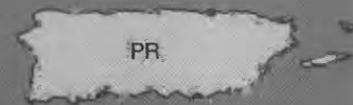


United States Geological Survey

Programs in Puerto Rico



The USGS provides maps, reports, and information to help others meet their needs to manage, develop, and protect America's water, energy, mineral, and land resources. We help find natural resources needed to build tomorrow, and supply scientific understanding needed to help minimize or mitigate the effects of natural hazards and environmental damage caused by human activities. The results of our efforts touch the daily lives of almost every American.

High-Energy Storms Shape Puerto Rico

Geologists have known for years that damage inflicted by hurricanes on coastal areas may be less important for the long-term evolution of a coast than the effects of less intense, but more frequent, storm events. Indeed, high-energy storms may be needed to maintain the health of delicate ecologies in the coastal environment. Marine geologists of the U.S. Geological Survey (USGS) working in the Commonwealth of Puerto Rico are confident that the long-term effects of Hurricane Hugo on the coastal environment are minimal, although the economic damage was significant. As part of the continuing research conducted in Puerto Rico, the shelf area offshore of the town of Luquillo was mapped using high-resolution sonar, seismic-reflection profiles, photographs, and bottom sampling following the passage of Hurricane Hugo. Sea-floor structure, local geology, and sediment characteristics indicate that a regional cross-shelf transport of sand occurs during storms, but that it is trapped by ridges to form sand deposits as much as 60 feet thick (fig. 1). Sand eroded from the beach front appears to move offshore, and the pathways for that movement can be documented by using remote imagery.

Real-Time Hazard Alert Network

The USGS maintains and operates a real-time hazard alert network throughout Puerto Rico in cooperation with 15 local government agencies. This is the only real-time hazard alert network in the Caribbean Basin.

The network provides information on rainfall, streamflow, and lake levels for drainage basins that contain water-supply reservoirs throughout Puerto Rico.

This information is used on a daily basis to monitor the effects these important hydrologic factors have on the surface-water supply in Puerto Rico. This system has proved to be very useful to local government agencies charged with public safety during storm and flood situations.

The real-time hazard alert network system consists of 132 hydrologic data-collection sites in Puerto Rico equipped with data-collection platforms. In this network, 81 of the stations transmit data on streamflow, 106 on rainfall, and 11 on lake levels. The network also contains five meteorological stations. Data collected at these sites are transmitted to a USGS facility by satellite every 4 hours under normal circumstances. During floods or intense rainfall the system switches to an emergency mode, transmitting data every 5 minutes. This information is transmitted from remote field sites to a satellite and then forwarded to a computer at the USGS where the data are immediately interpreted by the



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computer. The data are then available to cooperating agencies linked to the USGS computer, generally less than 5 minutes after being transmitted from the field sites.

Landslide Hazards Assessment

Landslides are common in the mountainous areas of Puerto Rico where mean



Figure 1. Aerial photographs of Escollo de Arenas, a shoal off the northeast corner of Isla de Vieques composed of 90 million cubic meters of sand and gravel, before (left) and after (right) the impact of Hurricane Hugo. Note that the sand ridges were suppressed by storm-induced currents and waves. The distance across the photographs from top to bottom is approximately 2 kilometers.

annual rainfall and the frequency of intense storms are high, and hillslopes are steep. Each year, landslides cause extensive damage to property and occasionally result in loss of life. Population density in Puerto Rico is high, 400 people per square kilometer, and is increasing. This increase is accompanied by the utilization of less desirable construction sites. As a result, human populations are more vulnerable to landslide hazards.

In 1987 the USGS began a 3-year study to determine the distribution of landslides and to assess landslide hazards in the Río Blanco, the Río Cibuco, and the Río Coamo Basins in Puerto Rico (fig. 2). The principal objective of this study was to evaluate the geographic relations of landslide distribution across the range of topography, climate, soils, and bedrock geology that occur in Puerto Rico. An additional objective was to determine the rainfall accumulation-duration characteristics of storms likely to trigger landslides in the central mountains of the island and to develop a rainfall accumulation/duration threshold for Puerto Rico. The results of this study have provided land-use managers and public-safety agencies with an inexpensive method that can be used to assess landslide hazards in Puerto Rico.

Public Water-Supply and Reservoir Sedimentation

Public water-supply reservoirs in Puerto Rico are rapidly filling with sand and other sediment. Sedimentation has reduced the storage capacity of these

reservoirs by as much as 60 percent over the last 50 years. This loss of capacity, coupled with a significant increase in population, has created the potential for long-term water-supply problems throughout Puerto Rico as demonstrated by the rationing of water to more than 1.7 million people during 1994 and 700,000 people during early 1995.

The USGS maintains hydrologic data-collection stations in drainage basins that contain public water-supply reservoirs. Streamflow, sediment load, and rainfall data from these stations provide local government agencies with the information needed to calculate the amount of water currently available in the reservoirs, to establish the rates at which the reservoirs are filling with sediment, and to identify the regions that contribute sediment to the reservoirs. Recent laws in Puerto Rico aim to reduce drastically soil erosion contributing to reservoir sedimentation. The information provided by the USGS will assist water managers to assess the effectiveness of these new laws.

Sand Resources

Years of sand mining from beaches and dunes have caused serious erosion, flooding, and storm-damage problems for coastal Puerto Rico. Sand is necessary for the construction industry and also is important for beach-replenishment projects. Available onshore sources of sand in Puerto Rico are expected to be depleted by the turn of the century. Because the cost of transporting sand is

high, Puerto Rico is looking for offshore deposits to fill the demand.

The USGS, in cooperation with the Puerto Rico Department of Natural and Environmental Resources, is systematically mapping sediments on the shelf surrounding Puerto Rico to identify potential sources of sand, and to increase our understanding of the dynamics of sediment transport in offshore areas. To date (1995), 9 of 15 reconnaissance maps have been completed, and three potentially minable deposits have been studied in detail. These maps are used by local government agencies to aid in making decisions about issuing mining permits. The USGS, in cooperation with individual municipalities, monitors beach erosion resulting from catastrophic events, such as hurricanes. These studies are of vital concern to Puerto Rico's large tourist and recreation industry and are valuable to local officials concerned with development and hazard mitigation.

Collection of Hydrologic Data

Since 1958, the USGS, in cooperation with 15 local and Federal agencies has been collecting a large amount of data pertaining to the water resources of Puerto Rico. These data constitute a valuable data base for developing an improved understanding of the water resources in Puerto Rico. Presently (1995), these data include records on surface- and ground water, water quality, and stream-sediment concentration and load (fig. 3).

Surface water is a major source of drinking water, industrial supply, and irrigation in Puerto Rico. The surface-water data-collection program measures stream discharge and the amount of rain falling in specific river drainage basins. Water samples are also collected to determine the physical, chemical, and bacteriological characteristics of lakes, streams, and rivers.

Long-term monitoring of groundwater levels gives insight into the withdrawal and recharge rates of aquifers, and provides essential information for the management of these important water resources. The USGS maintains a computer data base that contains information on the physical and chemical

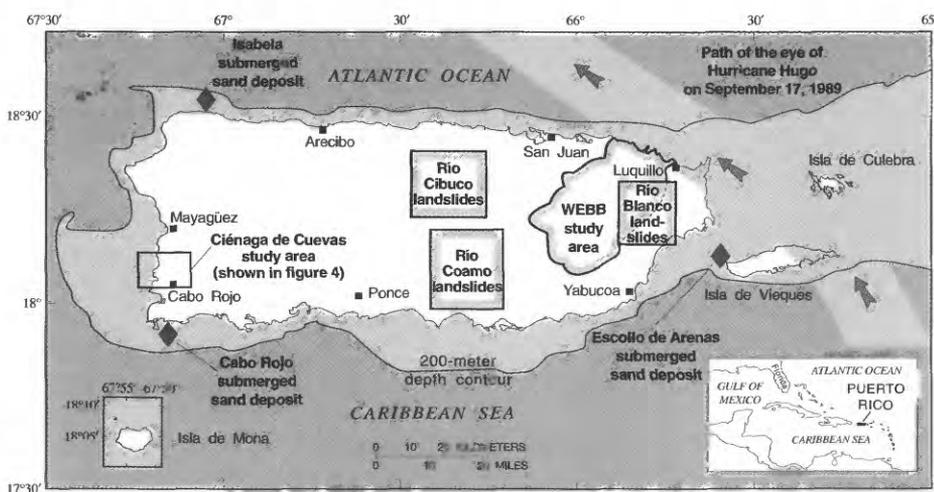


Figure 2. Location of Puerto Rico and various study sites.

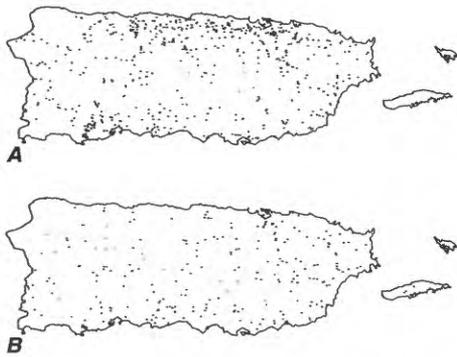


Figure 3. Water-quality (A) and surface-water (B) data-collection sites throughout Puerto Rico.

characteristics of water in about 5,700 wells and springs in Puerto Rico.

Earth Observation Data

Through its Earth Resources Observation Systems Data Center near Sioux Falls, South Dakota, the USGS distributes a variety of aerial photographs and satellite image data products that cover the entire island of Puerto Rico. Mapping photographs of some sites go back about 40 years. Satellite images dating from 1972 can be used to study changes in regional landscapes.

The USGS and the U.S. Environmental Protection Agency are cooperating to create computerized (digital) images from aerial mapping photographs of Puerto Rico. These digital images will form a seamless data set for a geographic information system useful for assessing potential hazards, such as oil spills and non-point pollution sources, related to water resources.

Saline-Water Intrusion

Saline-water intrusion is a common problem on islands and along most coastal areas. The withdrawal of fresh ground water for water supply and other uses can cause the saline water that underlies coastal aquifers to intrude into the fresher parts of the aquifers. Currently (1995) the USGS is conducting three projects in Puerto Rico to monitor saline-water intrusion and to examine the physical and chemical processes associated with this phenomenon.

The northern coastal region of Puerto Rico west of San Juan, which is characterized by caves, sinkholes, and underground drainage, contains aquifers of regional importance. The development of these aquifers has been limited by

saline water intrusion. The USGS, in cooperation with the Puerto Rico Aqueduct and Sewer Authority, is installing a number of observation wells to monitor saline-water intrusion and to determine the amount of freshwater available for development in this area.

The USGS, in cooperation with the Puerto Rico Aqueduct and Sewer Authority and the Puerto Rico Industrial Development Company, has been assessing ground-water quality and quantity in the Yabucoa valley, southeastern Puerto Rico, since 1987. A major portion of this work has been directed toward monitoring saline-water intrusion that occurs in the alluvial aquifer as a result of water withdrawals.

The USGS also is studying the chemical and physical processes along the saline-freshwater interface on Isla de Mona, Puerto Rico (fig. 2). The aquifer on Isla de Mona was selected for study because it has never been pumped or otherwise developed. The study has provided critical information useful for determining the pre-development conditions of the aquifers on islands around Puerto Rico.

National Mapping Program

Among the most popular and versatile products of the USGS in Puerto Rico are its 1:20,000-scale topographic maps (1 inch on the map represents about 1,667 feet on the ground). These maps depict basic natural and cultural features of the landscape, such as mountains, lakes and streams, highways, boundaries, and geographic names. Contour lines are used to depict the elevation and shape of the terrain. Puerto Rico is covered by 67 maps at a scale of 1:20,000, which are useful for civil engineering, land-use planning, natural-resource monitoring, and other technical applications. These maps have long been favorites with the general public for outdoor uses, including hiking, camping, and exploring.

Geologic mapping of Puerto Rico is now largely complete at a scale of 1:20,000. Only the Rincón quadrangle in northwestern Puerto Rico remains to be mapped. Work on the compilation of a digitized geologic map of Puerto Rico at a scale of 1:200,000 as well as numerous other derivative maps that deal with natu-

ral geologic economic resources and various mineral resources also is underway.

Tourism and Ground-Water Resources

The Cabo Rojo area in southwestern Puerto Rico is becoming a popular domestic and international tourist destination. This has resulted in increased water consumption and a consequent need to find and develop additional sources of potable water. The USGS, in cooperation with the Puerto Rico Aqueduct and Sewer Authority, recently conducted an investigation to define the occurrence and movement of ground water in the area and to determine the hydraulic properties on the Bajuras limestone aquifer near Cabo Rojo (fig. 4). This aquifer is the main source of potable water for the municipality of Cabo Rojo. Also, the possibility of a hydraulic connection between the Bajuras limestone aquifer and an associated freshwater wetland, the Ciénaga de Cuevas, also was investigated as part of this study.

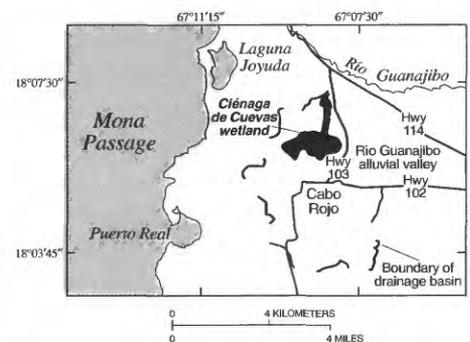


Figure 4. Location of features in the Ciénaga de Cuevas study area. See figure 2 for the study site location in Puerto Rico. The northeastern quadrant of the drainage basin boundary is not shown because it lies within the Río Guanajibo alluvial valley and cannot be precisely located at present.

The results of this investigation indicate that Ciénaga de Cuevas partially recharges the Bajuras limestone aquifer in response to the ground-water withdrawals from the aquifer. Furthermore, analysis of the data collected indicates that ground-water reserves in the Bajuras/ Ciénaga de Cuevas limestone aquifer system may be sufficient to partially or fully satisfy the future water-supply needs of the Cabo Rojo area. These findings have assisted the municipality of Cabo Rojo in their decision to include in

its Development Plan the Bajuras/Ciénaga de Cuevas area as a region to be preserved in its present state.

Geographic Information System

Since 1988, the USGS has been developing a geographic information system (GIS) for Puerto Rico to meet the need for spatial analysis in hydro-logic studies. Conversion of the 67 topographic quadrangles for this region to a digital format has been completed and includes such information as political boundaries, transportation (roads, trails, others), surficial hydrography (lakes, streams), and topographic contours. Other digital map information has been developed in cooperation with local and Federal Government agencies in Puerto Rico. A few of these include soils and land use at a scale of 1:20,000 and geology at a scale of 1:100,000. Data on ground-water wells have been retrieved from the USGS Ground Water Site Inventory data base and converted to a digital machine readable format and entered into the GIS. Slope maps and watershed boundaries have been developed from the GIS to update and enhance the information on existing maps. The GIS provides valuable spatial information needed by regional planners and environmental managers to assess the effects of urban and industrial development on the resources of Puerto Rico.

Long-Term Study of Water, Energy, and Biogeochemical Budgets

The humid tropics occupy 25 percent of the Earth's land surface and by 2000 will contain approximately 50 percent of

the Earth's population. Rapid destruction of forests in the humid tropics is recognized as a threat to both economic development of the affected areas and to global climate. Development stresses include major adverse effects on soil erosion, soil nutrients, surface-water quality, reservoir sedimentation, and increased short-term hazards as a result of landslides and floods. To understand these processes and provide information useful for developing solutions to these problems as they may affect Puerto Rico, the USGS has developed a long-term Water, Energy, and Biogeochemical Budget program (WEBB) research site in the Luquillo mountains in eastern Puerto Rico. The site consists of the 11,300-hectare U.S. Forest Service-administered Luquillo Experimental Forest and the Río Grande de Loíza drainage basin, an agriculturally developed watershed (fig. 2).

The research work focuses on tropical geomorphic and biogeochemical processes that control the movement and transformation of water, energy, bedrock weathering products, and nutrients in the earth-surface environment. Detailed data are being obtained on hillslope and fluvial transport and erosion processes, soil-development, and nutrient cycling. These data are being used to develop sediment and water budgets and a geomorphic model of tropical landform development. This model can assist resource managers to identify planning solutions to reservoir sedimentation, landslides, floods, and other development-related geomorphic problems that occur in densely populated tropical settings.

The National Landslide Information Center

The National Landslide Information Center (NLIC) in Golden, Colorado, is the focal point for collecting and disseminating information on significant landslide events, critical research results, and public-policy issues relating to landslides. The NLIC collects and distributes a vast amount of information related to landslides throughout the world. The NLIC maintains an important role in assisting the States and Puerto Rico in dealing with landslide hazards by providing a model for Federal/State interaction on such hazards issues.

Cooperative Programs

The USGS cooperates with more than 20 local and Federal agencies in Puerto Rico. Cooperators include public health agencies, natural-resource agencies, water and sanitation agencies, and Federal agencies. Cooperative activities include water-resources-data collection, interpretive water-availability and water-quality studies, mineral-resource assessments, and mapping. When Puerto Rico government agencies participate, some activities can be supported on a matching-funds basis. In addition to agencies already mentioned, the USGS cooperates with the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, and the Puerto Rico Department of Health, to name only a few.

The USGS provides support to the Puerto Rico Water Resources Research Institute in Mayagüez, which conducts a program of research, education, and information and technology transfer.

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Additional earth science information can be found by accessing the USGS "Home Page" on the World Wide Web at "<http://www.usgs.gov>".

For more information on all USGS reports and products (including maps, images, and computerized data), call 1-800-USA-MAPS.