hendricks noted that the interdisciplinary structure led to a need for interdisciplinary training. The reorganization had as a key item a career development plan for each professional and technical employee throughout the Division. The Regional Hydrologists were responsible for ensuring that a plan was prepared for each professional employee. The basic feature of the program was to provide continuing technical development for each individual tailored as closely as possible to the individual's desires and needs. The plan was to be developed jointly by the individual and his or her District Chief or Project Leader. The Career Development Forms to be used replaced the previous Employee Comment and Employee Appraisal Forms.

Additionally, each year, the Division selected approximately 15 professional employees for up to 1 year of graduate school training at outside institutions. Expenses, including salary, travel, shipment of household goods and effects, tuition, and related fees of those selected were paid by the Division. The general objective of graduate school training was to raise the level of professional competence within the Division in the field of hydrology. Eligible candidates, beginning October 26, 1966, were all professional personnel of WRD who had completed at least 2 years of full-time employment and who could fulfill the graduate school entrance requirements of the school they planned to attend.

Rocky Mountain Regional Training Facility

When Thad McLaughlin became Regional Hydrologist in the Rocky Mountain Region, he asked Ivan Johnson to join the Regional Staff as a ground-water specialist in charge of training and recruiting. McLaughlin and Johnson then established a formal training center to serve the international community and new WRD employees. Then, McLaughlin contacted the Associate Director for the Survey, William A. Radlinski, to acquire space and funds for a training center at the Denver Federal Center to serve all of WRD.

On August 7, 1968, the Rocky Mountain Regional Training Facility at Denver, Colo., was designated as a WRD Training Center. Johnson was appointed as Chief of the center, reporting administratively to the Regional Hydrologist, Central Region. The principal function of the Training Center was to conduct training courses for orientation of new professionals. The Training Center also was available for use on an optional basis to arrange housing and meeting facilities for seminars, short courses, and symposia offered on a Division-wide basis that were approved by the Assistant Chief for Research and Technical Coordination.

Johnson noted that the Training Center held two 24-week courses, each beginning in the second week of January and July. The 24-week course covered ground water, surface water, and water quality and provided 2 weeks of training in report writing for new WRD staff members. After new staff members completed the course, their resumes and evaluations then were sent to the WRD District Offices to determine their next assignment.

One- to 2-week seminars also were held on specific topics. Some seminars addressed the latest research results, and participants commented that the seminars inspired new research. The international community participated extensively in the Training Center's programs, and many of those who completed the program later advanced to positions of greater importance in their respective countries.

WRD Committee for Technical Training

To assist in developing and maintaining the WRD training program, on April 3, 1969, by WRD Memorandum No. 69.135, a Committee for Technical Training was established. This committee served in an advisory capacity to the Chief Hydrologist and other Division officials on matters pertaining to training as they influenced development of the technical competence of individuals and the development of skills required in carrying out the Division's mission. The committee assisted in formulating the technical content of the Division training programs. The committee also reviewed and evaluated the performance of Division technical training activities and advised the Chief Hydrologist on long-range training needs. The Committee for Technical Training consisted of the following:

- Assistant Chief, Research and Technical Coordination, Chairman;
- Chief, Manpower Section, Secretary;
- Three Branch Chiefs; and
- One representative from each Region selected by the Regional Hydrologist.

The Committee for Technical Training prepared an annual report summarizing activities and including recommendations for future training.

Responsibilities for the WRD Training Program

Also on April 3, 1969, WRD Memorandum 69.136 clarified responsibilities of the Headquarters staff for planning and carrying out the Division training program. The Chief, Manpower Section, had the primary responsibility for implementing the Division training program. This included organization and direction of the services and facilities required to carry out the training program and recommending policy on training and plans for future training activities. Also, it involved coordination of all training activities including those at established facilities such as the Division Training Center at Denver. The Assistant Chief Hydrologists shared the responsibility for development and review of the Division training program as follows:

- Assistant Chief, Research and Technical Coordination—Technical training for professionals and technicians.
- Assistant Chief, Administration and Technical Services—Training in management and administration.
- Assistant Chief, Reports and Data Processing—Training in methods and procedures to prepare, process, and disseminate data and reports.

WRD Training Initiatives

To cope with the personnel challenges, particularly during the 1970's when employment hiring basically was static, increased emphasis was placed on training programs and facilities. During 1970 to 1975, for example, the technical training program sponsored 158 courses, with a large part of the activity handled at the National Training Center. About 3,300 individuals participated in the program. Also during 1970 to 1975, a strong program of graduate school training was maintained by supporting a year of graduate school training in universities for 34 professionals. Staff participated in Civil Service Commission (CSC) sponsored training courses in administration, and 25 members of the executive-level management team completed courses at the Federal Executive Institute and other CSC-sponsored programs at Berkeley, Calif.; Kings Point, N.Y.; and Oak Ridge, Tenn.

During 1975, for example, 35 courses were given at the National Training Center to groups of WRD scientific, technical, and administrative personnel. These courses lasted 1 to 2 weeks. Participants included not only Survey personnel but also representatives of State cooperating agencies and foreign hydrologic organizations. In 1976, 38 courses were given, and in 1977, the Training Center increased its offerings to 71 courses in hydrology and related subjects in which 1,300 scientific and technical personnel participated. Subject matter ranged from instructions on the operation of hydrologic instruments to the programming of sophisticated hydrologic computer models. The classroom training was coupled with a video tape production system that provided video tapes of courses for loan to all offices. Some training courses were held outside Colorado at locations that provided either a hydrologic setting or laboratory facilities essential to the presentation of the course material.

In 1975, the Southeastern Region Office developed a Career Development Program that later was adopted in large part by the Division. Les Laird, Regional Hydrologist, with the help of Jerry Parker, designed employment history and comment forms and performance evaluation forms for use in the Southeastern Region in 1975. The Regional Hydrologist and Assistant Regional Hydrologist visited each District Office and most Subdistrict Offices to hold a career development discussion with each full-time employee. As part of this review, the supervisors held a separate, annual performance evaluation with each employee. The career development visits were well received by the employees and continued each year through 1979. Each employee had a chance to learn the requirements for desired positions. The Regional staff became familiar with all of the employees in the Region and their goals and aspirations, and then were able to identify talent for future assignments within the Region and Division. The WRD Manpower Section modified the forms developed for this purpose, and they were placed in use nationally in 1976. Other Regions, however, did not formally adopt the program.

Meritorious Service, Distinguished Service, and Conservation Service Award Recipients

During the period, WRD employees made significant contributions in many areas, and numerous employees received USGS awards. The following table lists recipients of the Distinguished Service, Meritorious Service, and Conservation Service Awards in chronological order.

Year	Recipient	Award
1967	Marjorie E. Allen	Meritorious Service
1967	Mary R. Armstrong	Meritorious Service
1967	Conrad D. Bue	Meritorious Service
1967	William P. Cross	Meritorious Service
1967	Warren Hastings	Distinguished Service
1967	Pauline L. Hendershott	Meritorious Service
1967	Sherman K. Jackson	Meritorious Service
1967	Wallace T. Miller	Meritorious Service
1967	Roy H. Monroe	Meritorious Service
1967	Hollis M. Oren	Meritorious Service
1967	Joseph Poland	Distinguished Service
1968	Francis Bell	Meritorious Service
1968	Paul Benedict	Meritorious Service
1968	Paul Bieber	Meritorious Service
1968	Robert Eaton	Meritorious Service
1968	Lawton Furness	Meritorious Service
1968	Lawrence Pierce	Meritorious Service
1968	Charles Riggs	Meritorious Service
1968	Stuart Schoff	Meritorious Service
1968	Herb Swenson	Meritorious Service
1968	Mark Meier	Distinguished Service
1968	Melvin Williams	Distinguished Service
1969	Horace M. Babcock	Meritorious Service
1969	G.L. Bodhaine	Meritorious Service

Year	Recipient	Award
1969	Elton Cook	Meritorious Service
1969	Dan Davis	Meritorious Service
1969	Dave Dawdy	Meritorious Service
1969	Henry Eagle	Meritorious Service
1969	Thomas Hanly	Meritorious Service
1969	Stephen Herrick	Meritorious Service
1969	Harry Hulsing	Meritorious Service
1969	William Lamar	Meritorious Service
1969	Glen Mesnier	Meritorious Service
1969	Al Moore	Meritorious Service
1969	Richard Petersen	Meritorious Service
1969	Wayne Travis	Meritorious Service
1970	Harlan M. Erskine	Meritorious Service
1970	Wilbur L. Heckler	Meritorious Service
1970	John Horton	Meritorious Service
1970	Nicholas Matalas	Meritorious Service
1970	Helen Moore	Meritorious Service
1970	Melvin Van Lewen	Meritorious Service
1970	Leon A. Wiard	Meritorious Service
1970	Henry C. Barksdale	Distinguished Service
1970	George E. Ferguson	Distinguished Service
1970	Thomas Robinson	Distinguished Service
1970	Wilbur T. Stuart	Distinguished Service
1970	Trigg Twichell	Distinguished Service
1971	Arlington D. Ash	Meritorious Service
1971	Kenneth R. Melin	Meritorious Service
1971	Charles Morgan	Meritorious Service
1971	Reuben C. Newcomb	Meritorious Service
1971	Stanley Lord	Distinguished Service
1971	Charles McDonald	Distinguished Service
1971	Charles L. McGuinness	Distinguished Service
1971	Roy Oltmann	Distinguished Service
1971	Harold Thomas	Distinguished Service
1972	Frank Barrick	Meritorious Service
1972	Dean B. Bogart	Meritorious Service
1972	Walter Hofmann	Meritorious Service
1972	Leslie B. Laird	Meritorious Service
1972	Edward A. Moulder	Meritorious Service
1972	Floyd F. Schrader	Meritorious Service
1972	Arvi O. Waananen	Meritorious Service
1972	Manuel A. Benson	Distinguished Service
1972	Rolland W. Carter	Distinguished Service

Year	Recipient	Award
1973	Alfred Clebsch, Jr.	Meritorious Service
1973	Joseph S. Cragwall, Jr.	Meritorious Service
1973	O. Milton Hackett	Meritorious Service
1973	Paul C. Benedict	Distinguished Service
1973	George C. Taylor	Distinguished Service
1973	Joseph E. Upson, II	Distinguished Service
1974	Joseph S. Callahan	Meritorious Service
1974	Clyde S. Conover	Meritorious Service
1974	Elliot Cushing	Meritorious Service
1974	Clayton Hardison	Meritorious Service
1974	Elwood R. Leeson	Meritorious Service
1974	Rex Meyer	Meritorious Service
1974	Saul Rantz	Meritorious Service
1974	Jacob Rubin	Meritorious Service
1974	Francis T. Schaefer	Meritorious Service
1974	Stanley W. Lohman	Distinguished Service
1974	Thomas Maddock, Jr.	Distinguished Service
1975	Thomas J. Buchanan	Meritorious Service
1975	Edith B. Chase	Meritorious Service
1975	Philip Cohen	Meritorious Service
1975	George Davis	Meritorious Service
1975	Robert J. Dingman	Meritorious Service
1975	William J. Drescher	Meritorious Service
1975	John D. Hem	Meritorious Service
1975	Paul H. Jones	Meritorious Service
1975	Ruth Malone	Meritorious Service
1975	John McCall	Meritorious Service
1975	Margaret Merchant	Meritorious Service
1975	Lee R. Peterson	Meritorious Service
1975	Medford Thomson	Meritorious Service
1975	George W. Whetstone	Meritorious Service
1975	Leonard Wood	Meritorious Service
1975	Nicholas Matalas	Distinguished Service
1975	Russell Brown	Distinguished Service
1975	Harry Hulsing	Distinguished Service
1976	Warren Daniels	Meritorious Service
1976	Tyrus B. Dover	Meritorious Service
1976	Malcolm D. Hale	Meritorious Service
1976	Eric Meyer	Meritorious Service
1976	Gerald Meyer	Meritorious Service
1976	Raymond O. Abrams	Meritorious Service
1976	Russell H. Langford	Meritorious Service
1976	Clyde Conover	Distinguished Service

Year	Recipient	Award
1976	Joseph S. Cragwall, Jr.	Distinguished Service
1976	O. Milton Hackett	Distinguished Service
1976	Saul Rantz	Distinguished Service
1976	Jacob Rubin	Distinguished Service
1977	Harry H. Barnes	Meritorious Service
1977	James E. Biesecker	Meritorious Service
1977	Richard J. Janda	Meritorious Service
1977	A. Ivan Johnson	Meritorious Service
1977	Stavros Papadopulos	Meritorious Service
1977	Eugene Shuter	Meritorious Service
1978	John D. Bredehoeft	Meritorious Service
1978	George D. Debuchananne	Meritorious Service
1978	Edwin E. Harris	Meritorious Service
1978	Charles Mongan	Meritorious Service
1978	John D. Hem	Distinguished Service
1978	Edward A. Moulder	Distinguished Service
1978	Lee R. Peterson	Distinguished Service
1978	Harold A. Thomas, Jr.	Conservation Service
1979	Philip M. Brown	Meritorious Service
1979	John H. Feth	Meritorious Service
1979	Hugh H. Hudson	Meritorious Service
1979	Howard Klein	Meritorious Service
1979	Howard F. Matthai	Meritorious Service
1979	Dorothy E. Niles	Meritorious Service
1979	Franklin Olmstead	Meritorious Service
1979	Charles J. Robinove	Meritorious Service
1979	Stanley P. Sauer	Meritorious Service
1979	Keith V. Slack	Meritorious Service
1979	Winchell Smith	Meritorious Service
1979	Walter F. White, Jr.	Meritorious Service
1979	Allen G. Winslow	Meritorious Service
1979	Alfred Clebsch, Jr.	Distinguished Service
1979	Philip Cohen	Distinguished Service
1979	Elliott M. Cushing	Distinguished Service
1979	George H. Davis	Distinguished Service
1979	Henry C. Riggs	Distinguished Service
1979	William H. Robinson	Distinguished Service
1979	Victor T. Stringfield	Distinguished Service

Commitment to Equal Employment Opportunity

In 1971, William Pecora, Director of the Survey, wrote a memorandum that was distributed to all Survey employees, outlining his interest in the Survey playing an active role in the effort to interest minority individuals to pursue a career in earth sciences. The Department of the Interior and the Colorado School of Mines subsequently sponsored a National Conference on Minority Participation in Earth Science and Mineral Engineering, which was attended by several representatives of WRD. Hendricks, in a message in the WRD Bulletin, July–December 1972, noted that WRD was in a unique position to affect the situation because of having offices in every State, which permitted contacting a cross section of minority individuals. Hendricks asked for ideas from the staff to promote outreach initiatives. He noted that the Survey, being the largest single employer of earth scientists, was committed totally to alleviating the inadequacy of representation of minority groups in the earth sciences. Hendricks stated, "It is my hope that one can take advantage of WRD's size and distribution and be a leader in this program within the Survey, and as such, nationwide. Your individual efforts are the only way this can be accomplished."

In 1975, Vincent E. McKelvey, Director of the Survey, then ordered each Division to:

> "Review the results of its personnel practices with respect to women and/or minority employees, Branch by Branch, to effect such personnel actions as may be needed to rectify inequalities in grade and to prepare such new statements or orders as may be needed to reorient or improve personnel policy and procedure within the Division."

McKelvey further requested that a plan for specific action to bring about improvements be drawn up and implemented. WRD responded to this challenge and increased its EEO (Equal Employment Opportunity) commitment. This memorandum was discussed in detail in WRD at a Manpower Resources Committee Meeting. Based on this meeting, Cragwall, in WRD Memorandum 76.19, August 18, 1975, stated that the following actions were to be accomplished Divisionwide. Supervisors were urged to meet with all employees on career development and to work specifically with all women and minority employees (GS–1 to GS–15) to prepare Individual Development Plans. Form 9–1688, Career Objectives and Training, was to be used for this purpose. Particular attention was to be given to training and education to ensure that existing skills were used effectively. Employees were to be provided opportunities for transfers or reassignments to other Survey offices that could make better use of presently unused skills. Serious thought was to be given to the charge that women and minorities were not really encouraged to seek training and that training was not readily available to these groups. Consideration was to be given to meaningful assignments and details, formal training, and other rotation of duties to build competence and provide candidates for promotion on a Survey-wide basis. Costs to implement the program, to include advanced training, were to be borne by the District or Project Office.

It was McKelvey's intent to ensure that by the end of calendar year 1975 there was no inequality in grading among employees of the Survey based on present merit and performance and that there was full opportunity for training.

As followup on WRD Memorandum 76.19, on February 23, 1976, WRD Memorandum 76.92 was issued. During the interim, the Manpower Resources Committee was assigned the task of designing a new career development package for use by all permanent full-time WRD employees. It was complete with the issuance of Memorandum 76.92. The package next was computerized with Regional access and input to the file for continual update. The purpose was to give all participating employees an opportunity to express their desires as to personal career development and to provide them with information on opportunities for advancement within the Division. The plan was to be used to determine individual potential and to ensure the effective, efficient, and economical use of personnel resources. The package consisted of four parts, each with a separate set of instructions. The first two parts, *Career Development Plan* and *Appraisal of Performance,* were to be completed by all employees and their supervisors. The third part, *Personnel Management Evaluation Data,* was to be completed by technical professionals and their supervisors. The fourth part, *Assessment of Management and Supervisory Potential,* was to be completed by the supervisors of all employees in grades GS–12 and above. Career Development Plan changes were to be made at any time, but March and April were designated as the time for the general update of the Manpower Career Development System data base.

EPILOGUE

The following contributions, by Thad G. McLaughlin and Joseph S. Cragwall, Jr., summarize some of the key activities underway in WRD during 1966–79 and present their observations on the history of WRD during this period from a regional and national perspective.

OBSERVATIONS ON THE HISTORY OF THE WATER RESOURCES DIVISION, 1966–79

by Thad G. McLaughlin

The Water Resources Division (WRD) continuously has undergone change—in organization, in objectives, in programs, and in staff. But no changes in my memory approach the magnitude of those made during the period of this history. The changes were long overdue, for we had "grown like Topsy" with a loosely knit organization that fostered rivalry between Branches as well as confusion among our State and local cooperators. We had three WRD Branches (Surface Water [SW], Ground Water [GW], and Quality of Water [QW]) negotiating with some State agencies, resulting in competition for State matching funds, frequent rivalry, and occasional animosity. The WRD was not unique in this respect; in fact, the USGS itself always has been rather loosely organized. For example, when Interior Secretary Rogers Morton once had temporary headquarters at the Denver Federal Center (DFC), each Interior Bureau was asked to supply the names of the **key** personnel in each Bureau for possible contact by the Secretary's Office. Most Bureaus supplied one or two names; the USGS supplied more than 35—and that was after the WRD had been reorganized!

The move to a better organizational structure resulted from a desire on the part of the Chief Hydrologist to improve our overall competence: (1) by consolidating Branch activities to facilitate a multidiscipline approach to water problems, (2) by increasing the educational and technical standards of recruits, and (3) by expanding our research efforts. I was Regional Hydrologist for the Rocky Mountain Region (RMR) from February 1967 until June 1972, and was then Assistant Director for the Central Region (CR) until I retired in December 1975; hence, I am very familiar with the first 6.5 years of this history, a little familiar with the next 3.5, and largely ignorant of the remainder. In addition, 21 years have passed since I left the WRD, and my memory "ain't what it used to be!" The following sections deal with my memory of several of the more significant facets of this period of WRD history.

National Training Center

My first request of the Chief Hydrologist, when he told me of my selection as Regional Hydrologist, was for the transfer of Ivan Johnson to the Regional Office to establish a training center to service what was then the 12-State Rocky Mountain Region. Ivan had been conducting ad hoc training sessions in the Ground Water Branch (GWB) Hydrologic Laboratory at the Denver Federal Center (DFC) for many years. A large number of the foreign participants who were sent to USGS at the DFC were directed to Ivan's laboratory to observe laboratory and field procedures, and it soon became apparent that many of them had not received adequate technical and educational training in their home countries, most of which were third-world nations. Almost singlehandedly—with inadequate space and facilities, with little or no extra funding, and with less than enthusiastic support from higher officials—Johnson supplied additional training for scores of foreigner participants. The first sessions involved basic sciences and laboratory procedures and techniques, much of which he taught. After a while, Johnson began to coax, beg, and coerce professionals from all parts of WRD to lecture at his training courses. The curriculum then was expanded gradually to include most of the principal hydrologic disciplines. Ivan Johnson went far beyond the call of duty to supervise, assist, monitor, and counsel the trainees and, with the outstanding cooperation of his wife Betty, the trainees were taken on field trips and on picnics and all of them were entertained frequently in the Johnson home.

After the transfer of the Training Center to the Regional Office, its utilization by the Rocky Mountain Region Districts developed rapidly. Other WRD Regional Offices sought to establish their own training centers, but unfortunately (or perhaps it was fortunate!), there was only one Ivan Johnson! The Denver facility served the entire RMR, and it soon became the Division Training Center. At about the time I joined the Director's staff, additional space became available in Building 53 (DFC). There was intense competition for the space by other Federal agencies and even by other Divisions of USGS. With the strong support of Associate Director Radlinski, funds were allocated to WRD for extensive remodeling of Building 53 to accommodate an expanded training center. As the Division Training Center had been so successful, we were able to convince the Director that he should establish, in the new space, a National Training Center to accommodate all Divisions but to be operated by WRD. The move to the new quarters was made under the supervision of Delbert Brown after Ivan had transferred to National Headquarters.

District Reviews

Another change during this period was the establishment of multidiscipline reviews of District operations. The Surface Water Branch (SWB) had for many years been reviewing streamflow records and techniques in the SW Branch Districts, and one or two Branch Area Chiefs in the Ground Water Branch (GWB) had been making detailed analyses of the Ground Water Branch GWB operations and projects in their respective Districts. As one of his many responsibilities, Hugh Hudson had been handling the SW reviews for our Regional Office. After John Moore joined our staff, we began periodic combined reviews of SW and GW disciplines in our Districts, and Hugh and John conducted the reviews. The QW discipline was added later when Arthur Beetem joined the staff. A much-improved method of review was begun by Al Clebsch when he became Regional Hydrologist. District staffs were brought to Denver for program review by the entire Regional staff.

Administrative Services Section

Administrative services in the RMR had traditionally been handled separately by each Branch District. The WRD administrative units at DFC were consolidated into an Administrative Services Section in the early 1960's, with Howard Boyden in charge and with overall supervision by the Water Resources Council. The Administrative Services Section was moved to the Regional Office in 1967 and has been under the supervision of the Regional Hydrologist since then. Its services were expanded considerably during the latter part of this period to give more assistance to the District and Project Offices.

Research Projects

Before reorganization, the WRD Branches had very small research programs, most of which were carried on by a few brilliant individuals such as Horton, Langbein, and Harbeck in SW, and Theis, Jacob, and Skibitzke in GW. The funds for research were so small that O.E. Meinzer once told his staff that almost all the research of GWB was surreptitious! The WRD research program increased markedly during the period of this history, due largely to the earlier efforts of Chief Hydrologist Luna Leopold and the continued actions of his successor, Roy Hendricks. Research projects require very long-term efforts; hence, the results of our expanded research program were not significantly evident to me while I was Regional Hydrologist. For awhile, administrative responsibility for research was given to the Regional Offices, while technical supervision remained at National Headquarters. Full responsibility later was moved to the Regional Offices, and Robert Stallman joined our staff as Regional Research Hydrologist to direct this effort in the RMR.

One of the most significant research developments preceding this period was Herbert Skibitzke's development of analog models to analyze the effects of withdrawing water from an aquifer. Before models became available, it was not possible to analyze the effects of withdrawals from more than a very few wells at a time—and then only after a prodigious number of calculations. Skibitzke's models solved that problem, and the GWB soon established an Analog Model Unit at Phoenix, Ariz., to build the models so that Herb could devote his time to research. For some time, however, the models were scarcely used by the Districts because of poor communications between the Districts and the Analog Model Unit. To break the logjam, Stallman was sent to the Texas District to instruct them on the compilation of their Houston-area data in proper format to permit construction of a model. Eugene Patton was placed in charge of the Analog Model Unit, and the resulting Houston model was a significant tool in predicting the effects of withdrawing large quantities of water for the NASA Space Center, which was being built near Houston. Analog models soon became major tools in analyzing aquifer systems throughout the country. Computers were not yet powerful enough to handle such analyses, but it took only a few years to develop ones with adequate capacity. John Moore, who had supervised the construction of a large analog model of the Arkansas Valley in Colorado, became responsible for modeling activities in the RMR.

Problems of Reorganization

The reorganization of WRD was almost complete when I became Regional Hydrologist—only Oklahoma and Colorado remained unchanged. The results of consolidating Branch Offices in every State, however, affected our operations for many years. Each District had two or three District Chiefs (DC) who were sometimes rivals. No more than one, however, could be appointed to head the consolidated WRD District Office. This meant that at least one and sometimes all three DC's were bypassed, thus causing major disappointments. The reorganization left a large number of administrators but a greatly reduced number of offices to administer! Each of these DC's was highly qualified, but few had the type of training and experience needed for the expanded research programs that WRD planned to staff primarily with Ph.D's. Most job openings were within District operations and, hence, were at grade levels below those of the former DC's.

The problem was "solved" by moving most of the former DC's to the Regional Offices or to projects under Regional Office supervision. There were at least eight such assignments to RMR/Central Region during this period. This was very difficult for all concerned. Those on the staff of the Regional Office when I became Regional Hydrologist were highly competent professionals who had been selected carefully because their background and training made them uniquely qualified for the positions they filled. I am sure that it was difficult for them, as well as for the DC's, when Regional Office positions were filled by DC's who were highly competent professionals but who now were placed in positions in which their talents generally were not properly or fully utilized. Many of the DC's were not too happy about moving to Regional Headquarters, as they generally had established "roots" at District Headquarters and most already had transferred several times at WRD's request.

Recruitment

Our method of recruiting new employees was much better after the reorganization. We developed good working relations with the principal universities, established high educational standards, and trained our District and Project Chiefs in recruitment techniques. The excellent work of Hugh Hudson and Tyrus Dover in this regard made it possible for us to hire more highly qualified people.

Cooperative Program Relations

Our relations with State and local cooperators and with other groups improved markedly during this period. The WRD traditionally had maintained close working relations with our cooperators and with their professional organizations such as the American Association of State Geologists, the Association of Western State Engineers, the National Reclamation Association, and the Colorado River Water Users Association. Our relations with these groups deteriorated rapidly in the late 1950's and early 1960's, with the result that we had a great many unhappy cooperators! Roy Hendricks' first instruction to me when I became Regional Hydrologist was to make a special effort to improve those relations. All the Regional staffs made that effort with, I believe, good results.

A POSTSCRIPT ON THE YEARS 1966–79 IN WRD

by Joseph S. Cragwall, Jr.

O.M. (Milt) Hackett and Thad G. McLaughlin have excellently highlighted the years of this volume of WRD history with their perspectives from national and Regional Headquarters. I shall add my impressions and recollections on a few specific areas that might be of some significance in recounting WRD affairs of those years.

Volume VI of WRD history characterized the Leopold years that ended in mid-1966 as "years of change." Because of marked changes in program mission and organizational structure within the Division, the Hendricks-Cragwall years that followed not only gave highest attention to implementing Leopold's actions, but encountered equally significant changes in Federal policies, legislation, and national issues that affected what USGS and WRD did and how we did it.

These years placed the Division under four Presidents, two of each political party, each determined to render more and better public service with less Federal government resources. There were five Secretaries of the Interior, each with new groups of assistants with new priorities for their Bureau programs, and three USGS Directors with varying program objectives. Increasing numbers of advisory and coordination committees also greatly influenced program direction and content. Even Mother Nature with her earthquakes, volcanic disturbances, floods, and droughts imposed additional and changing demands.

Basic programs and projects of information gathering, analysis, and interpretation of surface- and ground-water resources, including increasing attention to water quality and environmental impacts, dominated the field programs. Research activities became largely concentrated at the regional centers and increasingly focused on topics in support of major WRD thrusts that were responding to national water-involved issues. Administration and management attention increasingly had to be concerned with communicating program resource needs, coordination within the Federal family, cooperation with our non-Federal colleagues, collaboration with the Federal water and environmental agencies who either wanted more services from us or less involvement of us in "their business," and faster information service, preferably computer-delivered. The observations that follow are selective examples of my perceptions and personal preoccupations, all somewhat clouded by dimmed memory of three decades past.

Water Resources Planning

The WRD became much involved in the work of the Water Resources Council (WRC), which had been established to organize and lead national water-resources planning, structured on a river-basin framework and based upon assessment of continuing national water situations. WRD became directly involved in WRC efforts in three primary areas: delineating a national river-basin framework, designing and operating a national water-use data system, and supplying quantitative ground-water information at regional, river-basin scale. The Federal interagency committees of Hydrology and Sedimentation also had been assigned to the Council, and WRD continued its active involvement with those committees as principal representative of the Department of the Interior.

The Office of Water Data Coordination (OWDC) worked actively with the WRC and member agencies to define the river-basin planning framework and later adopted that framework with further subdivisions as its basis for cataloging water-data collection activities of all Federal and many State agencies.

The WRD had assembled available water-use data at 5-year intervals since 1950, but the information, gleaned from thither and yon mainly by WRD Districts, was ragged and of questionable reliability at best. The WRC pressed for the design of a continuing data-collection system structured to the river-basin framework, but contractual efforts failed to produce a workable, cost-effective design. It fell to WRD to build upon its existing program. With increased Federal-State cooperative funding finally becoming available late in this period, a systematic water-use data program came into being.

Early in the WRC's efforts to format national water-resources assessments at regional river-basin scale, deficiencies in quantified ground-water information were evident. While in the Program Office in DOI, I pressed for USGS funding to prepare for a series of river-basin, ground-water summaries. With a well-prepared proposal from WRD and with Departmental support in the budget-justification process, Federal multiyear funding was obtained, and a Professional Paper series of river-basin studies was near completion by the late 1970's. This effort highlighted shortcomings in WRD's available information to adequately assess ground-water quantities, quality, and use impacts at a regional scale. With the help of the widespread 1977 drought and the Congressional appropriation committees, a multiyear, multi-million-dollar program of regional aquifer-systems analysis (RASA) was launched in 1979 and has proceeded to virtual completion at this writing (1994).

The foregoing WRD activities for the WRC were of high priority to the Council and its member agencies. For regional assessment and planning, the conceptual model involved defining a water balance in each major river basin—how much water it had available, how much it used, how much flowed out of or was exported from it, what were its future water needs, and what would be the major effects resulting from meeting those needs. Complicating this model was the growing national insistence to include water-quality assessment and management in the model.

Water Quality Assessment and Management

Along with clean water legislation, the creation of the U.S. Environmental Protection Agency (USEPA), and sizable Federal funding grants to construct pollution-abatement works came recognition of the need to improve the national data base of water-quality information. Early in the period, WRD proposed, justified, and received Federal funding to establish a national network of water-quality stations (labeled NASQAN for National Stream Quality Assessment Network). Its purpose was to provide a basic level of information to assess, spatially and temporally, water-quality conditions and trends. This network was established and modestly enlarged through the period, but we did not reach the intensity of coverage we would have liked during this period. That was to come later.

In addition to this network of point data, OWDC's non-Federal advisory committee urged WRD to conduct a series of stream-quality assessment studies to develop methodology for characterizing water-quality conditions and cause/effect relations throughout a stream system. The WRD obtained some limited Federal funding and conducted studies in a few selected basins, as summarized by Hackett, thus gaining valuable "how to" experience and demonstrating WRD's professional competence to undertake such investigations. These demonstration studies extended into the 1980's, and very likely helped justify funding for WRD's NAWQA program, a much-enlarged national effort that was to follow.

In addition to these Federal activities, water-quality programs grew immensely at the District level, and requests mounted in the Cooperative Program for water-quality data and investigations. Likewise, research emphasis responded to water-quality needs. Support activities had to be stepped up with program growth—laboratory facilities and equipment, recruitment and training of personnel for the new tasks, reallocation of personnel resources among Districts, and computer applications to laboratory analysis and data processing. WRD programs did respond, indeed, to the national focus on water quality.

Underground Waste Storage

Along with the Nation's determination to clean up surface waters with laws and regulations to enforce cleanup came a growing interest in the possibilities for storing wastes underground. The underground storage alternative already was being used by industry and government for disposal of radioactive and other toxic wastes, and the tendency to resort to the "out of sight, out of mind" alternatives blossomed throughout industry and government. State pollution-control agencies were faced with increasing numbers of permitting/licensing decisions to emplace all kinds of wastes underground, ranging from municipal landfills for household wastes to deep-well injections of long-lived toxics. Naturally, the WRD, through its Cooperative Program and because of its competence in hydrogeology, was approached through many Districts to conduct site studies that would provide information for such public decisions. Hendricks, as Chief Hydrologist, was insistent that WRD maintain its fact-finding role and not be drawn into advocacy positions in the decision-making process. This policy was reinforced by the Survey and reiterated later many times by Director McKelvey, as we were increasingly involved in the environmental assessment/impact process. WRD was quite successful in walking the tightrope of objective neutrality in virtually all such projects and in extricating itself from embroilment in those other few situations (some involving DOI decisions). The early disposal-site studies were good training for our hydrologists, who later had to work on interagency and bureau-level environmental impact assessments.

Floods and Droughts

As in any other comparable period of WRD history, we experienced a number of record-breaking hydrologic events. Especially noteworthy were the floods resulting from Hurricanes Camille in 1969 and Agnes in 1972, across the middle Atlantic area of the Eastern United States, and several others elsewhere. These events stressed not only WRD personnel, but also fiscal resources to adequately document them. With the ensuing Federal involvement in flood-plain management, however, these events drew WRD into a multiyear program of flood-plain mapping throughout most of this period.

By 1977, record-breaking drought conditions extended across most of the United States. Documentation of this occurrence again demanded many personnel and fiscal resources. Water managers learned the value of drawing upon supplemental ground-water sources as a valuable adjunct in areas of short surface-water supplies. Largely because of this drought, the WRD was invited to propose for Federal funding the RASA program referred to earlier. Drought management also reinforced the need for the national water-use program getting underway in 1977.

Thus, floods and droughts of the 1966–79 period had a significant impact on WRD's resource management and even greater influence on program content and change.

The Energy Crisis

The infamous and noteworthy oil crisis of 1974 got everyone's attention when the price of gasoline tripled in a few months and all too often meant waiting in line for quite some time to "fill up" at the high price. The crisis led to creation of the cabinet-level Department of Energy. The Survey and WRD quickly became involved in new and expanded programs, largely associated with alternative energy sources for the United States—coal, hydropower, nuclear, and geothermal. But the crisis also drew upon the Survey for updated oil and gas reserves assessment, Alaska oil development, and another look at western oil-shale development (evaluated as not economically feasible in 1966–68). The Survey was called upon for stepped-up energy-resources surveys and became even more heavily involved in environmental impact assessments required for virtually all energy-development proposals.

The WRD was called upon to assist in most of the energy-source areas. A coal hydrology program was developed and conducted throughout the remainder of the period to assist with water problems associated with new coal development, especially in the Western States having low-sulphur coal (a new environmental consideration). Included was a major regional ground-water-resources assessment of the Madison Formation in Wyoming, a target for development between competing coal and agriculture interests. (The Madison study became a useful learning experience for the later oncoming RASA program).

The WRD also was involved, as it had been for some time, in all facets of radiohydrology in support of nuclear-energy development, but by now predominantly in nuclear-waste disposal, which was (and still is) the principal deterrent to an expanding nuclear energy industry. We also participated to a limited extent in the Survey's geothermal resources investigations. We took another look at water for and impacts from oil-shale development in Colorado. And, we were heavily involved through the mid-1970's in collecting and supplying water information needed for the design and construction of the Trans-Alaska pipe line. We also participated in environmental impact assessments of that project. And finally, WRD participated and provided support to President Carter's Water Policy Committee through Tom Buchanan. (As I recall, President Carter was looking at existing water projects [major reservoirs] for enhanced hydropower production and water supply.)

The energy crisis of 1974 wrought many changes in our country. The USGS and WRD benefited from the opportunities afforded to assist the Nation through the crisis. We learned how sensitive resource assessment can be in the world of domestic and international politics and how essential energy resources are to the well-being of the United States. We even got a little payback from Arabian oil profits of the mid-1970's. Saudi Arabia used some of its wealth to procure technical assistance from U.S. agencies for resources-development planning beginning about 1979. The USGS and WRD shared in that program.

Administrative and Management Issues

In returning to WRD from DOI in 1968 to serve as Assistant Chief Hydrologist, I soon became involved in designing and building a computer-based management-information system. With the efforts of several work groups, we developed a system with a number of component parts and phased these modules in over a period of years, concentrating at first on program/project/budgeting and personnel/career-development subsystems.

Following WRD reorganization of the mid-1960's, much attention was given to recruitment and career development. These efforts were led from Headquarters by Ray Abrams and staff of the Manpower Section. A nationwide recruitment program, spearheaded by a committee of regional representatives and based on demanding minimum qualification standards for hydrologists, was highly successful for several years until personnel ceilings constrained the all-out effort. Thad McLaughlin has summarized elsewhere the work of the Denver Training Center, where several levels of training were instituted and the operation became a full-time effort. Along with the in-house training, the Division supported a sizable contingent of career personnel annually for university-based graduate-level schooling, yielding a significant number of Master and Ph.D. degree awards and a resource pool of well-qualified candidates for higher level research and management positions. From 1969 onward, WRD sponsored its top-level supervisors for executive training at the then newly established Federal Executive Institute at Charlottesville, Va. (I was the first to attend and was so convinced of its value to Survey and Division leadership that one or more of our people have been sponsored annually ever since 1969).

I like to refer to the years 1966–79 as the years of the "CCC," meaning Coordination, Cooperation, and Collaboration. The Office of Water Data Coordination (OWDC) got us off to a good start with its Federal and non-Federal advisory committees. These groups served all three C's with participation of most "Who's Who" in the water business. Other coordination efforts and groups became so prevalent during the periods that many of us, it seemed, had little time for anything else. We had Survey-level coordination committees with the National Oceanic and Atmospheric Administration, the Soil Conservation Service, the Bureau of Land Management, the Association of State Geologists, the U.S. Environmental Protection Agency (later on), and probably others, on all of which WRD participated. In addition to its OWDC committees, WRD had its "C" groups, such as the National Weather Service, the U.S. Army Corps of Engineers, the Western State Engineers, the Interstate Conference on Water Problems, and the Hydrology and Sedimentation committees of WRC, and, at field level of course, the three "C's" were a way of life in WRD Districts. That WRD continued (and continues) its "C" responsibilities with success is attested to by its fiscal support from others who supply two-thirds of its program funding, year in and year out.

A Postscript to the Postscript

Looking back on the years 1966–79, I can say with certainty that we all kept busy. Budget justification converged to a process of keeping the funding we had. Personnel controls become a matter of resource allocation as critical as funding. We did respond to national needs and issues, some with added funding, some by reprogramming. We did achieve full conversion to a Division-line organization, staffed with personnel eager to do hydrology across the hydrologic system. We maintained a strong cooperative program supportive of enlarged efforts in water quality, water-use data, energy resources, and environmental concerns.

There were disappointments. Funding for growth in our core research program was not provided. We had to be content with allocations for research from funded thrust programs. We failed to convince the hierarchy of budget makers of our perceived need of new program starts in urban hydrology, subsurface waste storage, and other emerging needs for water research.

My most satisfying memories of the period were of the opportunities to work and associate with people in the U.S. Geological Survey, at Headquarters and in the field, and with the outside community of water and earth science professionals. My visit to the WRD Districts and many of the field offices during the period convinced me more than ever that we all worked for the best organization in the public service, and that we, and those who served ahead of us, made it that way. Those who follow will keep it so.

Significant Legislation Affecting Water Resources Division

Significant legislative initiatives occurred during the 1966–79 time period. The legislation that primarily affected WRD involved key changes in response to environmental concerns and issues. This section presents an overview of the significant legislation in terms of effects on WRD.

Public Law 90–542, the Wild and Scenic Rivers Act, was passed in October 1968. This legislation declared that a policy of building Federal dams and other public works on rivers needed to be balanced by a policy of preserving and protecting other rivers in their free-flowing condition so that they and their immediate environment might be enjoyed by present and future generations. The act provided for "instant" and "study" rivers; instant rivers were those included in the Wild and Scenic Rivers System, and the study rivers were those on which there was a moratorium on development until 1978, pending studies to be made to decide their eligibility and desirability for inclusion in the National Wild and Scenic Rivers System.

Public Law 90–515, National Water Commission Act, was signed on September 26, 1968. This act established a seven-person Commission with the mission to conduct a comprehensive review of national water-resource problems and programs and report to the Congress and the President within 5 years. The Commission was intended to take a long-range overall view of national water-resources management, planning, and policies but not to take positions on specific water-project proposals. The Commission was viewed as complementary to that of the Water Resources Council. It was authorized to use the services of Federal water-resource agencies, and Federal Departments and agencies were authorized to furnish needed information and temporary duty personnel. The act authorized 5 million dollars to be appropriated to finance the work; $150,000 was appropriated for FY 1969.

Public Law 91–190, National Environmental Policy Act of 1969, was signed on January 1, 1970, as U.S. Code Title 42, Section 4321. This act had a significant effect on WRD operations. It required all Federal agencies proposing legislation or other major Federal actions significantly affecting the quality of the environment to prepare a detailed statement for review explaining the effect on the environment of the proposed action. Executive Order 11514 and Departmental Manual Release 516 DM 103 delineated responsibilities for handling these environmental statements.

Departmental Manual Release 1222, "Environmental Quality," Part 516.3.50 stated: "Review comments on environmental statements provided by bureaus and offices directly to other Federal agencies are considered informal and are only for the purpose of providing technical assistance to the requesting agency. Official agency comments from the Department of the Interior, as called for in Section 8 of Interim Guidelines of the Council on Environmental Quality, will be transmitted by the Office of Policy Planning and Research." At this time, WRD and other Departmental field units were receiving requests to comment on preliminary drafts of environmental statements received directly from other Federal agencies. Departmental Release 1222 noted that this was an appropriate role for field units. WRD generally became involved in these environmental statements only in a review function. George H. Davis was designated on January 21, 1971, as the Division's coordinator at Headquarters for environmental statements, and Isabel Picken was designated as his alternate.

Public Law 92–500, Federal Water Pollution Control Act Amendments of 1972, was signed on October 18, 1972, as U.S. Code Title 33, Section 1251. Section "208" addressed planning studies, and Section "404" addressed dredge or fill permits, and so forth. This 89-page act was complex and required 36 sessions of conferences to work out basic Senate and House differences. WRD felt that the potential impact on water-quality programs could be profound, although the explicit language did not directly modify either the USGS authorization or responsibility. The implied potential stemmed from the enormous amount of water-quality data and associated environmental information that must be obtained before the objectives of the law could be achieved. Section 305, for example, specified a series of annual reports on the water quality of navigable waters to be required of each State and for the Nation. While the U.S. Environmental Protection Agency and the States were responsible for the administration of the act, the intent of the Congress was that the USGS be an important source of scientific information. In the Conference Committee Report, the Survey was added to the agencies to be used in conducting surveillance of water quality. Section 515(b)(4) of the act required the newly established Effluent Standards and Water Quality Information Advisory Committee to ". . . avail itself of the technical and scientific services of any Federal agency, including the United States Geological Survey, and any national environmental laboratories which may be established." Because of this legislation, the Survey began to direct greater attention to the problem of water-quality degradation resulting from urban runoff. The legislation served as an impetus for WRD's program in the area of hydrology of urban and suburban environments.

Public Law 92–583, Coastal Zone Management Act of 1972, October 27, 1972, U.S. Code Title 16, Section 1451. This act established a national policy and program for the management, beneficial use, protection, and development of the land and water resources of the Nation's coastal zones, among other purposes. Public Law 92–583 provided for a comprehensive, long-range, and coordinated national program in marine science. "Coastal zone" means the coastal waters and adjacent shorelands, strongly influenced by each other and in proximity to the shorelines of the several coastal States, and included transitional and intertidal areas, salt marshes, wetlands, and beaches.

Public Law 93–234, Flood Insurance Act of 1973. This act made flood insurance virtually mandatory for all structures in a flood plain. The magnitude and scope of the studies necessary to implement the legislation was immense, and the USGS role was not definite. Personnel limitations were such that it was certain that work for HUD's Flood Insurance Act would decrease nationally rather than grow.

Public Law 93–288, Disaster Relief Act of 1974, May 22, 1974, U.S. Code Title 42, Section 3231. Because disasters often cause loss of life, human suffering, loss of income, and property loss and damage, can disrupt the normal functioning of governments and communities, and do adversely affect individuals and families with great severity, this legislation allowed Congress to design special measures to assist and aid the States' efforts to reconstruct and rehabilitate the devastated areas. This act provided an orderly and continuing means of assistance by the Federal Government to State and local governments during disasters. Such support includes relief programs, disaster preparedness, and providing Federal assistance programs for both public loss and private losses sustained from disasters. Federal support also provides for a long-range economic recovery program.

Public Law 93–378, Forest and Rangeland Renewable Planning Act of 1974, August 17, 1974, U.S. Code Title 16, Section 1601. This act was amended to provide for the Forest Service, U.S. Department of Agriculture, to protect, develop, and enhance the productivity and other values of certain of the Nation's lands and resources, among other purposes.

Public Law 93–523, Safe Drinking Water Act, December 16, 1974, U.S. Code Title 42, Section 300f. The general features of this act were significant relating to: (1) contaminants in water supplies, both raw water and water delivered to the users; (2) geohydrologic aspects of waste disposal on the surface and underground; and (3) underground injection of fluids in connection with oil and gas production. The act gave the U.S. Environmental Protection Agency regulatory authority for the first time over public water supplies not used in interstate commerce and authority to require specific treatment technology for individual contaminants. The act did not result in the need to revise WRD policy but did cause a brief review of pertinent aspects of policy. It was decided that it was within the mission of WRD to make periodic assessments of the quality of the water used for public drinking-water supplies, including treated or distributed water, if a comparison of raw water with tap water was included in the study design. However, it was not considered appropriate for WRD personnel to engage in routine monitoring of drinking-water supplies for compliance with Federal or State regulations. Similarly, general areal studies or evaluations of existing data to define the effects of proposed waste-management alternatives on a stream or an aquifer were considered to be appropriate activities for WRD, but WRD was to avoid gathering specific site information for the purpose of supporting or evaluating individual waste disposal or deep-well injection operations unless the study was of a research nature and would have transfer value.

Public Law 93–579, The Privacy Act, September 27, 1975. The basic purpose of the act was to protect the individual against an invasion of personal privacy. This is done by requiring Federal agencies to permit each individual to learn about the records that are collected, maintained, used, or disseminated by the agency. Records gathered for one purpose cannot be used for another purpose without the consent of the person involved. Individuals may gain access to information about them in Federal agency record systems, obtain copies of all such information, and make corrections or amendments to these records if they so desire. All Federal agencies must make known to individuals the records of a personal nature that are being collected or maintained.

Public Law 94–168, Metric Conversion Act of 1975, December 23, 1975, U.S. Code Title 15, Section 205a. This act declared a national policy to coordinate the increased use of the metric system in the United States and established a United States Metric Board to coordinate the voluntary conversion to the metric system.

Public Law 94–370, Coastal Zone Management Act Amendments of 1976, July 26, 1976, U.S. Code Title 16, Section 1456a. The purpose of this act is to improve the coastal-zone management in the United States. The Coastal Zone Management Act will permit land uses and water uses within the coastal zone that have a direct and significant impact on the coastal waters. The legislation states that, "the national objective of attaining a greater degree of energy self-sufficiency would be advanced by providing Federal financial assistance to meet State and local needs resulting from new or expanded energy activities in or affecting the coastal zone."

Public Law 95–190, Safe Drinking Water Amendments of 1977, November 16, 1977, U.S. Code Title 42, Section 300j. This Act amended "Section 2 of the Safe Drinking Water Act (Public Law 93-523) to extend and increase the authorizations provided for public water systems.

Public Law 95–192, Soil and Water Conservation Act of 1977, November 18, 1977, U.S. Code Title 16, Section 2001. This act provided for furthering the conservation, protection, and enhancement of the Nations's soil, water, and related resources for sustained use, and for other purposes. "In order to further the conservation of soil, water, and related resources, it is declared to be the policy of the United States and purpose of this Act that the conduct of programs administered by the Secretary of Agriculture for the conservation of such resources shall be responsive to the long-term needs of the Nation, as determined under the provisions of this Act."

Public Law 95–217, Clean Water Act of 1977, December 27, 1977, U.S. Code Title 33, Section 466. This act amended the Federal Water Pollution Control Act to provide for additional authorizations. It served to improve coordination of efforts to reduce and eliminate pollution in concert with the program for managing water resources. Section 201 of the Federal Water Pollution Control Act was amended, by adding this new paragraph:

> The Administrator shall not make grants from funds authorized for any Fiscal Year beginning after September 30, 1978, to any State, municipality, or intermunicipal or interstate agency for the erection, building, acquisition, alteration, remodeling, improvement, or extension of treatment works unless the grant applicant has satisfactorily demonstrated to the Administrator that innovative and alterative waste-water treatment processes and techniques which provide for the reclaiming and reuse of water, otherwise eliminate the discharge of pollutants, and utilize recycling techniques, land treatment, new or improved methods of waste treatment management for municipal and industrial waste (discharge into municipal systems) and the confined disposal of pollutants, so that pollutants will not migrate to cause water or other environmental pollution, have been fully studied and evaluated by the applicant taking into account section 201(d) of this Act and taking into account and allowing to the extent practicable the more efficient use of energy and resources.

Public Law 95–87, Surface Mining Control and Reclamation Act of 1977. This legislation set national policy regarding the controls of the surface effects of coal mining on the environment. It included the potential for adverse effects on water resources and the need to assess and mitigate these potential effects. Section 507(b)(11) was directed to WRD to provide hydrologic information on the general area to the mining permit applicant.

SELECTED WRD MEMORANDUMS

SELECTED WRD MEMORANDUMS

The following is a list, in chronological order, of selected significant WRD memorandums issued during the period of this history.

65.41 Authority of the Regional Hydrologists and the Branch Chiefs

67.18 Issued August 16, 1966, regarding WRD Headquarters reorganization.

67.28 Advance draft of Departmental Manual, Chapter 120.7.

67.92 Role of WRD Regions in reports processing and review.

67.101 Issued May 10, 1967. Further guidelines for reorganization of WRD.

68.43 Emphasis on adequate colleague review of reports and documents.

69.18 Authorizing establishment of National Training Center.

69.135 Issued April 3, 1969. Committee for Technical Training established.

69.136 Clarification of WRD responsibilities for training program.

72.139 Change in Regional boundaries.

73.6 Concept of Central Laboratories.

73.29 Authority for ground-water and geothermal program planning and function in Western Region (Alfred Clebsch).

73.174 Issued May 1, 1973. Movement of Hydrobiological Laboratory from St. Louis to Atlanta, Georgia.

74.147 Clebsch succeeded by Lee Dutcher in 1973.

75.15 Issued August 15, 1974. WRD research program.

76.19 Issued August 18, 1975. Career Development policy.

76.92 Issued February 23, 1976. Manpower Resources Committee to design new career development policy.

77.43 Cooperative water-use data program.

77.71 Issued March 14, 1977. WRD involvement in hydrological activities with other Federal agencies, local agencies, and international agencies.

77.121 Issued June 7, 1977. Role of Administrative Officer in WRD.

78.32 Issued January 13, 1978. Development and supply of hydrologic instrumentation facility for WRD (HIF).

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