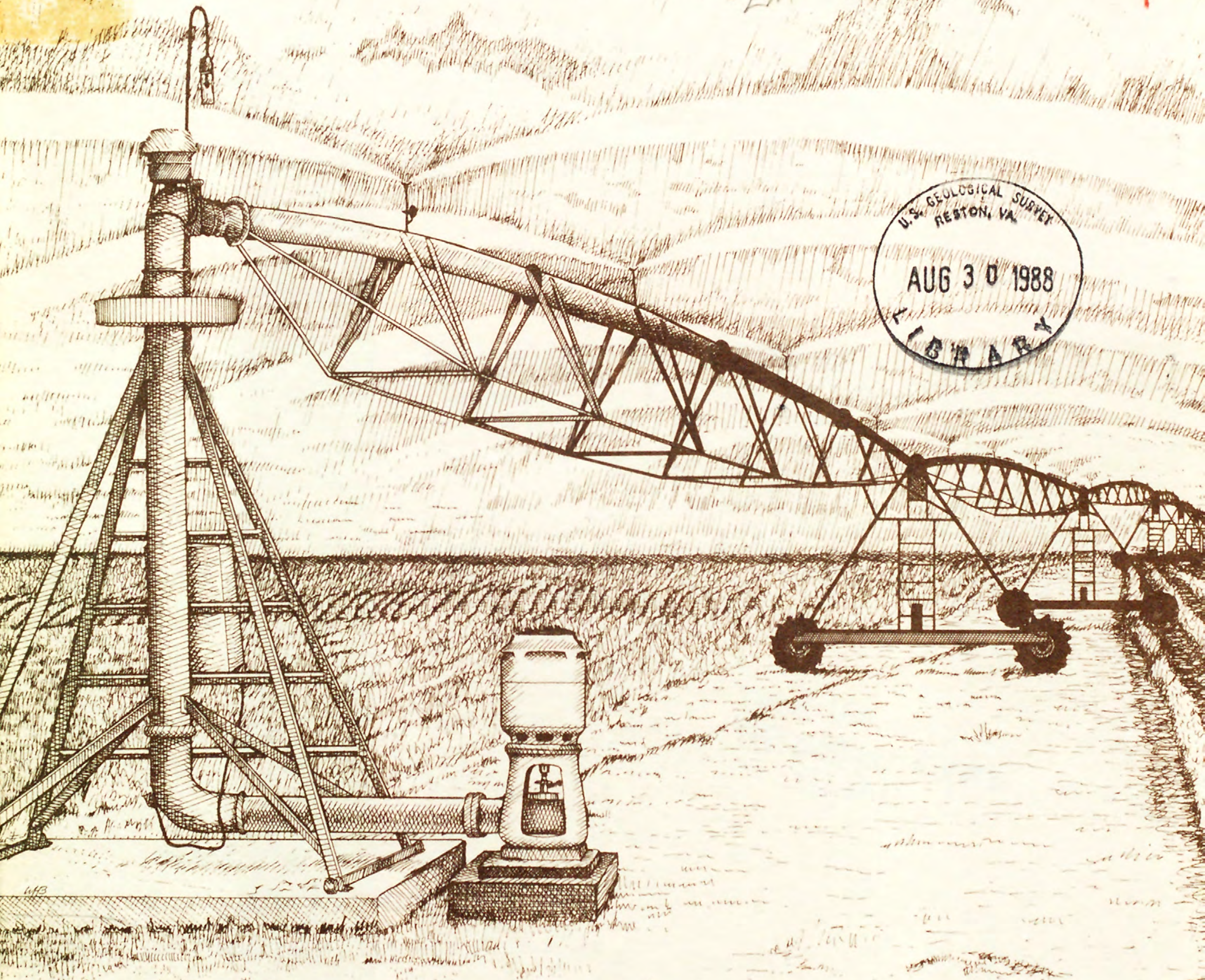


WATER RESOURCES ACTIVITIES, GEORGIA DISTRICT, 1987

U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT 88-185

WATER RESOURCES ACTIVITIES, GEORGIA DISTRICT, 1987

U.S. GEOLOGICAL SURVEY

Open-File Report 88-185

Prepared in cooperation with the

GEORGIA DEPARTMENT of NATURAL RESOURCES

and State, Local, and Federal Agencies

WATER RESOURCES ACTIVITIES, GEORGIA DISTRICT, 1987

By Carolyn A. Casteel and Mary D. Ballew

U.S. GEOLOGICAL SURVEY

Open-File Report 88-185

Prepared in cooperation with the

GEORGIA DEPARTMENT of NATURAL RESOURCES

and State, Local, 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
U.S. Geological Survey, WRD
6481 Peachtree Industrial Blvd.
Suite B
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 25425
Denver, Colorado 80225

CONTENTS

ILLUSTRATIONS

TABLES

WATER RESOURCES ACTIVITIES, GEORGIA DISTRICT, 1987

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 1986 water year for Georgia consists of records of stage, discharge, and water quality of streams; stage and contents of lakes and reservoirs; ground-water levels; and precipitation quality. This report contains discharge records of 107 gaging stations; stage for 13 gaging stations; stage and contents for 18 lakes and reservoirs; water quality for 111 continuous-record stations; peak stage and discharge only for 119 crest-stage partial-record stations and 30 miscellaneous sites; base-flow discharge measurements at 236 miscellaneous sites; water levels of 26 observation wells and water quality for four precipitation-quality sites. These data represent that part of the National Water Data System collected by the U.S. Geological Survey and cooperating State 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 Open-File Services Section, U.S. Geological Survey, Federal Center, 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 National Technical Information Service, U.S. Department of Commerce, 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 1987

State Agencies

Georgia Department of Natural Resources
- Environmental Protection Division
  - Georgia Geologic Survey
  - Water Protection Branch
  - Water Quality Control Section

Georgia Department of Transportation
Florida Department of Environmental Regulation

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 Moultrie
City of Thomaston
City of Thomasville
City of Valdosta
Bibb County
Glynn County
Gwinnett County
Clayton County
- Water Authority

Macon-Bibb County
- Water and Sewage Authority

Town of Blairsville

Federal Agencies

Department of Agriculture
- Agricultural Research Service

Department of the Army
- Corps of Engineers
  - Mobile District
  - Savannah District

Department of Commerce
- National Weather Service (NOAA)

Environmental Protection Agency
Federal Emergency Management Agency
Federal Energy Regulatory Commission
Federal Power Commission Licensees
Tennessee Valley Authority

SUMMARY OF HYDROLOGIC CONDITIONS,

1986 WATER YEAR

Streamflow

Runoff for the 1986 water year was well below normal throughout the State, except for the southeastern part where above normal runoff during the winter months caused a surplus for the year. For unregulated streams having more than 10 years of streamflow record, the ratio of runoff during the 1986 water-year to long-term runoff ranged from about 1.3 at Satilla River near Waycross to 0.2 at Heath Creek near Rome. The runoff ratio for most of Georgia was below 0.6, with the exception of the southeastern part where the ratio was generally above 1.0.

Monthly mean runoff in the northern part of the State was below normal for the entire year and flows during January through July totaled less than 40 percent of normal. In central Georgia, monthly mean runoff was above normal during November and December, about 50 percent of normal during October, January, February, March, and September, and about 20 to 30 percent of normal from April through August. Monthly mean flows in the southern part of the State were well above normal during November through February, slightly below normal during October and March, and well below normal from April through September. Figure 1 shows monthly and yearly mean discharges for the 1986 water year at three representative long-term gaging stations and the median monthly and yearly discharges for the period 1951-80.

Major flooding occurred in the southern part of Georgia in February owing to rainfall that totaled as much as 12 inches on February 4-11. The last few inches of this rainfall occurred rapidly on saturated ground on February 10-11, causing significant flooding in the Satilla, Suwannee, and Ochlockonee River basins. Peak flows in the Satilla River basin ranged from 2- to 40-year recurrence intervals whereas 15- to 25-year events were the norm on the larger streams. Several streams in the Suwannee and Ochlockonee River basins had extremely high peak flows. Two small streams near Tifton, Jacks Creek and Mill Creek, had peaks in excess of the 100-year flood flow. Peak flows at Okapilco Creek near Quitman and Ochlockonee River at Moultrie reached 100-year recurrence intervals and the peak flow at Little River near Adel was a 75-year event.

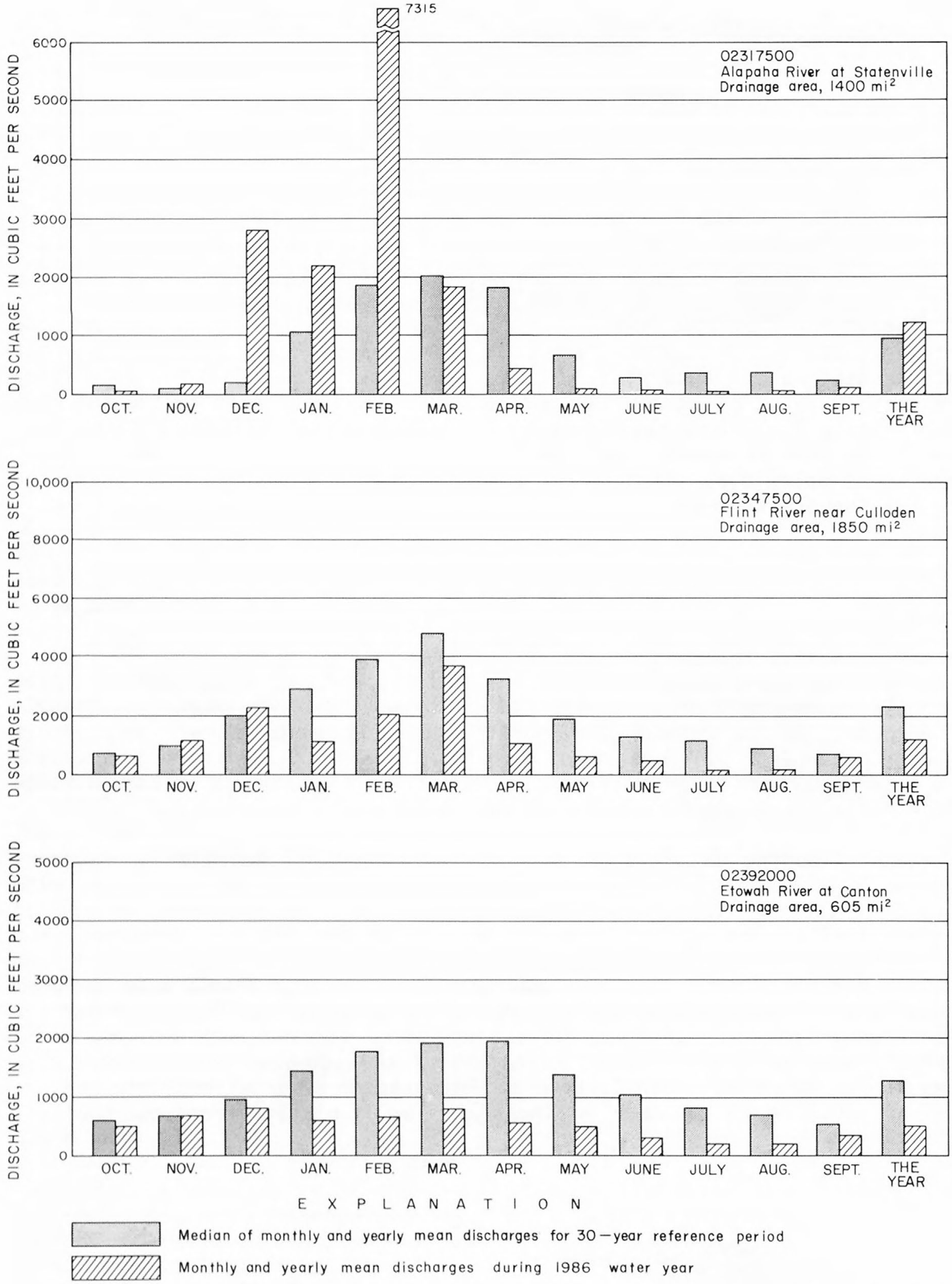


Figure 1.—Comparison of discharge at three representative long-term gaging stations during 1986 water year with median discharge for 30-year reference period.

A severe, prolonged drought occurred in most of Georgia during the year. The effects were most pronounced in the central and northern parts of the State where deficient winter and spring rainfall left streams at seasonally low levels prior to the summer months. Evapotranspiration from high air temperatures and vegetal growth, coupled with a continued lack of rain, caused flows to recede until mid-August when thunderstorms began to relieve the critially dry conditions. However, by the end of the 1986 water year flows again were falling rapidly. This drought was unusual in that most of the unregulated streams had minimum flows in late July or early August rather than in the fall.

The drought was severe from many perspectives. For instance, annual runoff for the 1986 water-year was the lowest on record for such long-term gaging stations as Broad River at Bell (55 years), Oconee River at Dublin (89 years), Chestatee River near Dahlonega (48 years), Chattahoochee River at Columbia (57 years), Flint River at Montezuma (64 years), Etowah River at Canton (59 years), Coosa River at Rome (55 years), and Toccoa River near Dial (74 years). Moreover, new minimum daily flows of record were set at many gaging stations on unregulated streams. Seven-day minimum flows reached recurrence intervals of 30 to 50 years in much of the State. An open-file report documenting the extent and magnitude of this drought is in preparation.

Water Quality

Georgia's surface-water resources are of generally good quality. A summary of surface-water quality for several constituents measured at 15 sites throughout the State is presented in table 2. The stations selected for analysis were chosen to provide good areal coverage of the State and to represent a wide range of basin characteristics, land use, and water use. Eleven of these sites are part of an 85-station network operated by the U.S. Geological Survey and the Georgia Department of Natural Resources, Environmental Protection Division. Five sites 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 2 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.

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	1968-86	173	6.6	161	13	150	5.4	160	0.03	159	0.04	132	2.2
		1986	12	6.7	12	15	12	5.7	12	.03	12	.07	12	3.2
Ogeechee River near Eden	02202500	1974-86	158	6.5	149	77	135	24	145	.11	145	.06	55	8.8
		1986	6	7.2	6	115	6	33	6	.18	6	.08	--d--	
Falling Creek near Juliette	02212600	1968-86	178	6.7	180	118	166	51	124	.07	123	.07	30	3.6
		1986	4	7.6	5	162	6	54	4	.11	4	.03	--d--	
North Oconee River at Athens	02217740	1974-86	137	7.0	137	56	125	21	137	.34	137	.04	133	3.0
		1986	12	7.1	12	65	12	24	12	.38	12	.03	12	4.7
Altamaha River near Everett	02226160	1974-86	189	6.8	194	124	178	28	188	.25	186	.07	145	8.6
		1986	17	7.1	17	166	17	37	17	.24	17	.07	11	10
Satilla River at Atkinson	02228000	1968-86	174	4.9	167	56	153	4.2	165	.12	165	.12	96	19
		1986	8	5.4	9	71	8	5.8	8	.10	8	.12	4	16
Suwannee River at Fargo	02314500	1968-86	171	4.1	157	55	103	1.1	154	.06	155	.04	129	38
		1986	11	3.9	11	62	11	1.0	11	.02	11	.06	11	44
Withlacoochee River near Clyattsville	02318960	1975-86	138	6.3	137	123	124	40	138	.30	138	.17	135	11
		1986	11	6.4	11	120	11	39	11	.20	11	.15	11	15
Chattahoochee River near Fairburn	02337170	1968-86	314	6.5	345	81	157	20	365	.58	356	.52	310	5.8
		1986	12	6.9	12	116	12	24	12	1.2	12	.72	12	5.6
Chattahoochee River at Andrew's L&D near Columbia	02343801	1983-86	24	7.2	24	70	24	18	24	.25	24	.04	--na--	
		1986	6	7.3	6	82	6	21	6	.21	6	.04	--na--	
Kinchafoonee Creek at Preston	02350600	1970-86	73	6.5	66	33	67	9.3	67	.15	67	.04	60	4.5
		1986	2	6.8	2	33	2	8.5	2	.18	2	.03	2	3.9
Flint River at Albany	02352500	1968-86	104	7.1	89	74	84	24	88	.25	88	.11	60	4.7
		1986	4	7.2	4	99	3	25	3	.22	3	.03	3	9.6
Flint River at Newton	02353000	1968-86	111	7.3	84	106	80	39	85	.42	84	.13	31	4.5
		1986	6	7.6	6	136	6	46	6	.54	6	.09	--d--	
Conasauga River near Dalton	02384748	1974-86	141	7.4	140	103	128	46	139	.20	138	.05	136	3.4
		1986	12	7.5	12	118	12	57	12	.21	12	.05	12	4.2
Conasauga River near Resaca	02387050	1974-86	138	7.3	137	165	126	60	137	.48	137	.63	135	6.1
		1986	12	7.4	12	203	12	66	12	.45	12	1.3	12	7.6

Ground Water

A prolonged drought and corresponding increases in pumping resulted in water-level declines throughout the State during the 1986 water year. Annual mean ground-water levels were from 4 feet higher to 12 feet lower than during the 1985 water year. Of the 26 wells having continuous water-level records selected for this report, 13 had record lows.

In the southwestern part of the State, mean water levels in the Floridan aquifer system (formerly the principal artesian aquifer) were from 2 feet lower to 4 feet higher than during the 1985 water year. In the Clayton aquifer, the mean water level was from 1 foot to 12 feet lower than in 1985. Record low water levels were measured in three wells in July and August 1986.

Along the coast, mean water levels in the Floridan aquifer system were from about the same to 3 feet lower than in the 1985 water year. In Savannah, the mean water level was from 1 foot to 3 feet lower than in 1985, and record lows were measured in three wells in July and August 1986. In the Jesup-Riceboro area, the mean water level was from about the same to 2 feet lower than in 1985, and record lows were measured in four wells in August and September 1986. The mean water level in the Brunswick area was 3 feet lower than in 1985, and in the Okefenokee Swamp area the mean water level was about the same as in 1985. The mean water level in the shallow water-table aquifer at Savannah was 3 feet higher than in 1985.

In the south-central and east-central parts of the State, the mean water level in the Floridan aquifer system was from 1 foot lower to 2 feet higher than in 1985. Record low water levels were measured in two wells near Valdosta in July and August 1986.

In the crystalline rock aquifers of the Piedmont province, the mean water level was from 1 foot to 2 feet lower than in 1985. A record low water level was measured in one well in the Atlanta area in July 1986.

More information concerning water-level fluctuations in the State can be found in open-file reports entitled, "Ground-water data for Georgia, 1985," which includes calendar year 1985, and "Ground-water data for Georgia, 1986," which includes calendar year 1986.

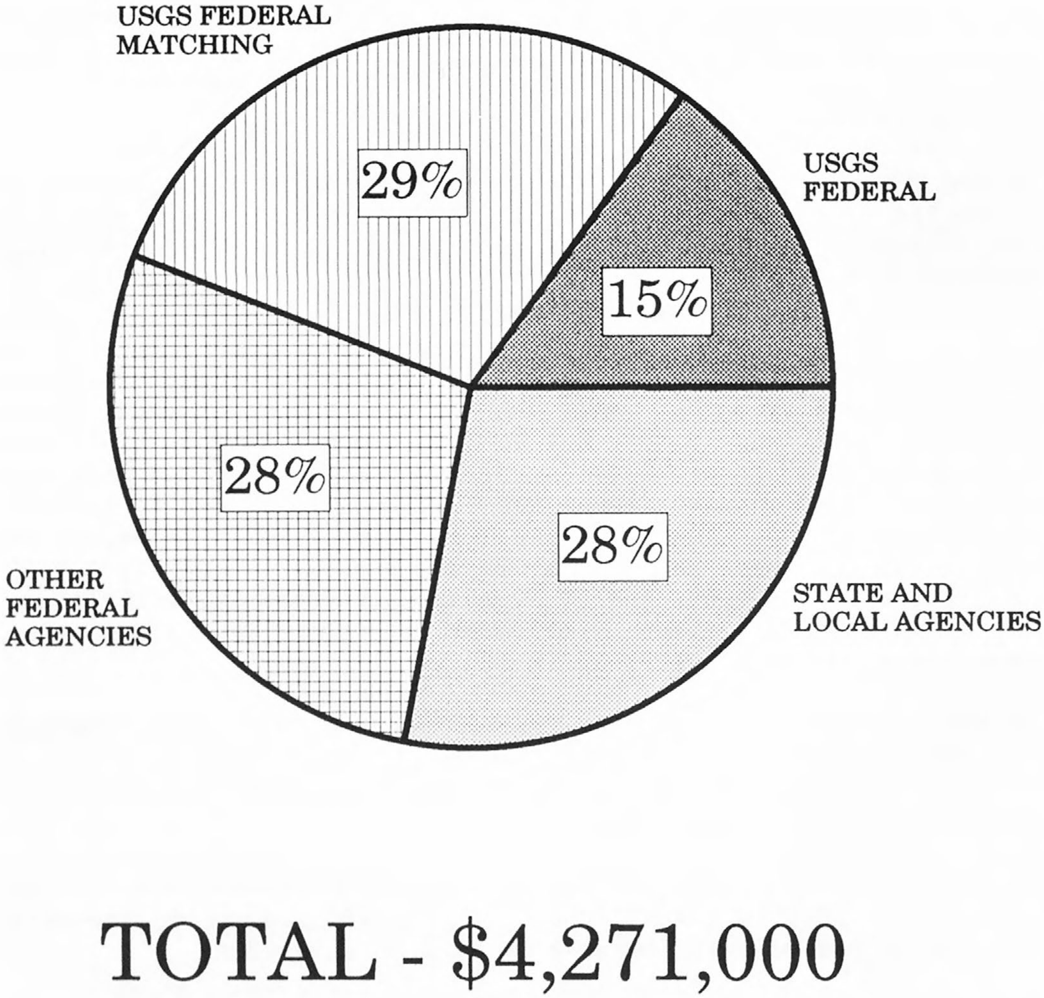


Figure 2. -- Program fund sources, Georgia District, fiscal year 1987.

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.

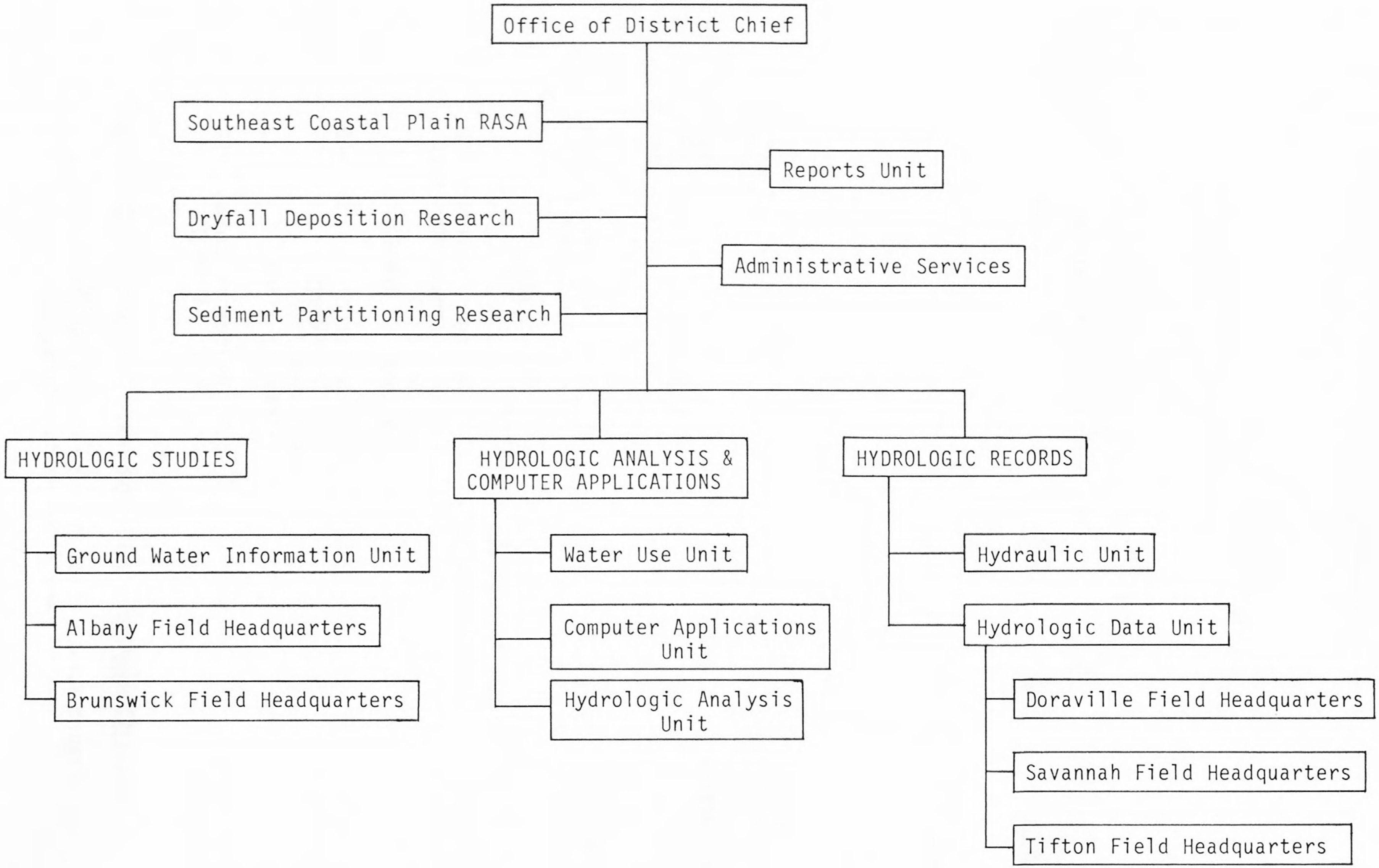


Figure 4.--District Office organization.

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 1987

Surface-Water Monitoring, GA001

Location: Statewide

Project Chief: William 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: Standard methods of data collection will be used as described in the series, "Techniques of Water-Resources Investigations of the Geological Survey." Partial-record gaging is used instead of complete-record gaging where it serves the required purpose.

Progress: Daily discharges were computed for 98 sites and peak stage and discharge were obtained at 119 peak-flow partial-record stations, and final processing of these data was completed. In late water year 1986 and early water year 1987, 194 flow measurements were made at 225 miscellaneous sites to provide documentation of the 1986 drought, and these data were processed for inclusion in the 1986 annual data report. During 1987, two daily-flow stations and two stage-only stations were installed. At the end of 1987 two daily-flow stations and two stage-only stations were discontinued. Computation and preparation of 1987 data for publication was about 55 percent completed. Numerous miscellaneous requests for streamflow data were answered during the year, with a sharp increase in requests concerning the 1986 drought. Minor updates were made to the District Surface-Water-Quality Assurance Plan and the District Flood Plan.

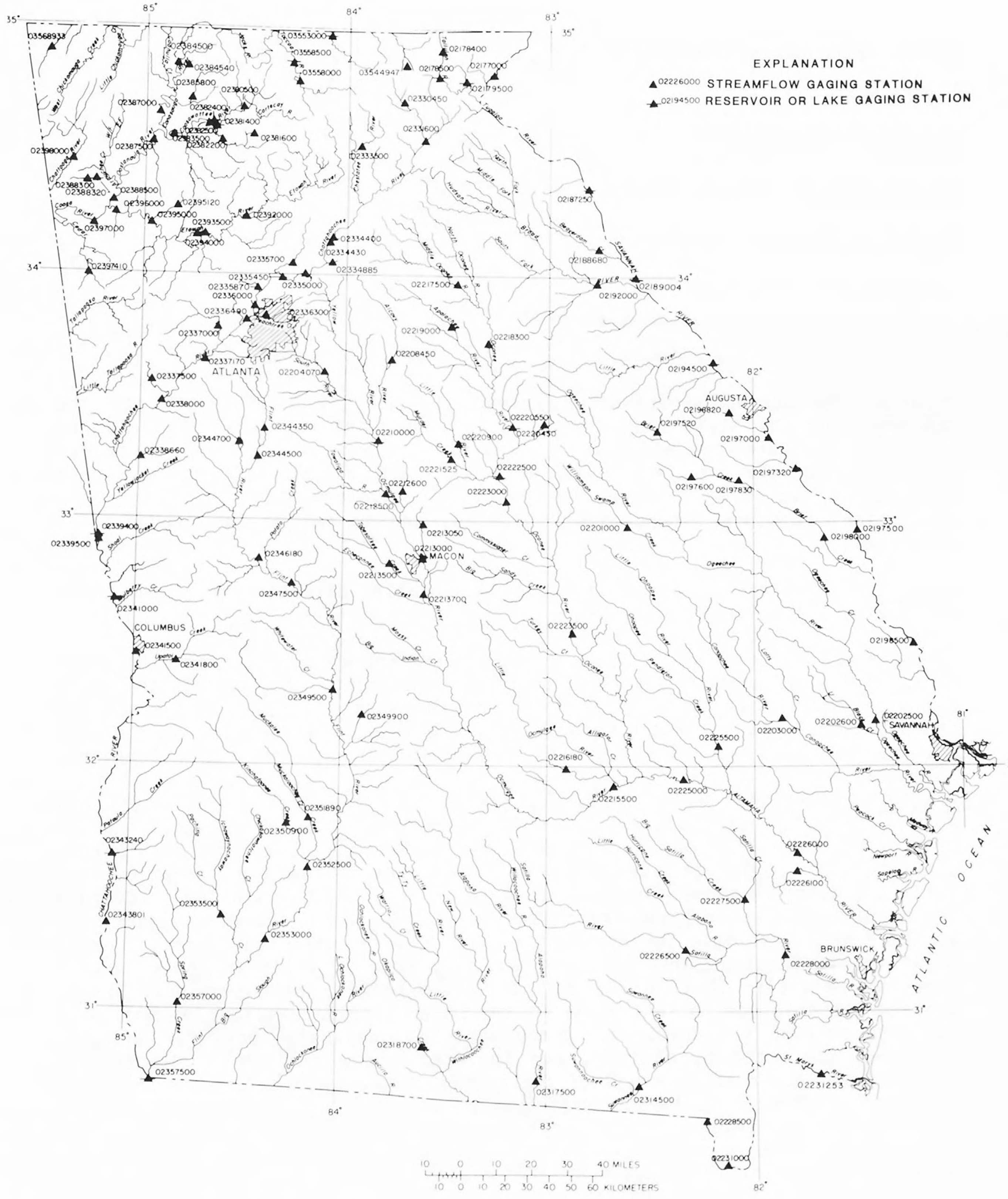


Figure 5.--Location of gaging stations.

Ground-Water Monitoring, GA002

Location: Statewide

Project Chief: John S. Clarke

Period of Project: Continuing

Cooperation: Many agencies

Problem: Monitoring ground-water levels and quality is essential to the management of the State's aquifers. Water-level and water-quality data are needed to evaluate the effects of climatic variations on recharge to and discharge from the aquifers. The data also are needed to provide a data base against which to measure the effects of development, to assist in the prediction of future ground-water supplies, and to manage the ground-water resources.

Objectives: Collect ground-water-level and quality data throughout the State to provide a long-term data base.

Approach: Evaluation of regional hydrogeology allows broad, general definitions 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: Continous water-level recorders were operated at 142 wells and approximately 750 periodic water-level measurements were collected during the year. Potentiometric maps were constructed for the Upper Floridan, Claiborne, Clayton, and Providence aquifers. A report describing the potentiometric surface and ground-water-flow system of the Upper Floridan aquifer in Georgia in May 1985 and water-level trends during 1980-85 was prepared and published by the Georgia Geologic Survey. Water samples were collected monthly from 12 wells in the Savannah area and semi-annually from 90 wells in the Brunswick area for analysis of chloride and dissolved-solids concentration. A map showing the chloride concentration in the Upper Floridan aquifer at Brunswick for October 1986 was prepared. The report, "Ground-Water Data for Georgia, 1986" was completed by midyear, and included a new section on Miocene-age aquifers and expanded coverage of the crystalline rock, shallow water-table, and Upper Floridan aquifers. Four quarterly reports outlining ground-water and climatic conditions at key locations were prepared and submitted to the cooperators. The preparation of well-inventory, water-level, and geologic data for entry into the National Water Data Storage and Retrieval System (WATSTORE) was continued and 152 sites were added to the system. Data sites presently in Ground-Water Site Inventory system (GWSI) were checked for accuracy. Daily values data from the Automated Data Recorder (ADR) system were converted to the Automated Data Processing System (ADAPS).

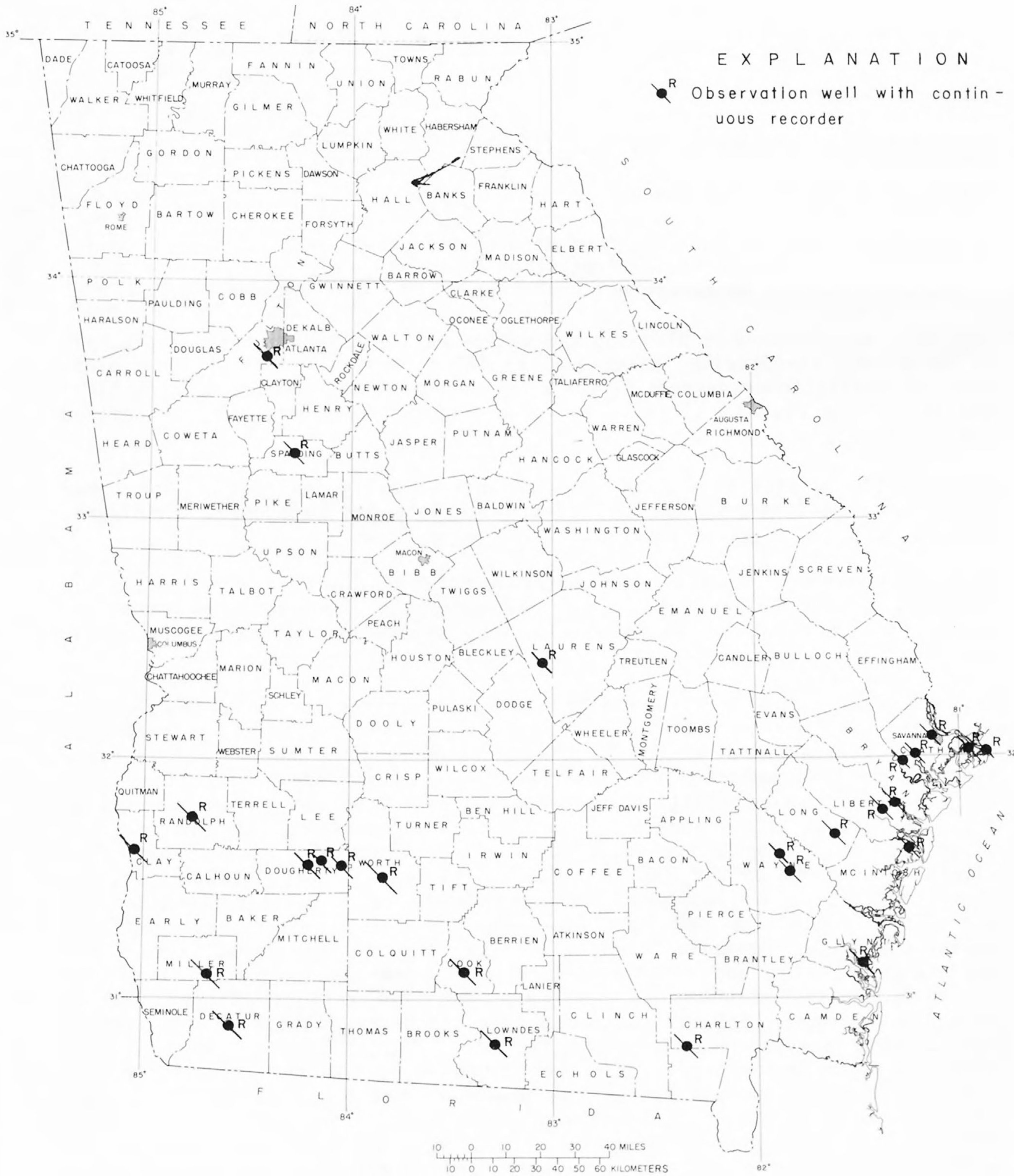


Figure 6.--Location of selected observation wells.

Quality-of-Water Monitoring, GA003

Location: Statewide

Project Chief: William 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.

Progress: Five flow-through monitors and eight minimonitors were in operation at stream sites at the beginning of the year. The standard four properties (pH, water temperature, dissolved-oxygen concentration, and specific conductance) were obtained at four flow-through sites and one minimonitor site. Dissolved-oxygen concentration and temperature were obtained from the remaining flow-through site. Specific conductance was observed at four minimonitor sites and water temperature was recorded at the remaining three minimonitor sites. By the end of the 1987 water year, the four-property minimonitor, the three temperature minimonitors, and one specific-conductance minimonitor had been discontinued. A new specific-conductance minimonitor was installed during the year. Periodic chemical-quality sampling was accomplished at 97 surface-water sites and data were furnished currently to cooperators. The periodic network includes one Benchmark and five National Stream Quality Accounting Network (NASQAN) stations. The Benchmark station and the NASQAN station were sampled quarterly and the other NASQAN stations were sampled bimonthly. One water sample from the NASQAN site, Altamaha River at Everett City, and one water sample from the Benchmark station, Falling Creek near Juliette, were analyzed for radio-chemical data. Periodic samples from wells in the Savannah and Brunswick areas were analyzed for chloride and nonrecurring chemical analyses were performed on samples from several other wells. Data for the 1986 water year were compiled in preparation for publication in the annual water-data report, and preparation of 1987 data for publication was 65 percent completed. Program quality-control activities were conducted according to quality assurance plans. Many requests for water-quality data were answered during the year.

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

Sediment Monitoring, GA004

Location: Statewide

Project Chief: William 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 projects of the U.S. Army Corps of Engineers. However, storm runoff was sampled on three occasions at only two of these sites, because of the general lack of surface runoff during the year. The 1986 water-year data were compiled for publication in the annual water-data report (see project GA001), and preparation of the 1987 data for publication was 30 percent completed.

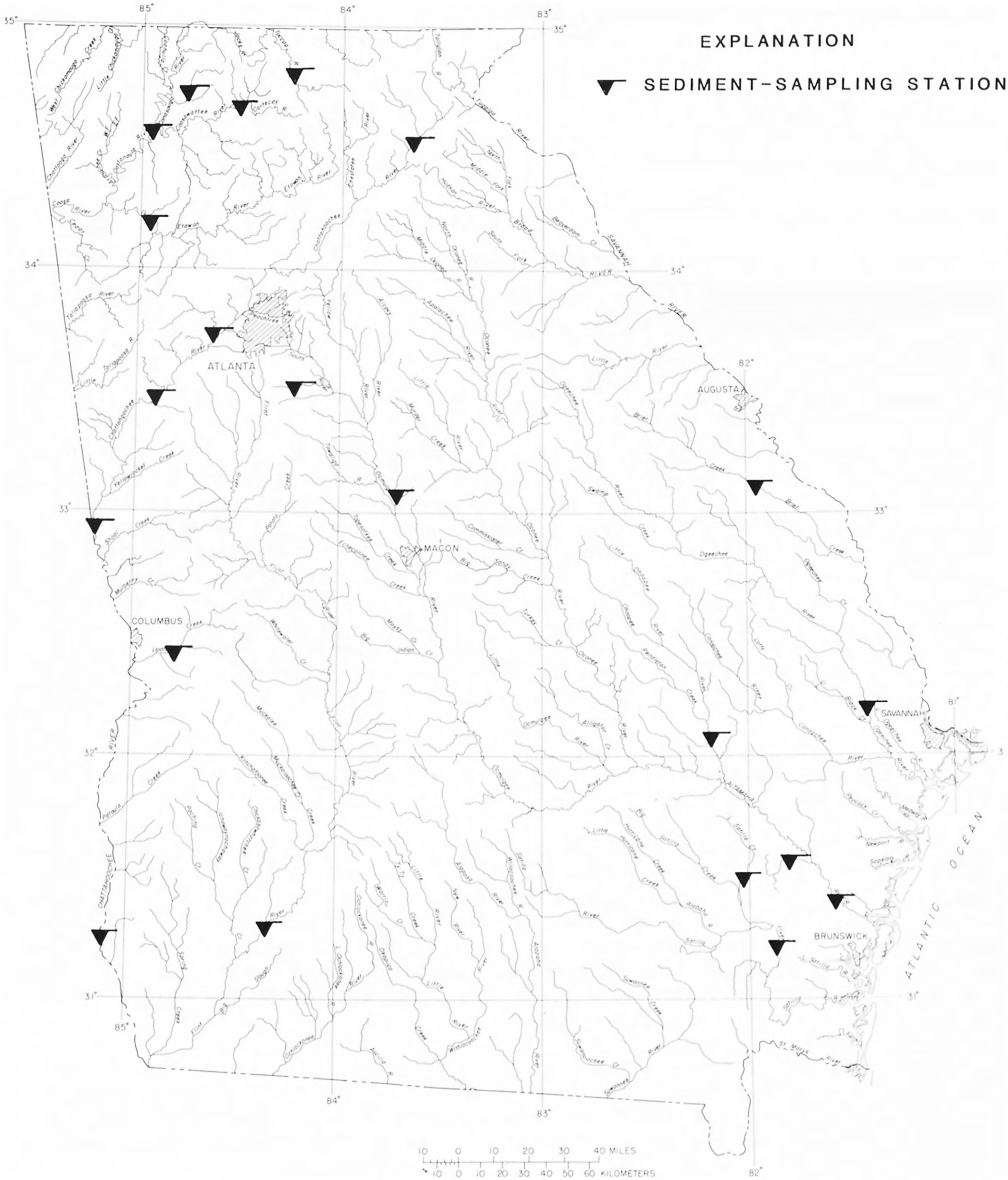


Figure 8.--Location of periodic sediment-sampling stations.

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) site 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, and major cations and anions. 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, wet-deposition samples were collected weekly as part of routine NTN monitoring activities, and the data were entered into WATSTORE and the District water-quality files. The site operator attended an operator training course sponsored by the Illinois State Water Survey Central Analytical Laboratory (CAL), Champaign, IL.

Flood Investigations, GA006

Location: Statewide

Project Chief: McGlone Price

Period of Project: Continuing

Cooperation: Federal Emergency Management Agency

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 were completed for Upson County and the cities of Hawkinsville, Fitzgerald, Eatonton, Lakeland, and Sylvester, and submitted to FEMA for final review.

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
Georgia Geologic Survey

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 was 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 1986 information for municipal, industrial and power-generation withdrawals and returns have been added to the system. Aggregated information for all water-use categories were compiled for entry in the report "Estimated Use of Water in the United States, 1985." Special studies included aquifer assignments for total water use in the municipal, industrial, commercial, and domestic categories by geohydrologists from both the District and the Georgia Geologic Survey; provided names, addresses, latitudes and longitudes of all municipal water systems in the State for the EPA Municipal Well Project.

Statewide Flood Studies, GA059

Location: Statewide

Project Chief: McGlone Price

Period of Project: Continuing

Cooperation: Georgia Department of Transportation

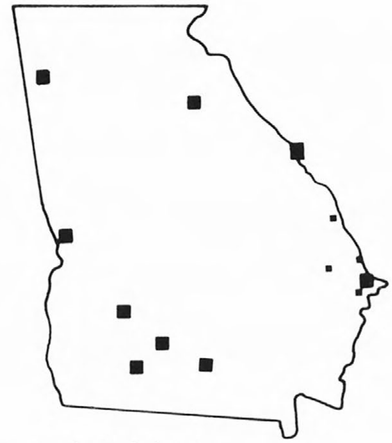
Problem: A knowledge of flood characteristics of streams is essential for the design of highway drainage structures, for planning the best use of flood-prone lands, and for establishing flood-insurance rates. Only through reliable estimates of flood magnitude and frequency is it possible to obtain economically 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 floods.

Approach: (1) Operate a network of crest-stage gages to supplement the statewide gaging-station network and to 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 seven stream reaches. The annual flood-peak data for 1987 were entered into the National Water Data Storage and Retrieval System (WATSTORE) peak-flow file for 86 crest-stage-gage sites. Flood information for 50 sites were furnished to State, Federal, and local agencies.

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
Cities of Albany, Moultrie, Thomasville, and Valdosta

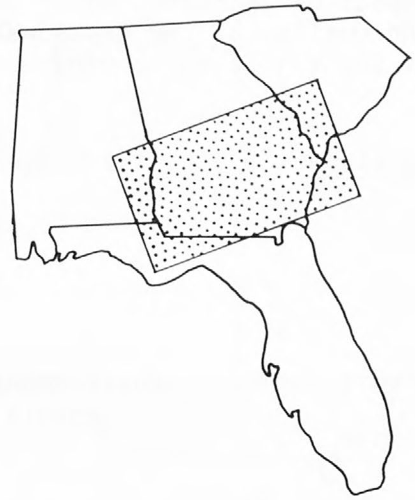
Problem: A method is needed for estimating the magnitude and frequency of floods occurring in streams in metropolitan areas of Georgia. Urban flood-frequency information is needed for bridge, culvert, and drainage design and for flood-mapping studies. Urbanization produces large changes in the flood 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. Significant flood-runoff events will be processed for use in calibrating the U.S. Geological Survey urban-hydrology models. 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 then will be defined from the synthesized flood peaks by 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: The rainfall-runoff model was calibrated at 29 of the 30 sites in Athens, Augusta, Columbus, Rome, and Savannah. Georgia Department of Transportation will delineate a topographic map for the final site for drainage area determination. Parameters from the rainfall-runoff model, unit and daily long-term rainfall, and long-term daily evaporation will be used to synthesize annual peaks for each site. These annual peaks are for 71 to 84 years depending upon the length of rainfall record. A log-Pearson Type III frequency curve was fitted to each series of flood peaks. Data collection is continuing at four new sites in Albany in addition to 18 other sites in Thomasville, Moultrie, and Valdosta.

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



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

Project Chief: Gregory C. Mayer

Period of Project: 1980 - 1987

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: Simulation has been completed. One report, "Ground-water flow and stream-aquifer relations in the northern Coastal Plain of Georgia and adjacent parts of Alabama and South Carolina," is in final review. The second report, "Geohydrologic framework and digital model analysis of Southeastern Coastal Plain clastic aquifers in Georgia and adjacent parts of Alabama and South Carolina," has been prepared and is in review. A third report, "Geologic and geohydrologic framework of the Coastal Plain of Georgia and adjacent parts of Alabama and South Carolina," also is in preparation.

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
Georgia Geologic Survey

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 more than 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 may further impact 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 geologic structures on the flow system, and (4) evaluate the effects of increased water use on the flow system.

Approach: Collect data to better define the geohydrology of the freshwater aquifer system and the saline-water-bearing formations underlying the aquifer system, including test drilling and modification of oil-test wells that fully penetrate the sequence of interest; geophysical logging; testing of aquifer characteristics; and water-quality sampling. Ground-water-flow models will be developed, including a regional, coastal-area model that uses data and model results from the Floridan Regional Aquifer-System Analysis (RASA) study. Management-level models will be developed for high-priority areas, such as Glynn County. These models will be used to predict the effects of increased water use on the system. Results of the study will be published in a geohydrologic report and in a resource-management report describing simulation.

Progress: Calibrated a three-dimensional ground-water flow model of the area and verified the calibration with the RASA and Glynn County models. Coupled the three models into a management package which simulates the flow system at three scales ranging from generalized to detailed. Began simulating hypothetical development scenarios. Began writing the documentation of the coupling process for publication. Compiled 1985 water-use data base for use in all models covering the study area. Compiled water-quality data for input to the District water-quality file. Finalized structure and thickness maps for stratigraphic horizons. Continued update and verification of the Ground-Water Site Inventory (GWSI) data base. The report, "Geology and Ground-Water Resources of the Coastal Area of 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 pesticides. The expanded use of land-applied toxic pesticides indicates the urgent need to thoroughly investigate the migration and degradation of toxic, agricultural chemicals so the quality of the ground-water resources in southwest Georgia can be preserved.

Objectives: (1) Evaluate the potential for degradation of ground-water quality by investigating the transport, degradation, and fate of the carbamate insecticide aldicarb and its two toxic metabolites sulfoxide and sulfone, and the herbicide metolachlor, in the unsaturated and saturated zones; and (2) develop a data base of site-specific field data to enable calibration of a solute-transport model that simulates the mass flux and concentration of pesticides in the crop-root zone and at a specified depth below the root zone within the unsaturated zone.

Approach: Field-monitor pesticide leaching through the soil profile and unsaturated zone into the saturated zone by using a network of wells, suction lysimeters, tensiometers, thermistors, and a weather station. The data will be used to (1) define the hydrogeology of the field site, (2) evaluate the mass flux and the concentration of pesticides in the unsaturated zone, (3) calibrate and test the solute transport model, and (4) establish degradation-rate constants and sorption coefficients for the pesticide aldicarb. In addition, assess chemical transport by applying and monitoring the movement of a conservative inorganic tracer (KBr).

Progress: Measured water levels weekly at the site, plotted hydrographs, and constructed water-table maps. Planted florunner peanuts, incorporated 15-percent formulated aldicarb, and applied the herbicide metolachlor as a spray. Surface-soil samples were collected on day-of-application and analyzed to determine pesticide-application variability. Sampled soil and water monthly for bromide analysis; results indicate that bromide may be moving downward through the soil profile in pulses rather than one single pulse. Developed data-base management system and incorporated historic and current data. Began statistical analyses of data.

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

Location: Glynn County

Project Chief: Morris L. Maslia

Period of Project: 1983 - 1987

Cooperation: City of Brunswick
Glynn County

Problem: Significant declines in water levels near Brunswick are causing 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: To (1) develop and implement a methodology that uses field data to determine if the Brunswick area can be analyzed using an equivalent porous media concept, (2) develop a simplified conceptual flow model explaining the movement of ground water through the fractured and faulted aquifer system, and (3) duplicate the potentiometric surface of the upper water-bearing zone near Brunswick using digital models that support the concepts of the simplified conceptual flow model.

Approach: Make initial estimates of aquifer hydraulic properties by using a modified two-dimensional finite-element model to simulate ground-water flow for the conceptualized fractured system. Determine if other mathematical models for describing fluid flow in fractured and faulted rock aquifers can be applied to the Brunswick area. Calibrate a steady-state two-dimensional flow model for December 1965 and test the calibration for May 1980 and October 1986 flow systems.

Progress: A steady-state two-dimensional ground-water-flow model has been calibrated for the stress period of December 1965. Simulation includes the flow characteristics (vertical leakage) of both conduits (faults and fractures) and the remaining semipermeable matrix of the confining bed. The report, "Geology, Hydrology, and Water Chemistry as Evidence of Fracture Zones in the Upper Floridan aquifer, Brunswick, Glynn County, Georgia," is in preparation.

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

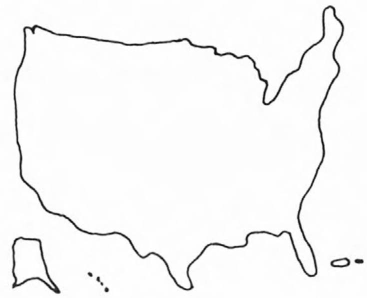
Problem: Acidic atmospheric deposition (acid rain) is thought to be responsible for acidification of surface waters in the Eastern United States. This acidification can have deleterious effects on fauna and flora through changes in the chemical regime. Atmospheric deposition of acids occurs as wet precipitation 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 surface water 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: Precipitation at Panola Mountain is acidic (pH 3.0 to 4.9) and is dominated by sulfuric and nitric acids. During storms the acidity of precipitation is reduced by reactions in the forest canopy. However, an acidic flood wave generated by runoff from a granite outcrop in the headwaters of the watershed moves rapidly downstream and causes stream acidity to increase. Soils at the base of the granite outcrop have higher water-soluble sulfate concentrations than those in the interior of the watershed. This difference, in part, is thought to regulate sulfate concentrations in runoff as it moves into the stream channel. Runoff from the granite outcrop also is more acidic than the precipitation. Increased acidity is caused by the washoff of acidic dry deposition that accumulates on the outcrop between 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 1982, the U.S. Geological Survey (USGS) purchased minicomputers to be located at the major offices of the Water Resources Division (WRD) and form a Distributed Information System (DIS). The DIS will 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 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 (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: NWIS, version 90.1, is being implemented by WRD. The Master Water Data Information System (MWDI)--water-quality component pseudo code--is now operational. The Georgia District is working on the data conversion and update activities associated with national water-quality data, including the construction, testing, and documentation of programs to index and validate water-quality data. Preliminary code outlines (pseudo code) were written and reviewed. The FORTRAN coding of program modules was completed.

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, Toxic Waste Ground Water Contamination Program

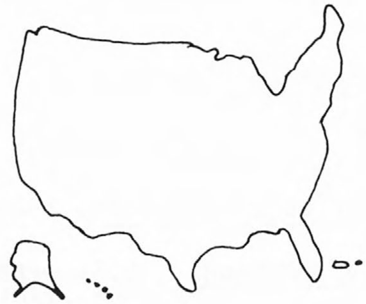
Problem: Increased demand for agricultural products has resulted in widespread multicropping in southwestern Georgia that requires the application of myriad organic and inorganic chemicals. These chemicals are being applied in recharge areas and may move into aquifers used for water supply. Little is 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) Conduct a hydrologic and lithologic evaluation; (2) determine the movement and fate of agricultural chemicals in the unsaturated (including the root zone) and saturated zones; and (3) improve processes to describe the infiltration rate and chemical nature of ground-water recharge in the unsaturated zone by using existing computer models.

Approach: Instrumentation and evaluation of two test plots located in a highly permeable, interfluve part of the study area and installation of 30 to 40 test/monitor wells will be completed. Lysimeters and ceramic soil-moisture collectors will be installed in the unsaturated zone. Ground-penetrating radar (GPR) will be used to identify and correlate strata. Four pits will be excavated and described. The infiltration rate and flow paths in the unsaturated zone along a transect extending from the interfluve area to the toe-slope area in the watershed will be evaluated. Aquifer testing will be conducted to determine hydraulic properties of the saturated zone and the hydraulic conductivity of the unsaturated zone.

Progress: Drilled nine monitor wells, two of which were completed for continuous water-level recording. Six pits were excavated, soils described, sampled, and submitted for analysis. GPR survey was conducted and used to delineate zonation in the unsaturated zone, and to correlate with data collected during pit excavation and with soil borings to evaluate the rate and flow paths of water infiltrating the unsaturated zone. Water samples were collected from selected wells during five sampling periods and analyzed for ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, chloride, alkalinity, orthophosphate-phosphorus, pH, and specific conductance. 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," are in review.

Determination of Inorganic Partitioning in Sediments and Related Environmental Effects, GA088



Location: Nationwide

Project Chief: Arthur J. Horowitz

Period of Project: 1983 - 1989

Cooperation: U.S. Geological Survey, Federal

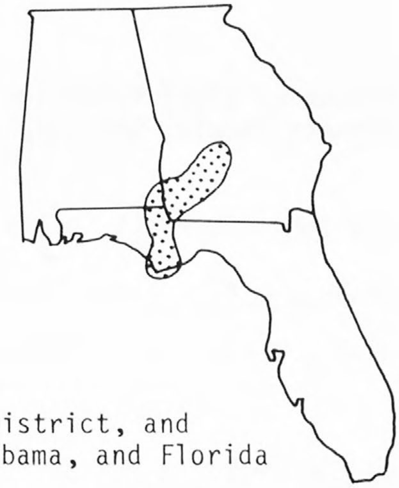
Problem: There is a strong association between trace elements and suspended and bottom sediments. The investigation of sediment-associated trace elements is a requisite for understanding the distribution, transport, and availability of these constitiuents in a hydrologic system. At present, WRD lacks 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: Analyses have indicated that arsenopyrite is the major source of arsenic in the Belle Fourche, Whitewood Creek, Cheyenne River, and Lake Oahe areas of South Dakota. Arsenic was released during mine processing operations and is now found in the banks and floodplains of Whitewood Creek and the Belle Fourche River. Arsenopyrite has been traced from the floodplain deposits to Lake Oahe and has been found in both oxidized and reduced bank material. Iron-oxide associated arsenic occurs in the oxidized bank material but the arsenic levels are about an order of magnitude lower. Other studies have indicated that surface area is an excellent proxy for grain size, and that there is a strong interrelationship between grain size, surface area, and geochemical substrate. Further, it appears that most fine-grained suspended sediments are transported in riverine systems as agglomerates.

Effects of Ground-Water Pumping on Streamflow in the Lower Part of the Apalachicola, Chattahoochee, and Flint (ACF) River System, Alabama, Florida, and Georgia, GA089



Location: Alabama, Florida, and Georgia

Project Chief: Lynn J. Torak

Period of Project: 1986 - 1988

Cooperation: U.S. Army Corps of Engineers, Mobile District, and Several State Agencies of Georgia, Alabama, and Florida

Problem: The limited surface- and ground-water resources of the Apalachicola-Chattahoochee-Flint (ACF) River Basin has caused concern over possible water-resources problems that have the potential to cause conflicts over water use in the three-State area. Because the Floridan aquifer system is hydraulically interconnected to the surface-water network throughout the basin, pumpage from the ground-water system has the potential to affect streamflow. Problems associated with recent drought conditions, fisheries production, navigation, wetlands, and freshwater-saltwater equilibria in Apalachicola Bay cause concern about the responsible utilization and management of the water resources of the basin.

Objectives: (1) Improve the definition of the surface- and ground-water relation in the parts of the basins where ground-water withdrawals are significant, (2) develop a conceptual model of the flow system that incorporates the hydrologic processes pertinent to evaluating surface- and ground-water components and the important hydrologic stresses to the flow system, (3) simulate the surface- and ground-water systems with a digital-flow model, and (4) test alternative management schemes for anticipated multiple uses of the basin's water resources using the model.

Approach: Review literature and unpublished information describing the surface- and ground-water systems in the ACF basin. Gather, analyze, and compile hydrologic data to refine the conceptualization of the flow system and to prepare input to the digital model. Design and construct a finite-element model that incorporates points of observation, stresses, aquifer geometry, and surface-water features. Modify the computer program to compute stream discharge and stage elevations. Perform model calibration and validity checks to observed data and simulate alternative management scenarios by inputting anticipated water-use demands to the model.

Progress: Surface- and ground-water measurements made in October, 1986, accurately monitored the effects of the drought on the ACF basin. Automated methods to design and refine a finite-element mesh were developed and applied to the study area.

A conceptual model of the surface- and ground-water-flow systems has been developed based on hydrologic and geologic information obtained from State cooperators in Alabama, Florida, and Georgia. Three distinct subsurface-flow systems were identified as being in contact with the surface-water system in the ACF basin, and collectively are being simulated in one model of the basin.

Effects of Flood Detention Reservoirs,
Gwinnett County, Georgia, GA090

Location: Gwinnett County, Georgia

Project Chief: Ernest J. Inman

Period of Project: 1986 - 1993

Cooperation: Gwinnett County, Georgia

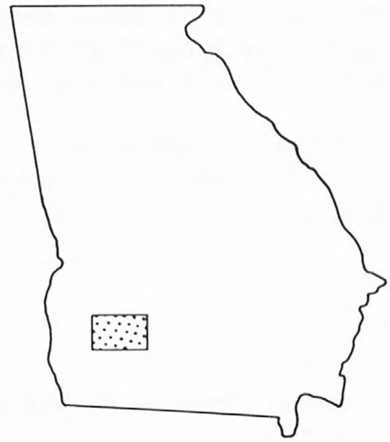
Problem: An ordinance of Gwinnett County requires developers to analyze runoff from land being developed, and provide detention reservoirs so that peak runoff does not exceed predevelopment or natural rates; but developers are not required to determine the effect of the reservoir outflows on the receiving streams. It is now recognized that in a few instances the reservoir outflow, because of changes in the magnitude and timing of the flows, may actually increase flood peaks downstream. This effect would then be contrary to the intent of the ordinance.

Objective: To define the effectiveness of existing and proposed detention reservoirs in reducing flood-runoff peaks in downstream reaches of streams in Gwinnett County. The DR3M model will be calibrated using observed data, generally 3 to 5 events per year, and will be used to simulate several long-term peak discharge data sets with long-term rainfall from the National Weather Service.

Approach: Stable drainage basins with one or more detention reservoirs will be selected for study. One or more recording-rain gages will be installed in the basin. A water-stage recorder will be installed to gage the cumulative flow of the entire basin. The first simulation with the calibrated DR3M model will be the "as is" condition with all detention ponds in place. Subsequent simulations will be made by removing one reservoir at a time, until the final simulation is a "no-detention" condition. Flood-frequency relations using the log-Pearson Type III analysis will be developed using the synthesized data storage-free conditions in a basin. Thus, the effect of existing or proposed detention reservoirs for a stream system can be analyzed using this technique.

Progress: Six sites were selected and recording-rain gages and water-stage recorders installed at those sites in Gwinnett County. Rainfall-runoff data were collected and entered into computer storage.

Hydrology of the Upper Floridan Aquifer in the Albany, Georgia Area, An Analysis from Digital Modeling, GA091



Location: Albany, Georgia

Project Chief: Lynn J. Torak

Period of Project: 1986-1989

Cooperation: City of Albany
Water, Gas, and Light Commission

Problem: Population growth and changes in farming practices have led to increased ground-water use in southwest Georgia, causing water levels in the principal aquifers used for public supply to decline 40 to 100 feet since the 1950's. The development potential of alternative sources of fresh water needs to be evauated, as withdrawals from these aquifers are approaching limits of hydrologic and economic feasiblilty. A promising alternative, the Upper Floridan aquifer, is a major source of water for industry and irrigation, but has not be developed extensively as a public-supply source, partly because of concern over possible ground-water contamination.

Objectives: (1) Define the components of the ground-water-flow system and quantify the interaction between ground and surface water, (2) evaluate the development potential of the Upper Floridan aquifer in the Albany area as a source of ground water for public supply, and (3) assess the effects of current and future withdrawals of ground water from the Floridan aquifer on the stream-aquifer system.

Approach: Use existing hydrologic information and selected data collection to conceptualize the flow system and design a finite-element model that simulates surface- and ground-water flow. Integrate this modeling effort with the finite-element model of the ACF Basin (see project 089), determine boundary conditions for the Albany model from those used in the ACF basin, and modify the existing computer code to include computation of river discharge and stage elevations. Calibrate model with data collected at observation points. Simulate selected ground-water-development scenarios that utilize the Upper Floridan aquifer as a source of water for public supply.

Progress: Ground- and surface-water data were collected during the period of low flow in October 1986. These data will be used to calibrate the model for that period and to provide a means of evaluating the accuracy of the model modifications. Base maps were prepared and computer programs were developed to portray model results in contour-map form. Geohydrologic data consisting of thickness, areal extent, and hydraulic characteristics of the Upper Floridan aquifer and the overlying overburden were compiled for the Albany area.

Development of State Geographic Information System to Support Environmental Management Activities in Georgia, GA092

Location: Statewide

Project Chief: S. Jack Alhadeff

Period of Project: 1987 - 1988

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

Problem: Throughout Georgia there are known waste landfills and facilities that generate, transport or store hazardous wastes. Each location represents a potential contamination source of public and private water supplies, as well as a contamination source of nearby land and atmospheric resources. A means of screening these locations, identifying areas of potential pollution such as nearby streams and aquifers, and correlating the many relevant earth science data bases (i.e., land use, land cover, lithology, environmental monitoring stations, and demographic information) is vitally needed.

Objectives: To develop for use by water managers and researchers (1) a statewide Geographic Information System (GIS) to assist in making large-scale (county or multi-county) environmental decisions, and (2) a data base (GIS) which provides tools for determining water-quality trends, siting regional water-supply reservoirs, locating sanitary landfills and hazardous-waste facilities, and processing permits for withdrawals and discharges.

Approach: Organize an interagency team of specialists to digitize, compile, review, and transform the data base. Concurrently, GIS construction, development, and reviewing of GIS analysis scenarios will determine utility in specific environmental resources assessments.

Progress: Approximately 800 megabytes of data were collected, digitized, reviewed, and entered into the GIS system. Significant layers include soils, significant recharge areas, elevation, transportation, hydrograph, land use and cover, public-supply wells, Resources Conservation Recovery Act Sites, Comprehensive Environmental Response Compensation and Liability Act (Superfund Sites, landfills, impoundments, National Water Information System Sites, Ground Water Site Inventory Sites, dams and land-disposal sites). Scenarios by the interagency team were conducted weekly, and management products were formulated.

SOURCES OF PUBLICATIONS

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.

Georgia Department of Natural Resources

Georgia Geologic Survey

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.

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 ground-water 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.

----- 1987, Low-flow profiles of the upper Savannah and Ogeechee River and tributaries in Georgia: Water-Resources Investigations Report 87-0791 (in press).

----- 1987, Low-flow profiles of the upper Oconee River and tributaries in Georgia: Water-Resources Investigations Report 87-0801 (in press).

----- 1987, Low-flow profiles of the Tennessee River and tributaries in Georgia: Water-Resources Investigations Report 87-0804 (in press).

----- 1987, Low-flow profiles of the Tallapoosa River and tributaries in Georgia: Water-Resources Investigations Report 87-0806 (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.

Surface-Water Resources--Continued

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.

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.

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, Transportation Research Record 1073, p. 15-23.

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.

Surface-Water Resources--Continued

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, July-December 1985, p. 37-40.

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

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

----- 1977, Techniques 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.

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

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

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

----- 1986, Verification of regression equations for estimating flood magnitudes for selected frequencies on small natural streams 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.

Surface-Water Resources--Continued

Price, McGlone, and Hess, G.W., 1986, Limited detail flood insurance study, city of Clarkesville, Habersham County, Georgia: Federal Emergency Management Agency, community no. 130103.

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

----- 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, community no. 130203.

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

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

----- 1987, Flood-flow characteristics of Nancy Creek at proposed Georgia Highway 400 extension near Atlanta, Georgia: U.S. Geological Survey Open-File Report 87-386.

----- 1987, Limited detail flood insurance study, City of Lakeland, Lanier County, Georgia: Federal Emergency Management Agency, community no. 130120 (in press).

----- 1987, Limited detail flood insurance study, City of Americus, Sumter County, Georgia: Federal Emergency Management Agency, community no. 130203 (in press).

----- 1987, Limited detail flood insurance study, City of Sylvester, Worth County, Georgia: Federal Emergency Management Agency (in press).

----- 1987, Limited detail flood insurance study, City of Fitzgerald, Ben Hill County, Georgia: Federal Emergency Management Agency (in press).

----- 1987, Limited detail flood insurance study, City of Eatonton, Putnam Hill 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.

Surface-Water Resources--Continued

Stokes, W.R., III, Hale, T.W., and Buell, G.R., 1987, Water resources data, Georgia, water year 1986: U.S. Geological Survey Water-Data Report GA-86-1.

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.

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.

Surface-Water Resources--Continued

U.S. Geological Survey, 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.

----- 1987, Water resources data for Georgia--water year 1986: U.S. Geological Survey Water-Data Report GA-86-1.

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., 1987, Potentiometric surface of the Upper Floridan aquifer, May 1985, and water-level trends, 1980-85: Georgia Geologic Survey Hydrologic Atlas 16.

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.

Ground-Water Resources--Continued

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.

----- 1986, Ground-water data for Georgia, 1985: U.S. Geological Survey Open-File Report 86-304.

Clarke, J.S., Longsworth, S.A., Peck, M.F., Joiner, C.N., McFadden, K.W., and Milby, B.J., 1987, Ground-water data for Georgia, 1986: U.S. Geological Survey Open-File Report 87-376.

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, south-west 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., Gill, H.E., and Longsworth, S.A., 1987, Hydrology, chemical quality, and availability of ground water in the Upper Floridan aquifer, Albany area, Georgia: Water-Resources Investigations Report 87-4145.

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.

Ground-Water Resources--Continued

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.

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., 1988, 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).

Ground-Water Resources--Continued

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

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., 1987, 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, 46 p.

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.

----- 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.

----- 1987, Analysis of rocks and sediments for mercury, by wet digestion, and flameless cold vapor atomic absorption: Varian Instruments at Work, no. AA-74, 5 p.

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 municipal 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, v. 67, p. 17-33.

----- 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).

----- 1987, The relation of stream sediment surface area, grain size and composition to trace element chemistry: Applied Geochemistry, v. 2, no. 4, p. 437-451.

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

McConnell, J.B., Radtke, D.B., Hale, T.W., and Buell, G.R., 1983, A preliminary appraisal of sediment sources and transport in Kings Bay and vicinity, Georgia and Florida: U.S. Geological Survey Water-Resources Investigations Report 83-4060.

Peters, N.E., 1986, Hydrologic controls on surface-water acidification [abs.]: American Institute of Hydrology, Washington, D. C., 1986 Fall Meeting, Water problems of national concern--session II, acid rain, proceedings.

----- 1986, Hydrochemical response of a stream in the Southeast to a rainstorm: U.S. Geological Survey Yearbook 1986 (in press).

Peters, N.E., and Murdoch, P.S., 1985, Hydrogeologic comparison of an acidic-lake basin with a neutral-lake basin in the west-central Adriondack Mountains, New York: Water, Air, and Soil Pollution, v. 26, p. 387-402.

Peters, N.E., and Shanley, J.B., 1985, Field verification of dry deposition rates and effects in a small watershed [abs. and research summary]: National Atmospheric Precipitation Assessment Program for the 1985 Peer Review Meeting, p. 89-91.

----- 1985, Field verification of dry deposition rates and effects in a small watershed [abs]: Second Annual Rain Conference for the Southern Appalachians, Tennessee Valley Authority, proceedings, p. 52.

----- 1986, Hydrochemical response of a stream in the Georgia Piedmont to a rain event [abs.]: EOS, Transactions of the American Geophysical Union, v. 67, no. 16, p. 282-283.

Radtke, D.B., 1983, Quality of surface water, in Hollyday, E.F. and others, Hydrology of Area 20, Eastern Coal Province, Tennessee, Georgia, and Alabama: U.S. Geological Survey Water-Resources Investigations Open-File Report 82-440, p. 36-55.

----- 1985a, Limnology of West Point Reservoir, Georgia and Alabama, in Subitzky, Seymore, ed., Selected papers in the hydrologic sciences, 1985: U.S. Geological Survey Water-Supply Paper 2290.

----- 1985b, Sediment sources and transport in Kings Bay and vicinity, Georgia and Florida, July 8-16, 1982: U.S. Geological Survey Professional Paper 1347.

Radtke, D.B., Buell, G.R., and Perlman, H.A., 1984, Limnological studies of West Point Reservoir, Georgia, Alabama, April 1978-December 1979: U.S. Army Corps of Engineers Water Quality Management Study Technical Report COESAM/PDEE-84/004.

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.

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., 1987, Georgia--hydrologic events and water supply and demand: in National Water Summary, 1987: U.S. Geological Survey Water-Supply Paper 2350 (in press).

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.

Turlington, M.C., Fanning, J.L., and Doonan, G.A., 1987, Water use in Georgia: Georgia Department of Natural Resources Information Circular 81.

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.

----- 1987, Water resources activities, Georgia District, 1986: U.S. Geo logical Survey Open-File Report 87-381.

General Water Resources--Continued

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, J.R., 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.

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.