Water Resources Investigations in Puerto Rico and the U.S. Virgin Islands

Open-File Report 85-556

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1984-1985

Programs and Activities of the U.S. Geological Survey Water Resources Division Caribbean District San Juan, Puerto Rico 1985

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A MESSAGE FROM THE CARIBBEAN DISTRICT CHIEF:

This report summarizes the activities of the Caribbean District of the U.S. Geological Survey, Water Resources Division during the last 18 months (October 1983-June 1985). The period was characterized by one of continued successes in the ongoing programs, development of new projects, completion of a record number of projects and reports, and record employment and financial growth.

During this period the District completed 7 projects and initiated 4 new investigations. Work continued on 7 ongoing projects in addition to the basic-data collection programs. The District staff increased to about 55 employees, from about 50 in 1983. Equally important, Federal and Commonwealth funding of the water resources program resulted in a record operating budget of about 2.8 million dollars.

The perspectives for the coming 1986 fiscal year are as promising as during the past few years. Two new projects were initiated in October, as well as several sattellite smaller sub-projects. Under federal funding, a comprehensive appraisal of the regional aquifer systems in Puerto Rico and the U.S. Virgin Islands began last October. The project will concentrate in the aquifers of the south coast of Puerto Rico and the Kingshill aquifer in St. Croix. In Puerto Rico it will supplement the ongoing "Comprehensive Appraisal of the North Coast Limestone Ground Water Resources" project, now in its second year. A second ground-water oriented project, also federally funded by the Environmental Protection Agency, will result in the publication of a comprehensive "atlas" of the most important aquifers in P. R. and the U.S.V.I. We will continue our efforts to maintain the flow of publications of prior investigations initiated several years ago. The computer-modeling efforts developed during he last three years are now being used effectively by the Department of Natural Resources and the Puerto Rico Aqueduct and and the Puerto Rico Aqueduct and Sewer Authority for practical applications in the area of water use and management. The results of our investigations of the quality of ground waters in Puerto Rico have resulted in the "discovery" of several areas contaminnated with toxic organic compounds. Three of these sites are now part of the "EPA Superfund" list of priority sites.

A milestone of the activities during the year was the celebration of the "International Symposium on Tropical Hydrology". The USGS organized and sponsored the activity with the cooperation of several Commonwealth and Federal agencies. Five papers were presented by District's hydrologists.

The mission of the Caribbean District of the USGS is to provide Commonwealth, U.S. Virgin Islands, and Federal agencies timely, accurate water-related information necessary for the management of the region's water resources. To achieve this goal, the District will continue to labor as a partner of the cooperating agencies. I feel very proud of the achievements of our staff. We are also very gratefull to the cooperating agencies that support the program.

Ferdinand Quiñones
District Chief,
Caribbean District WRD

PROGRAMS AND ACTIVITIES OF THE U.S. GEOLOGICAL SURVEY, WATER RESOURCES DIVISION, CARIBBEAN DISTRICT 1984-85

WATER RESOURCES INVESTIGATIONS AND ACTIVITIES DURING 1984-85

HYDROLOGIC-DATA SECTION:

The Hydrologic Data Section of the Caribbean District is responsible for the operation of the networks of basic-data stations. These networks, both short-range for special projects or long-range for general water-resources accounting, are the "backbone" of the District's program. This Section is also responsible for the preparation of the series of reports "Water Resources Data for Puerto Rico and the U.S. Virgin Islands."

The hydrologic records section personnel.

SURFACE-WATER STREAMFLOW NETWORK:

The Caribbean District operates a network of streamflow gaging stations throughout Puerto Rico and the U.S. Virgin Islands. In Puerto Rico the network is operated under the general water-resources investigations programs coordinated by the Environmental Quality Board in cooperation with the following Commonwealth and Federal Agencies:

Department of Natural Resources - (DNR)
Puerto Rico Industrial Development Company - (PRIDCO)
Puerto Rico Aqueduct and Sewer Authority - (PRASA)
Administration for Agricultural Development - (AFDA)
Department of Agriculture - (DOA)
Department of Health - (DOH)
Puerto Rico Rice Corporation - (PRRC)
Planning Board - (PB)
Puerto Rico Energy and Power Authority - (PREPA)
Department of Transportation and Public Works - (DTPW)
U.S. Army Corps of Engineers - (COE)
Water Resources Research Institute of the
University of Puerto Rico (Mayaguez Campus) - (WRRI)

Four stations are financed as part of the federally funded USGS National Stream Quality Accounting Network (NASQAN).

During 1984-85, the surface-water network in Puerto Rico included 53 recording and 1 non-recording stations (fig. 1). Ten stations were discontinued while 15 new stations were constructed. These new stations were established in support of the following projects:

North Coast Limestone - 5
Río Grande de Loíza Sedimentation Study - 5
South Coast Vegetables Area - 3
Lajas Valley - 2.

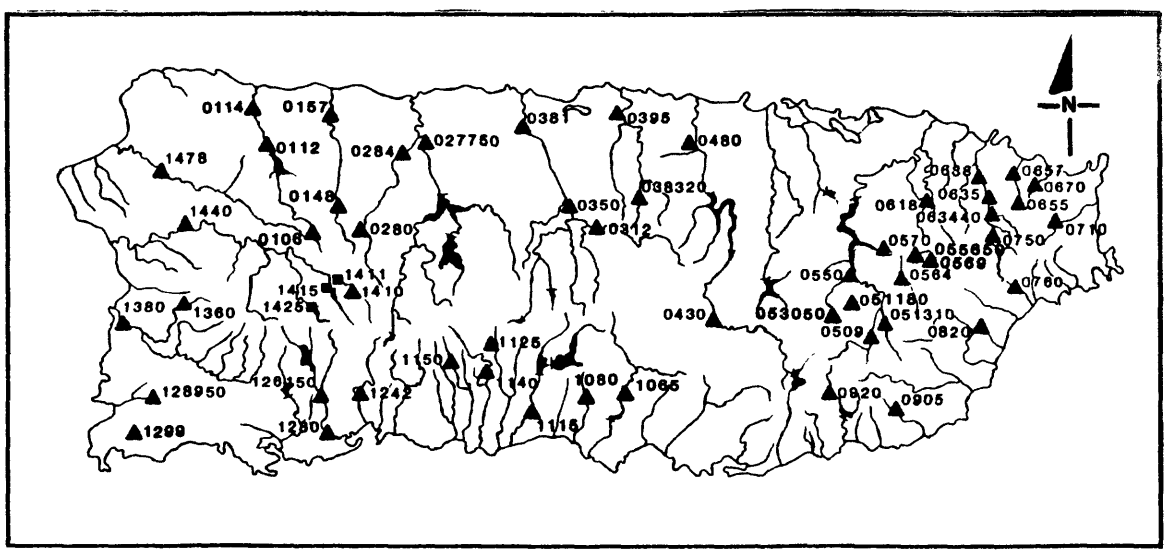


FIGURE 1.--Location of surface-water stations in Puerto Rico.

MINIMUM FLOWS:

Minimum flows (better known as low flows) are an important parameter for water-resourses planning and management. Knowledge about the frequency and magnitude of minimum flows are essential for waste-allocation programs, water-supply facilities design, and general resource assessments. During the 1983 fiscal year, the Caribbean District initiated within the basic-data program a project to define the magnitude and frequency of low flows in Puerto Rico. A network of about 100 measuring sites was selected in the eastern part of the Island. Two sets of measurements have been obtained each year representing drought and recession conditions at the streams. An Island-wide run to measure the total outflow to the ocean was also completed each year. The project, directed by Engineer Eloy Colon-Dieppa, will continue over the next seven years extending to other areas in Puerto Rico (fig.1a).

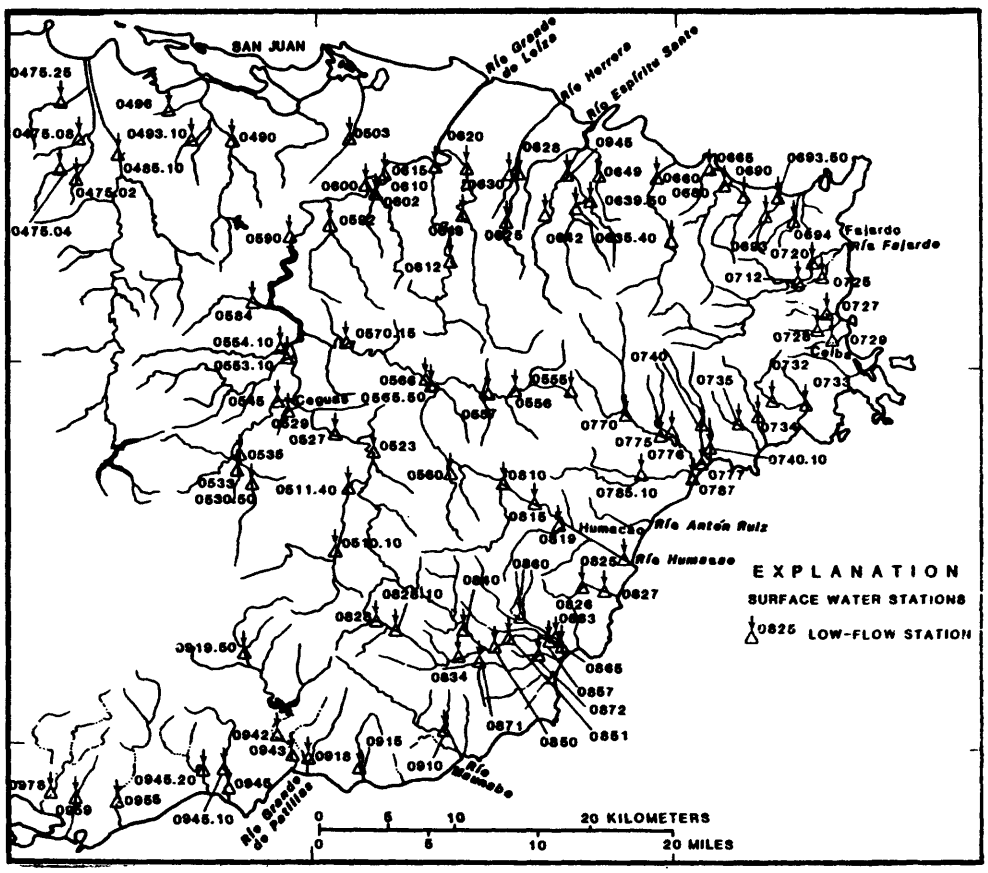


FIGURE 1a.--Location of low-flow partial-record stations in Eastern Puerto Rico.

U.S. VIRGIN ISLANDS:

In the U.S. Virgin Islands, operation on the network of 4 recording streamflow stations was continued in cooperation with the U.S. Virgin Islands Department of Public Works (fig. 2). In addition, one new recording streamflow station was established on Hawknest Bay Gut, St. John in support of the rainfall-runoff sedimentation study funded by the U.S. Park Service.

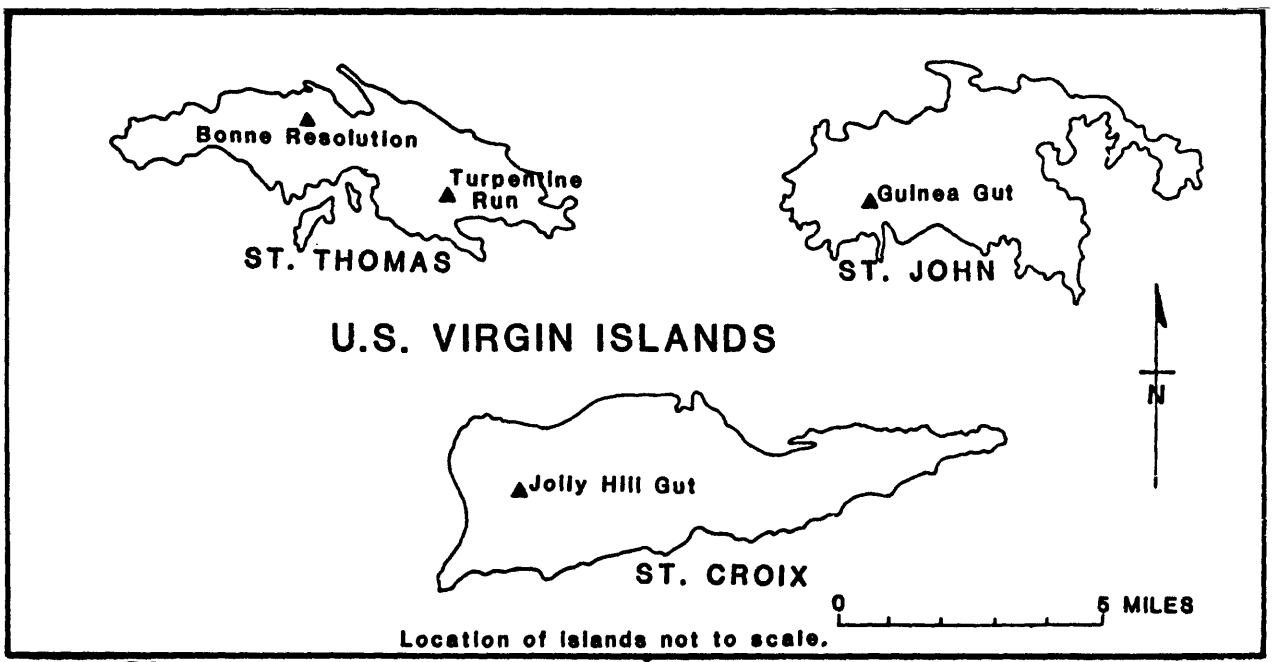


FIGURE 2.--Location of surface-water stations in the U.S. Vigin Islands.

SURFACE WATER-QUALITY NETWORK:

The U. S. Geological Survey operates a network of 74 long term water-quality stations (fig. 3) in cooperation with PREQB, USCOE, and PRDOA. Samples were collected every other month from 63 streamflow stations and lagoons and quarterly from 6 of the principal lakes in the Island. Samples were collected every other month at two of four federally supported National Stream Quality Accounting Network stations. The other two sites are sampled quarterly.

Several parameters were added to the sampling program this year. In almost all the stations, samples were collected for laboratory determinations of copper, iron, manganese, cyanide, sulfide, phenols, and methylene blue active substance (MBAS) in addition to the already established parameters. Analytical field and laboratory results of the sampling program for 1984 were published in the 'Water Resources Data for Puerto Rico', 1984 water year report.

The District does not operate any surface water quality monitoring stations in the U. S. Virgin Islands. However samples for selected chemical parameters and suspended sediment were collected at three streamflow stations in the Lesser Antilles (St. Lucia, St. Vincent, and Dominica).

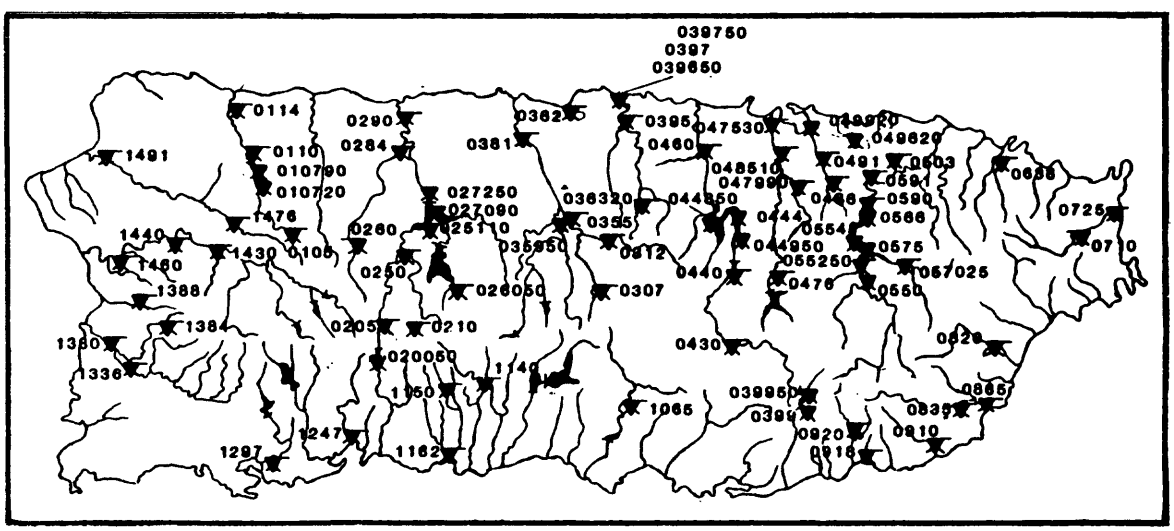


FIGURE 3.--Location of quality-water stations in Puerto Rico

GROUND-WATER LEVELS

The determination of long-term changes in ground-water levels is an important aspect of the basic-data collection program in the District. Ground-water levels provide an insight into withdrawals and recharge rates to the aquifers. As we move into the design and construction of ground-water flow models, the water-level data collected as part of the basic-data program are essential for the continuous updating of the models.

In Puerto Rico operation of the network of 12 recording and 52 non-recording wells was continued during the 1984 Fiscal year. The network was re-evaluated in January 1985 and gradually reduced to 11 recording wells (fig. 4). During the 1985 water year, about 80 recording wells will be installed in support of special projects. Ground-water levels for the 1982 and 1983 water years were published in the Water Resources Data for Puerto Rico report. Data for the 1984 water year is due for publication this summer.

In the U.S. Virgin Islands, the operation of 7 recording and 21 non-recording wells continued (fig. 4). Ground-water levels for the 1983 water year were published in the Water Resources Data for Puerto Rico and the U.S. Virgin Islands report last year.

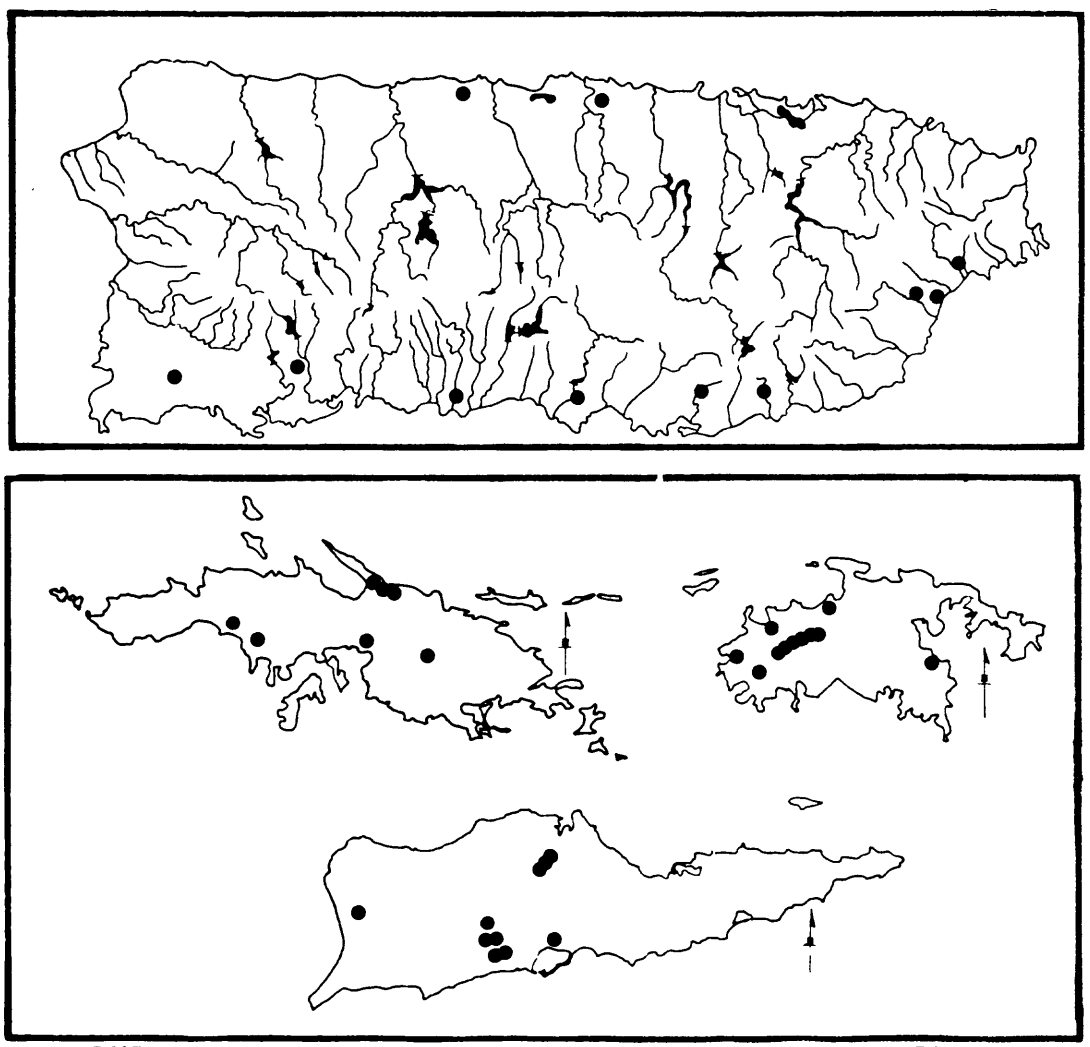


FIGURE 4.--Location of ground-water stations in Puerto Rico and U.S. Virgin Islands.

GROUND-WATER QUALITY MONITORING:

Ground water quality monitoring throughout Puerto Rico continued with great intensity during 1984 and the first part of 1985. The baseline data established during 1982 and 1983 were expanded with emphasis on determinations of organic compounds in ground-water used for drinking. In cooperation with the Puerto Rico Department of Health, a program was begun to collect samples from about 350 PRASA wells used for public supply. As a result of this program, two wells in Vega Alta, one in Caguas, two in Patillas, two in Cayey, and one in Comerío (fig.5) were closed by the Puerto Rico Department of Health due to high concentrations of trichloroethylene and tetrachloroethylene (TCE and PCE).

In the areas of Vega Alta and Guayama, where wells operate nearby known contaminated aquifer areas, sampling frequency was increased to a weekly basis. This program is conducted in cooperation with PRASA.

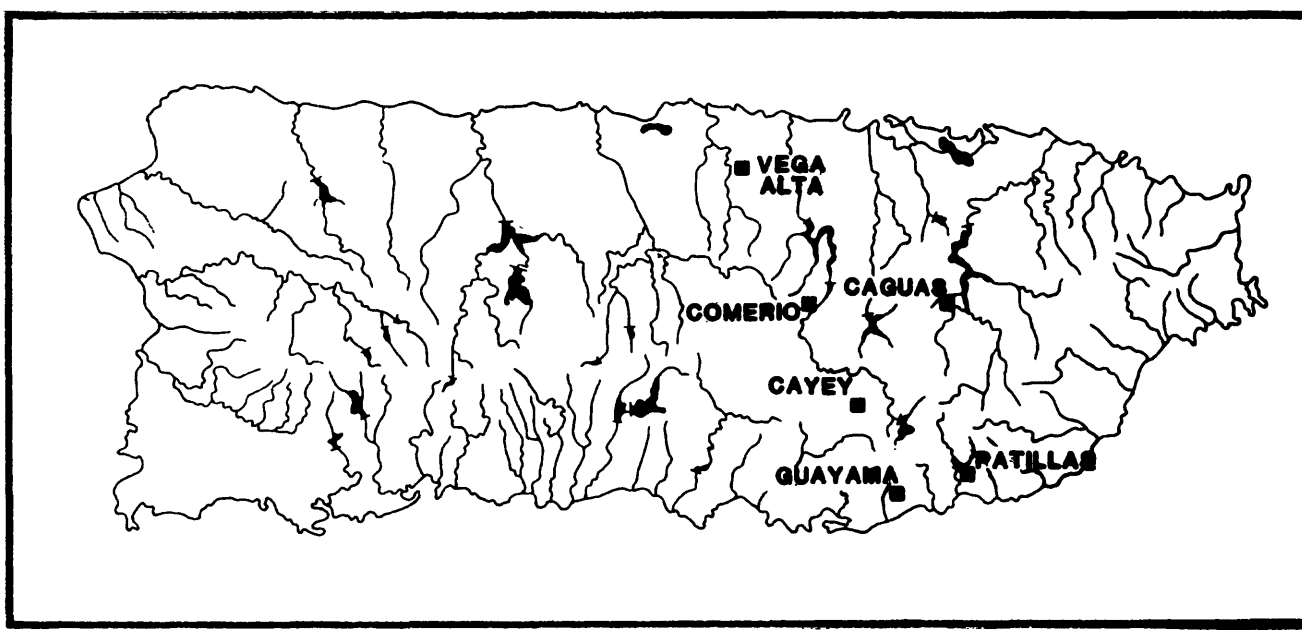


FIGURE 5.--Areas in Puerto Rico where wells contaminated with organic compounds are being monitored.

SUSPENDED-SEDIMENT DATA COLLECTION:

Suspended-sediment data collection activities continued this year with the operation of two daily sampling stations. Suspended-sediment samples were collected daily at Río Fajardo near Fajardo and at Rio Tanama near Utuado (fig. 6). The Río Fajardo station is operated in cooperation with USCOE and the Río Tanama site in cooperation with PREQB. An automatic sediment sampler was installed at Río Fajardo early in the year. This sampler is capable of collecting 24 sediment samples in a period of 9.5 hours starting on discharges above 100 cubic feet per second.

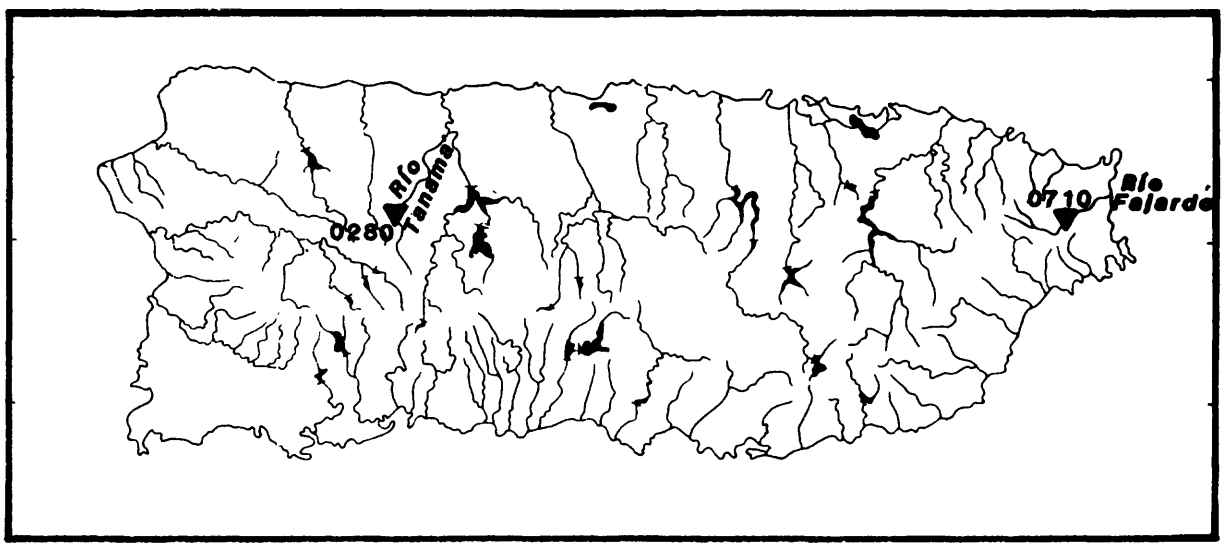


FIGURE 6.--Location of daily suspended-sediment stations.

WATER-USE DATA PROGRAM:

The water-use program in Puerto Rico continues to be one of our most significant basic-data projects. The collection, analyses, computerized-storage, and dissemination of water-use data for different categories are the main objectives of the program. The project is conducted in cooperation with PRASA, PRIDCO, DNR, DOA, and PREPA.

The report on "Public Water-Supplies in Puerto Rico, 1983" was published during the year. It included a listing of public water supply facilities serving Puerto Rico's 78 "municipios". The results revealed that surface-water sources supply nearly 300 million gallons per day (Mgal/d) of potable water, while ground water sources supply about 80 Mgal/d. A comprehensive report of the basic water-use data available for calendar years 1980, 1981, and 1982 will be published this year. The report will include details on water-use categories including public water-supply, rural use, irrigation, thermoelectric and hydroelectric power generation, as well as return flows to public waste-water treatment plants (fig. 7).

The main effort in the program for 1986 fiscal year will be the collection of data from calendar years 1983-85 with special emphasis on obtaining 1985 water-use data for industrial and irrigation purposes.

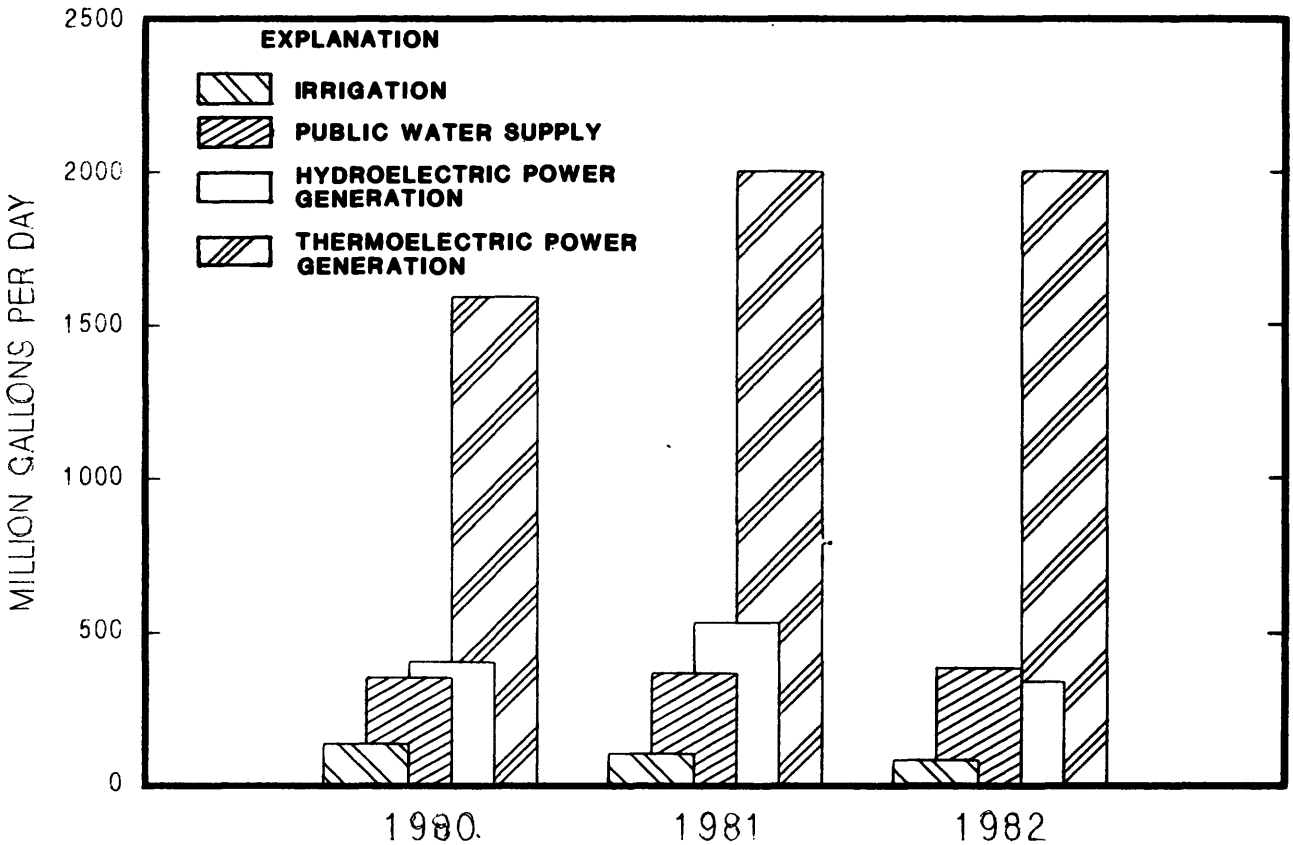


FIGURE 7.--Estimated water use by major use categories in Puerto Rico during 1980, 1981, and 1982.

WATER USE IN ST.THOMAS, U.S. VIRGIN ISLANDS:

A comprehensive water-use inventory was conducted in St. Thomas during 1983 and 1984 as part of the water-use program in the District. The publication of the report "Estimated Water Use in St. Thomas, U. S. Virgin Islands, July 1983-June 1984", was a major achievement. This inventory included water use categories of public-water supply, thermoelectric power generation, domestic and commercial self-supplied, and public waste-water treatment (fig. 8).

As a second effort in the water-use program in the U. S. Virgin Islands, an inventory will be conducted in St. Croix during this year.

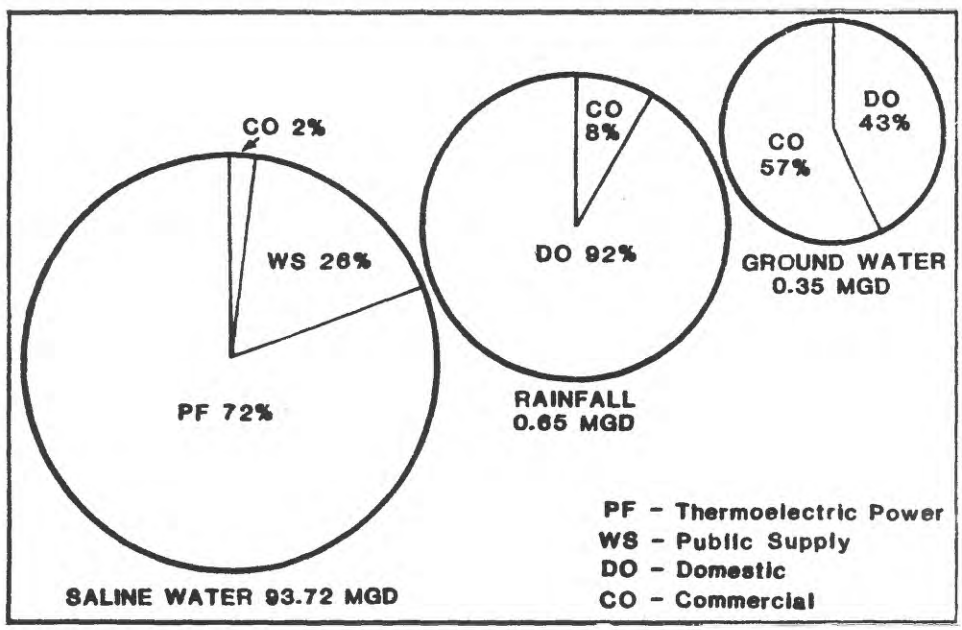


FIGURE 8.--Estimated water use by source and major use categories in St. Thomas during July, 1983 to June, 1984.

HYDROLOGIC INVESTIGATIONS SECTION - 1984-85 PROJECTS:

The Hydrologic Investigations Section in the District is responsible for the design, field execution and resulting technical reports of areal water-resources investigations. The District is fortunate to have a dedicated staff of hydrologists, geologists, engineers, and supporting technical personnel under the direction of Engineer Allen Zack. A combination of experienced scientists with a group of recently hired engineers and geologist has resulted in a productive team of investigators. Among the investigations completed or in progress in fiscal year 1985 were:

The hydrologic investigations section personnel.

GROUND-WATER FLOW IN THE GUANICA VALLEY:

A ground-water flow model of the Guánica alluvial valley (fig. 9) aquifer was completed and calibrated. The model, prepared in cooperation with the Department of Agriculture, is now being utilized by Commonwealth agencies for the management of the water resources in the valley. Although the model is now operational in the USGS computers, it is readily available to any user that wishes to test ground-water withdrawals in the area. The model will eventually be loaded into the DNR computers. The project was completed by Engineer Arturo Torres.

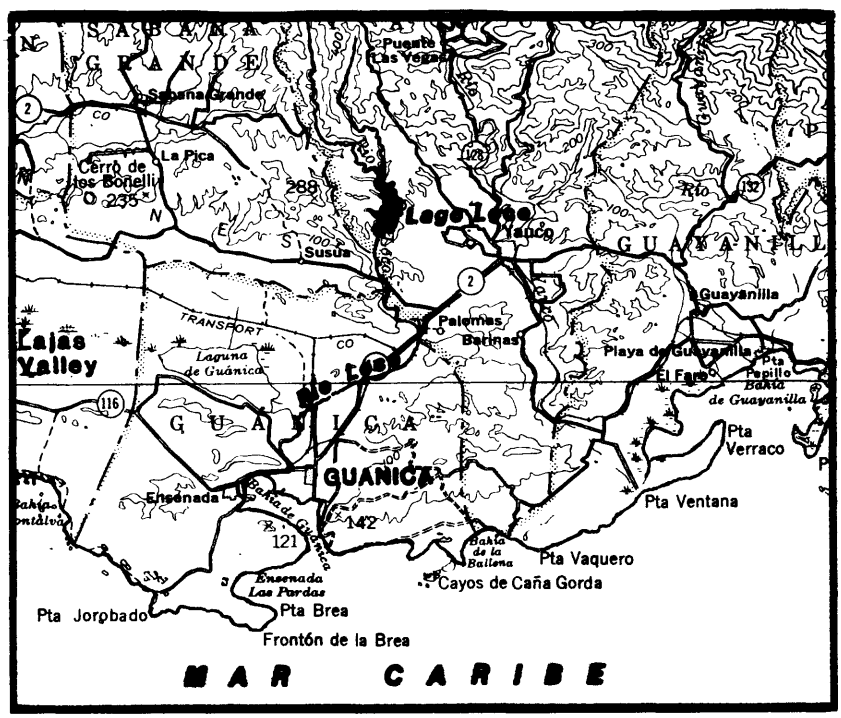


FIGURE 9.--The Lago Loco and Río Loco area.

WATER RESOURCES OF VIEQUES ISLAND, PUERTO RICO:

The investigation of the "Water Resources of Vieques Island" conducted in cooperation with the P. R. Land Administration and the DNR, was concluded during the year. Preliminary results of the investigation show that ground water resources in the Esperanza Valley are adequate to provide most of the needs of Vieques (fig. 10). However, strict management of withdrawals, from the aquifer would be required. A ground-water flow model of the alluvial aquifer in La Esperanza area was constructed and calibrated. The model can be used to simulate changes in ground-water levels with pumpage in the valley. Engineer Sigfredo Torres contributed to development and final calibration of the ground-water flow model.

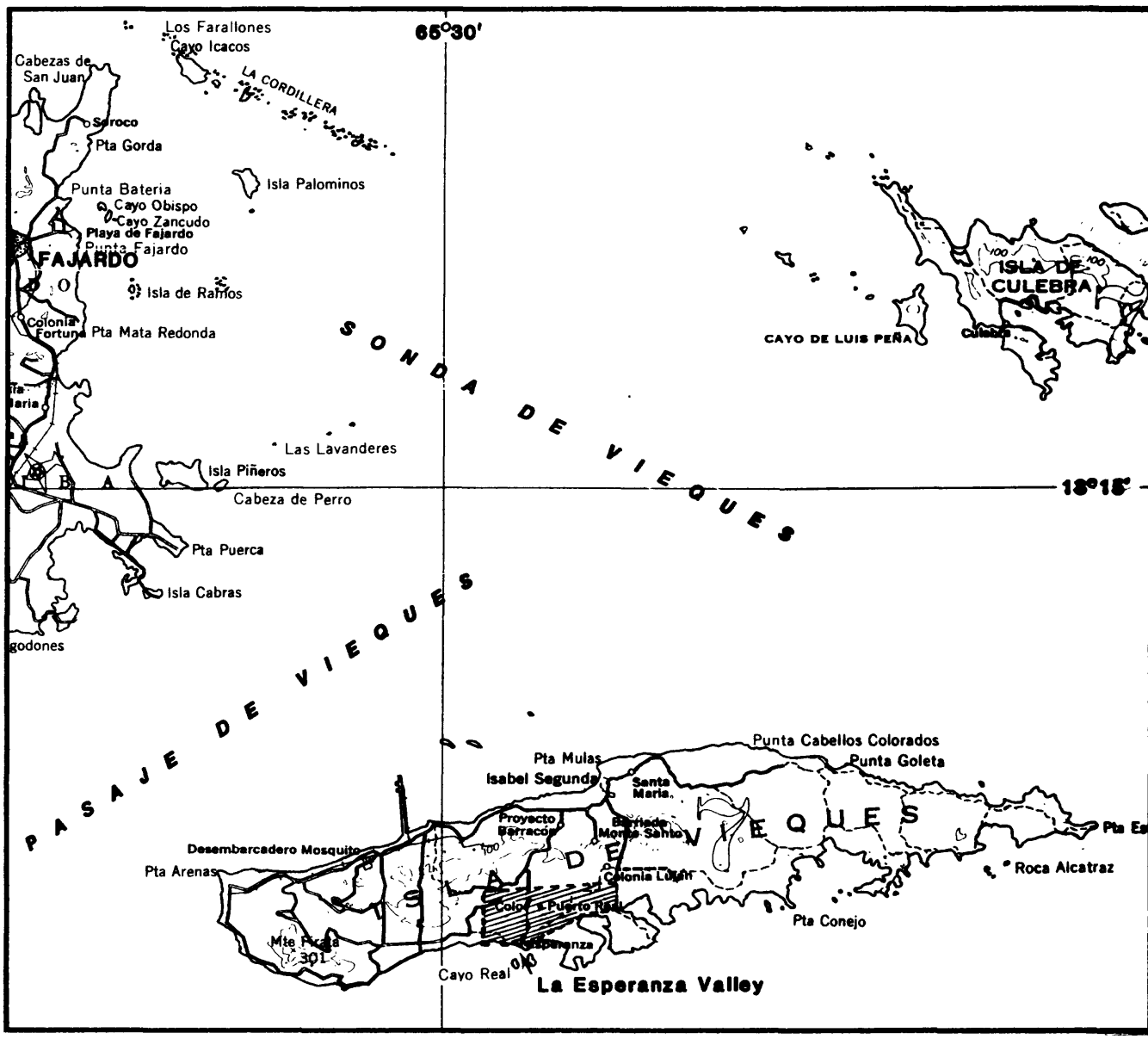


FIGURE 10.--La Esperanza Valley in the Vieques Island, P.R.

COMPREHENSIVE APPRAISAL OF THE GROUND-WATER RESOURCES OF THE NORTH-COAST LIMESTONE AQUIFERS OF PUERTO RICO:

The second year of activities of the "Comprehensive Appraisal of the Ground Water Resources of the North Coast Limestone Aquifers of Puerto Rico" continued at an accelerated pace (fig. 11). An intensive program of well inventory, borehole geophysics, hydrogeologic mapping, flow model conceptualization, and drilling arrangements was initiated early in Fiscal Year 1984. The investigation is conducted in cooperation with PRDNR and directed by Engineer Arturo Torres.

The well inventory of the North-Coast limestone area was completed in March 1985. More than 500 wells (active, abandoned or destroyed) have been or are used to obtain data on water levels, water quality, and ground-water withdrawals of the limestone aquifers. A series of cross sectional and areal-hydrogeologic maps were prepared to refine the regional hydrogeologic framework of the north-coast aquifers. A regional water-table contour map was prepared and shows important ground-water flow patterns in the study area. Simultaneous design and construction of regional and subregional ground-water flow digital models is presently being undertaken. A drilling contract was prepared for the application of dual-tube drilling techniques for 5-deep (over 1500 ft) north-coast wells. The dual-tube method provides continous, depth-representative samples (cores) and hydraulic information. Drilling costs for FY-85 and FY-86 are estimated at $250,000 per year.

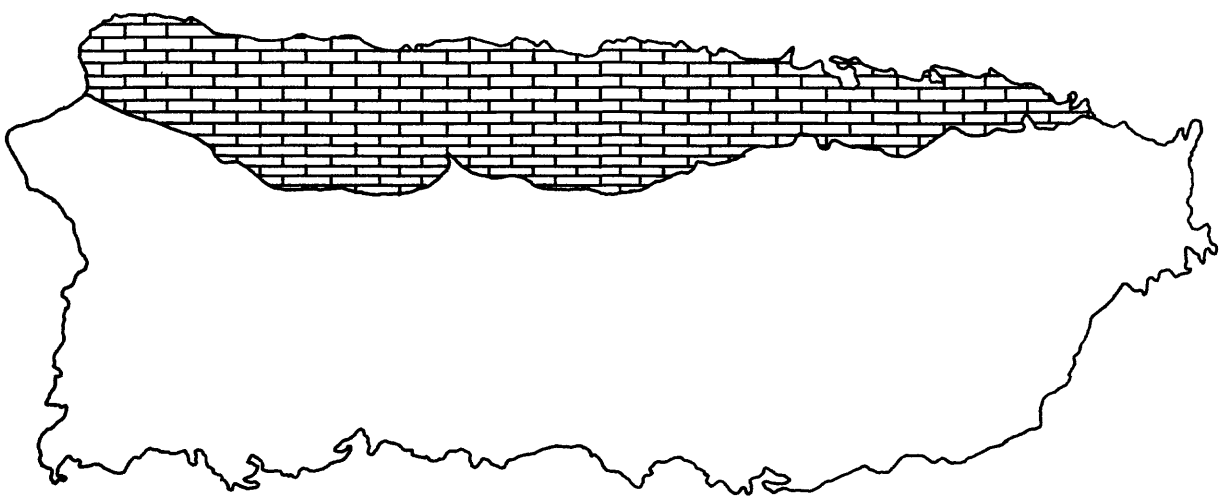


FIGURE 11.--The North Coast Limestone area of Puerto Rico.

GROUND-WATER RECHARGE IN THE LOWER RIO GRANDE DE ARECIBO VALLEY:

The feasibility of injecting excess surface water into a salty limestone aquifer as a means of storing freshwater for use when surface-water resources are minimal were investigated as part of the project in cooperation with the Puerto Rico Rice Corporation. Water from the Río Grande de Arecibo was injected into the Monte Grande well, stored for various lengths of time, and recovered (fig. 12).

A series of 6 injection and recovery tests were conducted at the site. Recharge rates up to 600 gal/min are readily accepted by the well. Recovery rates ranged from 5 to 26 percent of the water injected depending upon the quality of the injected water and the storage time. However as much as 16 to 42 percent of the recovered mixed water is suitable for irrigation, having a chloride concentration of less than 500 mg/L.

Although the project has demonstrated, unequivocally, that freshwater can be injected into saltwater aquifers, stored, and, at least, partially retrieved, the potential of the area studied for storing recharged water may be limited. The percentage of injected water recovered was low, even after only a short residence time, but could be considerably greater as the amount of water injected is increased. The project is directed by Engineer Allen Zack.

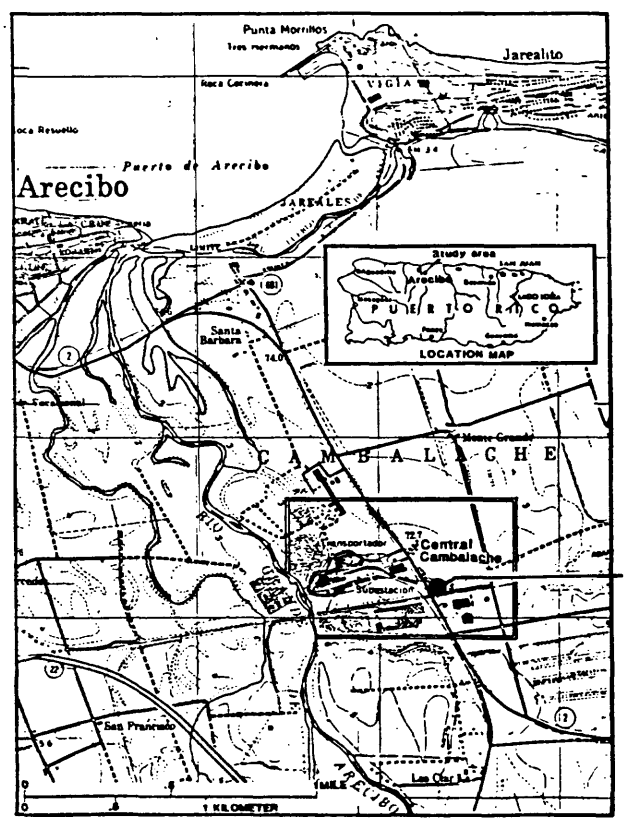


FIGURE 12.--Location of the ground-water recharge study area in the lower Río Grande de Arecibo valley.

LESSER ANTILLES:

An investigation designed to collect and analyze base data on streamflow, water quality and rainfall in selected watersheds in Dominica, St. Vincent and St. Lucia, Lesser Antilles (fig. 13) was begun in 1983. Streamflow and rainfall data are being collected continuosly, while water-quality samples are collected weekly and during special hydrologic events. The study is part of a 2-years effort for hydrologic-data collection through a cooperative agreement between the U. S. Forest Service, the U. S. Agency for International Development, the U.S. Geological Survey, and the local governments of each island.

Preliminary data for nine months of record showed average monthly discharges as follows: 290 cubic feet per second in Layou River, Dominica; 32 cubic feet per second in Buccament River, St. Vincent; and 20 cubic feet per second in Troumasse River, St. Lucia. Rainfall is relatively high as compared to other Caribbean Islands and varies from 60 inches per year in the coastal plains to 200 inches per year in the interior. Suspended-sediment concentrations ranged from 0 to 654 milligrams per liter. Preliminary water-quality analyses indicate that waters from the watersheds are similar to that from rain-forest areas in Puerto Rico.

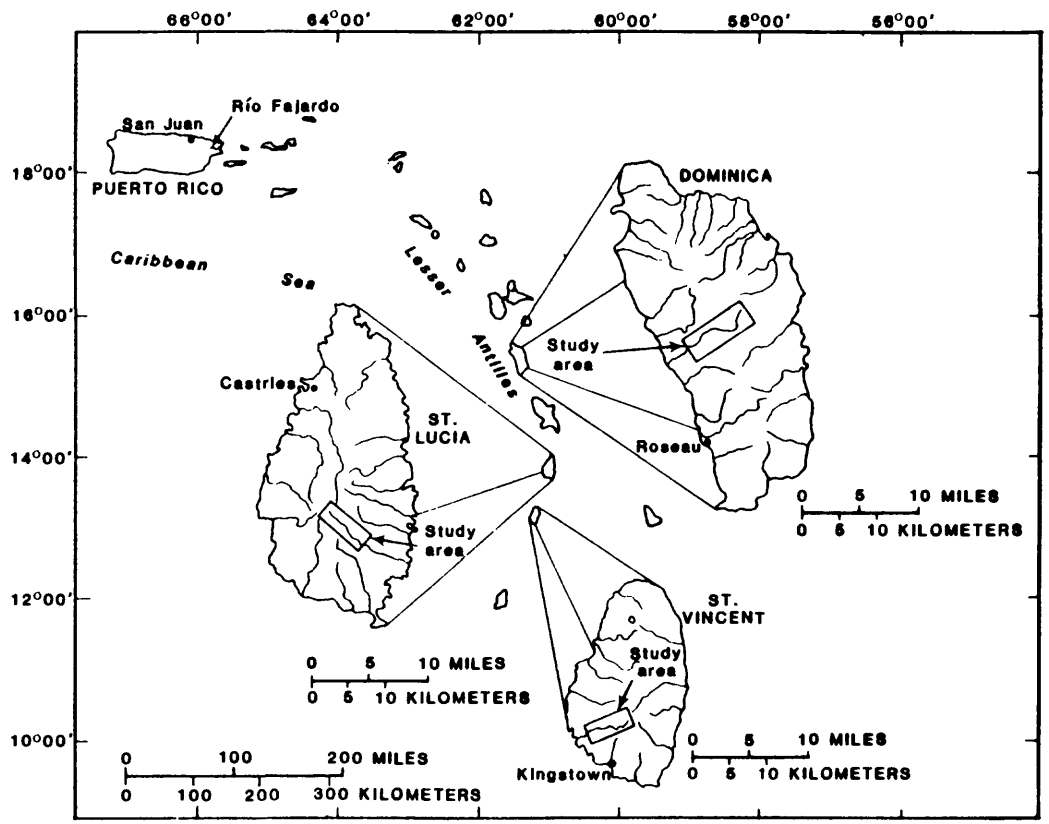


FIGURE 13.--Location of the Lesser Antilles study areas.

WATER USE FOR RICE IRRIGATION IN NORTHERN PUERTO RICO:

The "Water Use for Rice Irrigation" project, now in its third year is being conducted in cooperation with the Puerto Rico Rice Corporation, Department of Agriculture (fig. 14). The objective of this investigation is to determine the actual amount of water used to irrigate rice during a complete crop cycle, considering different soil types and climatic conditions. Five farms along the north coast have been instrumented to measure the actual water inputs and outputs. The data will provide baseline information regarding the water requirements for future rice growing areas.

During the year, data on rates of infiltration, evapotranspiration and water input and output to the five instrumented farms were measured. Meteorological data including temperature (maximum and minimum), pan evaporation, rainfall and wind velocity were collected at each rice-growing area. Preliminary results of the investigation show that the actual water pumped to the farms ranges from 2-4 times the amount needed. Infiltration rates are much lower than previously estimated. The project is directed by hydrologist Angel Roman Mas.

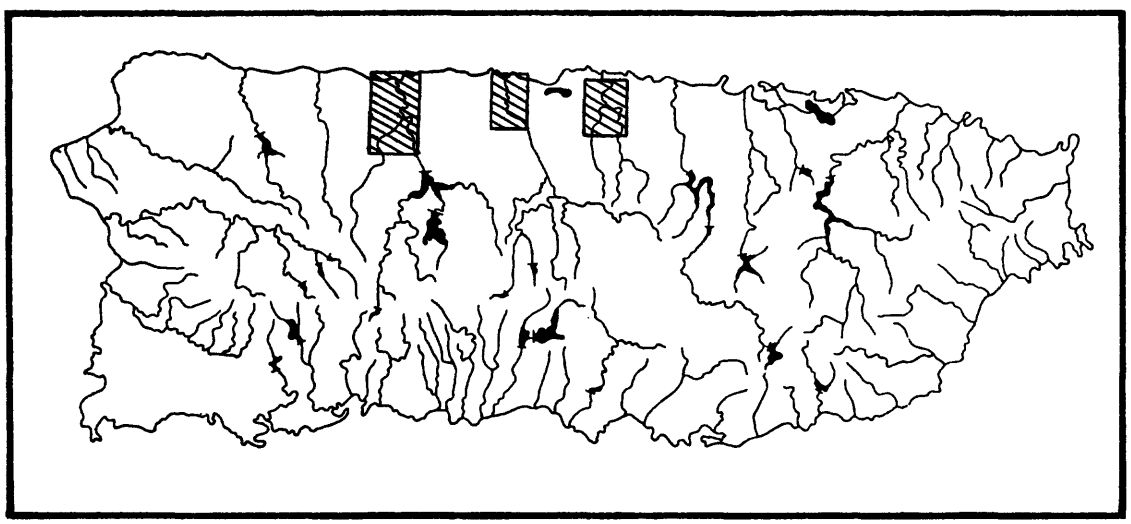


FIGURE 14.--Location of the rice irrigation study areas in Northern Puerto Rico.

WATER RESOURCES OF THE HUMACAO-NAGUABO AREA:

Field work on the investigation of the water resources of the Humacao-Naguabo area (fig. 15) was completed as part of a three year project in cooperation with the Puerto Rico Industrial Development Corporation. The final product of the investigation will define the occurence, availability, and quality of surface- and ground-water resources of the Humacao-Naguabo area. Under the direction of geologist Robert Graves, a two-dimensional, steady-state digital flow model of the Río Humacao basin was developed to estimate ground-water availability in the basin and to determine the effects of additional ground-water withdrawals on the aquifer water levels.

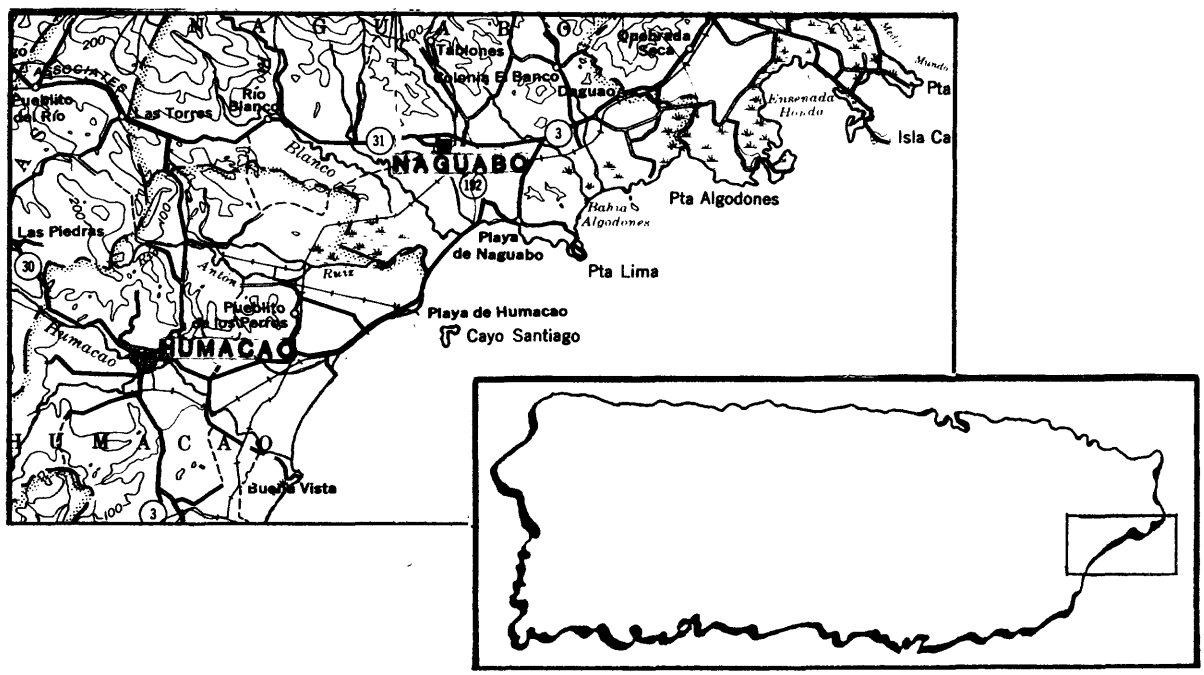


FIGURE 15.--Water resources of the Humacao-Naguabo area.

HYDROLOGY AND CHEMICAL QUALITY OF THE PRINCIPAL SPRINGS IN PUERTO RICO:

A summary of the physical, chemical and bacteriological data collected from 1982 to 1984 in 17 of the principal springs of Puerto Rico (fig. 16) is due for publication next year. The project was completed in cooperation with the Puerto Rico Department of Natural Resources and the Water Resources Research Institute of the University of Puerto Rico, Mayaquez.

Engineer Senén Guzmán-Ríos (project chief), indicated that the total mean daily discharge of the seventeen springs is about 50 cubic feet per second. The maximum recorded discharge occurred at San Pedro Spring near Arecibo (35 cubic feet per second). The second highest recorded occured at Ojo de Agua at Vega Baja (9.4 cubic feet per second). In these two springs continous automatic digital recorders were installed during the last year of the investigation. At Baños de Coamo, near Coamo, the springflow, temperature, and specific conductance were monitored continuously for a year. Springflow varied from 32,000 to 83,000 gallons of water per day (gal/d). Specific conductance and temperature did not vary significantly, averaging 2,300 microsiemens per centimeter(us/cm) and 43 degree Celsius(C) respectively.

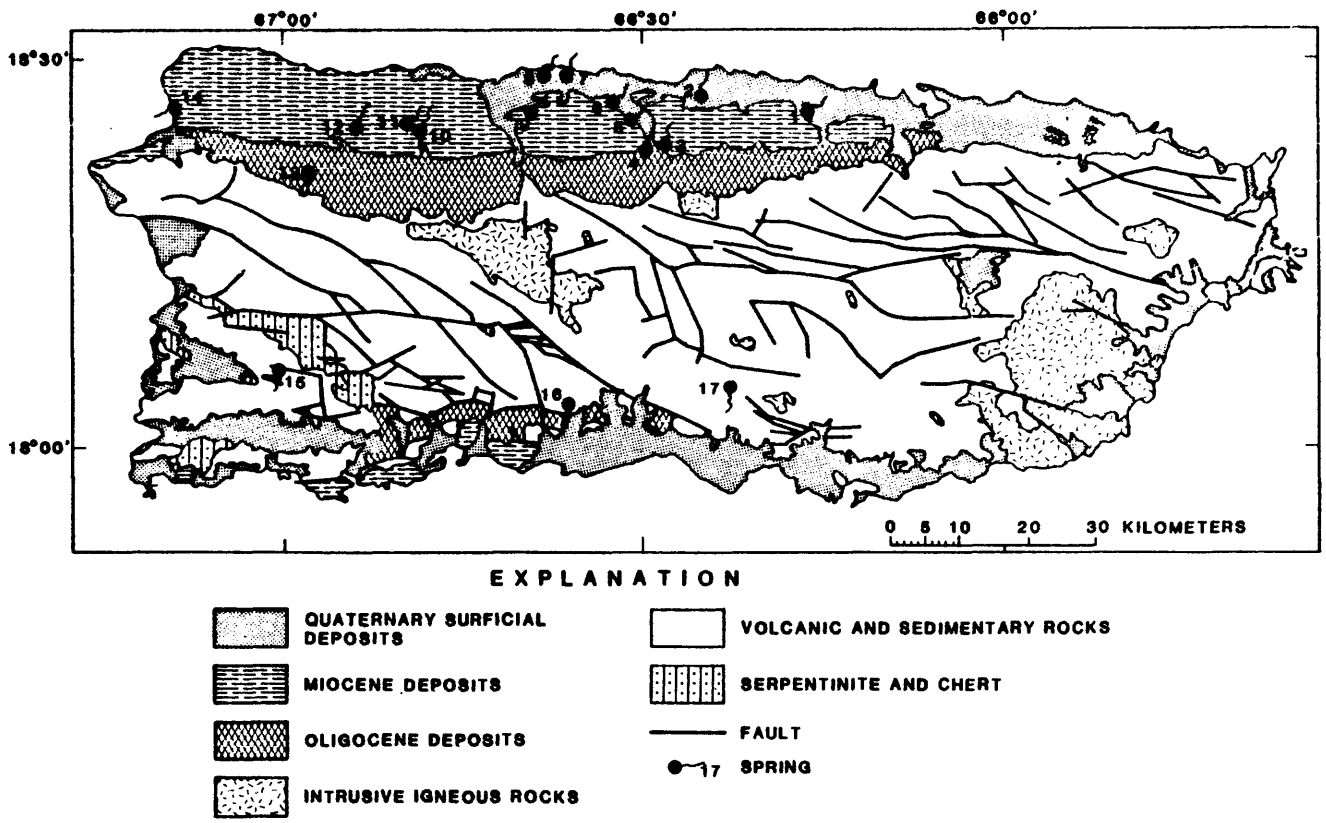


FIGURE 16.--Surficial geology and location of springs.

SOLID-WASTE DISPOSAL SITES:

A reconnaisance of fifty (50) solid-waste disposal sites throughout Puerto Rico was completed in 1984 as part of an evaluation of the hydrogeology, and the associated potential for contamination of surface and ground waters (fig. 17). Forty of the sites pose a threat to surface water quality, and 38 sites have the potential for ground water pollution. Eng. Sigfredo Torres completed the field work and a preliminary report was submitted to the Environmental Quality Board. The results of the study were presented by Eng. Torres at the First Environmental Symposium held in May 1985 by the Environmental Health Association of Puerto Rico.

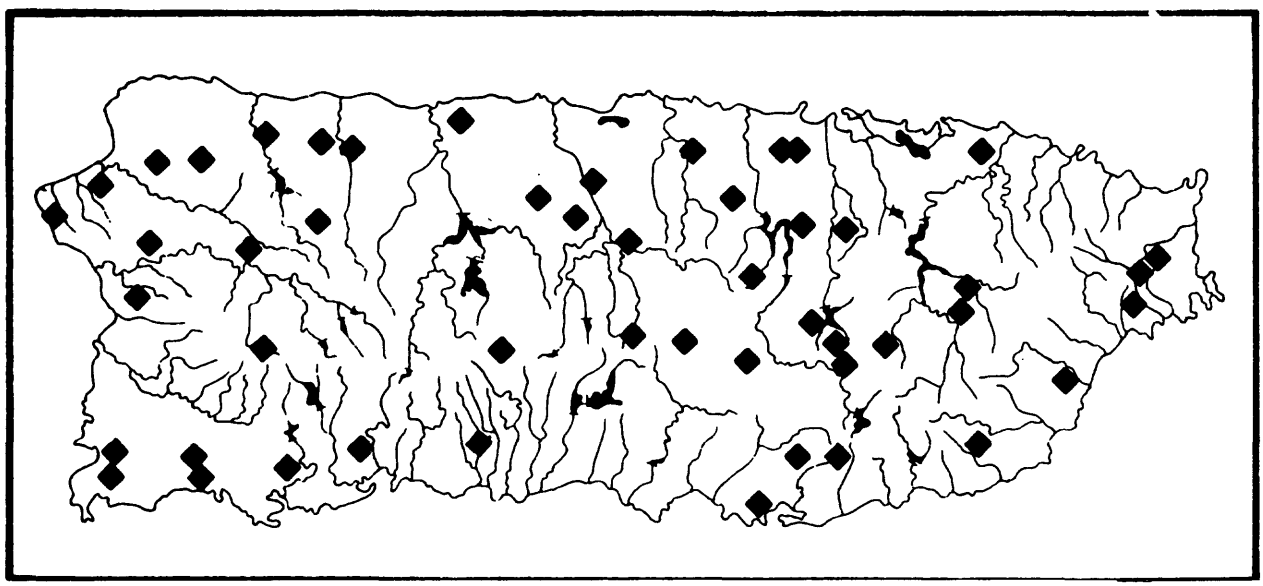


FIGURE 17.--Location of solid-waste disposal sites.

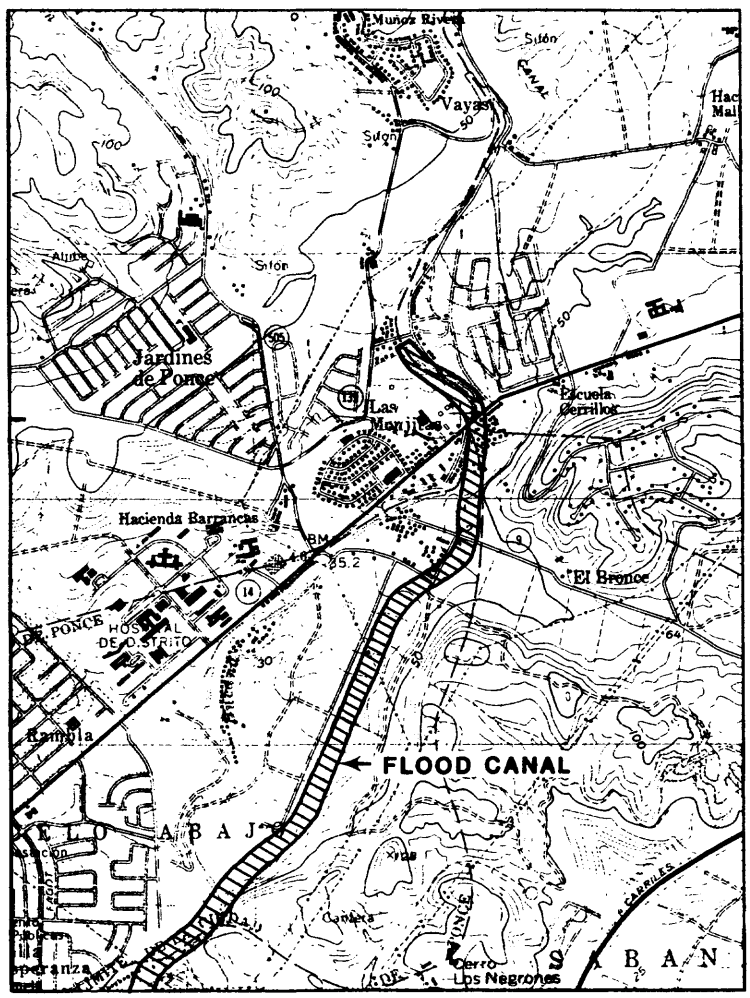
JOBOS AREA:

During the 1984-85 fiscal year, a preliminary assessment of the ground water system in the Jobos Area (fig. 18) will be made for the development of a two-dimensional ground-water flow model. General information on the hydrogeology will be obtained from from previous publications. After calibrating the ground-water flow model for this area, an attempt will be made to couple this model with a solute transport model. It will be used to define the flow rate and dispersion of pollutants detected at the Fibers public supply well field under the existing aquifer conditions. The project is being conducted in cooperation with the Puerto Rico Industrial Development Corporation.

FIGURE 18.--Jobos area including land affected by industrial spill.

EFFECTS OF CHANNELIZATION ON AQUIFER RECHARGE ALONG RIO BUCANA:

Fieldwork is being conducted in an effort to determine the effect of the channelization of Río Bucana near Ponce (fig. 19) on the aquifer. The project is being conducted in cooperation with the Puerto Rico Department of Natural Resources. The investigation, being conducted by hydrologist Vicente Quiñones, will determine the effect of the river channelization on the water table in the area. The study is scheduled to be completed during 1985.



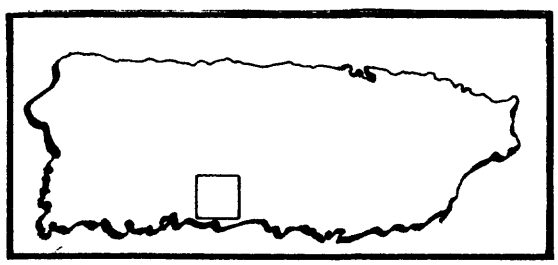


FIGURE 19.--Location of the Río Bucana study area.

GROUND WATER IN THE LAJAS VALLEY:

The second year of the appraisal of the ground-water resources in the Lajas Valley (fig. 20) is now in progress. The project is conducted in cooperation with the Puerto Rico Rice Corporation and directed by geologist Robert Graves. During the first year of data collection, 100 wells were inventoried in the valley. At Laguna Cartagena a multi-site of 11 test wells was drilled to determine hydraulic gradient and to determine if a salinity profile occurs in the near surface sediments. In conjunction with this multi-site a continuous recording surface-water gaging station was installed at the Laguna to determine elevation and outflow. Further plans for the valley include deep well drilling to 500 feet, shallow, multi test well sites at select locations, ground-water quality sampling, and aquifer tests.

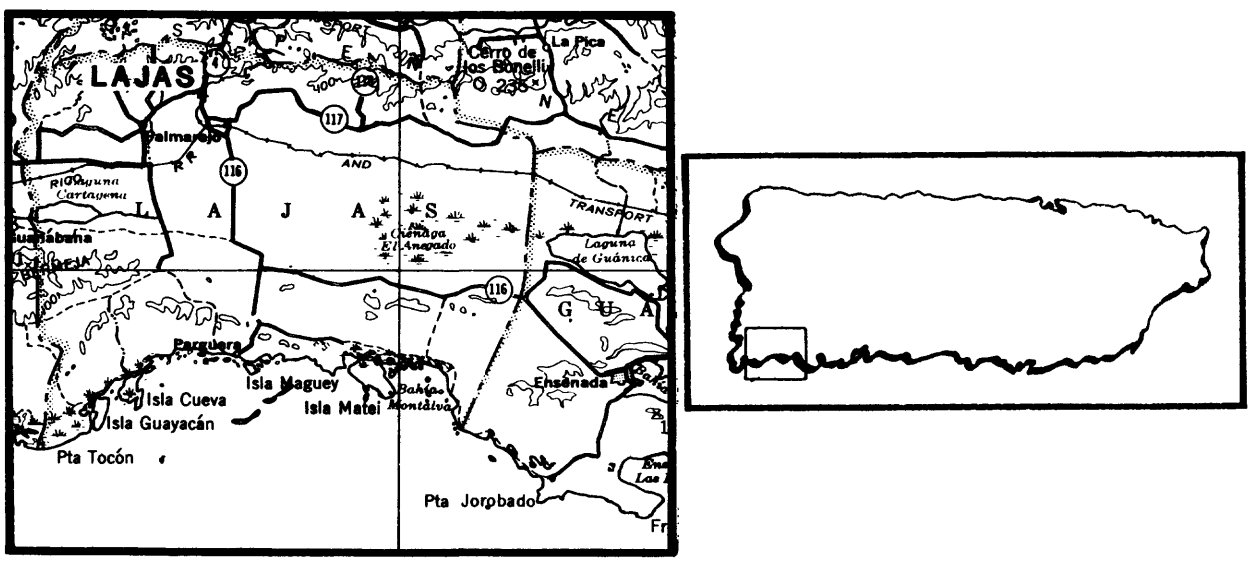


FIGURE 20.--The Lajas Valley area.

INVENTORY OF WATER WELLS IN PUERTO RICO:

An inventory of water wells in Puerto Rico was begun during 1984, in cooperation with the PRDNR. The objectives of this project are: to update the well inventory completed between 1959-61; to enter all the information into computerized data bases within the USGS local computer facilities; and to make the information available or accessible to all users in a publication and/or through the local computer via remote terminals. The well inventory data base is essential in the management of aquifers in Puerto Rico by Commonwealth agencies and as a repository for ground water information. The inventory is being conducted by hydrologist Hector Colon.

Compilation of data available in the Caribbean District and files in cooperating agencies indicate a dramatic increase in the number of wells in Puerto Rico (fig. 21). Overall, the number of wells have increased by about 80 percent from the previous number inventoried in 1959-61 (Ward and Truxes, 1964).

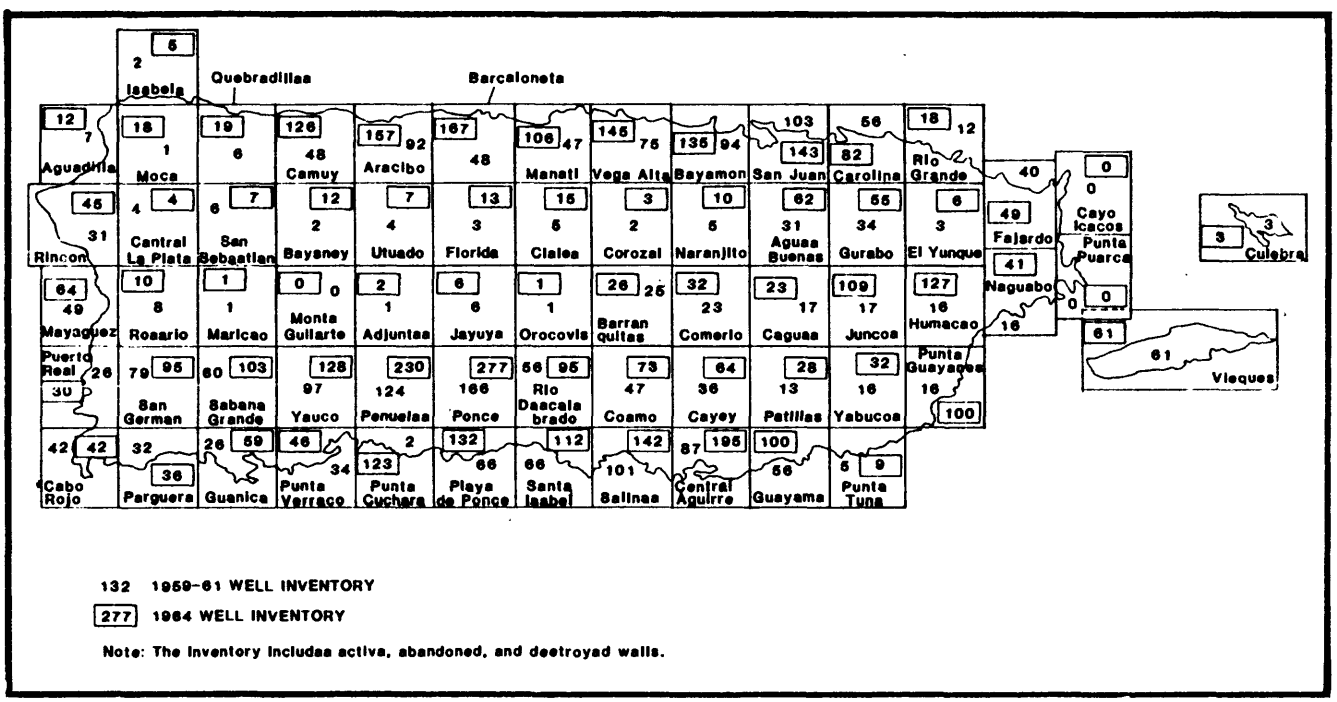


FIGURE 21.--Water wells inventory in Puerto Rico.

RAINFALL - RUNOFF SIMULATION IN THE RIO GRANDE DE LOIZA AT QUEBRADA ARENAS WATERSHED, PUERTO RICO:

In 1984, in cooperation with the Water Resources Research Institute of the University of Puerto Rico (Mayaguez Campus) Engineer Eloy Colón Dieppa completed a project designed to calibrate a rainfall-runoff model at a selected "pilot" basin in Puerto Rico using available data. Preliminary calibration of the model was completed for the Río Grande de Loíza at Quebrada Arenas.

The modeling at the pilot basin fairly simulated stream flow on an annual, monthly and daily basis during both the 2-year calibration interval and the 3-year verification interval. Differences between observed and simulated values during the calibration and verification period (fig. 22) have been attributed to the quality of the record and the rain gage location not representing average conditions for the entire watershed.

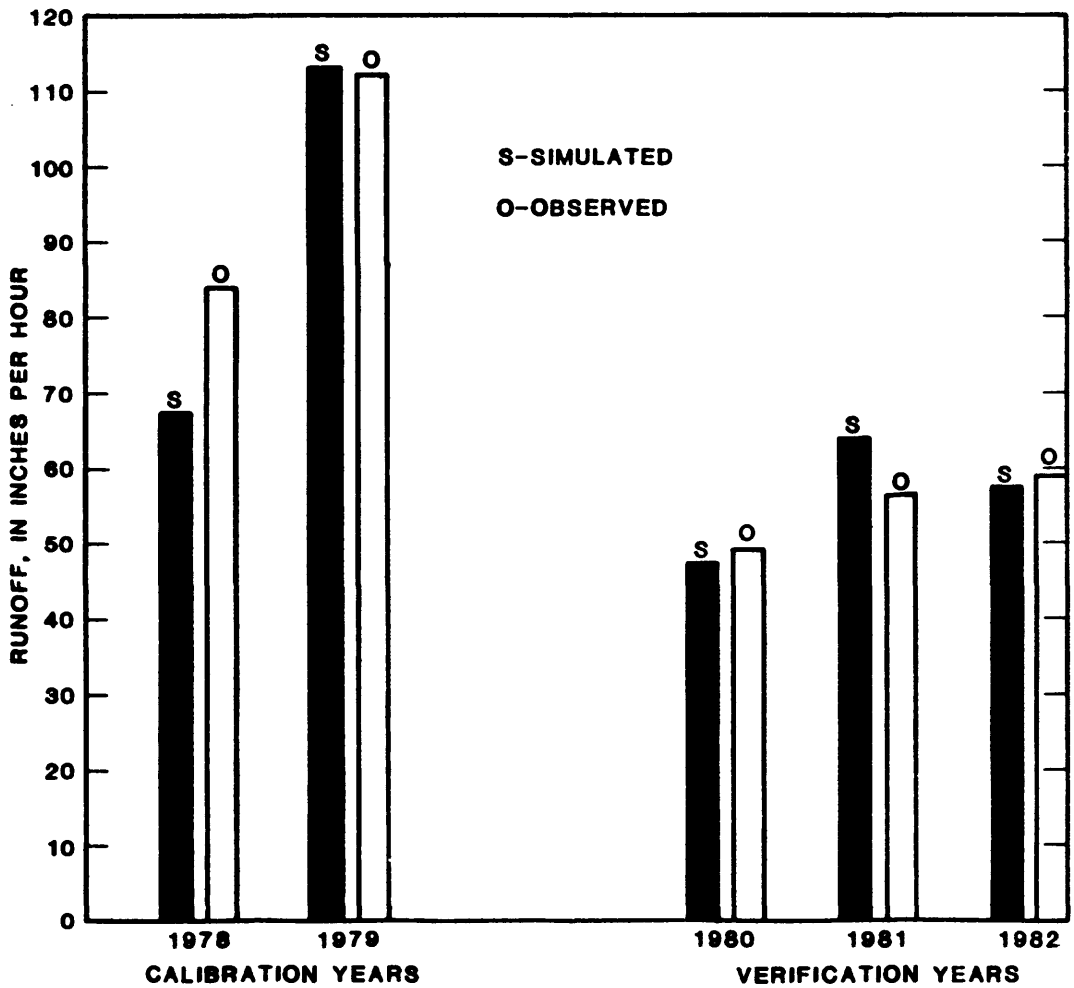


FIGURE 22.--Comparison of observed and simulated annual volumes recorded at Río Grande de Loíza at Quebrada Arenas, 1978-1982.

SUSPENDED SEDIMENT TRANSPORT IN THE RIO GRANDE DE LOIZA BASIN, PUERTO RICO:

In 1983 the USGS in cooperation with the USCOE, PRDNR, and PRASA started an investigation in the Loíza basin under the leadership of Engineer Senén Guzmán-Ríos. Total basin sediment transport and inflow to Lago Loíza will be accounted. The Universal Soil Loss Equation will be calibrated utilizing the collected data. The results will be used by the USCOE in the preliminary design of three proposed reservoirs upstream from Lago Loíza.

The Río Grande de Loíza Basin, in east-central Puerto Rico (fig. 23) is among the most intensively developed watersheds in the island. Developments in the basin include agricultural and industrial activities. Lago Loíza the only reservoir in the basin supplies about 75 million gallons per day (Mgal/d) of water to the San Juan metropolitan area. This reservoir is losing storage capacity at a rate of about 2 percent per year due to sedimentation. Preliminary results have shown that silt and clay account for most of the sediment. Although total inflow of sediment to the resevoir is known, contributions from individual subbasins and land-use effects, have not been well defined.

During the past year emphasis of the project has been placed on suspended-sediment sampling at 10 streamflow-sediment stations (fig. 23). Depth-integrated samplers were installed at 6 of the stations. At least three major flood events have been documented and preliminary results are being evaluated. To supplement these data, automatic sediment samplers will be installed in 5 of the stations by the end of this fiscal year. Bed material sampling and particle size analysis will be started during this fiscal year.

A progress report on the major findings of the investigation is due for completion early next calendar year.

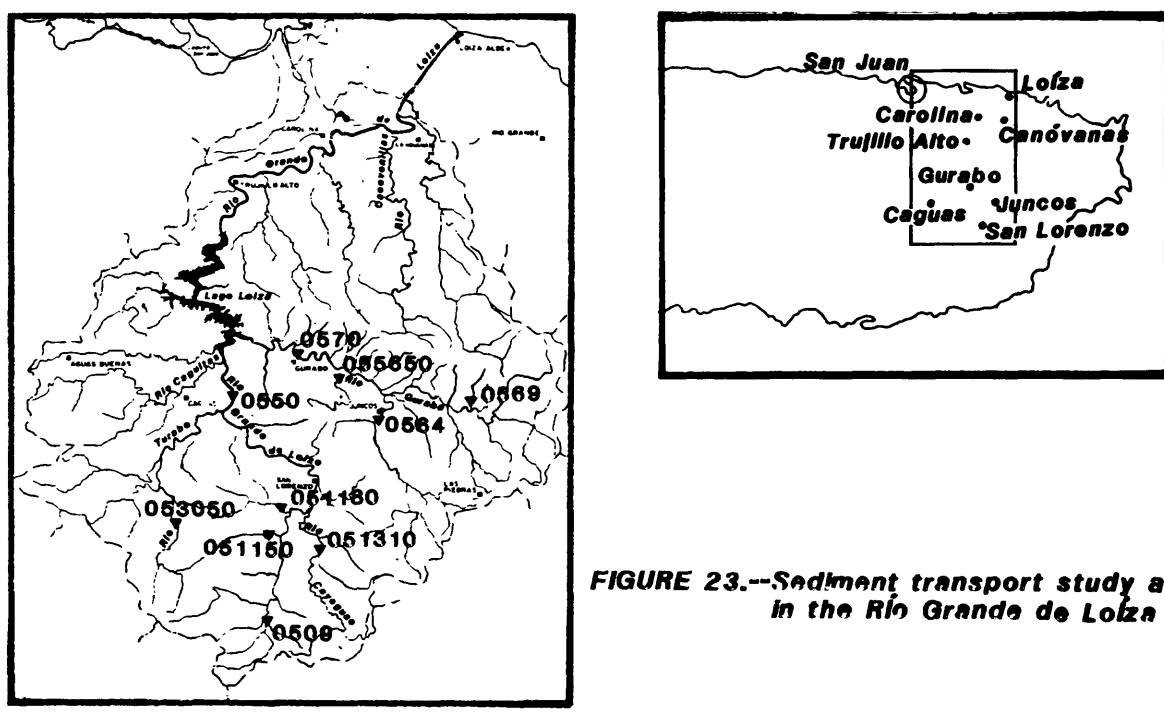


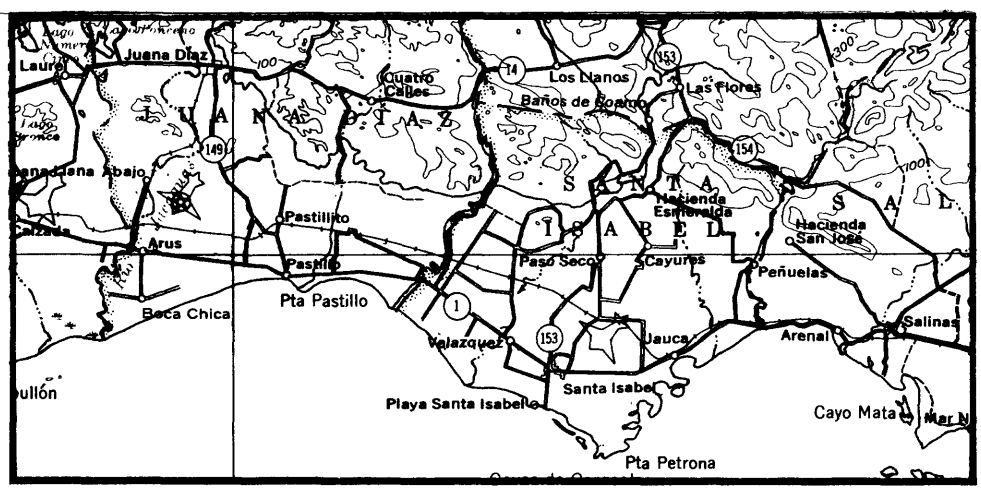
FIGURE 23.--Sediment transport study area in the Río Grande de Loíza basin.

GROUND WATER IN THE JUANA DIAZ - SANTA ISABEL AREA:

The Puerto Rico Department of Agriculture, through the Puerto Rico Vegetable Corporation, has initiated an intensive agricultural development program along the south coast of the island. Most of the current developments are located on the coastal piedmont alluvial plain between Río Jueyes near Salinas and Rio Jacaguas near Juana Díaz (fig. 24). The alluvial aquifer is the primary source of water for furrow and drip irrigation, although some surface water is also used. The Vegetable Corporation is concerned with how ground-water availability and quality will be affected as the area under cultivation expands and as more land is converted to drip irrigation.

The second part of an in-depth ground-water resources investigation, under the direction of geologist Dennis O'Connell, is in progress in cooperation with the Puerto Rico Vegetable Corporation. In the initial year of the project, a network of ground-water and surface-water monitoring stations was established. Stream discharge and seepage were measured during a period of low flow in January, 1985, and two preliminary potentiometric maps have been prepared from data collected during November, 1984 and January, 1985. Ground-water samples were collected during April, 1985 to measure chloride concentration and specific conductance.

Future efforts will be directed towards an inventory of water use in the region, and the development of a ground-water flow model which will be used as a tool to predict changes in water level due to pumpage or recharge.



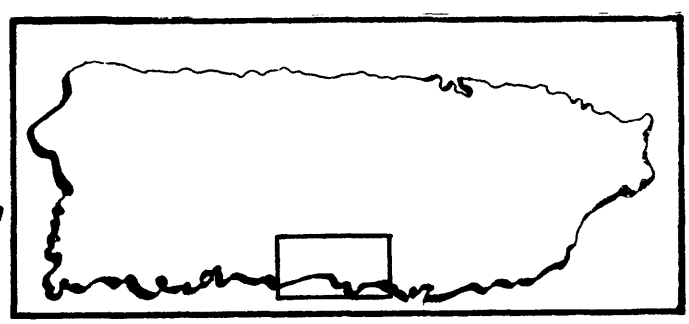


FIGURE 24.--The Juana Díaz-Santa Isabel study area.

OTHER ACTIVITIES OF THE HYDROLOGIC INVESTIGATIONS SECTION DURING 1984-85:

Monitoring of Organic Contaminants in Ground Water near Vega Alta, Barceloneta, and Guayama:

In cooperation with the P. R. Aqueduct and Sewers Authority, monitoring of contaminated well fields near Barceloneta (for Carbon Tetrachloride), Vega Alta (Trichloroethelene), and Guayama (Tetra- and Trichloroethelene) continued during the year. Samples are being collected weekly at public supply wells to ascertain that well water is free of the contaminants or that the concentration does not exceed drinking water standards.

Monitoring of Trihalomethanes in Drinking Water:

In cooperation with PRASA the USGS initiated a comprehensive appraisal of the concentration of trihalomethanes (THL's) in finished drinking water. Samples were collected from about 50 PRASA filtration plants. Preliminary results showed that EPA standards for THL's were exceeded at key plants serving the San Juan metropolitan area (fig. 25). Sampling of an additional 30 sites will continue this year.

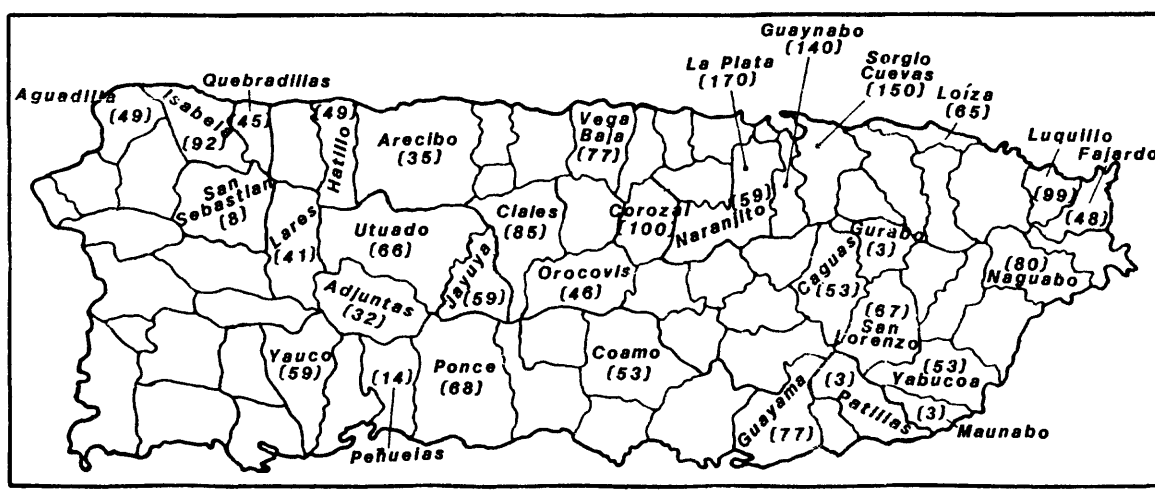


FIGURE 25.--Chloroform concentrations in the Puerto Rico Aqueduct and Sewer Authority purification plants during November 1984.

GROUND WATER FLOW SIMULATION IN THE VEGA ALTA TO DORADO AREA:

A two dimensional (2-D) ground-water flow model was constructed and calibrated for the 50 square mile (mi2) study area (fig. 26). The model has contributed significantly in advancing the knowledge of the local ground-water flow system. This project was begun in 1983 in cooperation with PRIDCO, DNR, and PRASA and will be completed by october 1985.

Among the most important findings are:

1. Rainfall infiltration through the outcrop area of the Aymamón Limestone unit is the principal source of recharge to the water table aquifer. Recharge through the Aymamón accounts for about 12 Mgal/d (millions of gallons per day) or almost 1/2 of the total aquifer recharge.

2. In general, the part of the water table aquifer within the Cibao Formation has little potential for ground-water development. Transmissivity values in this part are generally less than 1,000 ft2/d (feet squared per day), limiting development mostly to self supplied rural use.

3. The most productive part of the aquifer is the area located north of Highway PR-2, south of the coastal plain, and between Río Cibuco and de La Plata. In this area transmissivity ranges from 25,000 to at least 150,000 ft2/d.

4. The most productive part of the aquifer is already being pumped at almost 10 Mgal/d or approximately the estimated rate of rainfall recharge. Increased withdrawals within this area will lead to a thinning of the fresh-water lens (due to a lowering of the water table surface) and encroachment of seawater at coastal areas.

A publication documenting the conceptual basis of this model, its use and limitations, will be available by the end of calendar year 1985.

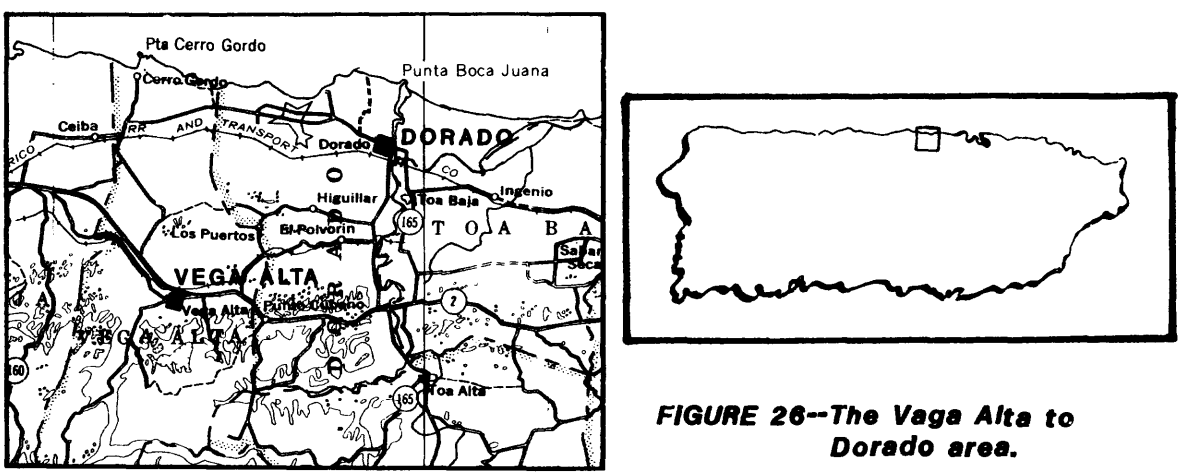


FIGURE 26--The Vega Alta to Dorado area.

NEW PROJECTS STARTED IN FISCAL YEAR 1984:

Although only one major project was started in fiscal year 1985, its scope, resources, and funding will have a significant impact in the District's program.

THE CARIBBEAN ISLANDS AQUIFER - RASA:

In 1977, the U. S. House of Representatives introduced a national program of regional aquifer analyses and stated that the U. S. Geological Survey was to implement the program (Committee Report 95-392). Twenty-eight aquifer systems covering all major ground-water basins were included in this effort and referred to as the Regional Aquifer System Analysis program. The Caribbean Islands Aquifer RASA was initiated with a federal assignment of $425,000 for FY1985. The project, under the leadership of Engineer Fernando Gómez, will concentrate its efforts in the alluvial aquifer of the south coast plain of Puerto Rico and the Kingshill aquifer of St. Croix, in the USVI. In addition, a special effort will be made to define more accurately the interrelationship between ground-water in the unconsolidated deposits and in the limestone aquifer system of northern Puerto Rico. The project goals are:

1. To provide a system analyses framework for the investigation of the indicated aquifers.

2. To develop areal maps of the principal aquifer properties including thickness, transmissivity, geology, geochemistry, salinity, and water levels.

3. Develop regional ground-water flow models of the three principal aquifers to enhance the understanding of their functioning.

The RASA project staff includes three (3) full time professionals and several support technicians. During the first nine months of the project, the following were the principal accomplishments:

1. Preparation of the "Planning Report for the Caribbean Islands Regional Aquifer Systems Analysis", outlining the objectives and scope, work elements, approach, and time table;

2. Meet the staff requirements;

3. Initiate work activities.

CARIBBEAN ISLANDS - RASA - GEOCHEMISTRY:

As part of the Caribbean Islands - Regional Aquifers System Analyses (RASA) project, a detailed investigation on the water quality and geochemistry of each aquifer under consideration is being conducted. The reconnaissance phase of this investigation consists of assembling the historical water quality data and preliminary geochemical modeling. This has been completed for the North Coast Limestone aquifer (Table 1 and fig. 27), and commenced for the South Coast Alluvial Plain aquifer and the Kingshill Aquifer in St. Croix.

The geochemical models will be valuable in assessing the ground water flow and other hydrogeological processes in the areas studied.

Table 1. Mass Transfer Calculations for a Sample Flow Path in the North Coast Limestone Aquifers.

	Montebello Limestone (From site 1 to site 2)	Aguada Limestone (From site 3 to site 4)	Aymamón Limestone (From Rainfall to sites)	Aymamón Limestone (From site 6 to site 7)
Calcite	-0.3280	0.2251	1.9123	1.9040
Dolomite	0.0870	0.0862	0.0227	---
Gypsum	0.0160	0.0886	0.0417	---
CO_2 (gas)	-0.2630	1.2564	2.3438	2.3106
Initial Solution (%)	---	76.30	---	9.50
Rainfall (%)	---	23.70	98.00	89.23
Sea Water (%)	---	---	2.00	1.26

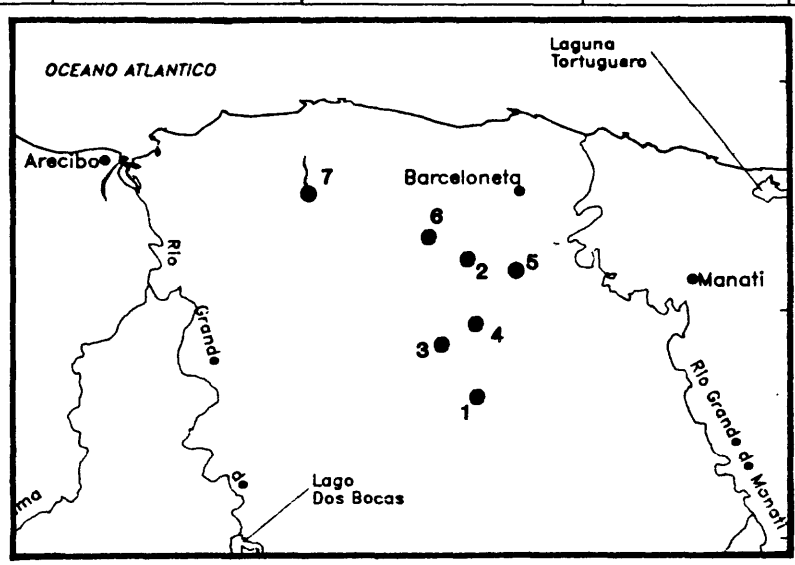


FIGURE 27.--Location of sites.

OTHER ACTIVITIES:

Automatic Data Processing Unit:

The computer section personnel.

The District's computer facilities continued to be modernized with the acquisition of additional memory units, terminals, and a drum plotter.

The Caribbean District entered the age of NESS-GOES (National Earth Satellite Service-Geostationary Operational Environmental Satellite). The month of May herald the installation of Data General's CRT and four-part modules (CPU, Memory, Floppy and I/O) and Synergetics' demodulator and receiver. This facility, coupled to remote transmitter at 5 streamflow gaging stations will allow the District to start receiving real-time flow data.

GOES uses Synergetics SCADA-SOFT application software for configuring the S-34 Bus System and Remote Computer modules into a Data Collection Platform (DCP). The SCADA-DCP's main feature is the maximum control and flexibility in determining sensor data collection and processing algorithms.

The District also acquired a software package to enable the data processing of the satellite data into the PRIME providing for graphics and other applications. We are also considering the acquisition of a multiplexor to enable inside and outside agency users to access our system.

The Districts minicomputer was upgraded from a 250 to a 750 CPU model, double the processing speed of the system, and from 5 to 25 terminals. The graphics capabilities have been enhanced with the addition of a drum plotter model HP7586B. This upgrade to our system gives more flexibility to the data manipulation that the on going projects need to ensure our agency goals.

ADMINISTRATIVE SECTION:

The Administrative Section of the Caribbean District under the direction of Mrs. Georgina Piñeiro, performs a variety of activities related to management, personnel, purchasing, and procurement. These functions are vital to our succesfull operations.

The administrative staff is also responsible for the preparation, drafting, and camera-ready production of the reports published by the Caribbean District. 1984-85 was again a very productive period in the reports unit.

The administrative and reports section personnel.

REPORTS PUBLISHED AND/OR APPROVED DURING 1984-85:

The following reports are published, approved for publication, or in the drafting or processing phase prior to printing and distribution:

1. Estimates of 7-day, 10-year Low Flow at Ungaged Streams in Puerto Rico, WRI 84-4089, (2-plates), by Eloy Colon-Dieppa and Vicente Quinones-Aponte.

2. Floods of April 18, 1983 in St. Thomas and St. John, USVI, WRI 84-4184, (1-plate), by Russell Curtis, Jr.

3. Reconnaissance of Ground-Water Quality in the Virgin Islands, July 1984. OFDR-84-807 (1-plate) by René García and Michael Canoy.

4. Reconnaissance of Trace Organic Compounds in Ground Water Throughout Puerto Rico, Oct. 1983: OFDR-84-810.

5. Surface-Water Data Network Analysis for Puerto Rico, WRI 83-4055, by Patrick W. McKinley.

6. Water Resources of the Lower Rio Grande de Arecibo Alluvial Valley, Puerto Rico, WRI-85-4160, by Vicente Quiñones-Aponte.

7. Simulation of Ground-Water Flow in the Rio Yauco Alluvial Valley, Yauco, Puerto Rico, WRI-85-4179, by Vicente Quinones-Aponte.

8. Planning Report for the Comprehensive Appraisal of the Ground Water Resources of the North Coast Limestone Area of Puerto Rico, OFDR-84-427, by Arturo Torres-González and Richard M. Wolansky.

9. Estimated Water Use in St. Thomas, USVI, July, 1983 - June, 1984, OFDR-84-721, (1-plate), by Heriberto Torres-Sierra and Rafael Dacosta.

10. A Reconnaissance of the Water Resources of the Central Guanajibo Valley, Puerto Rico, WRIR-82-4050, by Eloy Colón-Dieppa and Ferdinand Quiñones-Marquez.

11. Water Resources of the Sabana Seca to Vega Baja Area, Puerto Rico, WRIR-82-4115, by Arturo Torres-Gonzalez and Jose R. Diaz.

12. Water Resources of the Lower Rio Grande de Manati Valley, Puerto Rico, WRIR-83-4199, by Fernando Gomez-Gomez.

13. Publications of the U. S. Geological Survey, Water Resources Division for Puerto Rico and the U. S. Virgin Islands, 1946-1984, OFDR-84-229, by Ferdinand Quiñones-Márquez and Marisol Lopez.

14. Publications of the U. S. Geological Survey, Water Resources Division, for Puerto Rico and the U.S. Virgin Islands, 1946-1985, OFDR-85-414, by Ferdinand Quiñones-Márquez and Elba Rivera.

15. Flow Duration at Streamflow Gaging Stations in Puerto Rico, OFDR-84-127, by Ferdinand Quiñones-Márquez, Eloy Colón-Dieppa, and Max Juarbe.

16. Determinación de Caudal y Técnicas de Muestras en Agua Superficial, OFR-85-89, by Ferdinand Quiñones-Márquez and Senén Guzmán-Ríos.

17. Simulation of Ground-Water Flow in the Water Table Aquifer near Barceloneta, Puerto Rico, WRIR-84-4113, by Arturo Torres-González.

Water Resources Information Center:

One of the most important functions of the Hydrologic Data Section is to provide basic-data information to the water-resources data users. Government officials, engineers, planners, students, and private citizens constitute a constant stream of visitors to our office in search of information or reports. During the year, more than 400 persons visited our offices and around 600 telephone calls, related to data inquiries, were received.

International Symposium on Tropical Hydrology and 2nd Caribbean Islands Water Resources Congress:

The USGS, in cooperation with PREQB, PRDNR, and the USEPA, co-sponsored with the American Water Resources Association and the Water Resources Research Institute of UPR-Mayaquez an International Symposium on Tropical Hydrology. Nearly 170 hydrologists and scientists from 11 countries participated in the 3-day activity. A highlight of the activity was the presentation of 14 papers related to the hydrology of Puerto Rico. The Third Caribbean Islands Water Resources Congress is scheduled for July, 1986 in St. Croix, U.S. Virgin Islands.

Drilling and Logging Operations:

Test drilling and geophysical logging capabilities were fully utilized during 1984 and 1985 by the Hydrologic Investigations Section of the Caribbean District. Douglas Whitesides, Technical Support Coordinator, oversaw test-drilling operations and well construction at an EPA "Super Fund" cleanup site in Vega Alta, as well as project drilling in Humacao, Dorado, Toa Baja, Lajas Valley, Vieques, Ft. Allen, and Isabela. Most recently, test drilling on Isla Caja de Muertos, an island 6 miles from Ponce, revealed ânomolous artesian conditions and chloride concentrations greater than that of seawater.

A new geophysical logging unit was received in May. The unit has sonic-velocity capability, very valuable in estimating limestone porosity. The logger, operated by hydrologic technician Ramón Carrasquillo, is able to perform multiple tests at one time, considerably speeding up logging operations. The logging capabilities of the District surpass those of most USGS operations.

The Application of Rn(222) in Measuring Ground Water Discharge to the Río Grande de Manatí, Puerto Rico:

The U. S. Geological Survey, WRD, is actively engaged in testing a new method of assessing ground water - surface water interactions in the principal streams in Puerto Rico. The method utilizes a naturally occuring radioisotope, radon-222, which is far more abundant in ground water than in surface water. The contribution of groundwater to streamflow can be estimated by collecting water samples and measuring the concentration of radon-222 relative to background concentrations in the nearby ground-water samples.

Originally developed at the Lamont Doherty Geological Observatory, Columbia University, New York, the technique has been field-tested in Jamaica by a graduate student, Ms. Katherine-Kelly Ellins. Its application in Puerto Rico was tested on Rio Grande de Manati, a stream flowing along karstic terrain on the north coast of the island and having considerable ground-water contributions. Ms. Katherine-Kelly Ellins, assisted by geochemist Roger Lee formerly with the USGS Southeastern Region Office and hydrologist Angel Roman-Mas from the USGS Caribbean District office, obtained promising results from the methodology. Ground-water inputs were detected and a quantitative model of ground water - surface water interaction is being prepared as part of the Caribbean Islands - RASA project.

APPENDIX 1

ACTIVE RECORDING SW STATIONS IN PR AS OF 04/01/85

STATION NUMBER	NAME	D.A. (SQ MI)	LAT.	LONG.	DATE BEGAN	*TYPE
50010600	RIO GUAJATACA AB. LAGO DE GUAJATACA		181957	665529		
50011200	RIO GUAJATACA BELOW LAGO DE GUAJATACA		182401	665540	081269	D
50011400	RIO GUAJATACA AB.MOUTH NR QUEBRAD.		182831	665746	072569	D
50014800	RIO CAMUY NEAR BAYANEY		182348	664854		
50015700	RIO CAMUY NEAR HATILLO		182744	664956		
50027750	RIO GDE. DE ARECIBO ABOVE ARECIBO	140	182529	664144	060782	MGD
50028000	RIO TANAMA NEAR UTUADO	18.4	181802	664658	120159	D
50028400	RIO TANAMA AT CHARCO HONDO	57.6	182452	664252	022869	D
50031200	RIO GDE. DE MANATI NR MOROVIS	55.2	181745	662447	010165	MGD
50035000	RIO GDE. DE MANATI AT CIALES	128	181926	662736	100160	MGD
50038100	RIO GDE. DE MANATI HWY 2 NR MANATI	197	182552	663137	012370	MGD
50038320	RIO CIBUCO BELOW COROZAL	15.1	182113	662007	050169	D
50039500	RIO CIBUCO AT VEGA BAJA	99.1	182653	662229	011273	MGD
50043000	RIO DE LA PLATA AT PROY LA PLATA	54.8	180937	661344	040160	MGD
50046000	RIO DE LA PLATA AT HWY 2 NR TOA ALTA	200	182350	661517	010160	MGD
50050900	RIO GDE. DE LOIZA AT QUEB ARENAS	6.00	180710	655922	100177	MGD
50051150	QUEBRADA BLANCA AT EL JAGUAL	3.25	180939	655856	091184	D
50051180	QUEBRADA SALVATIERRA NR SAN LOREN.	3.74	181024	655838	050184	D
50051310	RIO CAYAGUAS AT CERRO GORDO	10.2	180927	655729	091577	MG
50053050	RIO TURABO AT BORINQUEN	7.89	181010	660237	122183	D
50055000	RIO GDE. DE LOIZA AT CAGUAS	89.8	181433	660034	120159	MGD
50055650	QUEBRADA CAIMITO NR JUNCOS	0.82	181408	655212	012584	D
50056400	RIO VALENCIANO NR JUNCOS	16.4	181258	655534	012871	MGD
50056900	QUEBRADA MAMEY NR GURABO	2.30	181452	655645	122983	D
50057000	RIO GURABO AT GURABO	60.2	181530	655805	100159	MGD
50061800	RIO CANOVANAS NR CAMPO RICO	9.84	181908	655321	032867	MGD
50063440	QUEBRADA SONADORA NR EL VERDE	1.04	181927	654906	032983	D
50063500	QUEBRADA TORONJA AT EL VERDE	0.19	181946	654916	040783	D
50063800	RIO ESPIRITU SANTO NR RIO GRANDE	8.62	182137	654849	080166	D
50065500	RIO MAMEYES NR SABANA	6.88	181946	654504	080167	MGD
50067000	RIO SABANA AT SABANA	3.96	181952	654352	102679	MGD
50071000	RIO FAJARDO NEAR FAJARDO	14.9	181756	654142	040161	MGD
50075000	RIO ICACOS NEAR NAGUABO	1.26	181638	654709	100179	D
50082000	RIO HUMACAO AT HWY 3 AT HUMACAO	17.3	180849	654937	101582	MGD
50092000	RIO GDE. DE PATILLAS NR PATILLAS	18.3	180204	660158	010166	MGD
50106500	RIO COAMO NEAR COAMO	46.0	180352	662210	022484	D
50108000	RIO DESCALABRADO NEAR LOS LLANOS	12.9	180308	662534	021784	D
50111500	RIO JACAGUAS AT JUANA DIAZ	49.8	180316	663040	041484	M
50112500	RIO INABON AT REAL ABAJO	9.70	180510	663346	070164	MGD
50114000	RIO CERRILLOS NEAR PONCE	17.8	180415	663451	050164	MGD
50115000	RIO PORTUGUES NEAR PONCE	8.82	180445	663801	070164	MGD
50124200	RIO GUAYANILLA NEAR GUAYANILLA	18.9	180240	664753	022470	MGD

APPENDIX 1--Continued

ACTIVE RECORDING SW STATIONS IN PR AS OF 04/01/85.

STATION NUMBER	NAME	D.A. (SQ MI)	LAT.	LONG.	DATE BEGAN	*TYPE
50129900	LAGUNA CARTAGENA NR BOQUERON		180052	670634	060584	MGD
50136000	RIO ROSARIO AT ROSARIO	16.4	181022	670431	051475	D
50138000	RIO GUANAJIBO NEAR HORMIGUEROS	120	180836	670857	011673	MGD
50144000	RIO GDE. DE ANASCO NR SAN SEB.	94.3	181705	670305	040163	MGD
50147800	RIO CULEBRINAS AT HWY 404 NR MOCA	71.2	182142	670533	071267	MGD

ACTIVE RECORDING SW STATIONS IN WEST INDIES AS OF 04/01/85

STATION NUMBER	NAME	D.A. (SQ MI)	LAT.	LONG.	DATE BEGAN	*TYPE
1311350-60153300	BUCCAMENT RIVER AT PEMBROKE, ST.V.	7.12	131135	601533	030184	D
1350220-60572400	TROUMASSEE RIVER AT MAHAUT,ST.LUCIA	5.44	135022	605764	030884	D
1524500-61234400	LAYOU RIVER AT L. VALLEY, DOMINICA	27.1	152450	612344	031584	D

ACTIVE RECORDING SW STATIONS IN VI AS OF 04/01/85

STATION NUMBER	NAME	D.A. (SQ MI)	LAT.	LONG.	DATE BEGAN	*TYPE
50252000	BONNE RESOLUTION GUT AT B.R.,ST.TH.	0.49	182157	645734	112562	MGD
50276000	TURPENTINE RUN AT MARIENDAL,ST.TH.	2.97	181948	645258	010163	D
50295000	GUINEA GUT AT BETHANY, ST. JOHN	0.37	181955	644650	010163	D
50345000	JOLLY HILL GUT AT JOLLY HILL,ST.CR.	2.10	174400	645147	010163	MGD

ACTIVE SW CREST STAGE STATION IN PR AS OF 04/01/85

STATION NUMBER	NAME	D.A. (SQ MI)	LAT.	LONG.	DATE BEGAN
50115900	RIO PORTUGUES AT HWY 14 AT PONCE	18.6	180109	663626	1965

*TYPE

D.A. DRAINAGE AREA
D DIGITAL RECORDER
MGD MANOMETER, GRAPHIC AND DIGITAL RECORDERS

APPENDIX 2

ACTIVE QW STATIONS IN PUERTO RICO AS OF 05-20-85

STATION NUMBER	NAME	LAT	LONG	BEGAN	TYPE
50010500	RIO GUAJATACA AT LARES	181801	665224	1975	P
50010720	LAGO GUAJATACA NO.3 NR MOUTH NR QUEBRADILLAS	182205	665436	1980	A
50010790	LAGO GUAJATACA NO.1 NR DAM NR QUEBRADILLAS	182356	665523	1980	A,*
50011000	CANAL DIVERSION AT LAGO GUAJATACA	182402	665525	1975	P
50011400	RIO GUAJATACA NR QUEBRADILLAS	182831	665746	1969	P
50020050	LAGO GARZAS NO.1 NR DAM NR ADJUNTAS	180821	664435	1980	A
50020500	RIO GRANDE DE ARECIBO NR ADJUNTAS	181054	664412	1979	P
50025000	RIO GRANDE DE ARECIBO NR UTUADO	181811	664159	1979	P
50025110	LAGO DOS BOCAS NO.3 AT WEST BR NR UTUADO	181915	664011	1980	A
50026050	RIO CAONILLAS AB LAGO CAONILLAS	181326	663822	1979	P
50027090	LAGO DOS BOCAS NO.1 NR DAM NR UTUADO	182009	664004	1980	A,*
50027250	RIO GRANDE DE ARECIBO BL DOS BOCAS NR FLORIDA	182050	664002	1975	P
50028000	RIO TANAMA NR UTUADO	181802	664658	1975	P,S/W
50029000	RIO GRANDE DE ARECIBO AT CENTRAL CAMBALACHE	182720	664210	1969	P
50030700	RIO OROCOVIS NR OROCOVIS	181420	662258	1979	P
50031200	RIO GRANDE DE MANATI NR MOROVIS	181745	662447	1979	P
50035500	RIO GRANDE DE MANATI AT HWY 149 AT CIALES	182046	662806	1976	P
50035950	RIO CIALITOS AT HWY 649 AT CIALES	182018	662828	1975	P
50038100	RIO GRANDE DE MANATI AT HWY 2 NR MANATI	182552	663137	1969	A,N,*
50038200	LAGUNA TORTUGUERO OUTLET NR VEGA BAJA	182829	662650	1964	A
50038320	RIO CIBUCO BELOW COROZAL	182113	662007	1975	P
50039500	RIO CIBUCO AT VEGA BAJA	182653	662229	1975	P
50039650	DRAINAGE DITCH B1 WARNER LAMBERT NR VEGA BAJA	182717	662109	1982	P
50039700	DRAINAGE DITCH AT RIO CIBUCO BL SAN VICENTE	182744	662152	1982	P
50039750	RIO CIBUCO BL CENTRAL SAN VICENTE	182747	662153	1982	P,*
50039900	LAGO CARITE NO.3 ON RIO LA PLATA NR CAYEY	180504	660603	1980	A
50039950	LAGO CARITE NO.1 NR DAM NR CAYEY	180439	660619	1980	A,*
50043000	RIO DE LA PLATA AT PROYECTO LA PLATA	180937	661344	1975	P
50044000	RIO DE LA PLATA NR COMERIO DAM	181433	661228	1979	P
50044400	LAGO LA PLATA NO.5 NR NARANJITO	181933	661228	1980	A
50044850	RIO GUADIANA NR NARANJITO	181839	661328	1979	P
50044950	LAGO LA PLATA NO.3 NR NARANJITO	182018	661401	1980	A,*
50046000	RIO DE LA PLATA AT TOA ALTA	182350	661517	1958	N,*
50047600	RIO DE BAYAMON NR AGUAS BUENAS	181439	660839	1974	P
50047990	RIO GUAYNABO NR BAYAMON	182232	660759	1975	P
50048510	RIO DE BAYAMON AT BAYAMON FLOOD CHANNEL	182439	660909	1974	P,*
50048530	RIO HONDO BL RIO HONDO AT BAYAMON	182613	660950	1979	P
50048800	RIO PIEDRAS NR RIO PIEDRAS	182215	660340	1972	P,*
50049100	RIO PIEDRAS AT HATO REY	182434	660410	1971	P
50049820	LAGUNA SAN JOSE NO.2	182550	660212	1974	A

APPENDIX 2--Continued

ACTIVE QW STATIONS ON PUERTO RICO AS OF 05-20-85.

STATION NUMBER	NAME	LAT	LONG	BEGAN	TYPE
50049920	BAHIA DE SAN JUAN NO.5	182637	660516	1974	A
50050300	QUEBRADA BLASINA NR CAROLINA	182327	655828	1972	P
50055000	RIO GRANDE DE LOIZA AT CAGUAS	184535	660035	1972	P
50055250	RIO CAGUITAS AT HWY 30 AT CAGUAS	181511	660126	1972	P
50055400	RIO BAIROA NR CAGUAS	181528	660213	1979	P
50057025	RIO GURABO NEAR GURABO	181556	655904	1979	P
50057500	LAGO LOIZA NO.4 NR MOUTH NR CAGUAS	181651	660035	1980	A,*
50058800	LAGO LOIZA NO.7 NR DAM NR TRUJILLO ALTO	181929	660047	1980	A
50059000	LAGO LOIZA AT DAM SITE (BELOW DAM)	181949	660100	1974	A
50059100	RIO GRANDE DE LOIZA BL TRUJILLO ALTO	182135	660015	1980	P
50063800	RIO ESPIRITU SANTO NEAR RIO GRANDE	182137	654849	1979	P
50071000	RIO FAJARDO NR FAJARDO	181756	654142	1961	P,S/D,*
50072500	RIO FAJARDO BL FAJARDO	181935	653847	1975	P
50082000	RIO HUMACAO AT HWY 3 AT HUMACAO	184938	654938	1969	P
50083500	RIO GUAYANES NR YABUCOA	180333	655403	1979	P,*
50086500	RIO GUAYANES AT PLAYA GUAYANES	180353	654944	1972	P
50091000	RIO MAUNABO AT MAUNABO	180024	655419	1975	P
50091800	RIO CHICO AT PROVIDENCIA	175916	660018	1979	P
50092000	RIO GRANDE DE PATILLAS NR PATILLAS	180204	660158	1960	N
50106500	RIO COAMO NR COAMO	180352	662210	1979	P
50114000	RIO CERRILLOS NR PONCE	180422	663453	1964	P
50115000	RIO PORTUGUES NR PONCE	180445	663803	1975	P
50116200	RIO PORTUGUES AT PONCE	180020	663628	1975	P,*
50124700	RIO GUAYANILLA AT CENTRAL RUFINA	180050	666704	1975	P,*
50129700	RIO LOCO AT GUANICA	175833	665452	1975	P,*
50133600	RIO GUANAJIBO NR SAN GERMAN	180718	670356	1979	P
50136400	RIO ROSARIO NR HORMIGUEROS	180936	670508	1979	P
50138000	RIO GUANAJIBO NR HORMIGUEROS	180836	670857	1969	P,*
50138800	RIO YAGUEZ NR MAYAGUEZ	181231	670707	1979	P
50143000	RIO GRANDE DE ANASCO NR LARES	181528	665505	1976	P
50144000	RIO GRANDE DE ANASCO NR SAN SEBASTIAN	181700	670302	1963	N
50146000	RIO GRANDE DE ANASCO AB RIO CANAS	181600	670805	1979	P,*
50147600	RIO CULEBRINAS NR SAN SEBASTIAN	182051	670240	1979	P
50149100	RIO CULEBRINAS NR AGUADA	182403	670940	1969	P,*

EXPLANATION OF TYPES:

P	POLLUTION.....55
*	PESTICIDE.....18
A	NAMP (& LAKES).....15
N	NASQAN..... 4
S/D	CONTINUING SEDIMENT STATION (DAILY)..... 1
S/W	CONTINUING SEDIMENT STATION (WEEKLY)..... 1

APPENDIX 3

ACTIVE GW WELLS NETWORK IN P.R. AS OF 05/20/85

LOCAL WELL NUMBER	STATION NAME	LATITUDE	LONGITUDE
*6	JUANA 5	175858	661002
*70	SABANA HOYOS	182647	662017
*87	ALOMAR 1	175829	662322
*96	Y-7	180415	655139
*132	PPG 4 OR YAUCO 2	180133	665033
*135	LEDERLE	182621	663433
*141	RESTAURADA 8A	175950	663542
*143	VIVONI - COL. AMISTAD	180132	670338
*171	USGS/ARROYO WELL # 1	181217	654530
*172	RIO HUMACAO GW STATION	180849	655024
*173	SQUIBB OBS. WELL #3	180908	654750

* RECORDING WELL

PR GW NETWORK- 11 RECORDING WELLS

ACTIVE GW WELLS NETWORK IN US VIRGIN ISLANDS AS OF 05/20/85

ST. CROIX

LOCAL WELL NUMBER	STATION NAME	LATITUDE	LONGITUDE
1	FAIRPLAINS #6	174225	644719
2	*USGS 10 - FAIRPLAINS #2	174225	644720
3	*GOLDEN GROVE #6	174243	644751
4	GOLDEN GROVE #1	174245	644758
5	MAHOGANY ROAD - 3	174336	645232

APPENDIX 3--Continued

ACTIVE GW WELLS NETWORK IN US VIRGIN ISLANDS AS OF 05/20/85

ST. CROIX

LOCAL WELL NUMBER	STATION NAME	LATITUDE	LONGITUDE
6	*ADVENTURE 28	174303	644844
7	CONCORDIA 14	174525	644606
8	CONCORDIA 1 (MAIN PUMP HOUSE)	174527	644601
9	CONCORDIA 7	174532	644603
10	BARREN SPOT 5	174329	644547
11	ADVENTURE 16	174308	644841

ST. THOMAS

1	USGS - 8 (FAMILY WELL - THATCH FARM)	182050	645804
2	MAHOGANY #15	182138	645431
3	MAHOGANY #16	182138	645425
4	MAHOGANY #17	182136	645419
5	DONOE #3	182029	645352
6	*GRADE SCHOOL #3	182038	645503
7	*WELL # 4 @ VI COLLEGE	182043	645816

ST. JOHN

11	*GUINEA GUT	181956	644645
10	DPW #1 (SUSSANABERG)	182044	644552
9	DPW #2 (SUSSANABERG)	182044	644550
8	DPW #3 (SUSSANABERG)	182044	644549
7	DPW #4 (SUSSANABERG)	182044	644548
6	DPW #5 (SUSSANABERG)	182044	644546
5	*DPW #6 (SUSSANABERG)	182042	644545
4	USGS #15 (CALABASH BOOM)	181951	644221
3	*NPS #6 (CINNAMON BAY)	182116	644510
2	NPS #5 (TRUNK BAY)	182109	644603
1	NPS #2 (CRUZ BAY)	182010	644726

* RECORDING WELL

V.I. GW NETWORK- 22 PARTIAL WELLS AND 8 RECORDING WELLS