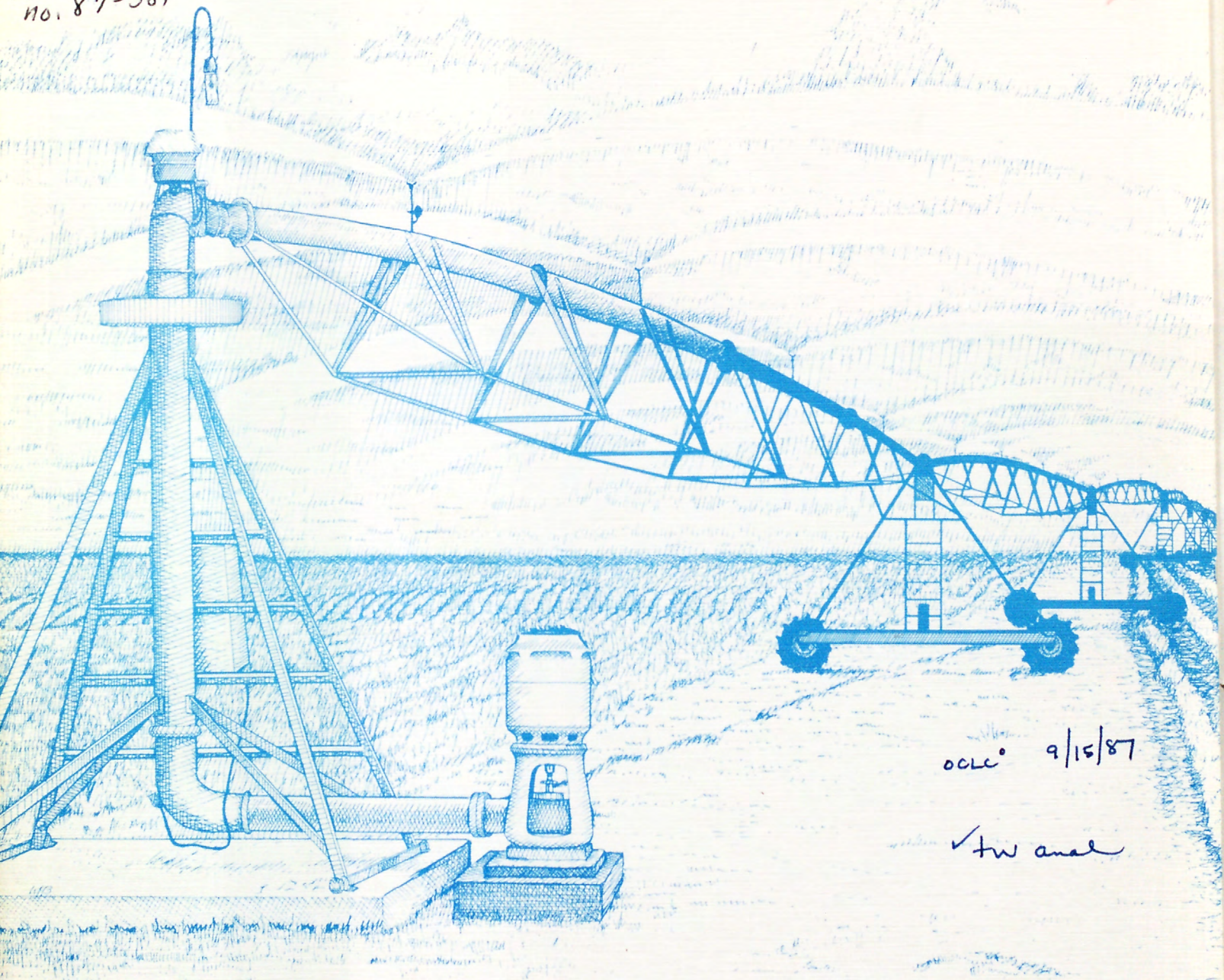

WATER RESOURCES ACTIVITIES, GEORGIA DISTRICT, 1986

U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT 87-381

United States Department of the Interior

GEOLOGICAL SURVEY
Water Resources Division
6481 Peachtree Industrial Blvd.
Suite B
Doraville, Georgia 30360
August 12, 1987

I am pleased to provide you with a copy of the report "Water Resources Activities, Georgia District, 1986." The report contains brief descriptions of water-resources projects in which the U.S. Geological Survey participates in Georgia. The report also includes a list of references that deal with the water resources of the State.

Additional or more detailed information can be obtained by contacting me at the U.S. Geological Survey, Water Resources Division, 6481-B Peachtree Industrial Blvd., Doraville, GA 30360.

Jeffrey T. Armbruster
District Chief

Enclosure

AUG 24 1987

WATER RESOURCES ACTIVITIES, GEORGIA DISTRICT, 1986

By Carolyn A. Casteel and Mary D. Ballew

U.S. GEOLOGICAL SURVEY

Open-File Report 87-381

Prepared in cooperation with the
GEORGIA DEPARTMENT of NATURAL RESOURCES
and other State, Municipal, and Federal Agencies

Doraville, Georgia

1987

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief, WRD
U.S. Geological Survey
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6481 Peachtree Industrial Boulevard
Doraville, Georgia 30360

Copies of this report can be
purchased from:

U.S. Geological Survey
Books and Open-File Reports
Federal Center, Bldg. 41
Box 25424
Denver, Colorado 80225

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WATER RESOURCES ACTIVITIES, GEORGIA DISTRICT, 1986

By Carolyn A. Casteel and Mary D. Ballew

INTRODUCTION

The U.S. Geological Survey, through its Water Resources Division, investigates the occurrence, quantity, quality, distribution, and movement of the surface and underground water that composes the Nation's water resources. The Geological Survey is the principal Federal water-data agency and, as such, collects and disseminates about 70 percent of the water data currently being used by numerous State, local, private, and other Federal agencies to develop and manage our water resources. This nationwide program, which is carried out through the Water Resources Division's District offices and Regional offices, consists of the collection of basic hydrologic data, areal resource appraisal and interpretive studies, research projects, and the analysis and dissemination of the data and results of its investigations. Much of the work is a cooperative effort in which planning and financial support are shared by State and local governments and other Federal agencies. The Geological Survey also is responsible for the coordination of specific water-data acquisition activities by other Federal agencies. Information on these activities is consolidated into a central file known as the "Catalog of Information on Water Data," which is maintained by the Geological Survey. Many State and local agencies and private organizations that have related water-data-acquisition activities also contribute information to this catalog. Indexes to the catalog are published at selected intervals.

This report contains a brief description of the water-resources investigations in Georgia in which the Geological Survey participates, and a list of selected references. Additional or more detailed information can be obtained from the District Chief, Water Resources Division, 6481 Peachtree Industrial Blvd., Suite B, Doraville, GA 30360.

Water-resources data for the 1985 water year for Georgia consists of records of stage, discharge, and water quality of streams; stage and contents of lakes and reservoirs; and ground-water levels. These data include discharge records for 108 gaging stations; stage and contents for 17 lakes and reservoirs; stage for 11 gaging stations; water quality for 4 continuous stations, 109 periodic stations, and miscellaneous sites; peak stage and discharge only for 130 crest-stage partial-record stations and 44 miscellaneous sites; and water levels of 27 observation wells. These data represent that part of the National Water Data System collected by the U.S. Geological Survey and cooperating State, local, and Federal agencies in Georgia.

Records of discharge and stage of streams, and stage and contents of lakes and reservoirs were first published in a series of U.S. Geological Survey Water-Supply Papers entitled, "Surface-Water Supply of the United States." Through September 30, 1960, these Water-Supply Papers were in an annual series and then in a 5-year series for 1961-65 and 1966-70. Records of chemical quality, water temperature, and suspended sediment were published

from 1941 to 1970 in an annual series of Water-Supply Papers entitled, "Quality of Surface Waters of the United States." Records of ground-water levels were published from 1935 to 1974 in a series of Water-Supply Papers entitled, "Ground-Water Levels in the United States." Water-Supply Papers may be consulted in the libraries of the principal cities in the United States or may be purchased from the U.S. Geological Survey, Books and Open-File Reports, Federal Center, Bldg. 41, Box 25425, Denver, CO 80225.

For water years 1961 through 1970, streamflow data were published by the Geological Survey in annual reports on a State-boundary basis. Water-quality records for water years 1964 through 1970 were similarly published either in separate reports or in conjunction with streamflow records.

Beginning with the 1971 water year, data for streamflow, water quality, and ground water are published in Survey reports on a State-boundary basis. These reports carry an indentification number consisting of the two-letter State abbreviation, the last two digits of the water year, and the volume number, for example, "U.S. Geological Survey Water-Data Report GA-82-1." These water-data reports may be purchased in paper copy or on microfiche, from the U.S. Department of Commerce, National Technical Information Service, Springfield, VA 22161.

BASIC MISSION AND PROGRAM

The mission of the Water Resources Division is to provide the hydrologic information and understanding needed for the optimum utilization 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 and non-Federal agencies, by:

- 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.

- Conducting analytical and interpretive water-resource appraisals describing the occurrence, availability, and the physical, chemical, and biological characteristics of surface and ground water.

- 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.

- Disseminating the water data and the results of these investigations and research through reports, maps, computerized information services, and other forms of public releases.

- Coordinating the activities of Federal agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and ground waters.

- Providing scientific and technical assistance in hydrologic fields to other Federal, State, and local agencies, to licensees of the Federal Energy Regulatory Commission, and to international agencies on behalf of the Department of State.

Table 1.--Agencies supporting water-resources investigations during fiscal year 1986

State Agencies

Georgia Department of Natural Resources,
    Environmental Protection Division
        Georgia Geologic Survey
        Water Quality Control Section
        Water Resources Management Branch
Georgia Department of Transportation

Local Agencies

City of Albany
    Water, Gas, and Light Commission
City of Brunswick
Consolidated Government of Columbus
City of Covington
City of Helena
City of Thomaston
City of Thomasville
City of Valdosta
Bibb County
Gwinnett County
Clayton County
    Water Authority
Macon-Bibb County
    Water and Sewerage Authority

Federal Agencies

Department of Agriculture
    Agricultural Research Service
Department of the Army
    Corps of Engineers
        Mobile District
        Savannah District
Environmental Protection Agency
Federal Energy Management Agency
Federal Power Commission Licensees
Tennessee Valley Authority
Department of Commerce
    National Weather Service (NOAA)

Streamflow

Annual runoff for the 1985 water year was well below normal throughout the State. For unregulated streams having more than 10 years of streamflow record, the ratio of the 1985 water-year runoff to long-term runoff ranged from about 0.8 at Sweetwater Creek near Austell to 0.2 at Canoochee River near Claxton. The runoff ratio for most of Georgia was about 0.6, with the exception of the southeastern part, where the ratio was close to 0.4.

Monthly mean runoff in the northern part of the State was above normal during August, near normal in February, and well below normal for the remainder of the year. In central Georgia, monthly mean runoff was near normal during February, slightly below normal in August, and well below normal for the remainder of the year. Monthly mean runoff in the southern part of the State was well above normal in September, near normal in August, and well below normal for the remainder of the year.

No significant flooding occurred in the State during the year. On most streams, 2-year recurrence-interval flows were not exceeded.

Although annual runoff was well below normal throughout the State, the only notable minimum flows occurred in the central and east-central parts of the State. Streams in these areas had minimum daily flows equivalent to 10- to 30-year recurrence intervals. Elsewhere in the State, minimum daily flows for the year ranged from less than the 2-year to the 6-year recurrence intervals.

Monthly and yearly streamflows for the 1985 water year at three representative long-term gaging stations and the average monthly and yearly streamflows for the period 1951-80 are shown in figure 1.

Water Quality

The chemical quality of surface water in Georgia during the 1985 water year was comparable to that of previous years with a few notable exceptions. This assessment is based on a comparison of mean values of selected water-quality constituents sampled during the 1985 water year versus the mean values for the respective periods of record. Fifteen waterquality sampling stations were selected for this comparison and the results are presented in table 1. Eleven of these sites are part of an 85-station cooperative network operated by the U.S. Geological Survey and the Georgia Department of Natural Resources, Environmental Protection Division. Five are part of the Geological Survey's National Stream-Quality Accounting Network (NASQAN) program, and one is part of the Geological Survey's Hydrologic Bench-Mark (HBM) program. The statistics presented in table 1 were calculated from water-quality data collected on a periodic basis (monthly for all but four sites). No continuous water-quality monitor data were used in the calculations.

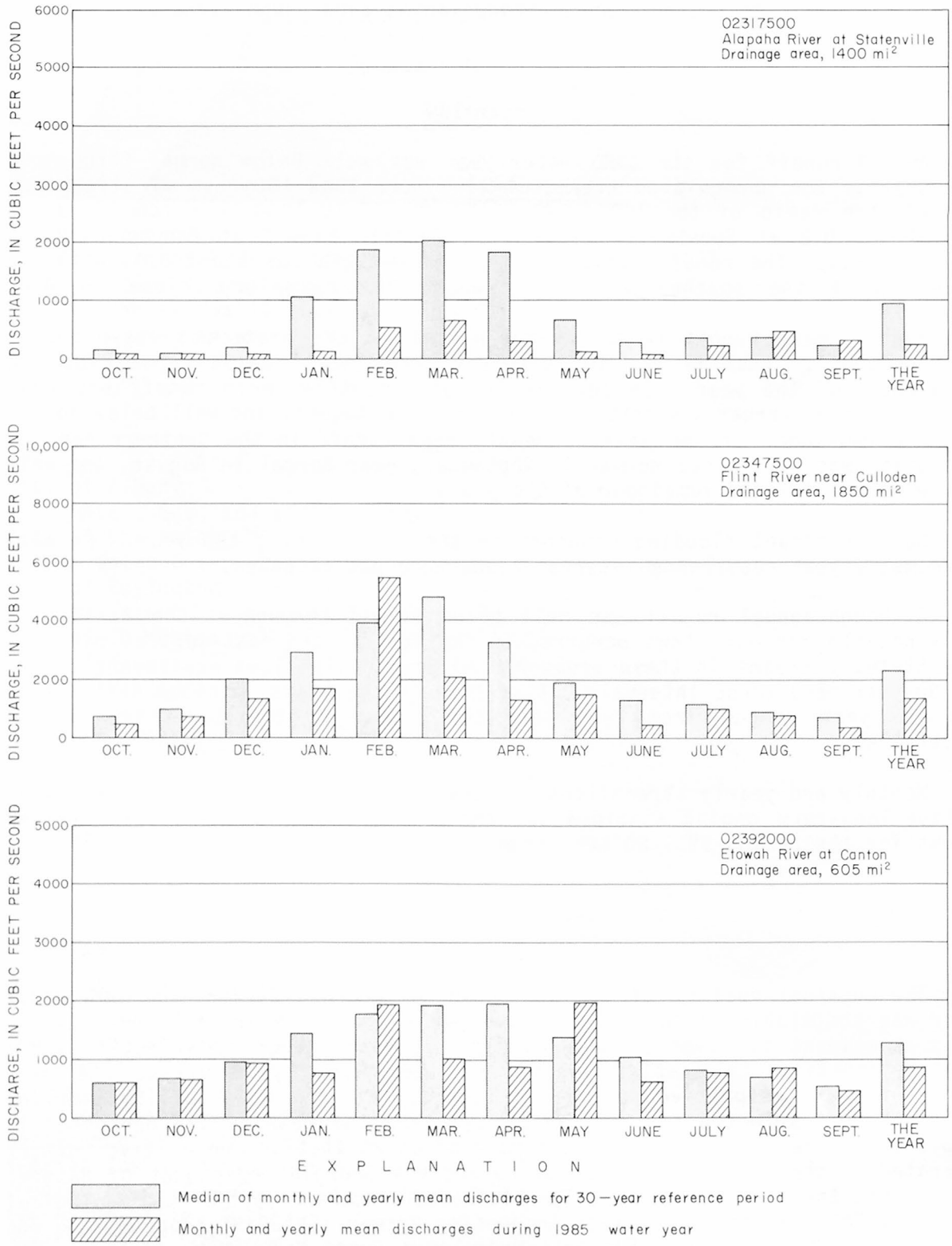


Figure 1.—Comparison of discharge at three representative long-term gaging stations during 1985 water year with median discharge for 30-year reference period.

Table 2.--Water-quality characteristics of Georgia surface water at selected periodic sampling stations

[N, number of samples; mean pH's calculated from antilogarithms; d, analysis discontinued; na, analysis not part of the station schedule]

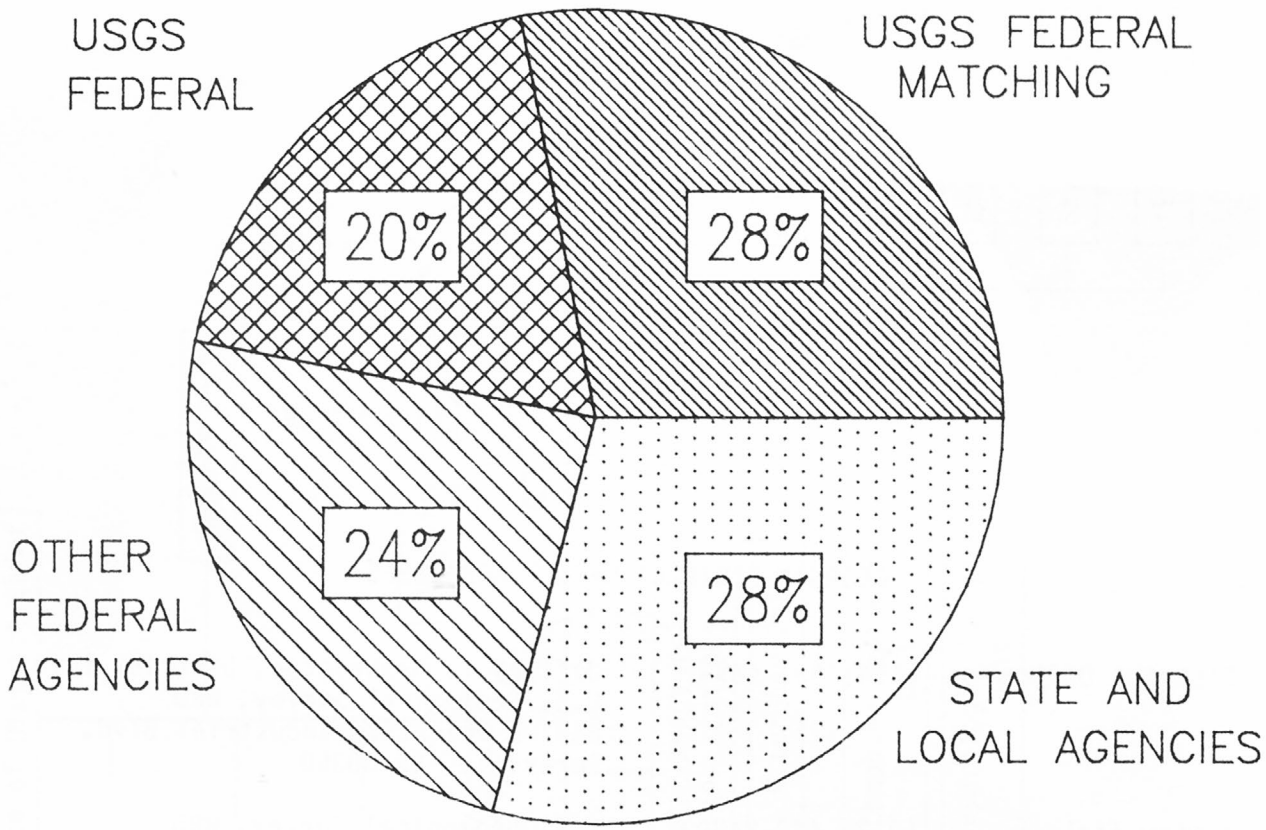
Stream and location	Downstream order number	Sample period (water years)	pH (standard units)		Specific conductance (µS/cm at 25°C)		Alkalinity (mg/L as $CaCO_3$)		Nitrogen, NO_2+NO_3 total (mg/L as N)		Phosphorus, total (mg/L as P)		Carbon, organic total (mg/L as C)	
			N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
Chattooga River near Clayton	02177000	1968-85	161	6.6	149	13	138	5.3	125	0.03	124	0.03	120	2.1
		1985	12	7.1	12	15	12	6.2	12	.02	12	.02	12	2.9
Ogeechee River near Eden	02202500	1974-85	152	6.5	143	75	129	23	94	.10	117	.05	55	8.8
		1985	6	7.4	6	95	6	31	0	d	6	.08	0	d
Falling Creek near Juliette	02212600	1968-85	177	6.7	177	116	161	51	77	.06	90	.09	30	3.6
		1985	4	7.6	5	114	4	57	0	d	4	.02	0	d
North Oconee River at Athens	02217740	1974-85	125	6.9	125	55	113	21	125	.34	125	.05	122	3.1
		1985	12	7.0	12	61	12	22	12	.38	12	.03	12	4.6
Altamaha River near Everett	02226160	1974-85	172	6.8	176	119	160	27	147	.25	170	.07	135	8.5
		1985	17	7.2	19	145	17	32	12	.30	17	.08	11	7.4
Satilla River at Atkinson	02228000	1968-85	166	4.9	158	55	145	4.1	119	.10	135	.09	93	20
		1985	8	5.1	8	64	8	3.5	4	.13	8	.16	4	26
Suwanee River at Fargo	02314500	1968-85	160	4.1	146	55	92	1.2	121	.04	122	.04	118	37
		1985	12	3.9	12	64	10	1.0	12	.03	12	.04	12	41
Withlacoochee River near Clyattville	02318960	1975-85	127	6.3	126	122	113	40	127	.31	127	.17	124	11
		1985	12	7.1	12	161	12	55	12	.39	12	.19	12	8.7
Chattahoochee River near Fairburn	02337170	1968-85	301	6.5	333	80	145	20	319	.58	319	.45	298	5.8
		1985	12	6.8	12	103	12	21	12	.90	12	.51	12	4.7
Chattahoochee River at Andrew's L&D near Columbia	02343801	1983-85	18	7.2	18	65	18	17	--na--		17	.04	--na--	
		1985	6	7.2	6	75	6	18	--na--		6	.02	--na--	
Kinchafoonee Creek at Preston	02350600	1970-85	71	6.5	64	33	65	9.4	60	.15	61	.03	57	4.5
		1985	2	6.8	2	35	2	11	2	.20	2	.01	0	d
Flint River at Albany	02352500	1968-85	100	7.1	85	72	81	24	62	.29	62	.11	57	4.4
		1985	5	7.3	5	106	5	29	5	.42	5	.04	5	3.2
Flint River at Newton	02353000	1968-85	91	7.3	76	102	72	38	36	.38	52	.07	30	4.5
		1985	6	7.7	6	137	6	45	1	.60	5	.06	0	d
Conasauga River near Dalton	02384748	1974-85	129	7.4	128	102	116	45	127	.20	126	.05	124	3.3
		1985	12	7.4	12	115	12	48	12	.20	12	.05	12	4.3
Conasauga River near Resaca	02387050	1974-85	126	7.3	125	161	114	59	125	.48	125	.57	123	6.0
		1985	12	7.3	12	178	12	63	12	.47	12	.67	12	4.3

Most of the observed departures from long-term averages seem to be flow-related. Streamflow records indicate that runoff was well below normal throughout the State. Higher conductivities were observed at all sites and are a good indicator of these widespread low-flow conditions. All sites show an inverse relation between flow and conductivity. Higher equivalent mean-pH values at sampling stations Chattooga River near Clayton, Ogeechee River near Eden, Falling Creek near Juliette and the Withlacoochee River near Clyattville also are possibly flow-related. Annual mean values for the 1985 water year for total nitrite-plus-nitrate nitrogen, total phosphorus, and total organic carbon were comparable to the periods-of-record means for most of the sites listed. Notable exceptions are: (1) increased nitrite-plus-nitrate nitrogen at sampling stations Chattahoochee River near Fairburn, Flint River at Albany, and Flint River at Newton; and (2) increased total phosphorous at Conasauga River near Resaca. There seems to be an inversed relation between nitrite-plus-nitrate and flow and a positive relation between nitrite-plus-nitrate and time at Chattahoochee River near Fairburn. Also, additional sewage effluent is now diverted to the Chattahoochee River upstream of this site. All three of these factors could be causing the higher nitrogen levels in the river. A definable relation between nitrite-plus-nitrate and flow has not been established for the Flint River stations. However, there is a positive relation between nitrite-plus-nitrate and time, thus, higher nitrogen concentrations in the lower Flint could be the result of changing land use. Total phosphorus at Conasauga River near Resaca varies inversely with flow and has been increasing with time. Therefore, low flows and changing land-use and water-use practices could be causing the higher phosphorous levels in the river.

Ground Water

During the 1985 water year, annual mean ground-water levels throughout the State were from about the same to 11 feet lower than during the 1984 water year. Record low water levels were measured in six wells in the summer of 1985. Most water-level declines can be attributed to below-normal rainfall during the second half of the 1984 water year and the first half of the 1985 water year.

In the Floridan aquifer system (formerly the principal artesian aquifer), mean water levels in the southwestern part of the State were 4 to 11 feet lower than during the 1984 water year. Monthly mean water levels in October and November 1985 generally were higher than in the same period of 1984, but they were below 1984 levels for the remainder of the water year. Along the coast, mean water levels were about the same to 3 feet lower than during the 1984 water year. Monthly mean water levels at Savannah were 5 feet lower to 8 feet higher than in 1984 and record lows were measured in two wells in the summer of 1985. Monthly mean water levels in the Jesup-Riceboro area were about the same to 5 feet lower than in 1984, and record lows were set in three wells in August 1985. In the Brunswick area, monthly mean water levels were 3 feet lower to 1 foot higher than in 1984. Monthly mean water levels in the Okefenokee Swamp area were about the same to 6 feet lower than in 1984. In the south-central and east-central parts of the State, monthly mean water levels were 14 feet lower to 1 foot higher than in 1984. A record low water level was measured in one well near Valdosta in June 1985.



TOTAL — $4,098,000

Figure 2. —— Program fund sources, Georgia District, fiscal year 1986.

GEORGIA DISTRICT OFFICE ADDRESSES

District Office	(404) 331-4858	Jeffrey T. Armbruster, District Chief U.S. Geological Survey, WRD 6481-B Peachtree Industrial Blvd. Doraville, GA 30360
Albany Field Headquarters	(912) 430-8420	U.S. Geological Survey, WRD 314 Roosevelt Avenue P. O. Box 1232 Albany, GA 31702
Savannah Field Headquarters	(912) 944-4350	U.S. Geological Survey, WRD 125 Bull Street, Room B-10 P. O. Box 8223 Savannah, GA 31412
Tifton Field Headquarters	(912) 382-6353	U.S. Geological Survey, WRD 225 Tift Avenue P. O. Box 721 Tifton, GA 31793
Brunswick Field Headquarters		U.S. Geological Survey, WRD Brunswick, GA 31521

Figure 3.--Location and addresses of District Office and Field Headquarters.

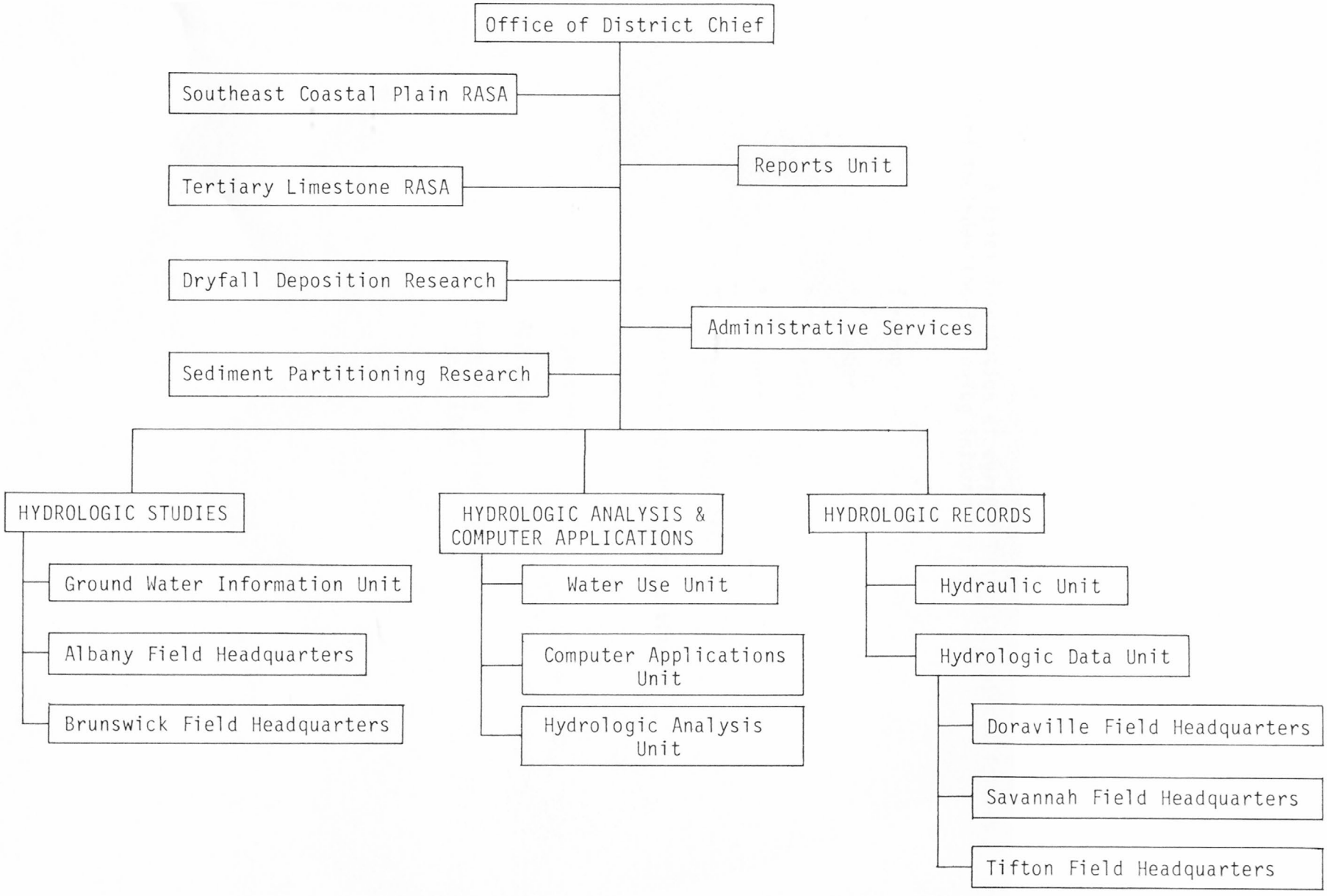


Figure 4.--District Office organization.

GEORGIA DISTRICT PROJECTS

A brief description of current District projects follows, and includes the following information.

- Name
- Number
- Location
- Project chief
- Period of project
- Cooperating agency or agencies
- Problem
- Objectives
- Approach
- Progress during fiscal year 1986

Surface-Water Monitoring, GA001

Location: Statewide

Project Chief: W. R. Stokes, III

Period of Project: Continuing

Cooperation: Many agencies

Problem: Surface-water information is needed for purposes of surveillance, planning, design, hazard warning, operation, and management in water-related fields such as water supply, hydroelectric power, flood control, irrigation, bridge and culvert design, wildlife management, pollution abatement, flood-plain management, and water-resources development.

Objectives: Collect surface-water data sufficient to satisfy needs for current-purpose uses, such as (1) assessment of water resources, (2) operation of reservoirs or industries, (3) forecasting, and (4) pollution control and disposal of wastes. Collect data necessary for analytical studies to define for any location the statistical properties of, and trends in, the occurrence of water in streams, lakes, and estuaries for use in planning and design.

Approach: Routine date collection and processing will continue. Immediate plans call for more than 200 low-flow measurements to be made early in the year. Other low-flow and flood data will be collected as determined by unusual hydrologic events. Two daily-flow stations will be installed, two will be relocated, and two probably will be discontinued. Data requests will be handled in a timely manner. The 1986 water-year data report will be published.

Progress: Daily discharges were computed for 103 sites and peak stage and discharge were obtained at 117 peak-flow partial-record stations. Final processing of these data was completed and the data report published. Seven daily-flow stations were installed and two were relocated. Three stage-only stations also were installed. Computation and preparation of 1986 data for publication were about 40 percent completed. Many requests for streamflow data were answered during the year. Minor updates were made to the District Surface-Water-Quality Assurance Plan and the Flood Plan. Approximately 200 low-flow measurements were made to assist in documentation of the 1986 drought.

Figure 5.--Location of gaging stations.

Ground-Water Monitoring, GA002

Location: Statewide

Project Chief: J. S. Clarke

Period of Project: Continuing

Cooperation: Many agencies

Problem: Long-term water-level records are needed to evaluate the effects of climatic variations on the recharge to and discharge from the ground-water systems, to provide a data base against which to measure the effects of development, to assist in the prediction of future supplies, and to provide data for management of the resource.

Objectives: Collect water-level and water-quality data sufficient to provide (1) a minimum long-term data base so that the general response of the hydrologic system to natural climatic variations and induced stresses is known and potential problems can be defined early enough to allow proper planning and management, and (2) provide a data base against which the short-term records acquired in areal studies can be analyzed.

Approach: Evaluation of regional hydrogeology allows broad, general definition of aquifer systems and their boundary conditions. Within this framework and with some knowledge of the stress on the system in time and space and the hydrologic properties of the aquifers, decisions can be made on the most advantageous locations for the observation of long-term system behavior.

Progress: Continuous water-level recorders were operated at 153 wells and approximately 170 periodic water-level measurements were collected. Potentiometric maps were constructed for the Claiborne and Clayton aquifers and the Floridan, Dublin, and Dublin-Midville aquifer systems. A report describing the potentiometric surface of the Upper Floridan aquifer in Georgia for May 1985 and water-level trends during 1980-85 was prepared and submitted for review. Water samples were collected monthly from 11 wells in the Savannah area and semiannually from 90 wells in the Brunswick area for analysis of chloride and dissolved-solids concentration. A map was prepared showing the chloride concentration in the Upper Floridan aquifer at Brunswick for October-November 1985. The report, "Ground-Water Data for Georgia, 1985," and four quarterly reports outlining ground-water and climatic conditions at key locations were completed. To monitor the effects of the 1986 drought, a 19-well network was established and weekly and monthly reports were submitted to the cooperator. The preparation of hydrogeologic data for entry into the National Water Data Storage and Retrieval System (WATSTORE) was continued. Data in the Ground-Water Site Inventory System (GWSI) were downloaded to the District's minicomputer and checked for accuracy. Geophysical logs were collected from 19 monitoring wells at the Powersville National Priority List (NPL) site and an assessment of geohydrologic studies related to the Fort Valley pre-NPL site was made for the U.S. Environmental Protection Agency.

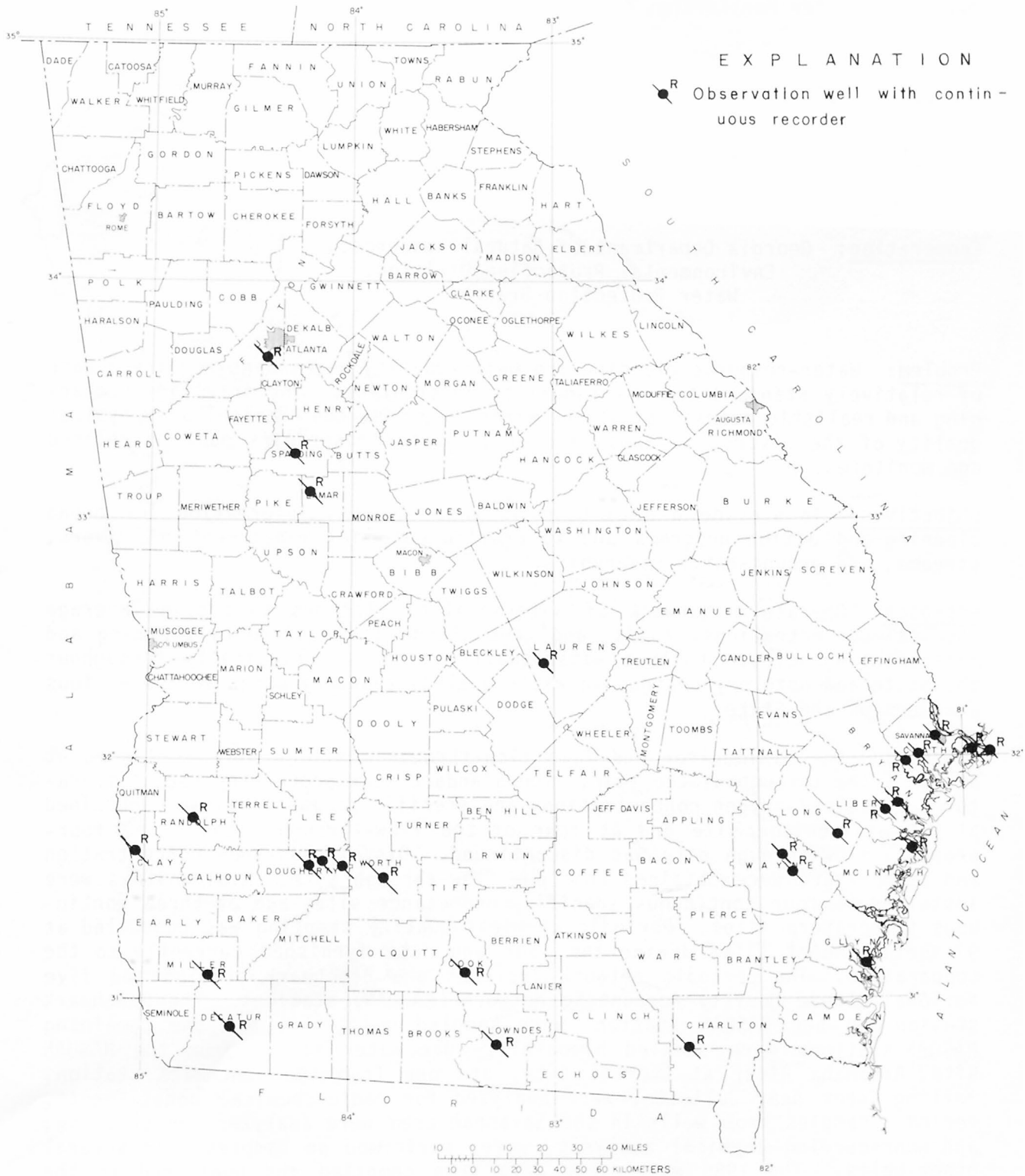


Figure 6.--Location of selected observation wells.

Quality-of-Water Monitoring, GA003

Location: Statewide

Project Chief: W. R. Stokes, III

Period of Project: Continuing

Cooperation: Georgia Department of Natural Resources, Environmental Protection Division, Water Protection Branch

Problem: Water-resource planning and water-quality assessment require a base of relatively standardized water-quality information. For intelligent planning and realistic assessment of the water resource, the chemical and physical quality of the rivers, streams, and ground-water reservoirs must be defined and monitored.

Objectives: To provide a data base of water-quality information for broad planning and action programs and to provide data for management of rivers, streams, and ground-water reservoirs.

Approach: Operate a network of water-quality stations to provide average chemical concentrations, loads, and time trends as required by planning and management agencies. Collect water-quality samples periodically throughout the State and note any changes in water quality that may occur in the various aquifers of the State.

Progress: One minimonitor and five flow-through monitors were continued at stream sites throughout the year. The standard four properties (pH, temperature, dissolved-oxygen concentration, and specific conductance) were obtained at the minimonitor site and at four of the flow-through sites. One four-property flow-through site was discontinued. Dissolved-oxygen concentration and temperature were obtained from one flow-through site. Minimonitors were installed at four continuous specific-conductance sites and at three continuous temperature sites. Periodic chemical-quality sampling was conducted at 97 surface-water sites during the year and data furnished currently to the cooperators. The periodic network includes one Benchmark station and five National Stream Quality Accounting Network (NASQAN) stations. The Benchmark station and one NASQAN station were sampled quarterly, and the remaining NASQAN stations were sampled bimonthly. One water sample from the NASQAN site, Altamaha River at Everett City, and one from the Benchmark station, Falling Creek near Juliette, were analyzed for radio-chemical constituents. Periodic samples from wells in the Savannah area were analyzed for chloride, and nonrecurring chemical analyses were performed on samples from several other wells. The 1985 water-year data were compiled and published in the annual water-data report (see project GA001), and the preparation of 1986 data for publication was 50 percent completed. Many requests for water-quality data were answered during the year. Program quality-control activities were conducted according to quality-assurance plans.

Figure 7.--Location of surface-water-quality stations.

Sediment Monitoring, GA004

Location: Statewide

Project Chief: W. R. Stokes, III

Period of Project: Continuing

Cooperation: U.S. Army Corps of Engineers, Mobile District

Problem: Water-resources planning and water-quality assessment require a base of relatively standardized sediment information. Sediment concentrations and discharges in rivers and streams need to be defined and monitored.

Objectives: To provide a base of sediment information for use in broad State and Federal planning and active programs and to provide data for management of interstate and intrastate waters.

Approach: Establish and operate a network of periodic and stormwater sampling stations to provide spatial averages of sediment concentration and particle size of sediment being transported by rivers and streams.

Progress: Periodic collection and analysis of sediment samples continued at 10 continuous-record streamflow stations. Sampling of storm runoff continued at five of these streamflow stations located in the vicinity of three major Corps of Engineers projects. However, storm runoff was sampled at only two of these sites, because of the almost total lack of surface runoff during the year. The 1985 water-year data were compiled and published in the annual water-data report (see project GA001), and preparation of 1986 data for publication was 45 percent completed.

Figure 8.—Location of periodic sediment-sampling stations.

Atmospheric Deposition Monitoring, GA005

Location: Statewide

Project Chief: Gary R. Buell

Period of Project: Continuing

Cooperation: U.S. Geological Survey, Federal

Problem: Data on the chemical quality of atmospheric deposition are needed to provide a baseline against which future changes in atmospheric chemical quality can be evaluated. These data also are an essential input to studies designed for assessment of possible aquatic and terrestrial effects related to atmospheric deposition of strong acids. Until recently, there has been no uniform data-collection effort aimed at providing a consistent precipitation chemical-quality data base on a national scale. There are a number of regional studies currently underway but these differ slightly in methods of collection and analysis and do not provide uniform national coverage. The anthropogenic influences on precipitation chemical quality and effectiveness of any mitigation strategies cannot be determined without national network coverage.

Objectives: (1) Define the chemical quality of wet precipitation in Georgia, and (2) analyze the spatial and temporal variability in the chemical quality of wet precipitation in Georgia.

Approach: In cooperation with the U.S. Department of Agriculture, Agricultural Research Service (ARS), and the U.S. Geological Survey, Office of Atmospheric Deposition Analysis, precipitation-sampling data from the Tifton ARS National Trends Network (NTN) sites will be verified and entered into the National Water Data Storage and Retrieval System (WATSTORE). Weekly composite wet-precipitation samples will be analyzed for pH, specific conductance, major cations and anions, and trace metals. These data will be coanalyzed with other regional network data for resolution of temporal and spatial trends in precipitation chemistry.

Progress: At the Tifton-ARS NTN site, 157 weekly composite wet-precipitation samples were collected. Preliminary lab results from the Illinois State Water Survey Central Analytical Laboratory were received for 139 of these sample sets.

Impact of Acid Deposition on Stream Chemistry of Brier Creek, Northeast Georgia, GA00501

Location: Towns County

Project Chief: Gary R. Buell

Period of Project: March 1984 - March 1987

Cooperation: U.S. Environmental Protection Agency
Region IV, Atlanta, Georgia

Problem: Acid precipitation is now recognized as a major environmental problem in North America. Data indicate that acidic precipitation (pH less than 5.6) now falls over nearly all the Eastern United States and that the acidity of this precipitation is increasing at most locations. Studies indicate that streams in many areas of the Southeastern United States may be vulnerable to acidification. Further studies are needed on watersheds in the Southeast that will provide systematic precipitation and stream-chemistry data which can be used to evaluate the effects of acid precipitation on stream chemical quality.

Objective: To determine whether the Brier Creek watershed is being acidified by atmospheric deposition of strong acids.

Approach: A chemical mass balance will be used to determine whether the buffering capacity of the Brier Creek watershed is changing with time and whether the system is accumulating strong acids. Net mass fluxes will be calculated for the major ions by subtracting the amount received in acidic precipitation from that transported from the watershed by the stream. Stream-chemistry data from storms will be used to assess the combined effects of hydrology, physical and chemical soils characteristics, topography, and vegetative cover on stream chemistry. An input-output chemical budget and data on the within-storm variation in stream chemistry should provide information on watershed processes which influence the stream chemistry.

Progress: The equipment installation at the Brier Creek watershed was completed. Four storm events were sampled. Three stream sites (two on Brier Creek and one on a Brier Creek tributary) were sampled on a weekly basis from August 1985. Continuous-discharge records are being collected. Compilation of watershed-characteristics data continued, and final data reduction and analysis was begun in preparation for a journal article and final report on the project.

Flood Investigations, GA006

Location: Statewide

Project Chief: McGlone Price

Period of Project: Continuing

Cooperation: Federal Emergency Management Agency (FEMA)

Problem: The National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 provide for the operation of the flood insurance program. The Federal Emergency Management Agency (FEMA) needs flood studies in selected areas to determine applicable flood insurance premium rates.

Objectives: To conduct the necessary hydrologic and hydraulic evaluations and studies of areas assigned by FEMA and to present the results in an appropriate format.

Approach: Conduct stream surveys by ground or photogrammetric methods. Determine flood-discharge frequency relations using local historical information, gaging-station records, or other applicable information. Determine water-surface profiles using step-backwater models or by other acceptable methods and furnish the results in reports prepared to FEMA specifications.

Progress: Limited detail flood insurance studies have been completed for the cities of Swainsboro, Vidalia, Young Harris, Clarkesville, and Barnesville and submitted to FEMA for final review. The report for the city of Americus was completed and is in colleague review. Surveying has been completed for FEMA limited detail studies of Upson County and the cities of Hawkinsville, Fitzgerald, Eatonton, Lakeland, and Sylvester.

Use of Water in Georgia, GA007

Location: Statewide

Project Chief: Robert R. Pierce

Period of Project: Continuing

Cooperation: Georgia Department of Natural Resources,
Environmental Protection Division,
Geologic Survey Branch

Problem: Water resources in Georgia are under mounting pressures from increasing population, growing industry, and the recent rapid increase in agricultural use. Information is being collected which describes the quantity and quality of available water, but relatively little information is being collected describing water use. Without such information, decision makers cannot resolve many critical problems such as water-quality residuals, environmental impact, energy development, and resources allocations. Methods for comprehensive acquisition of water-use data have not been developed. Data now in the files of State and Federal agencies are not in a form suitable for automatic storage and retrieval and contain many deficiencies.

Objectives: To (1) identify sources of water-use data, (2) develop and evaluate techniques for collecting water-use data, especially data not in State agency files, (3) identify requirements for a water-use data handling system, (4) select and implement a Georgia water-use data handling system, and (5) develop a system for sample verification of data reported to the State.

Approach: Responsibilities will be divided between the cooperator and the U.S. Geological Survey. Project management, data storage, and data processing will be the responsibility of the U.S. Geological Survey. Data acquisition will be the primary responsibility of the cooperator. The implementation phase of the project will be devoted to design of the data-collection system. The subsequent work will be for maintenance and updating.

Progress: The Georgia Water-Use Program has established a framework for collection of annual withdrawal and discharge information. The data are entered into the Georgia Water-Use Data System (GWUDS). GWUDS has evolved through the Program's continued handling of site-specific and area-based water-use data and an understanding of District project needs and the program needs of other State, Federal, and local agencies in Georgia. Updates of 1985 information for municipal, industrial, and power-generation withdrawals and returns have been added to the system. Data for the report "1985 Estimated Use of Water in the United States," was compiled by county and cataloging unit for all 12 categories of water use. Special studies included a survey of the 70 largest water-supply entities to ascertain the proportion of delivered water used for residential, commercial, industrial, and wholesale purposes. Georgia was selected to produce the only prototype for the 1987 National Water Summary.

Statewide Flood Studies, GA059

Location: Statewide

Project Chief: McGlone Price

Period of Project: Continuing

Cooperation: Georgia Department of Transportation

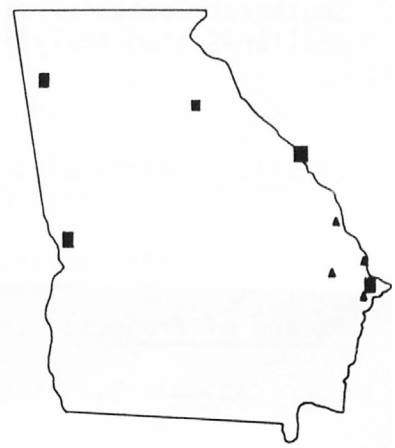
Problem: A knowledge of flood characteristics of streams is essential for the design of highway drainage structures, for planning the best use of flood-prone lands, and for establishing flood-insurance rates. Only through reliable estimates of flood magnitude and frequency is it possible to obtain economically optimum designs of highway bridges and culverts, to determine locations for waste-treatment and water-supply facilities, to prepare realistic zoning ordinances, and to establish equitable flood-insurance rates.

Objectives: (1) Collect supplemental flood data, (2) analyze the data and prepare reports describing the hydrologic and hydraulic characteristics of selected stream reaches, and (3) collect data and prepare reports describing unusual flood events.

Approach: (1) Operate a network of crest-stage gages to supplement the statewide gaging-station network and improve the areal distribution of flood data that provide the baseline data for determining the magnitude and frequency of floods on Georgia streams, (2) determine the hydraulic and hydrologic characteristics, including the determination of the flow distribution, backwater, and velocity studies, of selected stream reaches (3) make field measurements, including indirect measurements of peak flows for major floods, and (4) prepare reports describing unusual floods.

Progress: Reports were prepared describing the analyses of flood characteristics of eight stream reaches. The annual flood-peak data for 1985 were entered into the National Water Data Storage and Retrieval System (WATSTORE) peak-flow file for 46 crest-stage-gage sites. Flood information for 50 sites was furnished to State, Federal, and local agencies. An administrative report was prepared about the south Georgia flood of March 1986.

Flood-Frequency Characteristics of Urban Streams in Georgia, GA062



Location: Selected metropolitan areas in Georgia

Project Chief: Ernest J. Inman

Period of Project: 1978-1995

Cooperation: Georgia Department of Transportation

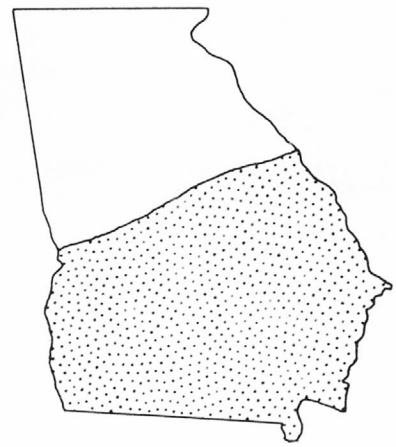
Problem: A method is needed for estimating the magnitude and frequency of floods occurring in streams in metropolitan areas of Georgia. Urban flood-frequency information is needed for bridge, culvert, and drainage design and for flood-mapping studies. Urbanization produces large changes in the flood runoff characteristics of streams; natural (rural) basin flood-frequency relations are, therefore, not applicable to urban or suburban streams. Few hydrologic data observations currently are available for streams in metropolitan areas.

Objectives: The objectives of this study are to (1) collect hydrologic data for selected urban streams in selected metropolitan areas of Georgia, and (2) analyze these data to develop relations that may be used to estimate the magnitude and frequency of floods in urban streams throughout the State.

Approach: Selected urban drainage basins will be instrumented to obtain flood-hydrograph and storm-rainfall data in Athens, Augusta, Columbus, Rome, and Savannah. These basins will represent a range in drainage area (0.2 to 20 mi^2), amount of impervious area, channel slopes, and types of land use. All significant flood-runoff events, generally from 3 to 6 events per year, will be processed for use in calibrating the U.S. Geological Survey urban-hydrology models. Depending on weather conditions, 4 to 7 years of data collection will be required to obtain the desired data base. When the rainfall-runoff model is calibrated for a station, National Weather Service long-term rainfall data will be used to simulate a long-term peak-discharge record for the calibrated sites. Flood frequency at each site will then be defined from the synthesized flood peaks using the log-Pearson Type III analysis. The multiple-regression method will be used to relate to physical and climatological basin characteristics. From the regional relation, estimates of the magnitude and frequency of floods can be made for an ungaged drainage basin.

Progress: Data collection was discontinued and the gages removed at 30 sites: six in Athens, six in Augusta, four in Columbus, six in Rome, and eight in or near Savannah. Model calibrations are being developed for Augusta and Columbus. Eighteen new sites are in operation in south Georgia (eight in Valdosta, six in Thomasville, and four in Moultrie).

Southeast Coastal Plain Regional
Aquifer-System Analysis (RASA), GA072



Location: Parts of the Georgia, Alabama, and South Carolina Coastal Plain

Project Chief: Robert E. Faye

Period of Project: 1980 - 1986

Cooperation: U.S. Geological Survey, Federal

Problem: Throughout the Georgia Coastal Plain, interlayered sand, clay, and limestone of Late Cretaceous and Tertiary age act regionally as several distinct aquifers. The regional effects of industrial and municipal pumping require study and evaluation of these aquifers in order to assure adequate water supplies of suitable quality.

Objectives: Study objectives include the determination of ground-water-flow patterns and boundaries of the various aquifer systems and their simulation through the use of digital models.

Approach: Pertinent information from the U.S. Geological Survey and other agencies will be reviewed and compiled. Water-level data will be used to construct potentiometric maps for each aquifer system. Geophysical data will be used to determine stratigraphic and hydrologic boundaries. Aquifer-test data will be analyzed and used to determine aquifer properties. Interpreted data will be applied to a digital model designed to simulate ground-water flow.

Progress: The calibrated steady-state and transient ground-water-flow models were refined to incorporate new water-level and water-use data. Two reports were approved for publication. Two additional reports are in review.

Impact of Increased Water Use on the Quantity and Quality of the Ground-Water Resources of Coastal Georgia, GA075

Location: Southeastern Georgia

Project Chief: Robert B. Randolph

Period of Project: 1981 - 1989

Cooperation: Georgia Department of Natural Resources, Environmental Protection Division, Geologic Survey Branch

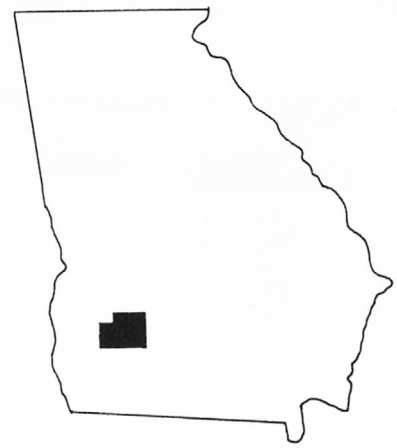
Problem: The Floridan aquifer system is the major source of water supply for the coastal area of Georgia, with ground-water withdrawal, including that in extreme northeast Florida, totaling over 400 million gallons per day. This heavy withdrawal has created problems of declining water levels and the contamination of the freshwater aquifer by highly mineralized water. In addition, the rapidly increasing use of large-scale irrigation systems in the area will produce an additional impact on the ground-water system.

Objectives: To (1) better define the geohydrology of the fresh ground-water flow system, (2) determine the occurrence, flow regimen, and quality of the water underlying and infiltrating the freshwater flow system, (3) determine the impact of faults on the flow system, and (4) evaluate the effects of increased water use on the flow system.

Approach: The first phase involved data collection to better define the geohydrology of the area--specifically, test drilling and modification of existing wells, particularly oil-test wells that fully penetrate the sequence of interest; geophysical logging; testing of aquifer characteristics; and water-quality sampling to better define the geohydrology of the freshwater aquifer system and the saline-water-bearing formations underlying the aquifer system, and to determine what impact the faults have on the flow system. Ground-water-flow models will be developed, including a regional, coastal-area model that uses data and model results from the Regional Aquifer-System Analysis (RASA) limestone study. Management-level models will be developed for high-priority areas, such as Brunswick. These models will be used to predict the effects of increased water use on the system. Results of the study will be published by the cooperator.

Progress: Constructed a well east of Savannah that penetrated the brackish-water zone underlying the Floridan aquifer system. The well was logged, tested, sampled, and equipped with a water-level recorder. Plotted well locations and constructed seven geologic sections showing structure and stratigraphy. Made preliminary maps of three stratigraphic horizons in sediments of post middle Eocene age. Began the developmental phase for the three-dimensional ground-water-flow model of the study area. Completed calibration of the Brunswick area three-dimensional model.

Development Potential of the Upper Floridan Aquifer as a Public-Supply Source in the Albany Area, Georgia, GA077



Location: Southwestern Georgia

Project Chief: David W. Hicks

Period of Project: 1981 - 1986

Cooperation: Albany Water, Gas, and Light Commission

Problem: Heavy ground-water pumpage in the rapidly growing Albany area of southwestern Georgia, presently averaging over 70 million gallons per day, has caused water levels to decline significantly in the Tallahatta, Clayton, and Upper Cretaceous aquifers. Declining water levels have cast doubt on the ability of these aquifers to meet increasing demands. The overlying Upper Floridan aquifer long has been a major source of irrigation, industrial, and domestic water supplies, but it has not been developed as a public-supply source, largely because of concern over possible ground-water contamination by agricultural and industrial chemicals and landfill leachate. A study was needed to evaluate the development potential of the Upper Floridan as a public-supply source.

Objective: Evaluate the development potential of the Upper Floridan aquifer as a public-supply source.

Approach: Data from more than 2,000 wells will define the framework of the Upper Floridan aquifer and determine the thickness and character of the undifferentiated overburden. Nine test-monitor wells will be drilled in the Upper Floridan; cores, cuttings, and geophysical logs will be correlated with those of other wells to delineate geohydrologic units. Multiple-well aquifer tests will be conducted at five sites. Transmissivity of the aquifer will be estimated from these tests and from specific-capacity data. A network of 10 to 15 wells tapping the Upper Floridan aquifer will be used to monitor the chemical quality of ground water throughout the period of study. Sinkholes in the area will be located and geologic hazards associated with developing the Upper Floridan will be evaluated.

Progress: Data from more than 2,000 wells were analyzed and used to construct maps showing the thickness and character (sand-clay ratio) of the overburden and thickness of the Upper Floridan. Eight wells were sampled to determine the chemical quality of water in the Upper Floridan aquifer. Sinkholes in the area were located on a map and geologic hazards evaluated. The report, "Hydrology and Contamination Potential of Ground Water in the Upper Floridan Aquifer, Albany Area, Georgia," is in review.

Migration of Pesticides Through the Unsaturated and Saturated Zones at a Selected Site in Southeast Lee County, Georgia, GA079

Location: Lee County

Project Chief: Sandra C. Cooper

Period of Project: 1983 - 1989

Cooperation: U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, Georgia

Problem: Increased agricultural productivity in southwest Georgia has resulted in the use of large-scale irrigation, multicropping, and increased applications of fertilizers and pesticides. The major water-bearing unit in the Dougherty Plain is the Upper Floridan aquifer of late Eocene age, which is recharged through permeable residuum of varying thickness. The expanded use of land-applied toxic pesticides indicates the urgent need to thoroughly investigate the migration and degradation of toxic chemicals so the quality of the ground-water resources in the Dougherty Plain can be preserved.

Objectives: Use field data to calibrate, test, and refine ground-water-flow and solute-transport models designed to predict movement of chemicals within the residuum and underlying aquifer.

Approach: Work elements include geologic and hydrologic evaluations of the study site, installation of a permanent ground-water-monitoring network using wells and lysimeters, and monitoring two small test tracts. Data collection includes water-quality samples; soils samples for biological, physical, chemical, and moisture-release analyses; climatic and surface-water data; and data concerning aquifer characteristics. Water-table and potentiometric maps will define the flow system; geophysical logs, drill cuttings, and cross sections will define the stratigraphic sequence and geohydrologic framework.

Progress: Measured water levels weekly at the site, plotted hydrographs, and constructed water-table maps and a potentiometric map of the Upper Flordian aquifer. Determined that several shallow wells were continuous producers (average yield was 0.75 gal/min); field tests indicated wells may not be hydraulically connected. Sampled soil and water for bromide analysis monthly from November 1985 to July 1986; analyses indicated both lateral and vertical bromide movement. Physical analysis of soil samples indicated a low hydraulic conductivity layer present in the profile at a depth of 5 ft. Planted 900 pounds of peanuts and incorporated 15-percent formulated aldicarb at a rate of 3 pounds of active ingredient per acre. Applied the herbicide metolachlor at a rate of 3 pints per acre immediately after planting. Collected 452 soil samples on the day of planting for aldicarb and metolachlor analysis. Collected 12-inch-deep soil samples monthly for aldicarb analysis. Began analyzing soil and water samples for bromide. Irrigated the field using cable-tow system; applied about 0.9 in. of water. Equipped six wells with digital recorders and two with analog recorders to measure the water level in the Upper Floridan and water-table aquifers.

Simulation of Fluid Flow in Fractured Limestone Formations near Brunswick, Georgia, GA083

Location: Glynn County

Project Chief: Morris L. Maslia

Period of Project: October 1983 - September 1987

Cooperation: Glynn County

Problem: Significant reductions in the potentiometric surface near Brunswick are allowing highly saline brines to move upward into the freshwater zone. Because faults and fractures in the limestone are believed to be vertical conduits for the upward movement of saltwater, it is necessary to be able to simulate flow in faulted and fractured media so that both vertical and lateral ground-water movement in the Brunswick area can be simulated accurately.

Objectives: (1) Available field data will be used to establish initial aquifer hydraulic properties for the area. (2) Review existing fractured-flow analyses, and develop an original mathematical model and accompanying analytical and numerical solutions for simulating flow in the fractured and locally faulted limestone aquifer in the area.

Approach: Determine initial estimates of aquifer hydraulic properties by using two- and three-dimensional digital models to model the conceptualized fractured flow system. These models are the conventional ground-water-flow and transport models. Research literature and develop mathematical models for describing fluid flow in fractured and faulted rock aquifers. Obtain simplified solutions to mathematical models. Develop numerical simulation models for fluid flow in fractured and faulted rock aquifers.

Progress: A steady-state two-dimensional ground-water-flow model has been calibrated for the stress period of December 1962. Calibrated parameter values have been checked against the potentiometric surface for May 1980. Simulation includes the flow characteristics (vertical leakage) of both conduits (faults and fractures) and the remaining semipermeable matrix of the confining bed. Two different scales were calibrated showing (1) a coarse-mesh county-wide model (650 mi^2) and (2) a fine-mesh model of the city of Brunswick area (35 mi^2).

Acid Rain, Dry Deposition, and Terrestrial Processes Research at Panola Mountain State Park, GA085

Location: Rockdale County

Project Chief: Norman E. Peters

Period of Project: 1984-1989

Cooperation: U.S. Geological Survey, Federal

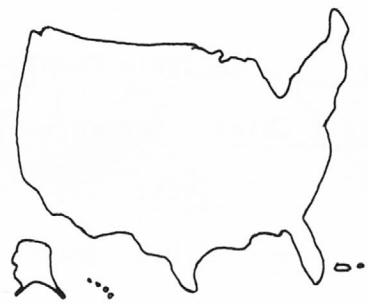
Problem: Acidic atmospheric deposition (acid rain) is thought to be responsible for acidification of surface waters in the Eastern United States. This acidification can have deleterious effects on fauna and flora through changes in the chemical regime. Atmospheric deposition of acids occurs as wet precipitation including rain, snow, and sleet and as dry deposition including impaction of aerosols, gravity settling of large particles, and gaseous transfer. Methodology is available for measuring the former but not the latter.

Objectives: To (1) evaluate and devise methods for measuring dry deposition, and (2) investigate terrestrial processes that control water chemistry, particularly with respect to the production of acids in the watershed and neutralization of acidic atmospheric deposition by the watershed.

Approach: Dry deposition will be estimated by chemical mass balance and micrometeorological methods. To evaluate processes controlling water chemistry, the flow system and related chemical characteristics will be identified. A primary focus of the sampling will be to identify variations in flow and related chemistry of precipitation, soil water, throughfall, ground water, and streamwater during storms. The composition of the above-ground biomass, soils, saprolite, and bedrock will be assessed and bedrock and soil maps produced. Two watershed models, the Precipitation-Runoff System (PRMS) and Integrated Lake-Watershed Acidification Study (ILWAS), will be calibrated to aid in process evaluation.

Progress: The primary instrumentation was installed and consists of three weekly wet-precipitation collectors, one weekly bulk-precipitation collector, one incremental wet-precipitation collector, a monitor for conductance and temperature of precipitation, three continuous streamflow sites fitted with automatic samplers, two meterological stations, 25 wells, six zero-tension soil lysimeters fitted with incremental samplers, and 32 throughfall collectors under both deciduous and coniferous canopy. Water-quality samples of precipitation, streamwater, and ground water are collected weekly and more frequently during storms. The precipitation is acidic (pH 3.8 to 4.5) and is dominated by sulfuric aicd. Runoff at the base of a 3-hectare granite outcrop in the headwaters is even more acidic than the precipitation. Streamwater at a site midway from the basin outlet to the granite outcrop is acidic but less so than runoff at the granite outcrop or precipitation. Streamwater at the basin outlet is neutral but alkalinity decreases almost to zero during storms.

Development of Interactive Controller Subsystem of WRD's National Water Information System (NWIS), GA086



Location: Nationwide

Project Chief: Thomas R. Dyar

Period of Project: 1984-1987

Cooperation: U.S. Geological Survey, Federal

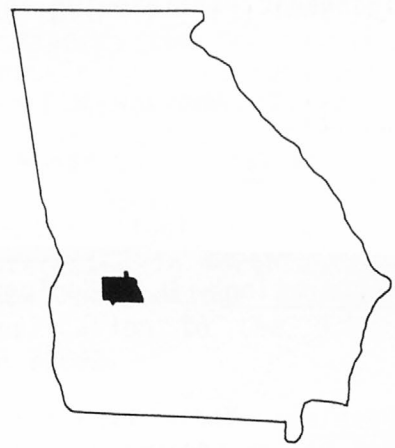
Problem: In September 1982, the U.S. Government awarded a multiyear contract to Prime Computer, Inc., for the purchase of up to 75 minicomputers to be located at the major offices of the Water Resources Division (WRD) of the U.S. Geological Survey. This Distributed Information System (DIS) is to provide an environment within which related information systems will be developed for the WRD in pursuit of its primary hydrologic mission and the performance of various managerial and administrative tasks. The major information system to be developed in the DIS is the National Water Information System (NWIS). The NWIS is needed to encompass all data processing, storage, analysis, and dissemination capabilities necessary at all levels of the WRD--District, Region, and National Headquarters.

Objective: To develop the first NWIS prototype, the Interactive Controller Subsystem (ICS).

Approach: A prototype of the Interactive Controller Subsystem (ICS) is being developed under the NWIS project of WRD's Office of Computer Technology, Scientific Publications and Data Management. The software development team is from the Georgia District. The NWIS furnishes the initial ICS conceptual design. The team then is responsible for the following steps: (1) ICS design specifications, (2) program specifications, (3) training and users guide, (4) design review, (5) systems testing, (6) development, (7) Alpha testing, (8) Beta testing, and (9) implementation of maintenance.

Progress: The MWDI conversion--water quality component pseudo code--was completed and reviewed. The initial Fortran coding is nearing completion.

Movement and Fate of Agricultural Chemicals in the Surface and Subsurface Environments, Southwest Georgia, GA087



Location: Ty Ty Creek, Sumter County

Project Chief: David W. Hicks

Period of Project: 1984-1989

Cooperation: U.S. Department of Agriculture, Agricultural Research Service
U.S. Geological Survey, Office of Hazardous Waste

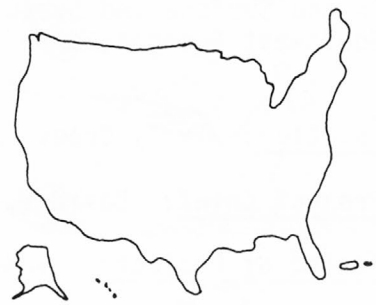
Problem: Increased demand for agricultural products in southwestern Georgia has resulted in widespread multicropping that requires the application of a myriad of organic and inorganic chemicals. These chemicals are being applied in recharge areas and may move into aquifers used for water supply. Little is known about the movement and fate of agricultural chemicals in the ground, or of their potential for degrading the quality of water in the area's aquifers.

Objectives: (1) Determine the movement and fate of agricultural chemicals in the unsaturated (including the root zone) and saturated zones. (2) Improve processes to describe the infiltration rate and chemical nature of ground-water recharge in the unsaturated zone by using existing computer models.

Approach: Borehole geophysical logs from more than 60 wells will be used to describe the lithology and stratigraphy of a 1.03-mi^2 watershed of Ty Ty Creek. Six wells will be installed and equipped with continuous water-level recorders and 44 wells will be measured periodically. Data from 60 to 80 wells penetrating the saturated zone will be used to describe the geohydrologic framework and determine the hydraulic charactristics of the saturated zone. A two-dimensional finite-element ground-water-flow model will be used to describe water movement from the land surface through the unsaturated zone into the saturated zone. Mathematical models will predict the movement of organic and inorganic substances in the individual components of the hydrologic system. Model calibration will be provided through field experiments conducted on a 12-acre test plot (controlled farming), beginning in the fall of 1987.

Progress: Drilled 45 monitoring wells, including two continuous-core holes, and installed water-level recorders on two additional wells. Eight pits were excavated and sampled. Ground-water-quality samples were collected from selected wells at 4- to 6-week intervals and analyzed for nitrogen species and chloride. Two reports, "Movement and Fate of Agricultural Chemicals in the Surface and Subsurface Environments, Southwestern Georgia--Work Plan" and "Preliminary Geologic and Hydrologic Evaluation of the Pesticide Migration Research Project Site near Plains, Georgia," were prepared and are in review.

Methods Development for the Determination of Inorganic Partitioning in Sediments, GA088



Location: Nationwide

Project Chief: Arthur J. Horowitz

Period of Project: 1983-1989

Cooperation: U.S. Geological Survey, Federal

Problem: There is a strong association between trace elements and suspended and bottom sediments. The investigation of sediment-associated trace elements is a requisite for understanding the distribution, transport, and availability of these constitiuents in a hydrologic system. At present, WRD lacks the capability to delineate the concentration and partitioning (physical and chemical) of trace elements with sediments.

Objectives: To (1) develop techniques for the total analysis of sediments and to determine trace element partitioning; (2) develop an understanding of the physical and chemical factors which control sediment-trace element interrelations; (3) apply the methods developed to natural aquatic environments; and (4) provide guidelines for the interpretive use of the procedures and techniques developed by the project.

Approach: The first two objectives will be met through intensive studies of a small suite of highly diverse natural samples collected from in and around the United States. Once various methods and interrelations have been developed, the techniques will be applied in full-scale investigations of natural aquatic systems. Technology transfer regarding project results (objective 4) will be accomplished through publications, presentations at meetings, and existing U.S. Geological Survey training programs. Where necessary, new training programs will be developed.

Progress: Analytical procedures have been established for the quantitation of all the standard major elements and most of the standard trace elements. Commonly, complete analyses can be carried out with as little as 5 mg of dried sediment. Appropriate techniques for separating various grain-size fractions and for the determination of sediment surface area also have been examined. In the process of developing and applying these various techniques, many of the interrelations between sediment-trace element chemistry and grain size, surface area, and geochemical phase have been elucidated.

Work on sediment cores from Lake Oahe in South Dakota has indicated that reducing conditions exist below 2 to 3 cm in the lakebed. Only As, and possibly Hg, seem to display elevated concentrations in the sediment column. The elevated As levels seem to be due to the transport of detrital arsenopyrite from the banks and floodplains of Whitewood Creek and the Belle Fourche River. Arsenopyrite and octahedral pyrite have been found in various core samples and in suspended sediment collected upstream from Lake Oahe.

PUBLICATIONS OF THE U.S. GEOLOGICAL SURVEY

Professional Papers, Bulletins, Water-Supply Papers, the Geological Survey's Annual Report, and other text products pertaining to Georgia are sold by the U.S. Geological Survey, Books and Open-File Reports, Federal Center, Bldg. 41, Denver, CO 80225. Hydrologic Investigations Atlases and other map series are available from the U.S. Geological Survey, Map Distribution, Federal Center, Building 41, Box 25286, Denver, CO 80225. Circulars are free upon application to the U.S. Geological Survey, National Center, Reston, VA 22092. For those interested in forthcoming reports, subscriptions to the monthly list, "New Publications of the Geological Survey," are available free upon application to the U.S. Geological Survey, 329 National Center, Reston, VA 22092.

PUBLICATIONS OF THE GEORGIA GEOLOGIC SURVEY, GEORGIA DEPARTMENT OF NATURAL RESOURCES

These reports can be obtained from the State Geologist, Georgia Geologic Survey, 19 Martin Luther King, Jr., Drive, S.W., Atlanta, GA 30334; or they may be inspected in the offices of the Georgia Geologic Survey.

A complete list of Georgia Geologic Survey reports may be obtained at the address above by asking for Circular No. 1.

REPORTS OF INVESTIGATIONS--SELECTED REFERENCES

Selected references on water in Georgia follow; many of them are available for inspection at the office of the U.S. Geological Survey, Doraville, Ga., and at the larger public and university libraries.

Surface-Water Resources

Bue, C. D., 1970, Streamflow from the United States into the Atlantic Ocean during 1931-60: U.S. Geological Survey Water-Supply Paper 1899-1.

Carter, R. F., 1959, Drainage area data for Georgia streams: U.S. Geological Survey Open-File Report.

----- 1970, Evaluation of the surface-water data program in Georgia: U.S. Geological Survey Open-File Report.

----- 1977, Low-flow characteristics of the upper Flint River, Georgia: U.S. Geological Survey Open-File Report 77-408.

----- 1983, Effects of the drought of 1980-81 on streamflow and on groundwater levels in Georgia: U.S. Geological Survey Water-Resources Investigations 83-4158.

----- 1983, Storage requirements for Georgia streams: U.S. Geological Survey Water-Resources Investigations 82-557.

Carter, R. F., and Fanning, J. D., 1982, Monthly low-flow characteristics of Georgia streams: U.S. Geological Survey Open-File Report 82-560.

Carter, R. F., Hopkins, E. H., and Perlman, H. A., 1986, Low-flow profiles of the upper Ocmulgee and Flint Rivers in Georgia: Water-Resources Investigations Report 86-4176 (in press).

Carter, R. F., and Gannon, W. B., 1962, Surface-water resources of the Yellow River Basin in Gwinnett County, Georgia: Georgia Department of Natural Resources Information Circular 22.

Carter, R. F., and Putnam, S. A., 1977, Low-flow frequency of Georgia streams: U.S. Geological Survey Water-Resources Investigations 77-127.

Carter, R. F., and Stiles, H. R., 1982, Average annual rainfall and runoff in Georgia, 1941-70: Georgia Geologic Survey Hydrologic Atlas 9.

Faye, R. E., and Blalock, M. E., 1984, Simulation of dynamic floodflows at gaged stations in the southeastern United States: U.S. Geological Survey Water-Resources Investigations Report 84-4.

Faye, R. E., and Cherry, R. N., 1980, Channel and dynamic flow characteristics of the Chattahoochee River, Buford Dam to Georgia Highway 141: U.S. Geological Survey Water-Supply Paper 2063.

Surface-Water Resources--Continued

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.

Hale, T. W., Stokes, W. R., III, Price, McGlone, and Pearman, J. L., 1985, Cost-effectiveness of the stream-gaging program in Georgia: U.S. Geological Survey Water-Resources Investigations Report 84-4109.

Hauck, M. L., and Pate, M. L., 1982, Flood hazard literature, annotated selections for Georgia: Georgia Department of Natural Resources Circular 6.

Inman, E. J., 1971, Flow characteristics of Georgia streams: U.S. Geological Survey Open-File Report.

----- 1983, Flood-frequency relations for urban streams in metropolitan Atlanta, Georgia: U.S. Geological Survey Water-Resources Investigations 83-4203.

----- 1986, Simulation of flood hydrographs for Georgia streams: U.S. Geological Survey Water-Resources Investigations Report 86-4004.

----- 1986, Simulation of flood hydrographs for Georgia streams: U.S. Geological Survey Water-Supply Paper 2317 (in press).

Inman, E. J., and Armbruster, J. T., 1986, Simulation of flood hydrographs for Georgia streams, in Transportation Research Board, 65th annual meeting, January 1986: Washington, D.C., National Research Council (in press).

Kilpatrick, F. A., 1964, Source of base flow of streams, in Symposium on surface waters, Berkeley, California, 1963, General Assembly, International Union of Geodesy and Geophysics: International Association of Scientific Hydrology Publication 63, p. 329-339.

Kilpatrick, F. A., and Barnes, H. H., Jr., 1964, Channel geometry of Piedmont streams as related to frequency of floods: U.S. Geological Survey Professional Paper 422-E.

Kilpatrick, F. A., Hale, T. W., and Peters, N. E., 1986, A dual, compound weir for gaging small basins: U.S. Geological Survey WRD Bulletin (in press).

Perlman, H. A., 1985, Sediment data for Georgia streams, water years 1958-82: U.S. Geological Survey Open-File Report 84-722.

Surface-Water Resources--Continued

Price, McGlone, 1971, Floods in vicinity of Ellijay, Georgia: U.S. Geological Survey Hydrologic Investigations Atlas HA-418.

----- 1977, Technique for estimating flood-depth frequency relations on natural streams in Georgia: U.S. Geological Survey Water-Resources Investigations 77-90.

----- 1978, Floods in Georgia--Magnitude and frequency: U.S. Geological Survey Water-Resources Investigations 78-137.

Price, McGlone, and Hess, G. W., 1985, Limited detail flood insurance study, city of Bainbridge, Decatur County, Georgia: Federal Emergency Management Agency, community no. 130204.

----- 1985, Limited detail flood insurance study, city of Gordon, Wilkinson County, Georgia: Federal Emergency Management Agency, community no. 130259 (in press).

----- 1985, Limited detail flood insurance study, city of Jesup, Wayne County, Georgia: Federal Emergency Management Agency, community no. 130188 (in press).

----- 1985, Limited detail flood insurance study, city of Swainsboro, Emanuel County, Georgia: Federal Emergency Management Agency, community no. 130229 (in press).

----- 1985, Limited detail flood insurance study, city of Winder, Barrow County, Georgia: Federal Emergency Management Agency, community no. 130234 (in press).

----- 1986, Verification of regression equations for estimating flood magnitudes for selected frequencies on small natural strams in Georgia: U.S. Geological Survey Water-Resources Investigations Report 86-4337, 39 p.

----- 1986, Limited detail flood insurance study, city of Barnesville, Lamar County, Georgia: Federal Emergency Management Agency, community no. 130207 (in press).

----- 1986, Limited detail flood insurance study, city of Clarkesville, Habersham County, Georgia: Federal Emergency Management Agency, community no. 130103 (in press).

----- 1986, Limited detail flood insurance study, city of Vidalia, Toombs County, Georgia: Federal Emergency Management Agency, community no. 130232 (in press).

Surface-Water Resources--Continued

Price, McGlone, and Hess, G. W., 1986, Limited detail flood insurance study, city of Young Harris, Towns County, Georgia: Federal Emergency Management Agency, community no. 130174.

----- 1986, Limited detail flood insurance study, city of Americus, Sumter County, Georgia: Federal Emergency Management Agency (in press).

----- 1986, Limited detail flood insurance study, city of Hawkinsville, Pulaksi County, Georgia: Federal Emergency Management Agency (in press).

----- 1986, Limited detail flood insurance study, Upson County, Georgia: Federal Emergency Management Agency (in press).

Sanders, C. L., Jr., and Sauer, V. B., 1979, Kelly Barnes Dam flood of November 6, 1977, near Toccoa, Georgia: U.S. Geological Survey Hydrologic Investigations Atlas HA-613.

Stokes, W. R., III, Hale, T. W., Pearman, J. L., and Buell, G. R., 1984, Water resources data, Georgia, water year 1983: U.S. Geological Survey Water-Data Report GA-83-1.

----- 1985, Water resources data, Georgia, water year 1984: U.S. Geological Survey Water-Data Report GA-84-1.

----- 1986, Water resources data, Georgia, water year 1985: U.S. Geological Survey Water-Data Report GA-85-1.

Thomson, M. T., 1950-54, The historic role of rivers of Georgia: Chapters 1-23: Georgia Mineral Newsletter, v. 3, no. 2 to v. 7, no. 2.

----- 1960, Streamflow maps of Georgia's major rivers: Georgia Department of Natural Resources Information Circular 21.

Thomson, M. T., and Carter, R. F., 1955, Surface-water resources of Georgia during the drought of 1954--Part 1, Streamflow: Georgia Department of Natural Resources Information Circular 17.

----- 1963, Effect of a severe drought (1954) on streamflow in Georgia: Georgia Department of Natural Resources Bulletin 73.

Surface-Water Resources--Continued

U.S. Geological Survey, 1971, Index to surface-water records to September 30, 1970--Part 3, Ohio River basin: U.S. Geological Survey Circular 653.

----- 1972, Index to surface-water records to September 30, 1970--Part 2, South Atlantic slope and Eastern Gulf of Mexico basin: U.S. Geological Survey Circular 652.

----- 1976, Water resources data for Georgia--water year 1975: U.S. Geological Survey Water-Data Report GA-75-1.

----- 1977, Water resources data for Georgia--water year 1976: U.S. Geological Survey Water-Data Report GA-76-1.

----- 1977, Index to stations in coastal areas--Atlantic Coast and Gulf Coast volumes: Reston, Virginia, Office of Water Data Coordination.

----- 1978, Water resources data for Georgia--water year 1977: U.S. Geological Survey Water-Data Report GA-77-1.

----- 1979, Water resources data for Georgia--water year 1978: U.S. Geological Survey Water-Data Report GA-78-1.

----- 1980, Water resources data for Georgia--water year 1979: U.S. Geological Survey Water-Data Report GA-79-1.

----- 1981, Water resources data for Georgia--water year 1980: U.S. Geological Survey Water-Data Report GA-80-1.

----- 1982, Water resources data for Georgia--water year 1981: U.S. Geological Survey Water-Data Report GA-81-1.

----- 1983, Water resources data for Georgia--water year 1982: U.S. Geological Survey Water-Data Report GA-82-1.

----- 1984, Water resources data for Georgia--water year 1983: U.S. Geological Survey Water-Data Report GA-83-1.

----- 1985, Water resources data for Georgia--water year 1984: U.S. Geological Survey Water-Data Report GA-84-1.

----- 1986, Water resources data for Georgia--water year 1985: U.S. Geological Survey Water-Data Report GA-85-1.

Ground-Water Resources

Applin, P. L., and Applin, Esther, 1964, Logs of selected wells in the Coastal Plain of Georgia: Georgia Department of Natural Resources Bulletin 74.

Brooks, Rebekah, Clarke, J. S., and Faye, R. E., 1985, Geology and hydrology of the Gordon aquifer system of east-central Georgia: Georgia Geologic Survey Information Circular 75.

Bush, P. W., 1982, Predevelopment flow in the Tertiary limestone aquifer, Southeastern United States--a regional analysis from digital modeling: U.S. Geological Survey Water-Resources Investigations 82-905.

Callahan, J. T., 1958, Large springs in northwestern Georgia: Georgia Mineral Newsletter, v. 11, no. 3, p. 80-86.

----- 1960, Wild-flowing wells waste water: Georgia Mineral Newsletter, v. 13, no. 1, p. 21-23.

----- 1964, The yield of sedimentary aquifers of the Coastal Plain Southeast River Basins: U.S. Geological Survey Water-Supply Paper 1669-W.

Callahan, J. T., and Blanchard, H. E., Jr., 1963, The quality of ground water and its problems in the crystalline rocks of Georgia: Georgia Mineral Newsletter, v. 16, nos. 3-4, p. 66-72.

Carver, R. E., 1978, Anomalous distribution of sinks in the upper Little River watershed, Tift, Turner, and Worth Counties, Georgia, in Georgia Department of Natural Resources, Short contributions to the geology of Georgia: Georgia Department of Natural Resources Bulletin 93, p. 8-10.

Cederstrom, D. J., Boswell, E. H., and Tarver, G. H., 1978, Summary appraisals of the Nation's ground-water resources--South Atlantic-Gulf Region: U.S. Geological Survey Professional Paper 813-O.

Clarke, J. S., Brooks, Rebekah, and Faye, R. E., 1985, Hydrogeology of the Dublin and Midville aquifer systems of east-central Georgia: Georgia Geologic Survey Information Circular 74.

Clarke, J. S., Faye, R. E., and Brooks, Rebekah, 1983, Hydrogeology of the Providence aquifer of southwest Georgia: Georgia Geologic Survey Hydrologic Atlas 11.

----- 1984, Hydrogeology of the Clayton aquifer of southwest Georgia: Georgia Geologic Survey Hydrologic Atlas 13.

Clarke, J. S., Longsworth, S. A., McFadden, K. W., and Peck, M. F., 1985, Ground-water data for Georgia, 1984: U.S. Geological Survey Open-File Report 85-331.

Ground-Water Resources--Continued

Clarke, J. S., Longsworth, S. A., McFadden, K. W., and Peck, M. F., 1986, Ground-water data for Georgia, 1985: U.S. Geological Survey Open-File Report 86-304.

Clarke, J. S., Peck, M. F., Longsworth, S. A., and McFadden, K. W., 1984, Ground-water data for Georgia, 1983: U.S. Geological Survey Open-File Report 84-605.

Clarke, J. S., and Pierce, R. R., 1984, Ground-water resources of Georgia: The Georgia Operator, v. 21, no. 4, p. 10.

----- 1984, Georgia water facts--ground water resources in the United States, in National Water Summary, 1984: U.S. Geological Survey Water-Supply Paper 2275.

Cooper, H. H., Jr., and Warren, M. A., 1945, Perennial yield of artesian water in the coastal area of Georgia, northeastern Florida: Economic Geology, v. 40, no. 4, p. 263-282.

Cooper, S. C., 1985, Geohydrology of a field site for the study of pesticide migration in the unsaturated and saturated zones, Dougherty Plain, southwest Georgia: American Chemical Society Symposium Series No. 315, p. 78-99.

----- 1986, Design and installation of a monitoring network for measuring the movement of aldicarb and its residues in the unsaturated and saturated zones, Lee County, Georgia, in Proceedings, Agricultural Impacts of Ground Water--A Conference: Omaha, Nebraska, National Water Well Association, August 11-13, 1986, p. 194-223.

Counts, H. B., 1971, Ground water--Our most abundant mineral: Atlanta Economic Review, School of Business Administration, Georgia State College of Business Administration, July, p. 22-25.

Counts, H. B., and Donsky, Ellis, 1963, Salt-water encroachment, geology, and ground-water resources of Savannah area, Georgia and South Carolina: U.S. Geological Survey Water-Supply Paper 1611.

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.

Ground-Water Resources--Continued

Cressler, C. W., 1963, Geology and ground-water resources of Catoosa County, Georgia: Georgia Department of Natural Resources Information Circular 28.

----- 1964, Geology and ground-water resources of the Paleozoic rock area, Chattooga County, Georgia: Georgia Department of Natural Resources Information Circular 27.

----- 1964, Geology and ground-water resources of Walker County, Georgia: Georgia Department of Natural Resources Information Circular 29.

----- 1970, Geology and ground-water resources of Floyd and Polk Counties, Georgia: Georgia Department of Natural Resources Information Circular 39.

----- 1974, Geology and ground-water resources of Gordon, Whitfield, and Murray Counties, Georgia: Georgia Department of Natural Resources Information Circular 47.

Cressler, C. W., Blanchard, H. E., Jr., and Hester, W. G., 1979, Geohydrology of Bartow, Cherokee, and Forsyth Counties, Georgia: Georgia Department of Natural Resources Information Circular 50.

Cressler, C. W., Thurmond, C. J., and Hester, W. G., 1983, Ground Water in the Greater Atlanta Region, Georgia: Georgia Geologic Survey Information Circular 63.

Croft, M. G., 1963, Geology and ground-water resources of Bartow County, Georgia: U.S. Geological Survey Water-Supply Paper 1619-FF.

----- 1964, Geology and ground-water resources of Dade County, Georgia: Georgia Department of Natural Resources Information Circular 26.

Davis, G. H., Small, J. B., and Counts, H. B., 1963, Land subsidence related to decline of artesian pressure in the Ocala Limestone at Savannah, Georgia, in Trask, P. D., and Kiersch, G. A., eds., Engineering Geology Case Histories, no. 4, Geological Society of America, Division of Engineering Geology, p. 1-8.

Davis, G. H., Counts, H. B., and Holdahl, S. R., 1977, Further examination of subsidence at Savannah, Georgia, 1955-1975, in Proceedings of the second international symposium on land subsidence, Anaheim, California, December 1976: Washington, D. C., International Association of Hydrologic Sciences Publication No. 121.

Gelbaum, Carol, 1978, The geology and ground water of the Gulf Trough, in Georgia Department of Natural Resources, Short contributions to the gelogy of Georgia: Georgia Department of Natural Resources Bulletin 93, p. 38-49.

Ground-Water Resources--Continued

Gregg, D. O., 1966, An analysis of ground-water fluctuations caused by ocean tides in Glynn County, Georgia: Ground Water, v. 4, no. 3, p. 24-32.

----- 1971, Protective pumping to reduce aquifer pollution, Glynn County, Georgia: Ground Water, v. 9, no. 5, p. 21-29.

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.

Hendricks, E. L., and Goodwin, M. H., Jr., 1952, Water-level fluctuaions in limestone sinks in southwestern Georgia: U.S. Geological Survey Water-Supply Paper 1110-E.

Herrick, S. M., 1961, Well logs of the Coastal Plain of Georgia: Georgia Department of Natural Resources Information Circular 70.

----- 1965, Subsurface study of Pleistocene deposits in coastal Georgia: Georgia Department of Natural Resources Information Circular 31.

Herrick, S. M., and LeGrand H. E., 1949, Geology and ground-water resources of the Atlanta area, Georgia: Georgia Department of Natural Resources Bulletin 55.

Herrick, S. M., and Vorhis, R. C., 1963, Subsurface geology of the Georgia Coastal Plain: Georgia Department of Natural Resources Information Circular 25.

Hicks, D. W., Krause, R. E., and Clarke, J. S., 1981, Geohydrology of the Albany area, Georgia: Georgia Geologic Survey Information Circular 57.

Georgia District, 1985, National Water Summary, 1984--Georgia ground-water facts, in National Water Summary 1984: U.S. Geological Survey Water-Supply Paper 2275.

Georgia District, 1986, National Water Summary, 1985--Georgia ground-water facts, in National Water Summary 1985: U.S. Geological Survey Water-Supply Paper 2300.

Johnston, R. H., Bush, P. W., Krause, R. E., Miller, J. A., and Sprinkle, C. L., 1982, Summary of hydrologic testing in Tertiary limestone aquifer, Tenneco offshore exploratory well--Atlantic OCS, lease-block 427 (Jacksonville NH 17-5): U.S. Geological Survey Water-Supply Paper 2180.

Ground-Water Resources--Continued

Johnston, R. H., Healy, H. G., and Hayes, L. R., 1981, Potentiometric surface of the Tertiary limestone aquifer system, Southeastern United States, May 1980: U.S. Geological Survey Open-File Report 81-486.

Johnston, R. H., Krause, R. E., Meyer, F. W., Ryder, P. D., Tibbals, C. H., and Hunn, J. D., 1980, Estimated potentiometric surface for the Tertiary limestone aquifer system, Southeastern United States, prior to development: U.S. Geological Survey Open-File Report 80-406.

Krause, R. E., 1972, Effects of ground-water pumping in parts of Liberty and McIntosh Counties, Georgia, 1966-70: Georgia Department of Natural Resources Information Circular 45.

----- 1978, Geohydrology of Brooks, Lowndes, and western Echols Counties, Georgia: U.S. Geological Survey Water-Resources Investigations 78-117.

----- 1982, Digital model evaluation of the predevelopment flow system of the Tertiary limestone aquifer, southeast Georgia, northeast Florida, and southern South Carolina: U.S. Geological Survey Water-Resources Investigations 82-173.

Krause, R. E., and Counts, H. B., 1975, Digital model analysis of the principal artesian aquifer, Glynn County, Georgia: U.S. Geological Survey Water-Resources Investigations 1-75.

Krause, R. E., and Gregg, D. O., 1972, Water from the principal artesian aquifer in coastal Georgia: Georgia Department of Natural Resources Hydrologic Atlas 1.

Krause, R. E., and Hayes, L. R., 1981, Potentiometric surface of the principal artesian aquifer in Georgia, May 1980: Georgia Geologic Survey Hydrologic Atlas 6.

Krause, R. E., Matthews, S. E., and Gill, H. E., 1984, Evaluation of the ground-water resources of coastal Georgia--Preliminary report on the data available as of July 1983: Georgia Geologic Survey Information Circular 62.

Krause, R. E., and Randolph, R. B., 1985, Hydrology of the Floridan aquifer system in southeast Georgia and adjacent parts of Florida and South Carolina: U.S. Geological Survey Professional Paper 1403-D (in press).

LaMoreaux, P. E., 1946, Geology and ground-water resources of the Coastal Plain of east-central Georgia: Georgia Department of Natural Resources Bulletin 52.

Ground-Water Resources--Continued

LeGrand, H. E., 1962, Geology and ground-water resources of the Macon area, Georgia: Georgia Department of Natural Resources Bulletin 72.

----- 1967, Ground-water of the Piedmont and Blue Ridge provinces in the Southeastern States: U.S. Geological Survey Circular 538.

Maslia, M. L., and Hayes, L. R., 1986, Hydrogeology and simulated effects of ground-water development of the Floridan aquifer system, southwest Georgia, northwest Florida, and extreme southern Alabama: U.S. Geological Survey Professional Paper 1403-H (in press).

Maslia, M. L., and Randolph, R. B., 1986, Methods and computer program documentation for determining anisotropic transmissivity tensor components of two-dimensional ground-water flow: U.S. Geological Survey Open-File Report 86-227, 64 p.

----- 1986, Methods and computer program documentation for determining anisotropic transmissivity tensor components of two-dimensional ground-water flow: U.S. Geological Survey Water-Supply Paper 2308 (in press).

Matthews, S. E., Hester, W. G., and McFadden, K. W., 1982, Ground-water data for Georgia, 1981: U.S. Geological Survey Open-File Report 82-904.

Matthews, S. E., Hester, W. G., and O'Byrne, M. P., 1981, Ground-water data for Georgia, 1980: U.S. Geological Survey Open-File Report 81-1068.

Matthews, S. E., and Krause, R. E., 1984, Hydrologic data from the U.S. Geological Survey test wells near Waycross, Ware County, Georgia: U.S. Geological Survey Water-Resources Investigations Report 83-4204.

McCollum, M. J., 1966, Ground-water resources and geology of Rockdale County, Georgia: Georgia Department of Natural Resources Information Circular 33.

McCollum, M. J., and Counts, H. B., 1964, Relation of salt-water encroachment to the major aquifer zones, Savannah area, Georgia and South Carolina: U.S. Geological Survey Water-Supply Paper 1613-D.

Miller, J. A., 1982a, Thickness of the Tertiary limestone aquifer system, Southeastern United States: U.S. Geological Survey Open-File Report 81-1124.

----- 1982b, Geology and configuration of the base of the Tertiary limestone aquifer system, Southeastern United States: U.S. Geological Survey Open-File Report 81-1176.

----- 1982c, Geology and configuration of the top of the Tertiary limestone aquifer system, Southeastern United States: U.S. Geological Survey Open-File Report 81-1176.

Ground-Water Resources--Continued

Miller, J. A., 1982d, Configuration of the base of the upper permeable zone of the Tertiary limestone aquifer system, Southeastern United States: U.S. Geological Survey Water-Resources Investigations Report 81-1177.

----- 1982e, Thickness of the upper permeable zone of the Tertiary limestone aquifer system, Southeastern United States: U.S. Geological Survey Water-Resources Investigations Report 81-1179.

Mitchell, G. D., 1980, Potentiometric map of the principal artesian aquifer in Georgia, 1979: U.S. Geological Survey Open-File Report 80-585.

----- 1981, Hydrogeologic data of the Dougherty Plain and adjacent areas, southwest Georgia: Georgia Department of Natural Resources Information Circular 58.

Odom, O. B., 1961, Effects of tides, ships, trains, and changes in atmospheric pressure on artesian water levels in wells in the Savannah area, Georgia: Georgia Mineral Newsletter, v. 14, no. 1, p. 28-29.

Owen, Vaux, Jr., 1963, Geology and ground-water resources of Lee and Sumter Counties, southwest Georgia: U.S. Geological Survey Water-Supply Paper 1666.

----- 1964, Geology and ground-water resources of Mitchell County, Georgia: Georgia Department of Natural Resources Information Circular 24.

Pollard, L. D., Grantham, R. G., and Blanchard, H. E., Jr., 1978, A preliminary appraisal of the impact of agriculture on ground-water availability in southwest Georgia: U.S. Geological Survey Water-Resources Investigations 79-7.

Pollard, L. D., and Vorhis, R. C., 1980, The geohydrology of the Cretaceous aquifer system in Georgia: Georgia Geologic Survey Hydrologic Atlas 3.

Radtke, D. B., Cressler, C. W., Perlman, H. A., Blanchard, H. E., Jr., McFadden, K. W., and Brooks, Rebekah, 1986, Occurrence and availability of ground water in the Athens Region, northeastern Georgia: U.S. Geological Survey Water-Resources Investigations Report 86-4075.

Randolph, R. B., and Krause, R. E., 1984, Analysis of the effects of proposed pumping from the principal artesian aquifer, Savannah, Georgia, area: U.S. Geological Survey Water-Resources Investigations Report 84-4064.

Randolph, R. B., Krause, R. E., and Maslia, M. L., 1985, Comparison of aquifer characteristics derived from local and regional aquifer tests: Ground Water, v. 23, no. 3, p. 309-316.

Ground-Water Resources--Continued

Sever, C. W., 1962, Acid waters in the crystalline rocks of Dawson County, Georgia: Georgia Mineral Newsletter, v. 15, no. 3, p. 57-61.

----- 1964, Ground-water conduits in the Ashland Mica Schist, northern Georgia, in Geological Survey Research 1964, Chapter D: U.S. Geological Survey Professional Paper 501-D, p. D141-D143.

----- 1964, Geology and ground-water resources of crystalline rocks, Dawson County, Georgia: Georgia Department of Natural Resources Information Circular 30.

----- 1965, Ground-water resources of Bainbridge, Georgia: Georgia Department of Natural Resources Information Circular 32.

----- 1965, Ground-water resources and geology of Seminole, Decatur, and Grady Counties, Georgia: U.S. Geological Survey Water-Supply Paper 1809-Q.

----- 1966, Reconnaissance of the ground water and geology of Thomas County, Georgia: Georgia Department of Natural Resources Information Circular 34.

----- 1969, Hydraulics of aquifers at Alapaha, Coolidge, Fitzgerald, Montezuma, and Thomasville, Georgia: Georgia Department of Natural Resources Information Circular 36.

----- 1972, Ground-water resources and geology of Cook County, Georgia: U.S. Geological Survey Open-File Report.

Sever, C. W., and Callahan, J. T., 1962, The temperature of the ground and ground water, Dawson County, Georgia: Georgia Mineral Newsletter, v. 15, nos. 1-2, p. 25-28.

Stewart, J. W., 1958, Effect of earthquakes on water levels in wells in Georgia: Georgia Mineral Newsletter, v. 11, no. 4, p. 129-131.

----- 1960, Relation of salty ground water to fresh artesian water in the Brunswick area, Glynn County, Georgia: Georgia Department of Natural Resources Information Circular 20.

----- 1962, Water-yielding potential of weathered crystalline rocks at the Georgia Nuclear Laboratory, in Geological Survey Research 1962, Chapter B: U.S. Geological Survey Professional Paper 450-B, p. B106-B107.

----- 1962, Relation of permeability and jointing in crystalline metamorphic rocks near Jonesboro, Georgia, in Geological Survey Research 1962, Chapter D: U.S. Geological Survey Professional Paper 450-D, p. D-168-D170.

Stewart, J. W., 1964, Infiltration and permeability of weathered crystalline rocks, Georgia Nuclear Laboratory, Dawson County, Georgia: U.S. Geological Survey Bulletin 1133-D.

Ground-Water Resources--Continued

Stewart, J. W., and Blanchard, H. E., Jr., 1962, Geology and hydrologic data relating to disposal of waste in crystalline rocks, Georgia Nuclear Laboratory, Dawson County, Georgia: U.S. Geological Survey Open-File Report.

Stewart, J. W., and others, 1964, Geologic and hydrologic investigation at the site of the Georgia Nuclear Laboratory, Dawson County, Georgia: U.S. Geological Survey Bulletin 1133-F.

Stiles, H. R., and Matthews, S. E., 1983, Ground-water data for Georgia, 1982: U.S. Geological Survey Open-File Report 83-678.

Stringfield, V. T., 1966, Artesian water in Tertiary limestone in the Southeastern States: U.S. Geological Survey Professional Paper 517.

U.S. Geological Survey, 1977, Ground-water levels and quality data for Georgia, 1977: U.S. Geological Survey Open-File Report 79-213.

----- 1978, Ground-water levels and quality data for Georgia, 1978: U.S. Geological Survey Water-Resources Investigations 79-1290.

----- 1979, Ground-water data for Georgia, 1979: U.S. Geological Survey Open-File Report 80-501.

Vincent, H. R., 1983, Geohydrology of the Jacksonian aquifer in central and east-central Georgia: Georgia Geologic Survey Hydrologic Atlas 8.

Vorhis, R. C., 1961, A hydrogeologic reconnaissance of reservoir possibilities in northern Lowndes County, Georgia: Georgia Mineral Newsletter, v. 14, no. 4, p. 123-129.

----- 1964, Earthquake-induced water-level fluctuations from a well in Dawson County, Georgia: Seismological Society of America Bulletin, v. 54, no. 4, p. 1023-1034.

----- 1973, Geohydrology of Sumter, Dooly, Pulaski, Lee, Crisp, and Wilcox Counties, Georgia: U.S. Geological Survey Hydrologic Investigations Atlas HA-435.

Wait, R. L., 1958, Summary of the ground-water resources of Crisp County, Georgia: Georgia Mineral Newsletter, v. 11, no. 2, p. 44-47.

----- 1960a, Summary of the ground-water resources of Clay County, Georgia: Georgia Mineral Newsletter, v. 13, no. 2, p. 93-101.

----- 1960b, Summary of the ground-water resources of Terrell County, Georgia: Georgia Mineral Newsletter, v. 13, no. 2, p. 117-122.

Ground-Water Resources--Continued

Wait, R. L., 1960c, Source and quality of ground water in southwestern Georgia: Georgia Department of Natural Resources Information Circular 18.

----- 1962, Interim report on test drilling and water sampling in the Brunswick area, Glynn County, Georgia: Georgia Department of Natural Resources Information Circular 23.

----- 1963, Geology and ground-water resources of Dougherty County, Georgia: U.S. Geological Survey Water-Supply Paper 1539-P.

----- 1965, Geology and occurrence of fresh and brackish ground water in Glynn County, Georgia: U.S. Geological Survey Water-Supply Paper 1613-E.

Wait, R. L., and Callahan, J. T., 1965, Relations of fresh and salty ground water along the Southeastern U.S. Atlantic Coast: Ground Water, v. 3, no. 4, p. 3-17.

Wait, R. L., and Gregg, D. O., 1973, Hydrology and chloride contamination of the principal artesian aquifer in Glynn County, Georgia: Georgia Department of Natural Resources Hydrologic Report 1.

Wait, R. L., and McCollum, M. J., 1963, Contamination of fresh-water aquifer through an unplugged oil-test well in Glynn County, Georgia: Georgia Mineral Newsletter, v. 16, nos. 3-4, p. 74-80.

Warren, M. A., 1944, Artesian water in southeastern Georgia, with special reference to The coastal area: Georgia Department of Natural Resources Bulletin 49.

----- 1945, Artesian water in southeastern Georgia, with special reference to The coastal area--well records: Georgia Department of Natural Resources Bulletin 49-A.

Watson, T. W., 1981, Geohydrology of the Dougherty Plain and adjacent area, southwest Georgia: Georgia Geologic Survey Hydrologic Atlas 5.

Zimmerman, E. A., 1977, Ground-water resources of Colquitt County, Georgia: U.S. Geological Survey Open-File Report 77-56.

Zurawski, Ann, 1978, Summary appraisals of the Nation's ground-water resources--Tennessee Region: U.S. Geological Survey Professional Paper 813-L.

Quality of Water

Bradford, W. L., Miller, R. L., and Peters, N. E., 1986, Specific conductance: theoretical considerations and applications to laboratory quality control: U.S. Geological Survey Water-Supply Paper 2311 (in press).

Brooks, M. H., and McConnell, J. B., 1983, Inland travel of tide-driven saline water in the Altamaha and Satilla Rivers, Georgia, and the St. Marys River, Georgia-Florida: U.S. Geological Survey Water-Resources Investigations Report 83-4086.

Buell, G. R., and Grams, S. C., 1985, The hydrologic bench-mark program: a standard to evaluate time-series trends in selected water-quality constituents for streams in Georgia: U.S. Geological Survey Water-Resources Investigations Report 84-4318.

Cherry, R. N., 1961, Chemical quality of water of Georgia streams, 1957-58--A reconnaissance: Georgia Department of Natural Resources Bulletin 69.

Cherry, R. N., Faye, R. E., Stamer, J. K., and Kleckner, R. L., 1980, Summary of the river-quality assessment of the upper Chattahoochee River basin, Georgia: U.S. Geological Survey Circular 811.

Cherry, R. N., Lium, B. W., Shoaf, W. T., Stamer, J. K., and Faye, R. E., 1979, Effects of nutrients on algal growth in West Point Lake, Georgia: U.S. Geological Survey Open-File Report 78-976.

Dyar, T. R., and Stokes, W. R., III, 1973, Water temperatures of Georgia streams: Georgia Department of Natural Resources, Environmental Protection Division.

Ehlke, T. A., 1978, The effect of nitrification on the oxygen balance on the upper Chattahoochee River, Georgia: U.S. Geological Survey Water-Resources Investigations 79-10.

Elrick, K. A., and Horowitz, A. J., 1986, Analysis of rocks and sediments for arsenic, antimony, and selenium, by wet digestion and hydride generation atomic absorption: Varian Instruments at Work, January 1986, no. AA-56, 5 p.

----- 1986, Analysis of rocks and sediments for arsenic, antimony, and selenium, by wet digestion and hydride generation atomic absorption: U.S. Geological Survey Open-File Report 86-497, 14 p.

----- 1986, Analysis of rocks and sediments for mercury, by wet digestion, and flameless cold vapor atomic absorption: U.S. Geological Survey Open-File Report 86-529, 15 p.

----- 1986, Analysis of rocks and sediments for mercury, by wet digestion, and flameless cold vapor atomic absorption: Varian Instruments at Work (in press).

Quality of Water--Continued

Faye, R. E., Carey, W. P., Stamer, J. K., and Kleckner, R. L., 1980, Erosion, sediment discharge, and channel morphology in the upper Chattahoochee River basin, Georgia: U.S. Geological Survey Professional Paper 1107.

Faye, R. E., Jobson, H. E., and Land, L. F., 1979, Impact of flow regulation and powerplant effluents on the flow and temperature regimes of the Chattahoochee River--Atlanta to Whitesburg, Georgia: U.S. Geologial Survey Professional Paper 1108.

Flint, R. F., 1971, Fluvial sediment in North Fork Broad River subwatershed 14 (tributary to Toms Creek), Georgia: U.S. Geological Survey Open-File Report.

Grantham, R. G., and Stokes, W. R., III, 1976, Ground-water-quality data for Georgia: Doraville, Georgia, U.S. Geological Survey.

Hendricks, E. L., and Goodwin, M. H., Jr., 1952, Observations on surface-water temperatures in limesink ponds and evaporation pans in southwestern Georgia: Ecology, v. 33, 3, p. 385-397.

Hirsch, R. M., and Peters, N. E., 1986, Discussion: the statistical confirmation of trends in autocorrelated data: Atmospheric Environment, v. 20, p. 229-234.

----- 1986, Short-term trends in sulfate deposition: Atmospheric Environment (in press).

Horowitz, A. J., 1985, A primer on trace metal-sediment chemistry: U.S. Geological Survey Water Supply Paper 2277.

----- 1986, Comparison of methods for the concentration of suspended sediment in river water for subsequent chemical analysis: Environmental Science and Technology, February 1986, v. 20, no. 2, p. 155-160.

----- 1986, Trace metal analysis of rocks and sediments by graphite furnace atomic absorption spectroscopy: U.S. Geological Survey Open-File Report 86-305.

----- 1986, Trace metal analysis of rocks and sediments by graphite furnace atomic absorption spectroscopy: Varian Instruments at Work, September, 1986, AA-64.

Horowitz, A. J., and Elrick, K. A., 1985, Multielement analysis of rocks and sediments by wet digestion and atomic absorption spectroscopy: Varian Instruments at Work, AA-47.

----- 1986, An evaluation of air elutriation for sediment particle size separation and subsequent chemical analysis: Environmental Technology Letters, v. 7, p. 17-26.

Quality of Water--Continued

Horowitz, A. J., and Elrick, K. A., 1986, Interpretation of bed sediment trace metal data: methods of dealing with the grain size effect, in Proceedings of the EPA symposium on chemical and biological characterization of muncipal sludges, sediments, dredge spoils, and drilling muds: Cincinnati, Ohio, U.S. Environmental Protection Agency (in press).

----- 1986, The geochemistry of sediments from the Cheyenne River arm of the Oahe Reservior, South Dakota: Chemical Geology (in press).

----- 1986, Surface area and its interrelation with grain size, geochemical phase, and sediment-trace element chemistry: Geochemical et Cosmochimica Data (in press).

----- 1986, An examination of methods for the concentration of suspended sediment for direct metal analysis, in Proceedings of the EPA symposium on chemical and biological characterization of municipal sludges, sediments, dredge spoils, and drilling muds: Cincinnati, Ohio, U.S. Environmental Protection Agency (in press).

Jobson, H. E., and Keefer, T. N., 1979, Modeling highly transient flow, mass, and heat transport in the Chattahoochee River near Atlanta, Georgia: U.S. Geological Survey Professional Paper 1136.

Jobson, H. E., Land, L. F., and Faye, R. E., 1979, Chattahoochee River thermal alterations: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 105, no. HY4, p. 295-311.

Kennedy, V. C., 1964, Sediment transported by Georgia streams: U.S. Geological Survey Water-Supply Paper 1668.

Krause, R. E., 1976, Occurrence and distribution of color and hydrogen sulfide in water from the principal artesian aquifer in the Valdosta area, Georgia: U.S. Geological Survey Open-File Report 76-378.

Lamar, W. L., 1955, Fluoride content of Georgia water supplies: Georgia Department of Public Health.

Lium, B. W., Stamer, J. K., Ehlke, T. A., Faye, R. E., and Cherry, R. N., 1979, Biological and microbiological assessment of the upper Chattahoochee River basin, Georgia: U.S. Geological Survey Circular 796.

McConnell, J. B., 1980, Impact of urban storm runoff on stream quality near Atlanta, Georgia: Cincinnati, Ohio, U.S. Environmental Protection Agency Municipal Environmental Research Laboratory, EPA-600/2-80-094.

McConnell, J. B., Hicks, D. W., Lowe, L. E., Choen, S. Z., and Jovanowich, A. P., 1984, Investigation of ethylene dibromide (EDB) in ground water in Seminole County, Georgia: U.S. Geological Survey Circular 933.

Quality of Water--Continued

Radtke, D. B., McConnell, J. B., and Carey, W. P., 1980, A preliminary - appraisal of the effects of agriculture on stream quality in southwest Georgia: U.S. Geological Survey Water-Resources Investigations Report 80-771.

Rittmaster, R. L., and Peters, N. E., 1986, Acid sensitivity of two streams in Central Massachusetts [abs.]: Transactions of the American Geophysical Union, v. 67, no. 16, p. 283.

Salotti, C. A., and Fouts, J. A., 1967, Specifications in ground water related to geologic formations in the Broad quadrangle, Georgia: Georgia Department of Natural Resources Bulletin 78.

Schefter, J. E, and Hirsch, R. M., 1980, An economic analysis of selected strategies for dissolved-oxygen management, Chattahoochee River, Georgia: U.S. Geological Survey Professional Paper 1140.

Shanley, J. B., 1986, Manganese biogeochemistry in a small Adirondack forested lake-watershed: Water Resources Research, v. 22, no. 12, p. 1647-1656.

Shanley, J. B., and Peters, N. E., 1986, Precipitation chemistry at Panola Mountain State Park near Atlanta, Georgia [abs.]: Ft. Collins, Colorado, Colorado State University, NADP/NTN Coordinator's Office, National Atmospheric Deposition Technical Committee Meeting 1986, p. 3.

Sonderegger, J. L., Pollard, L. D., and Cressler, C. W., 1978, Quality and availability of ground water in Georgia: Georgia Department of Natural Resources Information Circular 48.

Sprinkle, C. L., 1982a, Chloride concentration in water from the upper permeable zone of the Tertiary limestone aquifer system, Southeastern United States: U.S. Geological Survey Water-Resources Investigations Report 81-1103.

----- 1982b, Dissolved-solids concentration in water from the upper permeable zone of the Tertiary limestone aquifer system, Southeastern United States: U.S. Geological Survey Water-Resources Investigations Report 82-94.

----- 1982c, Sulfate concentration in water from the upper permeable zone of the Tertiary limestone aquifer system, Southeastern United States: U.S. Geological Survey Water-Resources Investigations Report 812-101.

----- 1982d, Total hardness of water from the upper permeable zone of the Tertiary limestone aquifer system, Southeastern United States: U.S. Geological Survey Water-Resources Investigations Report 81-1102.

Quality of Water--Continued

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.

Water Use

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.

Fanning, J. L., 1985, The Georgia water-use program: U.S. Geological Survey Open-File Report 85-481.

Pierce, R. R., and Barber, N. L., 1981, Water use in Georgia, 1980--a preliminary report: Georgia Department of Natural Resources Circular 4.

----- 1982, Water use in Georgia, 1980--summary: Georgia Department of Natural Resources Circular 4A.

Pierce, R. R., Barber, N. L., and Stiles, H. R., 1982, Water use in Georgia by county for 1981: Georgia Department of Natural Resources Information Circular 59.

----- 1984, Georgia irrigation, 1970-80--A decade of growth: U.S. Geological Survey Water-Resources Investigations Report 83-4177.

General Water Resources

Bredehoeft, J. D., Counts, H. B., Robson, S. G., and Robertson, J. B., 1976, Solute transport in ground-water systems, in Rodda, J. C., ed., Facets of hydrology: London, John Wiley, p. 229-256.

Callahan, J. T., 1960, Water for Georgia's expanding economy: Georgia Mineral Newsletter, v. 13, no. 4, p. 152-158.

Callahan, J. T., Newcomb, L. E., and Geurin, J. W., 1966, Water in Georgia: U.S. Geological Survey Water-Supply Paper 1762.

Casteel, C. A., and Ballew, M. D., 1986, Water resources activities, Georgia District, 1985: U.S. Geological Survey Open-File Report 86-234.

Cosner, O. J., 1974, Stratigraphy of an archeological site, Ocmulgee flood plain, Macon, Georgia: U.S. Geological Survey Water-Resources Investigations 54-73.

Cressler, C. W., Franklin, M. A., and Hester, W. G., 1976, Availability of water supplies in northwest Georgia: Georgia Department of Natural Resources Bulletin 91.

Dyar, T. R., Tasker, G. D., and Wait, R. L., 1972, Hydrology of the Riceboro area, coastal Georgia: Georgia Water Quality Control Board, Final Report.

George, John, 1980, Status of water knowledge, U.S. Geological Survey, in Kundell, J. E., ed., Georgia water resources, issues and options: Athens, Georgia, University of Georgia Institute of Government.

Georgia District, 1985, Water-resources activities, Georgia District, 1984: Doraville, Georgia, U.S. Geological Survey.

Harkins, J. R., and others, 1982, Hydrology of Area 24, Eastern Coal Province, Alabama and Georgia: U.S. Geological Survey Water-Resources Investigations 81-1113.

MacKichan, K. A., 1962, Water for industry: Georgia Mineral Newsletter, v. 15, nos. 1-2, p. 20-22.

Murray, C. R., and Reeves, E. B., 1977, Estimated use of water in the United States, 1975: U.S. Geological Survey Circular 675.

Peyton, Garland, 1954, The characteristics of Georgia's water resources and factors related to their use and control: Georgia Department of Natural Resources Information Circular 16.

Stewart, J. W., 1973, Dewatering of the Clayton Formation during construction of the Walter F. George Lock and Dam, Fort Gaines, Clay County, Georgia: U.S. Geological Survey Water-Resources Investigations 2-73.

General Water Resources

Stewart, J. W., and Herrick, S. M., 1963, Emergency water supplies for the Atlanta area in a national emergency: Georgia Department of Natural Resources Special Publication 1.

Thomson, M. T., Herrick, S. M., and Brown, Eugene, 1956, Availability and use of water in Georgia: Georgia Department of Natural Resources Bulletin 65.

U.S. Geological Survey, 1975, Hydrologic unit map--1974, State of Georgia: Reston, Virginia, U.S. Geological Survey.