

Quality-Assurance Plan for Water-Use Program Activities of the Caribbean District

By Wanda L. Molina-Rivera

U.S. GEOLOGICAL SURVEY

Open-File Report 98-547

**U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary**

**U.S. GEOLOGICAL SURVEY
Thomas J. Casadevall, Acting Director**

For additional information write to:

District Chief
U.S. Geological Survey
GSA Center, Suite 400-15
651 Federal Drive
Guaynabo, Puerto Rico 00965-5703

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286

CONTENTS

Abstract	1
Introduction	1
Description of the Caribbean Water-Use Information Program.....	2
Quality-Assurance Plan.....	2
Responsibilities of District Personnel.....	3
Training.....	4
Report	4
Documentation.....	4
Data Entry and Checking Procedures	5
Methods of Estimating Water Use	6
Category 1: Public Water Supply	6
Category 2: Domestic Water Use	7
Category 3: Commercial Water Use.....	8
Category 4: Industrial Water Use	8
Category 5: Mining Water Use.....	9
Category 6: Livestock Water Use.....	9
Category 7: Irrigation Water Use	10
Category 8: Thermoelectric Power Generation Water Use	10
Category 9: Hydroelectric Power Generation Water Use	11
Category 10: Wastewater Treatment Water Use.....	11
Category 11: Reservoir Evaporation	11
Corrective Actions	12
Selected References	12

TABLE

1. Daily livestock water requirements	9
---	---

CONVERSION FACTORS AND ACRONYMS

	Multiply	By	To obtain
	foot	0.3048	meter
	acre-foot	1233.489	cubic meter
	cubic foot per second	0.02832	cubic meter per second
	gallon per day	0.003785	cubic meter per day
	million gallon per day	43.81	liter per second
	square mile	2.590	square kilometer

Acronyms used in this report:

AWUDS	Aggregate Water-Use Data System
HUC	Hydrologic Unit Code
MSHA	U.S. Mine Safety and Health Administration
NWIP	National Water-Use Information Program
PRASA	Puerto Rico Aqueduct and Sewer Authority
PRDNER	Puerto Rico Department of Natural and Environmental Resources
PRDOH	Puerto Rico Department of Health
PREPA	Puerto Rico Electric Power Authority
PREQB	Puerto Rico Environmental Quality Board
SWUDS	State Water-Use Data System
USGS	U.S. Geological Survey
VIDPW	Virgin Islands Department of Public Works
VIWAPA	Virgin Islands Water and Power Authority
WUDS	Water-Use Data System

Quality-Assurance Plan for Water-Use Program Activities of the Caribbean District

By Wanda L. Molina-Rivera

Abstract

The U.S. Geological Survey Caribbean District Water-Use Information Program was implemented in 1980 for the management of water-resources data in Puerto Rico and the U.S. Virgin Island and to meet the need for a uniform accounting system of water-use data and categories. The water-use data are obtained from a variety of sources. Large amounts of the data collected were developed by the water users (typically, Commonwealth agencies in Puerto Rico, local government agencies in the U.S. Virgin Islands, federal agencies, or private entities), whereas other data collected are based on a variety of estimation techniques.

The quality-assurance plan for the water-use program activities in the Caribbean District presented in this report includes a description of the Caribbean Water-Use Information Program, responsibilities of the U.S. Geological Survey Caribbean District personnel, reports, training, forms, documentation, data entry and checking procedures, methods of estimating water use, and corrective actions.

INTRODUCTION

The National Water-Use Information Program (NWIP) of the U.S. Geological Survey (USGS) is a Federal-State Cooperative Program designed to compile, store, and disseminate water-use information

locally and nationwide. The Caribbean Water-Use Information Program was implemented in 1980, as an extension of the NWIP to provide data for the management of water resources in Puerto Rico and U.S. Virgin Islands. Prior to the establishment of the Caribbean Water-Use Information Program, water-use estimates were derived from many sources and were based on a variety of data collection methods which varied in accuracy. Historically, the data base was not provided as a current, readily accessible, and reliable source of information. Without adequate information on the amount of water used, where it is used, and how it is used; planners and managers cannot resolve many of the critical water problems facing Puerto Rico and the U.S. Virgin Islands. Water management problems require attention to maintaining an adequate water supply and water quality.

A reliable water-use data base is needed in Puerto Rico and the U.S. Virgin Islands to provide historic water-use information to enable scientists to estimate the hydrologic effect of future water demands. The Caribbean Water-Use Information Program is designed to meet the need for a water-use data base with a uniform accounting system of water-use data and categories. Predictions and decisions related to specific water-use categories can be made with confidence supported by a dedicated program of quality assurance. The purpose of the quality-assurance plan is to provide a formal standardization, documentation, and review of the policies and activities of the Caribbean District for assuring the technical quality and reliability of its water-use data.

DESCRIPTION OF THE CARIBBEAN WATER-USE INFORMATION PROGRAM

The Caribbean Water-Use Information Program began in 1980 to provide data to government agencies in Puerto Rico and the U.S. Virgin Islands, water resources managers and planners, and the general public. Since 1980, seven reports have been prepared: “Estimated water use in Puerto Rico, 1980” (Gómez-Gómez and others, 1983), “Estimated water use in Puerto Rico, 1980-82” (Torres-Sierra and Aviles, 1986), “Estimated water use in St. Thomas, U.S. Virgin Islands, July 1983 - June 1984” (Torres-Sierra and Dacosta, 1984), “Estimated water use in St. Croix, U.S. Virgin Islands, October 1983 - September 1985” (Torres-Sierra, 1987), “Estimated water use in Puerto Rico, 1986-87” (Molina and Dopazo, 1995), “Estimated water use in Puerto Rico, 1988-89” (Dopazo and Molina, 1995), and “Public-supply water use and wastewater disposal during 1990” (Molina, 1996).

The major objectives of the Caribbean Water-Use Information Program are to create a computerized data base which facilitates retrieval of water-use information at the local, regional, and national levels; compile water-use data of uniform quality; implement new methodologies for obtaining high quality water-use data; improve the collection, analysis, and dissemination of water-use information; and present information through reports and other means that will help in projecting the future water needs of Puerto Rico and the U.S. Virgin Islands. In order to meet the general objectives of the Caribbean Water-Use Information Program and to maintain an adequate data base, the USGS maintains cooperative agreements with the Puerto Rico Aqueduct and Sewer Authority (PRASA), the Puerto Rico Department of Natural and Environmental Resources (PRDNER), and the Puerto Rico Environmental Quality Board (PREQB) to compile water-use data for major use categories of importance to water managers and planners in Puerto Rico. The USGS does not maintain any cooperative agreements to compile water-use data in the U.S. Virgin Islands.

The NWIP was implemented to complement the USGS’s data on the availability and quality of the Nation’s water resources. Under the direction of the

NWIP, a Water-Use Data System (WUDS) was developed and distributed to support the water-use data storage and retrieval needs at the District level. The WUDS has two components. The first component, the Site-Specific Water-Use Data System (SWUDS), was created for storage of site-specific data. The second component, the Aggregate Water-Use Data System (AWUDS), was created for storage of water-use data aggregated at the municipio level. A municipio is the minimum legal or jurisdictional unit in Puerto Rico as used by the U.S. Department of Commerce, Bureau of Census.

Since 1950, the NWIP compiles water-use data every 5 years (Mackinchan, 1951, 1957; Mackinchan and Kammerer, 1961; Murray, 1968; Murray and Revees, 1972, 1977; Solley and others, 1983, 1988, 1993). These reports are used to develop and evaluate trends in water use and to plan for more effective uses of the Nation’s water resources in the future. Since 1980, the Caribbean District has updated the AWUDS every 5 years.

QUALITY-ASSURANCE PLAN

This quality-assurance plan is founded on the following principles:

1. The District water-use program and all water-use projects will be planned to efficiently provide information required to solve high-priority water-use problems within the Commonwealth of Puerto Rico and the U.S. Virgin Islands.
2. Field and office activities will be performed in accordance with specified USGS standards, practices, and policies.
3. All water-use activities and procedures will receive appropriate and timely review for completeness, reliability, credibility, and conformance to specified standards.
4. Remedial actions will be taken to correct any observed or suspected program or project deficiency.

Responsibilities of District Personnel

To accomplish project goals in an efficient manner, it is important that District personnel understand individual responsibilities related to the Caribbean Water-Use Information Program. The following is a list of individuals involved in the program and their respective responsibilities:

- District Chief
- Ground-water and water-quality investigations section chief
- Caribbean Water-Use Information Program project chief
- District administrative officer
- District training officer
- Southeastern Region water-use representative

The **District Chief** is responsible for:

1. Managing and directing the District program, including the Caribbean Water-Use Information Program.
2. Ensuring that the Caribbean Water-Use Information Program meets the needs of the Federal Government, the Caribbean District, and the cooperating agencies (agencies that provided water-use data).
3. Providing final resolution of any project conflicts or disputes.
4. Keeping the ground-water and water-quality investigations section chief and the project chief briefed on project expectations and communications from Region and Headquarters.
5. Providing guidelines to the project chief on maintaining direct contact with cooperating agencies.

The **ground-water and water-quality investigations section chief** is responsible for:

1. Managing and directing projects assigned to the section, including the Caribbean Water-Use Information Program, and ensuring that the stated objectives are met in a timely manner.

2. Providing the project chief with technical and administrative support as needed.
3. Ensuring that project milestones are developed and that program goals are completed on time.
4. Ensuring that the project chief receives adequate and appropriate training.

The **Water-Use Information Program project chief** is responsible for:

1. Conducting the technical work of the Caribbean Water-Use Information Program, including all phases of data collection, data storage, and report preparation.
2. Communicating project progress, plans, and problems to the ground-water and water-quality investigations section chief, District Chief, and the Southeastern Region water-use representative by providing a written quarterly review.
3. Identifying agencies or individuals as appropriate data sources, and contacting and maintaining a positive working relationship with those agencies or individuals.
4. Ensuring that the best possible aggregate data have been correctly entered into the AWUDS.
5. Communicating need for assistance to the ground-water and water-quality investigations section chief.
6. Ensuring that program activities are carried out in a timely manner.
7. Instituting improved methods of data collection, and developing better data sources whenever possible.

The **District administrative officer** is responsible for:

1. Maintaining administrative files for all District projects, including the Caribbean Water Information Program.
2. Providing the project chief with administrative support in terms of correspondence and budget information.

The **District training officer** is responsible for:

1. Ensuring that a complete list of training nominees is prepared according to Caribbean District staff suggestions in a timely manner.
2. Maintain record files of all nominations and ensure that the paper documentation, with training costs, travel and lodging reservations, are done on time.

The **Southeastern Region water-use representative** is responsible for:

1. Communicating to the project chief and the District Chief the needs of Region and Headquarters.
2. Providing technical assistance to the project chief, and assisting the project chief to contact appropriate individuals knowledgeable about water-use data.
3. Coordinating the data collection and data transfer for the 5-year national publication.

Training

The responsibility to ensure that water-use studies personnel involved in water-use studies are adequately trained in prescribed practices and procedures is shared by the District training officer and the District Chief. The training will vary according to the needs of the individual, but usually will consist of a combination of on-the-job training, District seminars or workshops, and courses developed and directed by the Branch of water-use information and held at the National Training Center.

The District Chief, with the advice from the ground-water and water-quality investigations section chief, will nominate appropriate personnel for water-use training at the USGS National Training Center. Nominations will be based on specialized needs to fulfill project and program commitments and to foster career development. All training and training needs will be documented in individual Career Development Plans.

Report

The collection of water-use data by the USGS has evolved since 1950 when the USGS began publishing estimated water-use summaries at 5-year intervals (Mackichan, 1951, 1957; Mackichan and Kammerer, 1961; Murray, 1968; Murray and Reeves, 1972, 1977; Solley and others, 1983, 1988, 1993), until the present, with a distributed data base where data can be processed over a network of computers at the USGS offices throughout the United States and its territories. The report "Estimated Use of Water in the United States" is published with the purpose of presenting consistent and current water-use estimates by State, and water-resources regions for the United States, Puerto Rico, and the U.S. Virgin Islands. The report presents estimates of water withdrawn from surface- and ground-water sources, estimates of consumptive use, and estimates of instream use and wastewater releases. The series of reports can be used to develop and evaluate trends in water use and to plan for more effective uses of the Nation's water resources in the future.

This series of reports presents data for eleven water-use categories: public supply, domestic, commercial, industrial, mining, thermoelectric power, hydroelectric power, livestock, irrigation, reservoir evaporation, and wastewater treatment. The data are designed to make water-use categories available to users without interpretations or conclusions.

Documentation

Four major forms of documentation are maintained in the Caribbean District. The purposes of thorough documentation are to promote consistency during periods of transition from one project chief to the next, identify how certain data were obtained or estimated so that methods can be repeated efficiently or improved upon, and provide historical information that enables determinations to be made on whether water-use data from one period of time can be correctly compared to data from another period of time. The four forms of documentation are:

1. The project chief prepares written reports on a quarterly basis and provides copies to the section chief, the District Chief, and the District administrative officer. These quarterly reports are placed in the District administrative file maintained by the administrative officer, and in the project files maintained by the project chief. Project files are paper copies of information grouped into well organized and well labeled folders stored in the filing cabinet dedicated to water-use related material. The contents of these quarterly reports list progress during the most recent 3-month period, such as significant activities, communication with cooperators, types of data obtained or estimated during the period, and status of aggregated-data input. These reports also include a section listing plans for the next quarter and identifying problems or potential problems.
2. Each year a detailed work plan and budget are prepared by the project chief. Copies of these documents are given to the section chief, the District Chief, and the District administrative officer. The project chief addresses comments provided by these individuals and modifies them appropriately. A copy of the finalized work plan and budget is placed in the District administrative file and in the project files.
3. The project chief maintains a collection of all significant correspondence, including official memoranda and letters to or from cooperators. Cover letters associated with the exchange of water-use data are included. This information is stored on paper copies in an organized designated water-use file cabinet.
4. The project chief keeps a daily log, briefly describing significant telephone contacts, requests for data, dates, types of work, and data base updates. This daily log provides details that can be summarized quickly into quarterly reports. It also lists names, dates, and addresses for future reference. This log is stored for an indefinite period of time in order to be readily available for future use.

Data Entry and Checking Procedures

One of the goals of the Caribbean Water-Use Information Program is to ensure that the water-use data compiled and stored are as accurate as possible within the limits of cost and practicality. Large portions of the data collected are developed by the other groups, typically Commonwealth agencies in Puerto Rico, local government agencies in the U.S. Virgin Islands, Federal agencies, or private entities. Once the data are obtained by the USGS, they often require varying amounts of processing by the project staff prior to data entry for computer storage. The quality-assurance activities associated with the data vary according to the type and source of the data. For aggregated data for entry into AWUDS, the quality assurance is designed to ensure that the data in the data base agree with the original data.

Some data collected require sorting, conversion of units or mathematical manipulation prior to storage in the State Water-Use Data System (SWUDS). An example of this type of data would be the deliveries and wastewater data provided by the PRASA. The quality assurance for these data is designed to ensure that the data are aggregated using a consistent methodology.

Other water-use data are the result of calculations between census data provided by federal agencies such as the Census of Agriculture. Examples of this type of data include estimates of water use by domestic self-supplied withdrawals and livestock withdrawals. The quality assurance for these data includes confirming the use of the most recent census data and the best-documented coefficients, and checking for coding errors and incorrect use of statistical packages.

Data-coding forms are created by the project chief for each municipio, by 8-digit hydrologic unit code (HUC), and for the Caribbean Region aquifers. The format of the coding forms follows the example provided by the NWIP for the most recent 5-year compilation. Data are entered from the coding form into the SWUDS.

Data entered into SWUDS are checked against values written on the coding forms, preferably by different individuals who input the data. The SWUDS quality-control utilities are used to assist in identifying

errors. These utilities include multi-year comparisons, State total comparison, and ranked tables.

In addition to checking all values in AWUDS against corresponding values on the coding forms, where data on the coding forms are not considered the original data, at least 20 percent of the values for that category are checked against the original data. For data provided to the USGS by other agencies, such as withdrawals, deliveries, and wastewater data received by the PRASA, the data are considered to be original data. For data written on coding forms that are census estimates and coefficients, the data on the coding forms are considered to be original data.

Methods of Estimating Water Use

The Caribbean Water-Use Information Program includes data for 11 offstream and instream categories. Offstream water-use categories include withdrawal or diversion of water from around or surface sources and transferal of the water from the place where it was withdrawn to the place of use.

The offstream and instream categories are: public supply, domestic, commercial, industrial, mining, freshwater for thermoelectric power, livestock, and irrigation. In addition, a water-use related category is included: wastewater treatment. The instream water-use categories include the use of water within the stream channel. These categories include hydroelectric power, saline water use for thermoelectric power, and reservoir evaporation.

Water-use data were obtained from the PRASA, the Puerto Rico Department of Health (PRDOH), the Tourism Company of Puerto Rico, the Puerto Rico Electric and Power Authority (PREPA), the U.S. Virgin Islands Water and Power Authority (VIWAPA), the U.S. Virgin Islands Department of Public Works (VIDPW), the U.S. Bureau of Census, the U.S. Mine Safety and Health Administration (MSHA), the Census of Agriculture, and the National Weather Service.

The Caribbean Water-Use Information Program in Puerto Rico is part of a cooperative agreement with three local government agencies: the PRASA, the PRDNER, and the PREQB. The USGS does not maintain any cooperative agreements to compile

water-use data in the U.S. Virgin Islands. In the cooperative agreement with Commonwealth agencies in Puerto Rico, the USGS has the responsibility to direct, manage, and standardize the local Water-Use Information Program to provide a consistent and comprehensive program. Field activities for acquisition of the data are the responsibility of the local and Federal government agencies which obtain water use or related data as part of their mission. All of the sources and methods described in the following section are based on the data source and procedures used in compiling water-use data for 1990.

Category 1: Public-Water Supply

Puerto Rico

The public-supply category refers to water withdrawn by public and private water suppliers who provide water to various users, such as domestic, commercial, industrial, thermoelectric power, and public. Public suppliers are those that provide water to at least 25 people or have a minimum of 15 hookups or customers. The public-supply category also includes the public uses, such as water for firefighting, street washing, municipal parks, and swimming pools.

Water withdrawals and water-use data for public-supply systems in Puerto Rico, including the offshore municipios of Vieques and Culebra, are obtained from the PRASA. The PRASA is responsible for maintaining records for these facilities, which includes water withdrawals and distribution from public-supply systems. In addition, the PRASA maintains records of return flows from wastewater disposal facilities.

Water withdrawals and deliveries are published in annual and bi-monthly reports prepared by the PRASA. The annual reports contain data on the amount of freshwater withdrawals (surface water and ground water) by the facility and by the municipio in million gallons per day (Puerto Rico Aqueduct and Sewer Authority, 1990-91). The bi-monthly reports contain water deliveries to domestic, commercial, and industrial users, and the number of metered and unmetered connections (Puerto Rico Aqueduct and Sewer Authority, 1990). These data are compiled according to municipio and water source.

The public-water supply for domestic uses also includes public-supply facilities which are not operated by the PRASA, but serve more than 25 people or have a minimum of 15 hookups and are known as Non-PRASA systems. These data are supplied by the PRDOH (Puerto Rico Department of Health, computer retrieval, 1990).

The surface-water public-supply population is calculated by dividing surface-water withdrawals by total withdrawals, and then multiplying the quotient by the estimated total public-supply population (PRASA + Non-PRASA population). The ground-water public-supply population is estimated by subtracting the population served by surface-water systems from the total public-supply population. To estimate the per capita water use, the annual domestic water use is divided by the population using potable water. This total is divided by the number of days in a year to obtain daily per capita use.

Water use estimates by HUC are made by multiplying the domestic-use coefficient by HUC population, obtained from the Census of Population and Housing (U.S. Department of Commerce, 1991). The Census of Population and Housing contains data of population and the number of housing units with public-water supply connections for each municipio and also for smaller units called “barrios” which the Bureau of Census recognizes as the primary legal subdivision of municipios. The HUC populations are determined by regrouping the barrios to fit within the HUC boundaries. The Census of Population within the barrios is totaled within the HUC boundaries and multiplied by the domestic use coefficient.

U.S. Virgin Islands

The U.S. Virgin Islands consists of the islands of St. Croix, St. Thomas, and St. John. Water use for public-supply systems is supplied primarily from two seawater desalination plants (one in St. Croix and one in St. Thomas) and from 35 ground-water wells located within the islands (25 wells in St. Croix, 5 wells in St. Thomas, and 5 wells in St. John). Water-use data for public-supply systems are supplied by the VIWAPA and the VIDPW.

The U.S. Virgin Islands’ public-supply facilities furnish water for domestic and commercial customers. Ground-water use data by public-supply facility are provided upon request from the VIDPW. Seawater supply systems exist in St. Thomas and St. Croix and consist of distribution systems involving only the urban areas. The purpose of the seawater distribution systems is twofold—they provide a secondary water supply for sanitary use and supply fire hydrants, and they are used to flush storm-water sewers. Water-use data pertaining to the seawater supply distribution system are provided by the VIDPW. Public-supply water-use totals for each HUC within the U.S. Virgin Islands are determined as the sum of site-specific data and aggregated by island.

Category 2: Domestic Water Use

Puerto Rico

The domestic water-use category includes water used for household purposes such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, car washing, and watering lawns and gardens. Self-supplied domestic use in Puerto Rico is estimated by multiplying the estimated population not served by a public-supply system in each municipio by the per capita water use of daily water consumption, calculated for areas served by public supply. The self-supplied domestic population was determined by subtracting the public-supply population served by the PRASA and Non-PRASA systems from the total population. The U.S. Department of Commerce (1991) publishes municipio population, the PRASA provides estimates of population served by municipio, and the PRDOH provides estimates of population served by Non-PRASA systems.

Hydrologic unit code aggregation estimates are made the same way as for public supply. Population values for each barrio are subtracted from population-served figures for public suppliers and the remaining population is accounted as domestic self-supplied. These domestic self-supplied totals are then regrouped by land area located within their respective HUC.

U.S. Virgin Islands

The populations located outside urban areas, which are not connected to public-supply systems, are considered to represent the self-supplied domestic use category. Water used for domestic purposes in areas outside the public-supply service areas is supplied by rainfall, water haulers, and wells. Cisterns that store roof-top rainfall runoff are required by law and are an important source of water supply for self-supplied domestic users. The quantity of rainfall collected in a cistern is principally determined by the amount of rainfall, roof-top catchment area, and cistern capacity. Estimates of monthly rainfall recovery and cistern yield are made considering the following factors: (1) number of non-served housing units in each district of the islands, (2) roof-top area of 1,000 square feet per housing unit, (3) monthly rainfall in each district that is applied, and (4) a total rainfall recovery rate of 70 percent (Jordan and Cosner, 1973). The number of non-served housing units in each planning district of the U.S. Virgin Islands is provided by the Virgin Islands Department of Commerce. The estimated roof area assumption of 1,000 square feet per housing unit is derived after consultation with the Virgin Islands Department of Conservation and Cultural Affairs. Rainfall and other climatological information are provided by the National Weather Service, with some supplemental rainfall data obtained from raingages installed by the USGS.

Ground-water withdrawals data are provided by the Virgin Islands Department of Conservation and Cultural Affairs. Deliveries from wells operated by private water haulers are obtained from a complete survey conducted by the VIDPW. Domestic ground-water use totals for HUC areas are determined by disaggregation of data based on the percentage of the population located within the HUC.

Category 3: Commercial Water Use

Puerto Rico

Commercial water use includes water used by commercial facilities, such as hotels, motels, restaurants, office buildings, government and military facilities, prisons, educational institutions, and retail

sales stores. Water supply for commercial purposes is provided by public-supply systems. The data are provided by the PRASA and are compiled by municipio (Puerto Rico Aqueduct and Sewer Authority, 1990-91). The report displays the deliveries for each municipio broken down by number of metered and unmetered customers. The data are provided in cubic meters and must be converted to inch-pound units. Public supply deliveries to commercial facilities also include the water distributed by the PRASA to government installations. Commercial water-use totals for each HUC within the Commonwealth are determined by aggregation of site-specific data located within these specific areas.

U.S. Virgin Islands

The principal self-supplied commercial users in the U.S. Virgin Islands are hotels and condominiums. The water used primarily is seawater and it is used as feedwater for small desalination plants, for swimming pools, and flushing toilets. Water-use data pertaining to self-supplied commercial users is estimated by field surveys. Field surveys have indicated that the various hotels and condominiums maintain good records for water production at these small desalination plants as well as visitation records. Some additional water is provided by roof-top rainfall catchment systems. Ground water is used also, to a lesser extent, at other commercial facilities, such as the airport, laundries, and gas stations. Deliveries from public-supply systems are provided by the VIWAPA. Commercial water-use totals for each HUC within the U.S. Virgin Islands are determined by aggregation of site-specific data located within these specific areas.

Category 4: Industrial Water Use

Puerto Rico

Industrial water use in Puerto Rico principally includes water used to manufacture pharmaceutical products, electronic devices, textiles, and petroleum refining products. The deliveries from public-supplied facilities are available in bi-monthly reports from the PRASA (Puerto Rico Aqueduct and Sewer Authority, 1990). The self-supplied industrial estimates are made

available from a listing prepared by the PRDNER in their permits and franchise records. From this listing, a survey is conducted to determine the self-supplied users and the amount of water used by each industry. Industrial water-use totals for each HUC within Puerto Rico are determined by aggregation of site-specific data located within these specific areas.

U.S. Virgin Islands

The largest self-supplied industrial use is petroleum refining and rum distilleries located in St. Croix. Saline ground water is also used for processing crude oil. Rum distilleries use ground water and, to a lesser extent, rainwater collected in cisterns. Data relevant to the self-supplied industrial water-use category are collected from a complete inventory of industrial users. Data on deliveries of water from public-supply systems to industrial users are provided by the VIDPW. Consumptive use is considered to be 100 percent for industrial uses. Industrial water-use totals for each HUC are determined by aggregation of site-specific data located within these specific areas.

Category 5: Mining Water Use

Puerto Rico

Mining water-use category includes water withdrawn for extraction of minerals. In Puerto Rico, water used for mining is primarily for the processing of sand and gravel. Surface- and ground-water withdrawals used for mining purposes are obtained from the Permits and Franchises Division of the PRDNER and from an inventory conducted by the MSHA. Mining water-use totals for each HUC in Puerto Rico are determined by aggregation of site-specific data located within specific geographic areas.

U.S. Virgin Islands

Water use for mining operations in the U.S. Virgin Islands is considered negligible; therefore, no estimates are made in this category.

Category 6: Livestock Water Use

Puerto Rico

The livestock water use includes water for stock watering, feed lots, dairy operations, fish farming, and other farm needs. Also included are such animal specialties as horses, rabbits, bees, pets, fur-bearing animals in captivity, and fish in captivity. To estimate the total freshwater withdrawals for livestock, the number of animals in each municipio is multiplied by the estimated daily amount of water required per animal. The total water use estimate for livestock is obtained by multiplying the daily average watering requirements as maximum rates in the life cycle given in table 1 (Kirk and others, 1982). The livestock population by municipio is provided by the most recent Census of Agriculture (U.S. Department of Commerce, 1989). Livestock water use for HUC areas is determined by disaggregation of municipio data based on the percentage of the livestock population located within the HUC.

Table 1. Daily livestock water requirements

Livestock	Water required (gallons per day)
Dairy cows	35
Cattle, horses, mules	12
Hogs	4
Sheep, goats	2
Rabbits	1
Chicken	0.06

U.S. Virgin Islands

Water use for livestock is considered negligible; therefore, no estimates are made in this category.

Category 7: Irrigation Water Use

Puerto Rico

Irrigation water use refers to water distribution on lands for the purposes of growing crops and pasture or maintaining recreational lands, such as parks and golf courses. Water-use data for the irrigation category are available only for farmland irrigated by the publicly owned surface-water Irrigation Districts. The amount of water diverted from publicly owned irrigation canals, in addition to the amount of ground-water irrigation wells divided by the total acreage within a geographic area under a given crop, is used to estimate the total water application for a given crop type. The coefficients obtained are used to estimate total irrigation use in other municipios in the vicinity of the island's south coast not served by publicly owned irrigation systems. The total of the calculations is the amount of water used by crop type for irrigation.

In order to obtain the data components necessary to make a water-use estimate for irrigation, it is necessary to obtain the following data: (1) the number of acres irrigated for all crop types by municipio, (2) the amount of water diverted from publicly owned irrigation canals, and (3) the amount of ground water withdrawn from wells within geographic areas of intensive agriculture use. Acquiring this information requires contacting several sources. Irrigated acreage values by crop type are published by the U.S. Department of Commerce (1989). Surface-water withdrawals from government Irrigation Districts are supplied by the Irrigation Division of the PREPA. Ground-water withdrawals for irrigation on the south coast are provided by the Puerto Rico Sugar Corporation (for sugar cane) and by the Administración para el Fomento y Desarrollo Agrícola for vegetable crops in lands administered by the Puerto Rico Lands Authority. Irrigation water-use totals for HUC areas are determined by disaggregation of municipio data using the percent of the municipio land area located within the HUC.

U.S. Virgin Islands

The U.S. Virgin Islands had no accountable irrigation water use for 1990.

Category 8: Thermoelectric Power Generation Water Use

Puerto Rico

Thermoelectric power water use includes the amount of water used in the production of electric power generated with fossil fuel. Fossil fuel includes coal, oil, and natural gas. The water used may be self-supplied delivered by a water supplier through a distribution system. There are four thermoelectric power facilities in Puerto Rico. The withdrawal of seawater for thermoelectric cooling in the production of electricity accounts for almost all seawater withdrawals in Puerto Rico. Freshwater usage consists of ground-water withdrawals and deliveries from public-supply systems. Thermoelectric power production data, discharge information, and other related data are provided by the PREPA. Deliveries from public-supply systems for thermoelectric generation are provided by the PRASA. Power generation water-use totals for each HUC within Puerto Rico are determined by aggregation of site-specific data located within these specific areas.

U.S. Virgin Islands

Thermoelectric power generation is the largest water user in the U.S. Virgin Islands. Fossil-fuel plants are located in the U.S. Virgin Islands, one on St. Croix and one on St. Thomas. These plants are operated by the VIWAPA. Seawater is used as the primary source of all water for thermoelectric power generation. The seawater is used for condenser cooling at these facilities. In addition to the seawater, approximately 1 percent of water used is freshwater obtained directly from the desalination plants and mainly used for boiler feed. All water-use data relevant to thermoelectric power in the U.S. Virgin Islands are provided by the VIWAPA. Power generation water-use totals for each HUC within the U.S. Virgin Islands are determined by aggregation of site-specific data located within these specific areas.

Category 9: Hydroelectric Power Generation Water Use

Puerto Rico

Hydroelectric power water use refers to the use of water in generating electricity at power plants where the turbine generators are driven by falling water. Hydroelectric power generation water use is an instream use of water in Puerto Rico. Instream water-use data are obtained from monthly power generation reports prepared by the PREPA. The amount of water used for hydroelectric power is obtained from the amount of power generated by each facility on a monthly basis. The following equation is used to estimate daily instream use

$$\text{Water Use} = (P) (F) / N$$

where P is the gross monthly power generation, in kilowatt-hours; F is a specific factor for each reservoir, given the relation between monthly energy production and instream water requirements, in acre-feet per kilowatt-hour; and N is the number of days in a month.

U.S. Virgin Islands

There are no hydroelectric power facilities located in the U.S. Virgin Islands; therefore, no water-use estimates are made.

Category 10: Wastewater Treatment Water Use

Puerto Rico

Wastewater is defined as water that carries waste from homes, businesses, and industries. The processing of wastewater for the removal or reduction of contained solids or other undesirable constituents is considered a wastewater treatment (Solley and others, 1993). The PRASA maintains records pertaining to public wastewater treatment releases in Puerto Rico. These data are reported by municipio and contain information about the number of domestic, commercial, and industrial connections. The PRASA records include data pertaining to monthly and annual discharges for all 78 municipios. Wastewater release totals for each HUC within the Commonwealth are

determined by aggregation of site-specific data located within these specific areas.

U.S. Virgin Islands

The VIDPW provides information about public wastewater treatment facilities for the U.S. Virgin Islands. These data are for the seven facilities on St. Thomas and one on St. Croix. Information relevant to the number and type of connection, as well as their treated releases for each facility, also are provided by the VIDPW. Wastewater treatment release totals for each HUC within the U.S. Virgin Islands are determined by aggregation of site-specific data located within these specific areas.

Category 11: Reservoir Evaporation

Puerto Rico

The reservoir evaporation category includes water loss by evaporation from artificial impoundments which have a normal capacity equal to or greater than 5,000 acre-feet. Evaporation of water from a reservoir is considered to be a consumptive use associated with the storage of water. The annual water loss to evaporation for 14 reservoirs throughout Puerto Rico is calculated using the following equation:

$$\text{RE} = (\text{RA}) (\text{PE}) (\text{K})$$

where RE is the reservoir evaporation, in thousands of acre-feet per year; RA is the reservoir area, in thousand of acres; PE is the class A annual pan evaporation, in feet; and K is a constant, equal to 0.07.

The surface area for each reservoir is obtained from the PREPA and the PRDNER. Reservoir levels are assumed to be at the spillway elevation. Class A pan evaporation is taken from the National Oceanic and Atmospheric Administration data (U.S. Department of Commerce, 1990).

U.S. Virgin Islands

The reservoir evaporation category is not included in the U.S. Virgin Islands water-use estimates, as there are no significant reservoirs on the islands.

Corrective Actions

All values stored in AWUDS will be checked against the coding forms. Additionally, at least 20 percent of values for each category will be checked against the original data, if the coding forms are not considered original data. Values in AWUDS found to be incorrect when checked against the coding forms will be corrected immediately. If data stored in AWUDS are found to be incorrect when checked against original data, all data in that category will be checked and corrected in AWUDS and on the coding forms. If any other category contains values that were derived from erroneous data, or were used to derive the erroneous data, all values in those categories will be checked against the original data. All corrections will be documented in the daily log maintained by the project chief.

SELECTED REFERENCES

- Arvin, D.V., 1993, Quality-assurance plan for the U.S. Geological Survey Indiana District water-use program: U.S. Geological Survey Open-File Report 93-88, 21 p.
- Dopazo, Teresa, and Molina, W.L., 1995, Estimated water use in Puerto Rico, 1988-89: U.S. Geological Survey Open-File Report 95-380, 31 p.
- Gómez-Gómez, Fernando, Dacosta, Rafael, Orona, Miguel, 1983, Estimated water use in Puerto Rico, 1980: U.S. Geological Survey Open-File Report 83-689, 1 pl. [Separately published by the Puerto Rico Department of Natural and Environmental Resources and their Water Resources Division Miscellaneous Map Series, 1 sheet]
- Holland, T.W., 1992, Water-use data collection techniques in the Southeastern United States, Puerto Rico, and U.S. Virgin Islands: U.S. Geological Survey Water-Resources Investigations Report 92-4028, 75 p.
- Jordan, D.G., and Cosner, O.J., 1973, A survey of the water resources of St. Thomas, U.S. Virgin Islands: U.S. Geological Survey Open-File Report 72-201, 55 p.
- Kirk, J.R., Jarboe, J., Sanderson, E.W., Sasman, R.T., and Lonquist, C., 1982, Water withdrawals in Illinois, 1980: Illinois State Water Survey Circular 152, 47 p.
- Mackinchan, K.A., 1951, Estimated water use in the United States, 1950: U.S. Geological Survey Circular 115, 13 p.
- _____, 1957, Estimated water use in the United States, 1955: U.S. Geological Survey Circular 398, 18 p.
- Mackinchan, K.A., and Kammerer, J.C., 1961, Estimated use of water in the United States, 1960: U.S. Geological Survey Circular 456, 26 p.
- Molina, W.L., 1996, Public-supply water use and wastewater disposal during 1990: U.S. Geological Survey Fact Sheet 098-96, 4 p.
- Molina, W.L., and Dopazo, Teresa, 1995, Estimated water use in Puerto Rico, 1986-87: U.S. Geological Survey Open-File Report 95-358, 31 p.
- Murray, C.R., 1968, Estimated use of water in the United States, 1965: U.S. Geological Survey Circular 556, 53 p.
- Murray, C.R., and Reeves, E.B., 1972, Estimated use of water in the United States, 1970: U.S. Geological Survey 676, 37 p.
- _____, 1977, Estimated use of water in the United States, 1975: U.S. Geological Survey Circular 765, 37 p.
- Puerto Rico Aqueduct and Sewer Authority, 1990, Statistical report for executive director: Monthly Report, 53 p.
- _____, 1990-91, Annual water production report: 25 p.
- Puerto Rico Department of Health, 1990, Non-PRASA systems inventory: computer retrieval, 36 p.
- Solley, W.B., Chase, E.B., and Mann, W.B., IV, 1983, Estimated use of water in the United States in 1980: U.S. Geological Survey Circular 1001, 56 p.

- Solley, W.B., Merk, C.F., and Pierce, R.R., 1988, Estimated use of water in the United States in 1985: U.S. Geological Survey Circular 1004, 82 p.
- Solley, W.B., Merk, C.F., and Pierce, R.R., and Perlman, H.A., 1993, Estimated water use in the United States in 1990: U.S. Geological Survey Circular 1082, 76 p.
- Torres-Sierra, Heriberto, 1987, Estimated water use in St. Croix, U.S. Virgin Islands, October 1983-September 1985: U.S. Geological Survey Open-File Report 86-537, 1 sheet.
- Torres-Sierra, Heriberto, and Avilés, Ada, 1986, Estimated water use in Puerto Rico, 1980-82: U.S. Geological Survey Open-File Report 85-557, 77 p.
- Torres-Sierra, Heriberto, and Dacosta, Rafael, 1984, Estimated water use in St. Thomas, U.S. Virgin Islands, July 1983-June 1984: U.S. Geological Survey Open-File Report 84-721, 1 sheet.
- U.S. Department of Commerce, 1989, 1987 Census of Agriculture: Puerto Rico, Bureau of Census, AC 87-A-52, 217 p.
- _____ 1990, Climatological data annual summary, Puerto Rico and the U.S. Virgin Islands: National Oceanic and Atmospheric Administration, v. 36, no. 13, 21 p.
- _____ 1991, 1990 Census of Population and Housing: Puerto Rico, Bureau of Census, CPH-1-53, 199 p.