# A RECONNAISSANCE OF THE WATER RESOURCES OF THE CENTRAL GUANAJIBO VALLEY, PUERTO RICO

By Eloy Colón-Dieppa and Ferdinand Quiñones-Márquez

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COVER PICTURE:
Guanajibo Valley across Hwy. 2 looking to the west.

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## FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM OF UNITS (SI)

**For the convenience of readers who may want to use International System (SI), the data may be converted by using the following system:**

| Multiply inch-pound units | By | To obtain SI units |
|---|---|---|
| inches (in) | 25.4 | millimeters (mm) |
| feet (ft) | 0.03048 | meters (m) |
| feet per second (ft/s) | 0.3048 | meters per second (m/s) |
| feet per mile (m/km) | 0.1894 | meters per kilometer |
| feet squared per day ($ft^2/d$) ($m^2/d$) | 0.09290 | meters squared per day |
| miles (mi) | 1.609 | kilometers (km) |
| square miles ($mi^2$) | 2.590 | square kilometers ($km^2$) |
| gallons per minute (gal/min) | 0.06309 | liters per second (L/s) |
| gallons per minute per feet (gal/min)/ft | 0.2070 | liters per second per meter (L/s)/m |
| cubic feet per second ($ft^3/s$) | 0.02832 | cubic meters per second ($m^3/s$) |
| tons per square mile ($tons/mi^2$) | 0.03753 | metric ton per square kilometer ($t/km^2$) |
| tons per year (tons/year) (t/year) | 0.9072 | metric tons per year |

# A RECONNAISSANCE OF THE WATER RESOURCES OF THE CENTRAL GUANAJIBO VALLEY, PUERTO RICO

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## ABSTRACT

A reconnaissance of the water resources in the Central Guanajibo Valley was conducted from 1979-80. The study included an area of about 25 square miles in the lower reaches of the Guanajibo River from the vicinity of San Germán to Hormigueros.

Precipitation averages 56 inches per year. The principal soils are associations of the Coloso and Toa groups. These are generally deep, slightly acid, and with available water capacities ranging from 0.11 to 0.16 inch per inch of soil. The geology of the area is dominated by folded, faulted, and weathered volcanic rocks of Cretaceous age overlain by surface deposits. Limestone of Late Cretaceous age occurs to the southwestern part of the area. Layers of clay, sand, gravel and limestone underlie most of the surficial deposits. Geophysical surface techniques were used in conjunction with well logs to study the subsurface geology. The tests showed that the surficial deposits extend over most of the area to a of about 70 feet. Limestone in excess of 200 feet thick underlies most of the surface deposits.

Streamflow in the study area varies seasonally. The mean-annual flow of Río Guanajibo near Hormigueros is about 200 cubic feet per second. Floods in the valley are frequent and severe; the valley has been flooded at least 18 times since 1899. Seasonal fluctuations can reduce the flow of Río Guanajibo to as low as 5.0 cubic feet per second. Monthly 7-day, 10-year minimum flows near Hormigueros range from 7.8 to 58 cubic feet per second. At Highway 114, upstream from agricultural areas, the monthly 7-day, 10-year minimum flows of Río Guanajibo range from 1.7 to 33 cubic feet per second. The quality of the water in Río Guanajibo and Río Rosario is suitable for most uses, including irrigation. High fecal coliform bacteria counts may require precautions in handling water in agricultural areas. The mean annual suspended-sediment load of Río Guanajibo near Hormigueros is about 134,000 tons per year.

Ground water occurs in sand and gravel deposits and fractured and porous limestone. Water moves through the aquifer from upland areas into the valley and toward the sea. Water-table gradients are about 14 feet per mile. Ground-water levels range from 15 to 110 ft above mean sea level. The most favorable aquifer characteristics occur in the southwest part of the area. Specific capacities of wells range from 2.4 to 40 gallons per minute per foot. Transmissivities range from 670 to 11,000 feet squared per day. Ground water is of good chemical quality. No evidence of salt-water intrusion into the aquifer was detected. The southwest part of the area shows the most potential for future development.

# 1.0 INTRODUCTION

## 1.1 Objective

**WATER RESOURCES RECONNAISSANCE COMPLETED IN THE CENTRAL GUANAJIBO VALLEY**

**Information on occurrence, availability, and chemical quality of surface water and ground water is presented**

The Government of Puerto Rico is engaged in a program to foster agricultural development. The program includes an ambitious effort to convert most of the coastal plains, now producing sugarcane, to rice production.

In 1979, the U.S. Geological Survey began a series of studies in cooperation with the Puerto Rico Department of Agriculture, to determine the availability of water for irrigation in several coastal areas (fig. 1.1-1). The studies included a reconnaissance of the water resources of the Central Guanajibo Valley, in western Puerto Rico.

This report summarizes the finding of the 1-year study, designed to provide general information on the quantity, quality, availability and occurrence of surface and ground water in the study area. Emphasis on the study was placed on the surface-water resources. In-depth definition of the ground-water resources of the area will require additional investigations.

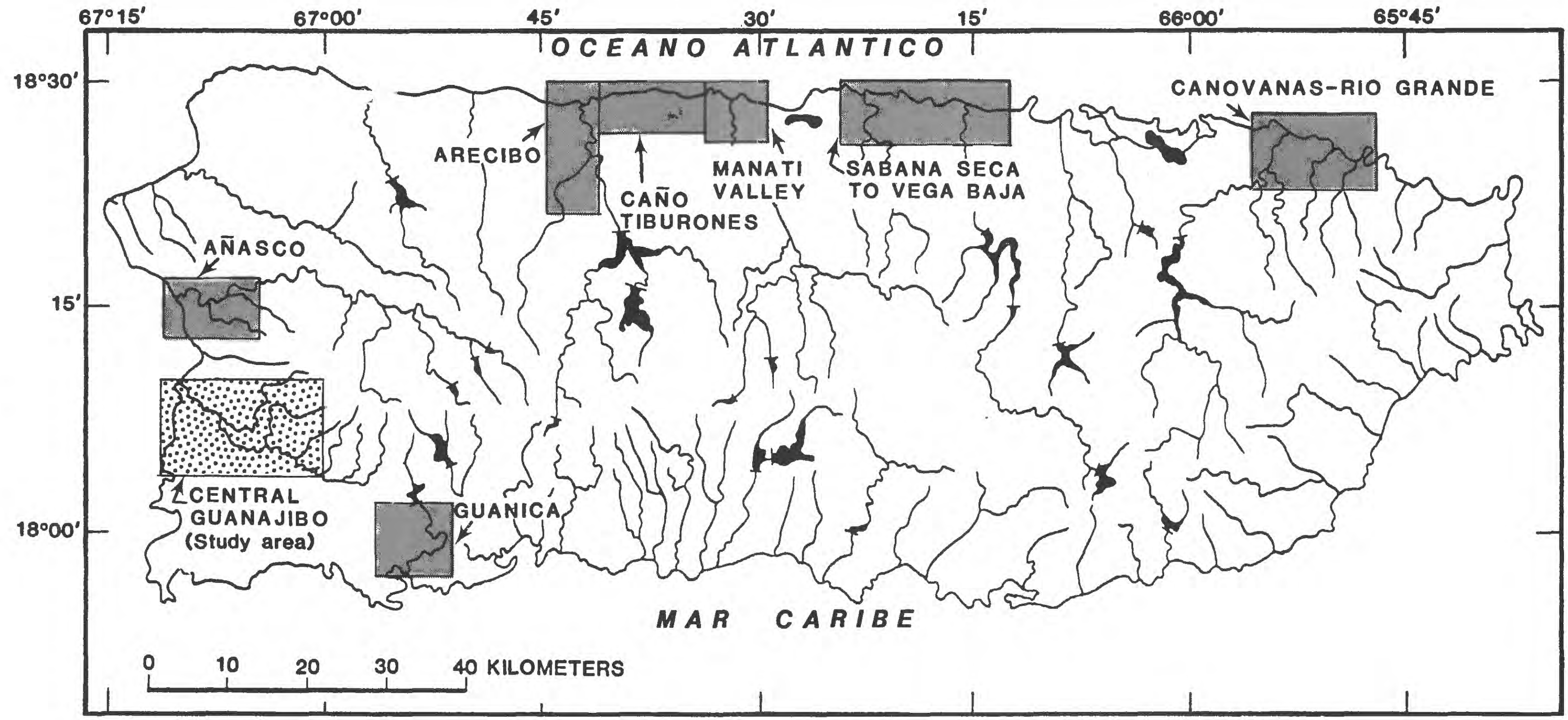



Figure 1.1-1 Location of study area and other water-resources investigations by the U.S. Geological Survey in cooperation with the Puerto Rico Department of Agriculture.

## 1.2 Study Area

### CENTRAL GUANAJIBO VALLEY EXTENDS FROM SAN GERMAN TO HORMIGUEROS

**The Río Guanajibo, the principal stream in the area, traverses a broad alluvial valley.**

The Central Guanajibo Valley includes most of the flood plain and lower reaches of the Guanajibo River. The study area included about 25 $mi^2$ from the vicinity of San Germán northwesterly to the narrow valleys west of Hormigueros (fig. 1.2-1). The valley ranges from 3 to 4 mi wide and is about 7 mi long.

Río Guanajibo and its tributaries (Río Rosario, Río Duey, Río Hoconuco, Río Caín, and Río Viejo) are the principal streams in the valley. Río Guanajibo traverses a broad alluvial valley, lying between disected hills and steep ridges. Elevations of the valley floor above mean sea level range from 15 ft in the narrows west of Hormigueros to 140 ft near San Germán.

Drainage areas of the principal streams in the study area are as follows:

| | Square miles |
|---|---|
| Río Guanajibo at Highway 2 | 72 |
| Río Duey at mouth | 11.1* |
| Río Viejo at mouth | 16.4* |
| Río Guanajibo at junction w/Río Rosario | 90 |
| Río Rosario at Rosario (gaging station 50136000) | 17.6 |
| Río Rosario at mouth | 24 |
| Río Guanajibo nr Hormigueros (gaging station 50138000) | 120 |
| Río Guanajibo nr Hormigueros excluding Río Rosario | 96 |

*Some undetermined areas.

The population of the valley is about 90,000, (1980 Census) of which 45 percent lives in the urban areas of San Germán (13,000), Hormigueros (12,000), and Cabo Rojo (10,000). Sugarcane is the principal crop, with small tracts dedicated to vegetables and pastureland.

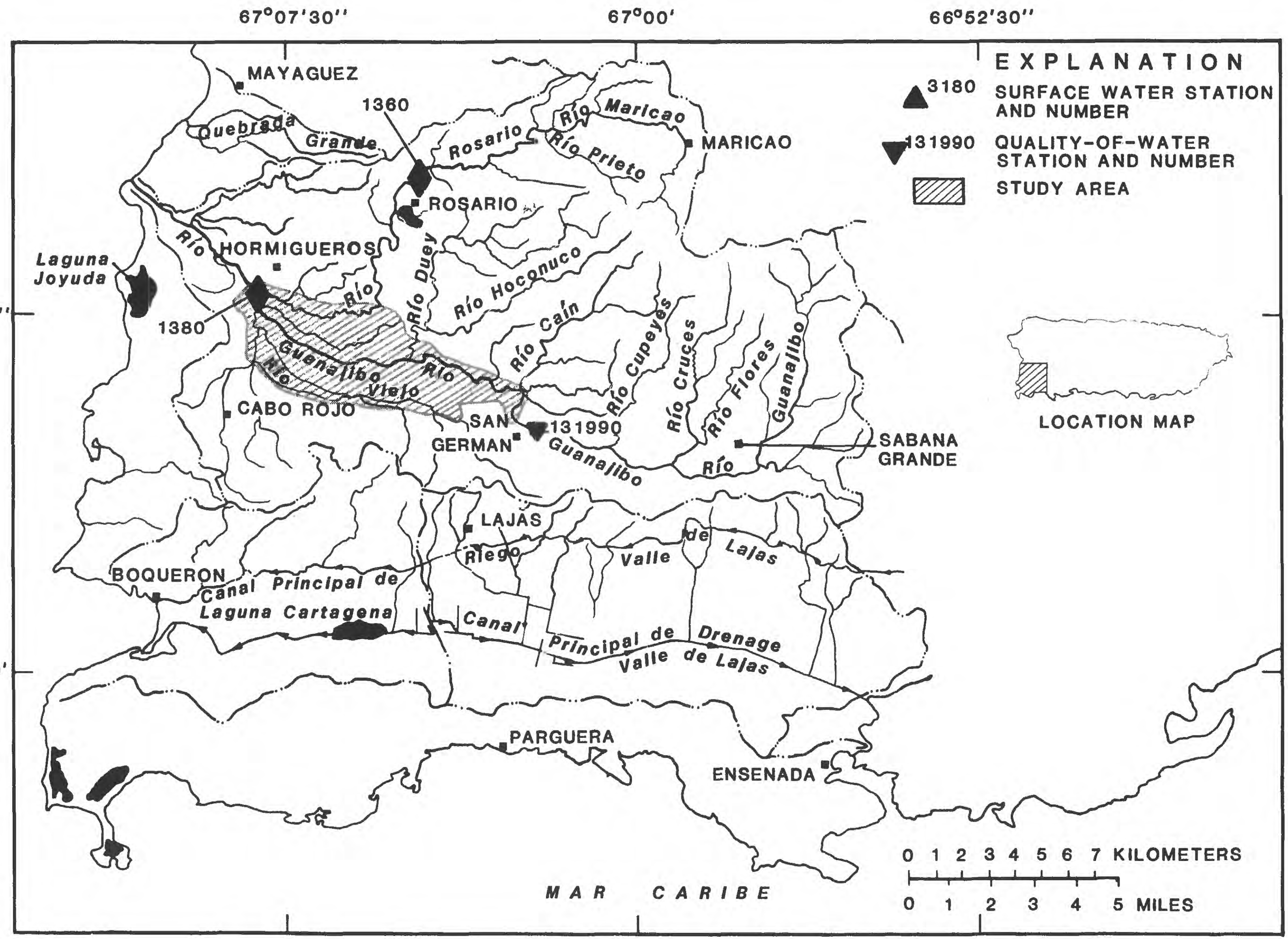



Figure 1.2-1 Río Guanajibo basin and study area.

## 2.0 GENERAL FEATURES

### 2.1 Precipitation

**PRECIPITATION AVERAGES 56 INCHES PER YEAR**

**Intense precipitation occurs from August through November and during May. The driest months normally are December through March.**

Precipitation in the Central Guanajibo Valley follows the general pattern of most of the north and west coasts of Puerto Rico. The rainy season occurs from late August through early November. Significant precipitation also occurs in early summer, during May. The driest period occurs from December through March. Occasionally, this wet-dry season pattern is altered by cold fronts, tropical waves, and other disturbances, resulting in intense precipitation during any month of the year.

The average annual precipitation in the lower valley is about 56 inches. Upstream from the study area, near Sabana Grande, the average is about 65 inches. Three precipitation stations have been operated by the National Weather Service in the lower valley for periods ranging from 7 to 15 years. Monthly averages and extreme values at the sites (fig. 2.1-1) show a general uniform pattern throughout the valley. Significant variations occur between the Margarita and Hormigueros-Cabo Rojo gages. Maximum values at Margarita and Cabo Rojo occur during May and July, while at the other two gages the maximums occur during September and October. In the Cabo Rojo area, this could be due to localized coastal precipitation.

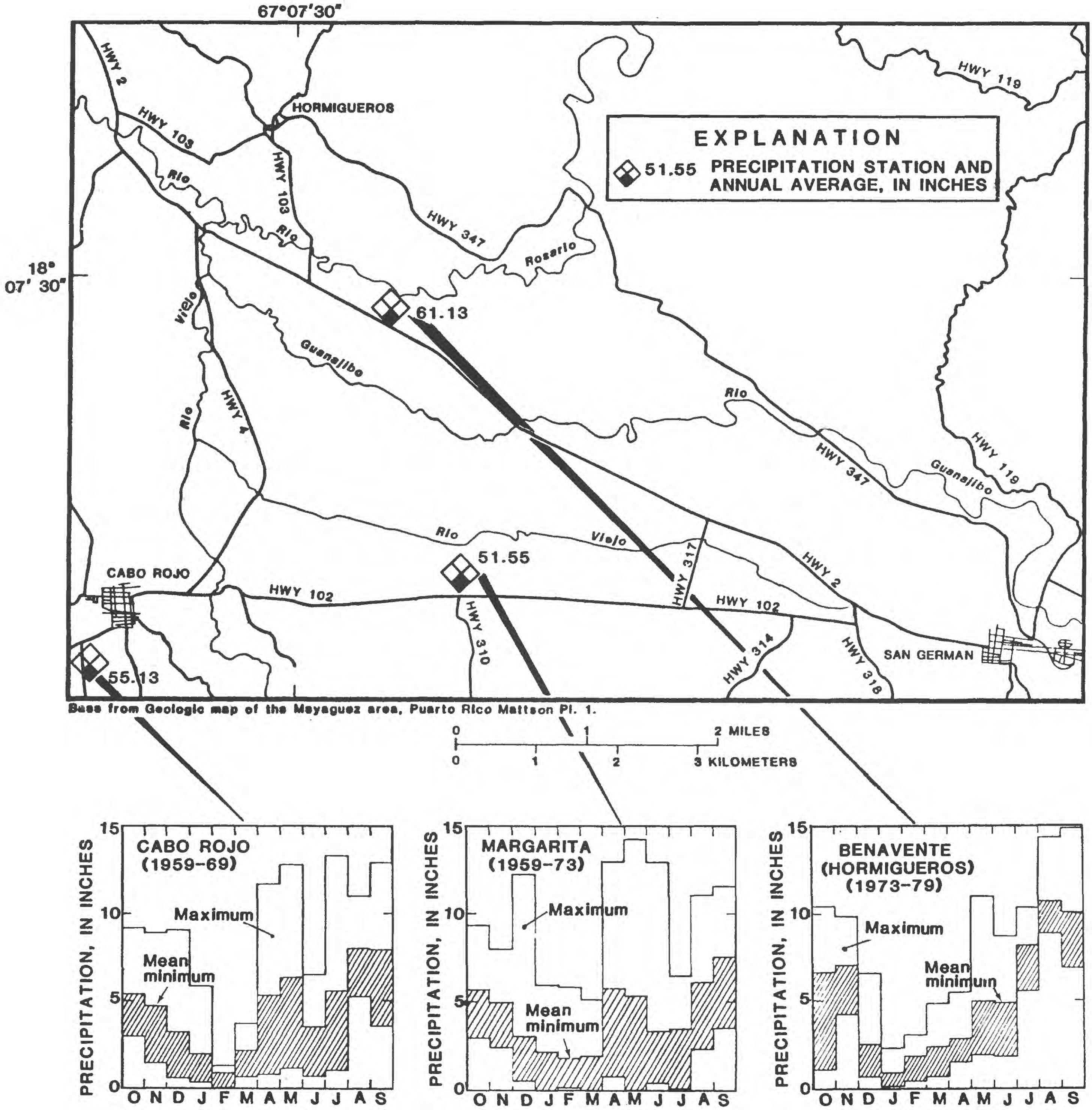



Figure 2.1-1 Monthly and annual precipitation averages in the Central Guanajibo Valley.

## 2.2 Soils

### COLOSO AND TOA SOILS PREDOMINATE IN THE VALLEY

**The soils are generally deep, slightly acid, fertile, and have high available water capacity.**

The principal soil associations in the Central Guanajibo Valley are the Coloso, Toa, Manî and Dique (Gierbolini, 1975). The Coloso group is the most important soil in the valley, covering most of the south-central part of the study area (fig. 2.2-1 and table 2.2-1). The Toa association is the second most important soil, spread over the north-central valley.

The soils in the valley are deep, moderately permeable, and slightly acid. The Coloso and Toa soils were formed in stratified, moderately fine-textured alluvial sediments washed from volcanic and limestone hills. They are fertile and with high available water capacity. Erosion is not considered a hazard in the soils of the valley.

**Table 2.2-1 General Characteristics of the principal soil associations in the Central Guanajibo Valley.**

| SOIL ASSOCIATION | DEPTH (inches) | DOMINANT TEXTURE | PERMEABILITY (Inches per hour) | AVAILABILITY WATER CAPACITY (Inches per inch of soil) | pH (Units) | SHRINK SWELL-POTENTIAL |
|---|---|---|---|---|---|---|
| COLOSO | 0-58 | Silt clay loam | 0.6-2.0 | 0.11-0.14 | 5.6-6.5 | Moderate |
| DIQUE | 0-60 | Loam silt | 0.6-2.0 | 0.14-0.16 | 5.6-6.0 | Low |
| MANI | 0-58 | Clay | 0.2-0.6 | 0.11-0.13 | 5.6-6.5 | Moderate |
| TOA | 0-60 | Silt clay loam | 0.6-2.0 | 0.12-0.14 | 6.1-7.8 | Moderate |

(Modified from Gierbolini, 1975)

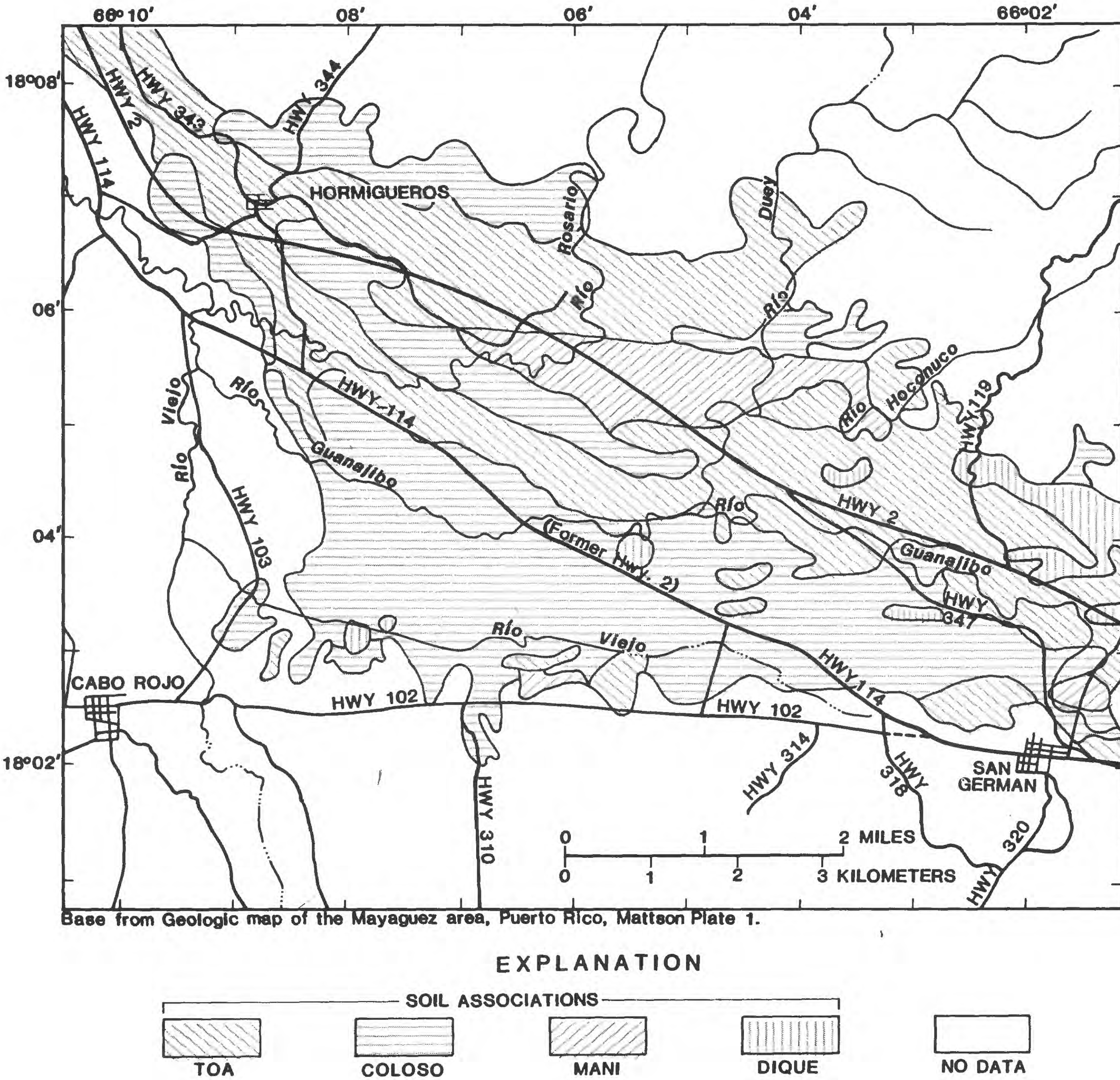



Figure 2.2-1 Principal soil associations in the Central Guanajibo Valley.

## 2.0 GENERAL FEATURES (Continued)

### 2.3 Geology

#### 2.3.1 General Geology

**GUANAJIBO VALLEY FORMED BY EROSION AND FAULTING**

**Geology consists mostly of folded, faulted, and weathered Cretaceous volcanic rocks and by surface deposits.**

The geology of the Guanajibo valley was described and mapped by Mattson (1960) in his investigation of the Mayagüez area (fig. 2.3.1-1). The stratigraphic nomenclature used in this report follows the usage of Mattson (1960) and does not necessarily agree with the usage of the U.S. Geological Survey.Those geologic formations that are exposed in the area of this report, or that are believed to be present in the subsurface, are from oldest to youngest: Serpentinite or serpentinized periodotite of the Bermeja Complex of Cretaceous age or older; undifferentiated volcanic rocks, mostly andesite, of probably Cretaceous age; the Río Loco Formation consisting of andesite, tuff, breccia, and limestone of Late Cretaceous age; the Sabana Grande Andesite, Yauco Mudstone, Parguera Limestone, and Brujo Limestone, all of the Mayagüez Group of the Late Cretaceous age; the San Germán Formation, a thick sequence of andesite with the Cabo Rojo Agglomerate Member near the base and the Cotui Limestone Member near the top of the sequence, of Late Cretaceous age; and unconsolidated surface deposits of Quaternary age. Volcanic rocks, limestone, and clastic deposits of Tertiary age are found elsewhere in western Puerto Rico, and these may occur under the surface deposits of the valley floor, but their presence is not indicated in surface exposures in the vicinity.

All of the Cretaceous rocks have been highly weathered and deeply eroded since their deposition. They have been folded and faulted, and rivers have carved valleys through the structural lows. The valleys subsequently have been filled with alluvial deposits. The Guanajibo Valley is essentially an anticline that has been breached by erosion and is bounded in part by faults and partially filled by Quaternary alluvium (Mattson, 1960, p. 321).

The nature and thickness of the materials which underly the valley floor, because of their water-bearing potential, are of prime interest to the present investigation and were studied in much more detail than the exposed units. Surface resistivity and seismic traverses were run in the valley, and three exploratory wells were drilled to bedrock at selected locations to verify the resistivity and seismic interpretations. Well logs of existing wells also were examined and used in the analysis and following discussion of the subsurface deposits.

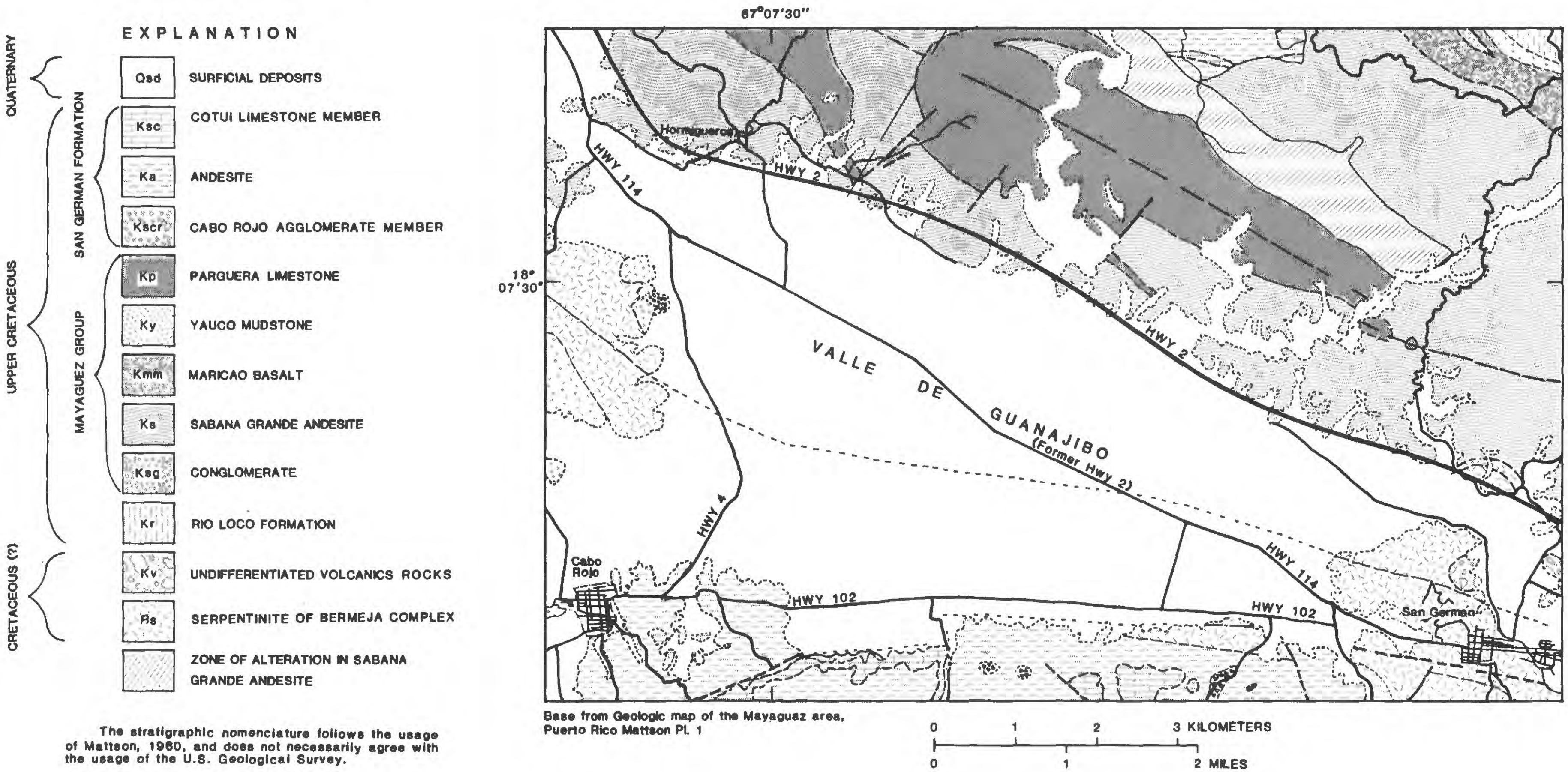



Figure 2.3.1-1 Geology of the Central Guanajibo Valley. (Modified from Mattson, 1960.)

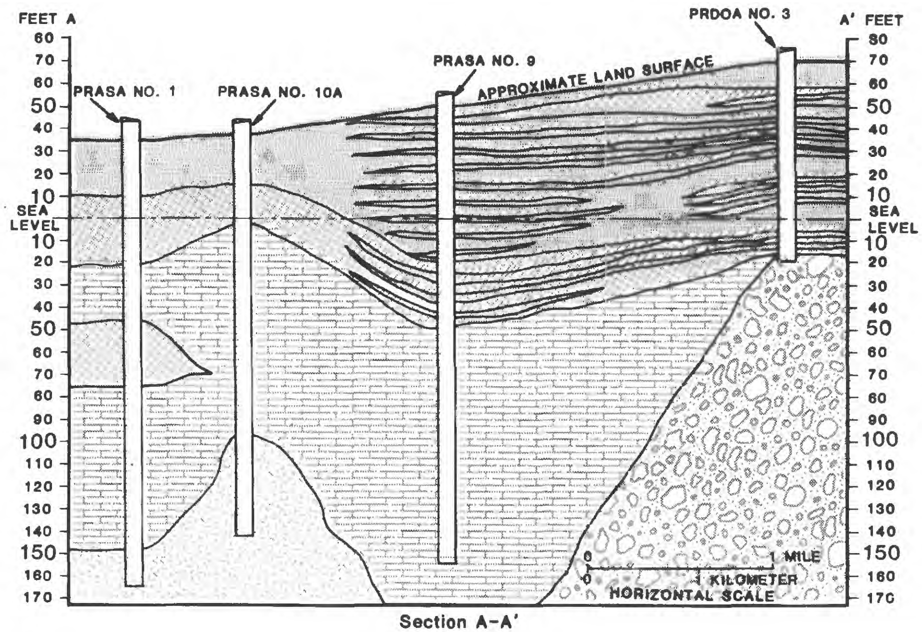
### 2.3.2 Subsurface Geology

## CLAY, SAND, GRAVEL, AND LIMESTONE UNDERLIE MOST OF THE AREA

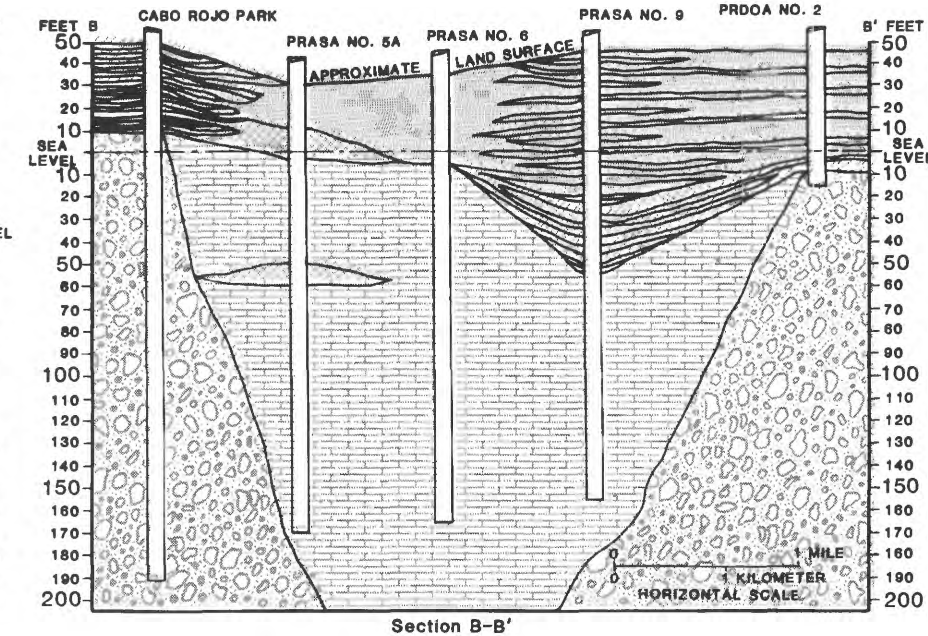
**The limestone is limited to the southwestern part of the valley.**

Geologic sections through the Central Guanajibo valley show that clay is present near the surface, generally underlain by sand, sand and clay, or sand and gravel. These are in turn underlain by limestone or directly by basalt. The geologic sections (fig. 2.3.2-1) were defined from drillers logs supplied by the Puerto Rico Aqueduct & Sewer Authority and the Puerto Rico Department of Agriculture.

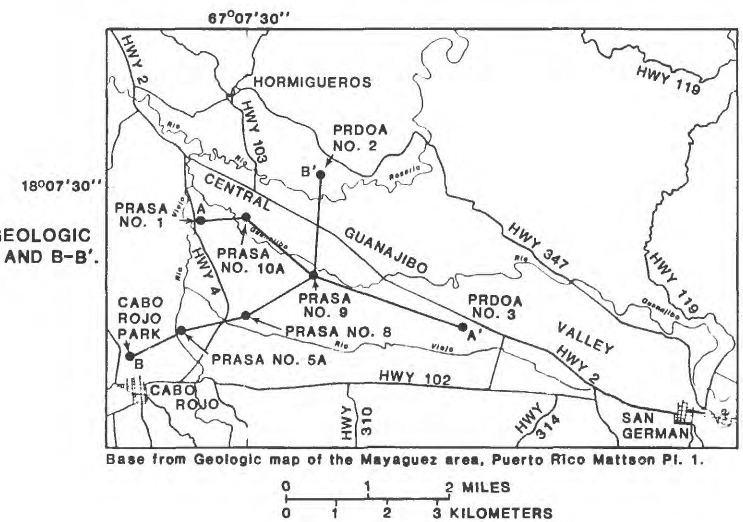
The eastern and northern parts of the area have no limestone in the subsurface, and sandy and gravely clay directly overlie "basalt", probably a dark basaltic andesite. The identification of the "blue rock" in some of the logs is not known, although the latter could refer to Yauco Mudstone or an andesite, both of which are present in nearby surface exposures.




Section A-A'




Section B-B'




Base from Geologic map of the Mayaguez area, Puerto Rico Mattson Pl. 1.

LOCATION OF GEOLOGIC SECTIONS A-A' AND B-B'.

EXPLANATION

SAND
GRAVEL
CLAY
LIMESTONE
GRAY ROCKS
BASALT

Figure 2.3.2-1 Generalized geologic sections in the Central Guanajibo Valley.

### 2.3.3 Geophysical Techniques

## SURFACE GEOPHYSICAL TECHNIQUES USED TO STUDY SUBSURFACE GEOLOGY

**Surface resistivity and seismic tests were conducted throughout the valley to assist in defining the subsurface geology.**

The subsurface geology in the Central Guanajibo Valley varies considerably with location and depth (Mattson, 1960). Surface-geophysical tests were utilized to assist in defining the types of materials, extent of formations, and depth at which potential aquifers occur. The tests were conducted at 37 sites in the valley (fig. 2.3.3-1).

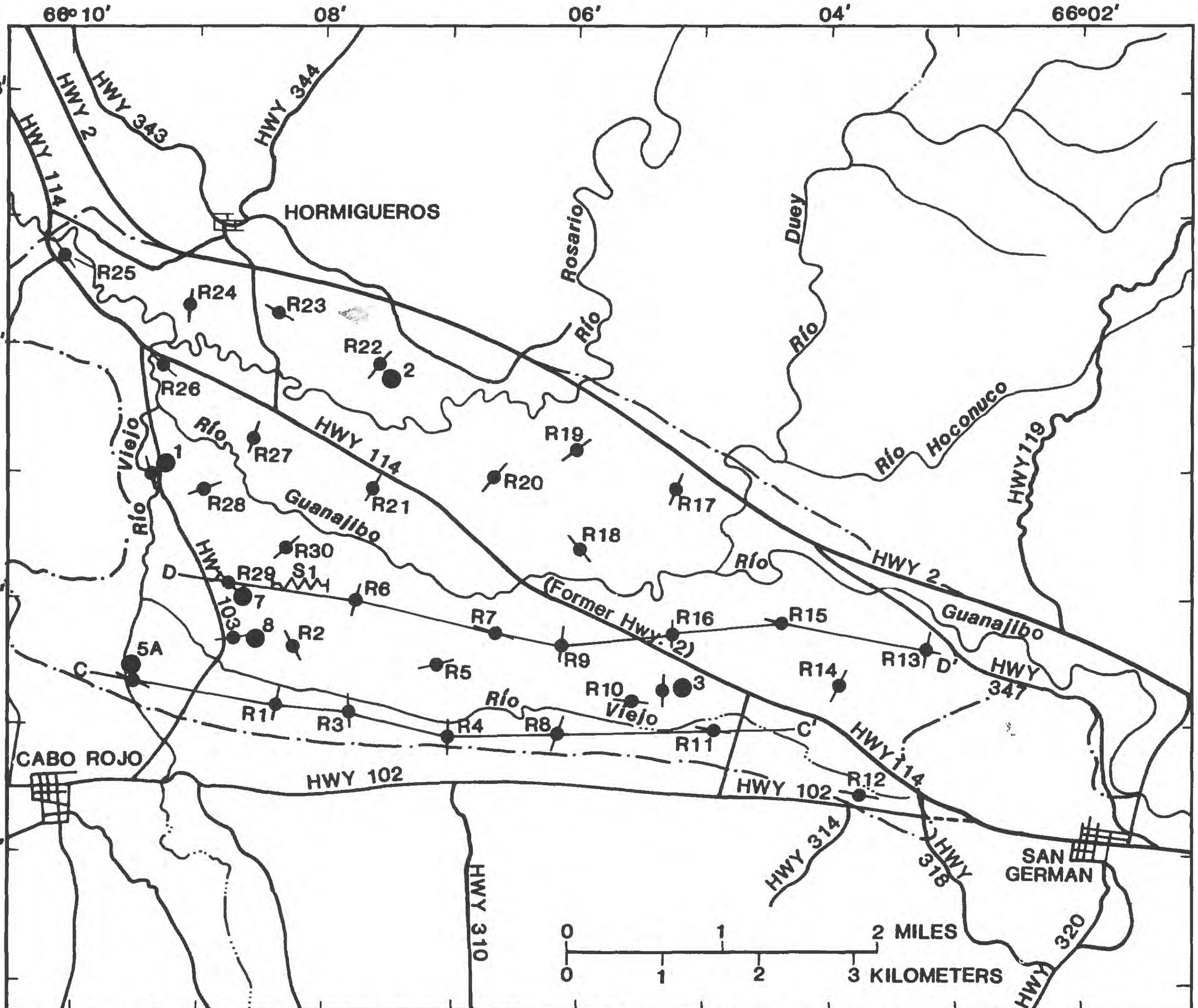
Surface-resistivity surveys were conducted utilizing a Schlumberger configuration (Zhody and others, 1974). In surface-resistivity tests, an electric current is introduced into the ground through two electrodes. The difference in voltage potential between two other electrodes is measured to determine the electrical resistivity of the material. The resistivity varies with the amount, distribution, and salinity of water in the material. Saturated materials have lower resistivities than unsaturated or dry media. Low resistivities are characteristic of high porous material saturated with high salinity water. Clays and conductive material reduces the resistivity values.

In general, resistivity values can be correlated to the type of materials as follows (Modified from Soiltest, 1968):

| Resistivity range (ohms per meter) | Description |
|---|---|
| 1-15 | Wet to moist clay, silty-clay, and silty soils. |
| 15-30 | Moist-to-dry silty-clayey soils. |
| 20-150 | Moist to dry gravely-clayey, clayey-gravely soils; wet to moist limestones, sandstones and conglomerates; decomposed igneous rocks; saturated sand, sand-gravel, gravel and silt. |
| 150-1,000 | Dry limestones, sandstones and conglomerates. |
| 1,000-2,500 | Dry sand and gravel; fractured igneous rocks. |
| 2,500+ | Undecomposed massive hard igneous rock. |

Seismic tests are based on the principle that sound travels slower in loose material and heavily fractured rocks. Velocities are higher in strongly cemented materials or hard rocks. Seismic-refraction tests in the study area were conducted using a graphical 12-channel recording instrument with Kinipac* explosives as an energy source.

*The use of brand names in this report does not constitute endorsement by the U.S. Geological Survey.




Base from Geologic map of the Mayaguez area, Puerto Rico, Mattson Plate 1.

**EXPLANATION**

| | |
| --- | --- |
| R12 | RESISTIVITY TEST SITE AND NUMBER |
| S1 | SEISMIC TEST SITE AND NUMBER |
| 3 | WELL AND WELL NUMBER |
| C——C' | TRACE OF IDEALILZED CROSS SECTION USED FOR INTERPRETATION OF GEOPHYSICAL TESTS |
| —·—·— | VALLEY BOUNDARY |

Figure 2.3.3-1 Location of geophysical tests sites in the Central Guanajibo Valley.

### 2.3.4 Geophysical Tests

## SURFACE GEOPHYSICAL TESTS CORRELATE WITH CROSS-SECTIONAL DATA

**The surface resistivity and seismic tests show that clay, sand, gravel, and limestone occur at depths suggested by the generalized cross sections.**

The surface resistivity tests in the Lower Guanajibo Valley indicate that the subsurface is very amorphous. At a depth of about 70 feet, about half of the material exhibits resistivity values in the 0-20 ohms per meter (ohms/m) range (fig. 2.3.4-1A). This suggests the presence of mostly moist to dry silty and clayey soils. Sand and gravel, clay and sand, and clay and gravel layers probably occur toward the center of the lower valley, where resistivities at 70 feet range from 20 to 40 ohms/m. The cross-sectional data derived from well logs (fig. 2.3.2-1) agree with the conclusions from the resistivity data for this depth.

At a depth of 140 feet (fig. 2.3.4-1B) most of the material exhibits resistivity values in a range from 40-60 ohms/m (typical of wet to moist limestone, among other materials). The data from the geologic sections show mostly limestone, at this depth, except to the southwestern part of the study area. The limestone layers appear to dissipate toward the northeast.

At a depth of 300 feet, the resistivity data suggest that the limestone formation is still present (fig. 2.3.4-1C). There are no well data to correlate with the resistivity tests, as wells do not penetrate deeper than about 200 feet (fig. 2.3.2-1).

Interpretation of the resistivity data along cross sections A-A' and B-B' generally agree with the well information (figs. 2.3.4-2 and 2.3.3-1). A low resistivity layer (2-20 ohms/m) coincides with the sand-clay-gravel layers described in the well logs. The cross-sectional interpretation below 70 feet is partially obscured by apparent lack of homogeneity. However, in general, the resistivity values are in the range typical of the limestone layers recorded from the well logs.

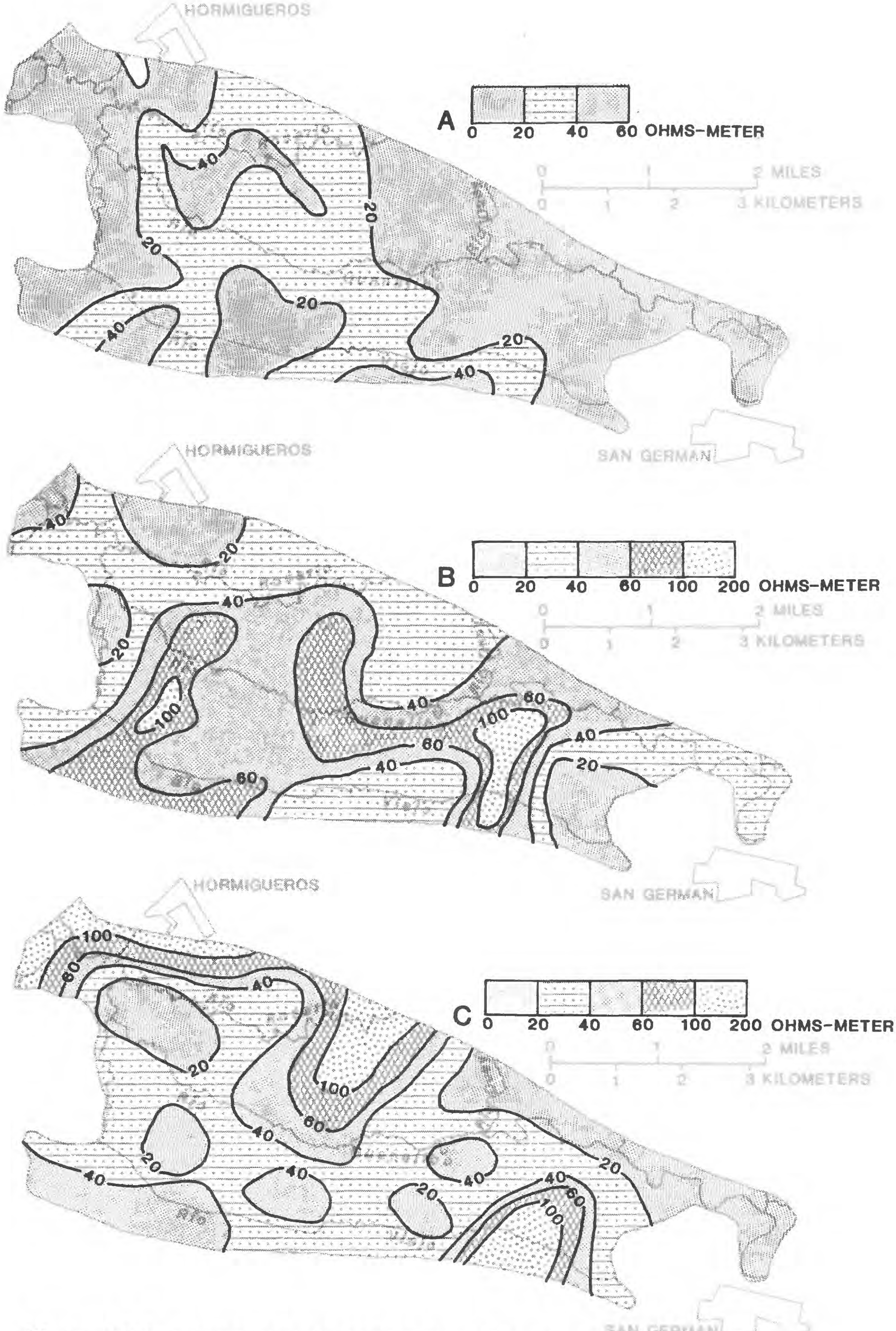



**Figure 2.3.4-1 Equiresistivity contour maps at various depths. (Generalized equal-resistivity areas at (A) 70 feet, (B) 140 feet, and (C) 300 feet.)**

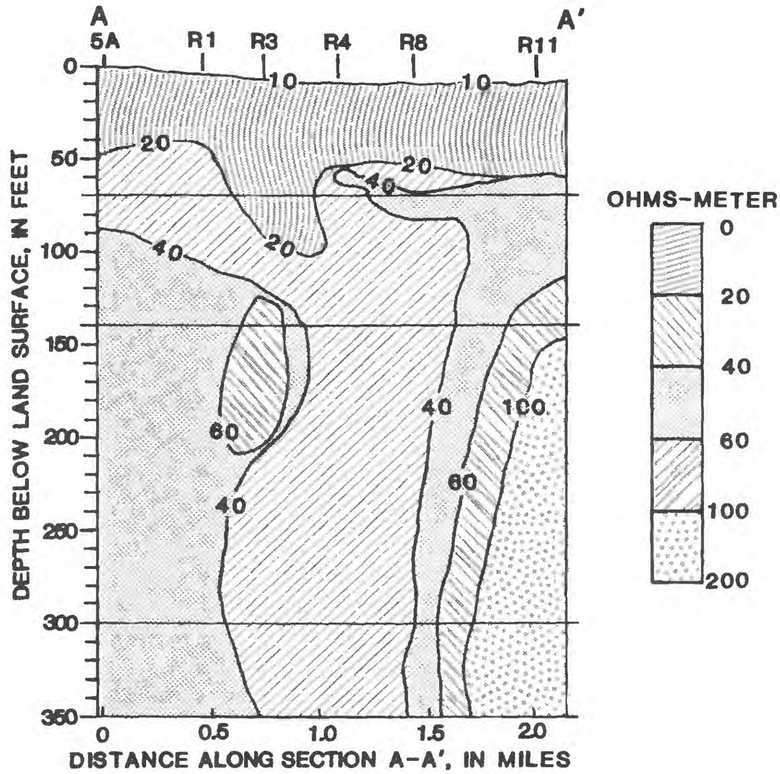
## SURFACE GEOPHYSICAL TESTS CORRELATE WITH CROSS-SECTIONAL DATA (Continued)

The seismic tests identify four layers of material in the valley (table 2.3.4-1). The lower velocities correspond to the unsaturated alluvial-clay layer. Below the water table (about 10 ft below land surface) the same material occurs, but the saturation causes an increase in the seismic velocities. The next increase in velocity (4760-5950 ft/s) corresponds with the limestone layers observed in the area. The higher velocities at depths from 388 to 545 ft, correspond to the igneous rocks or serpentinite of the Bermeja Complex described by Mattson (1960).

**Table 2.3.4-1 Seismic data at test sites 1 and 2 in the lower Guanajibo Valley.**

| SITE 1 (HACIENDA LA RATINA) | | SITE 2 (NEAR MARGARITA) | |
|---|---|---|---|
| Depth below land surface (feet) | Acoustic Velocity (feet per second) | Depth below land surface (feet) | Acoustic Velocity (feet per second) |
| 0-18 | 1,360 | 0-9 | 1,500 |
| 18-27 | 5,950 | 9-87 | 4,760 |
| 27-388 | 7,420 | 87-545 | 7,430 |
| 388-> | 14,300 | 545-> | 15,200 |

(See fig. 2.3.3-1 for location of test sites.)



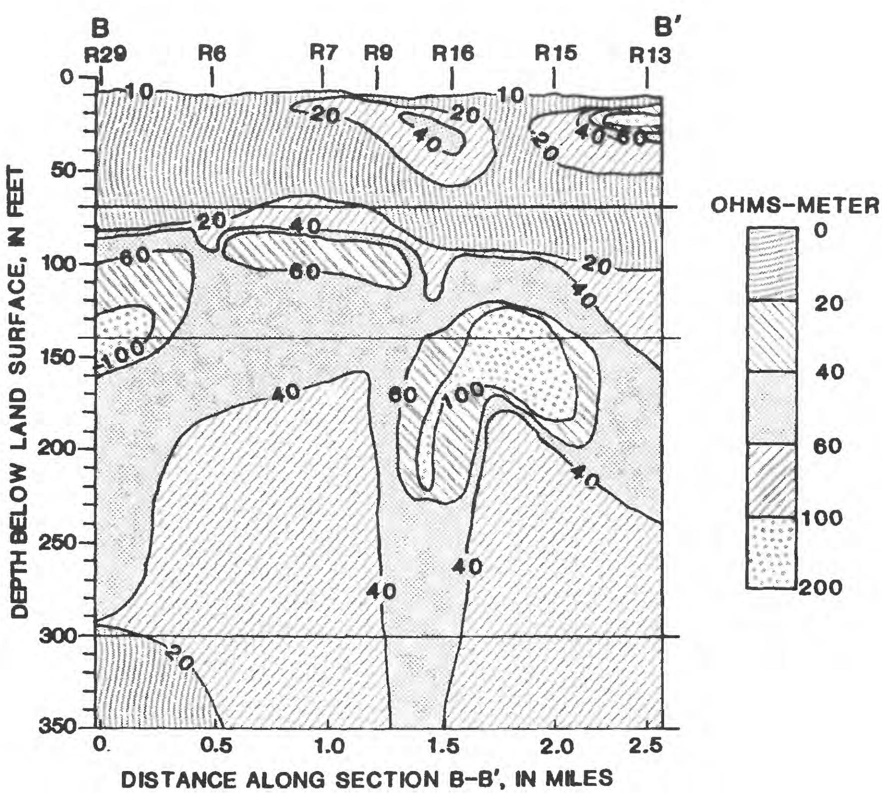




Figure 2.3.4-2 Apparent resistivity profiles along sections A-A' and B-B'. (For location of sections see fig. 2.3.2-1.)

## 3.0 SURFACE WATER

### 3.1 Streamflow Characteristics

**STREAMFLOW VARIES SEASONALLY**

**The mean-annual discharge at Río Guanajibo near Hormigueros is about 200 cubic feet per second. However, mean-monthly values range from 9.2 to 2,075 cubic feet per second.**

Streamflow in the Guanajibo Valley fluctuates significantly on a seasonal and yearly basis. Precipitation in the upper basins of Río Rosario and Río Guanajibo varies seasonally and can range from 70 to 100 inches from one year to the next. Streamflows fluctuate in response to the periods of intense precipitation (normally August to November), approaching bankfull or nearly flood conditions. During the rainy season, mean daily discharges at Río Guanajibo near Hormigueros seldom are lower than 100 $ft^3/s$ with an annual mean of 200 $ft^3/s$. However, mean-monthly values have ranged from 9.2 (1973-78 period of record) to 2,075 $ft^3/s$. The highest mean discharge for 30 consecutive days was 826 $ft^3/s$ during October at the Hormigueros station. At Río Rosarío, the principal tributary to Río Guanajibo, the mean-annual discharge for the period of record is 35 $ft^3/s$, while the 30-day highest discharge was 190 $ft^3/s$ also in October.

Typical hydrographs for the gaging stations on Río Rosarío at Rosarío and Río Guanajibo at Hormigueros are shown in figures 3.1-1 and 3.1-2. Precipitation in the basin during the 1977 water year was about 20 percent less than during the 1976 water year and is reflected by stream discharge. The base flows (minimum) at both sites normally occur during the dry season from December or January through June. The differences in base flows between a "wet" year (1976) and a "dry" year (1977) at the Guanajibo site can be as much as 40 to 50 $ft^3/s$.

Mean-monthly discharges are commonly used for water supply planning purposes. The mean-monthly discharge provides a time variation of the available flow at a stream site. Data for the gaging stations at Río Rosario and Río Guanajibo are shown in tables 3.1-1 and 3.1-2. The values in the tables reflect the significant seasonal flow changes in the basin.

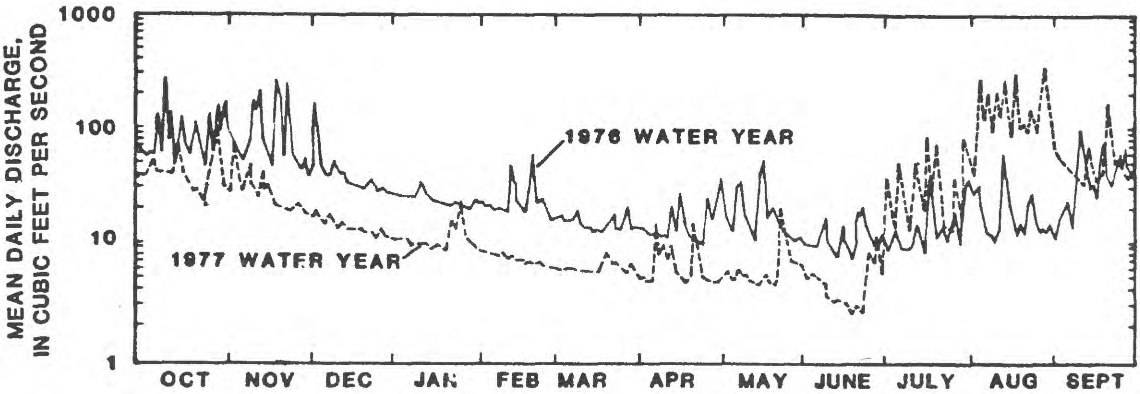



Figure 3.1-1 Typical mean-daily discharge hydrographs for Río Rosario at Rosario.

Table 3.1-1 Mean-monthly discharges for Río Rosario at Rosario.

| YEAR | OCT | NOV | DEC | JAN | FEB | MARCH | APRIL | MAY | JUNE | JULY | AUG | SEPT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1960 | * | * | * | * | * | * | * | * | 41.3 | 83.3 | 89.8 | 84.6 |
| 1961 | 111.00 | 102.00 | 77.2 | 56.3 | 24.1 | 63.0 | 75.9 | 39.3 | 37.4 | 78.4 | 133.00 | 120.00 |
| 1962 | 118.00 | 44.8 | 58.4 | 25.2 | 16.8 | 12.1 | 31.2 | 32.5 | 66.0 | 40.3 | 44.1 | 65.9 |
| 1963 | 88.0 | 50.[illegible] | 21.6 | 15.2 | 12.1 | 10.0 | 28.5 | 88.5 | 34.6 | 91.5 | 161.00 | 131.00 |
| 1964 | 10[illegible].00 | 69.7 | 31.9 | 18.5 | 19.6 | 11.5 | 54.1 | 20.0 | 4[illegible].0 | 32.4 | 41.3 | 64.8 |
| 1965 | 109.00 | 33.9 | 17.1 | 12.4 | 10.3 | 8.27 | 18.4 | 149.00 | 61.5 | 55.3 | 151.00 | 166.00 |
| 1966 | 167.00 | 123.00 | 53.0 | * | * | * | * | * | * | * | * | * |
| 1975 | * | * | * | * | * | * | * | * | 24.5 | 37.3 | 46.4 | 305.00 |
| 1976 | 94.2 | 104.00 | 43.7 | 24.0 | 24.6 | 15.1 | 16.6 | 19.9 | 11.6 | 15.9 | 21.0 | 46.1 |
| 1977 | 45.5 | 28.3 | 14.0 | 10.9 | 7.24 | 6.17 | 6.94 | 6.29 | 4.48 | 33.9 | 144.00 | 53.8 |
| 1978 | 93.5 | 103.00 | 30.9 | 16.7 | 18.7 | 12.3 | 19.7 | 16.9 | 28.1 | 32.6[illegible] | 43.6 | 49.0 |

* NO DATA

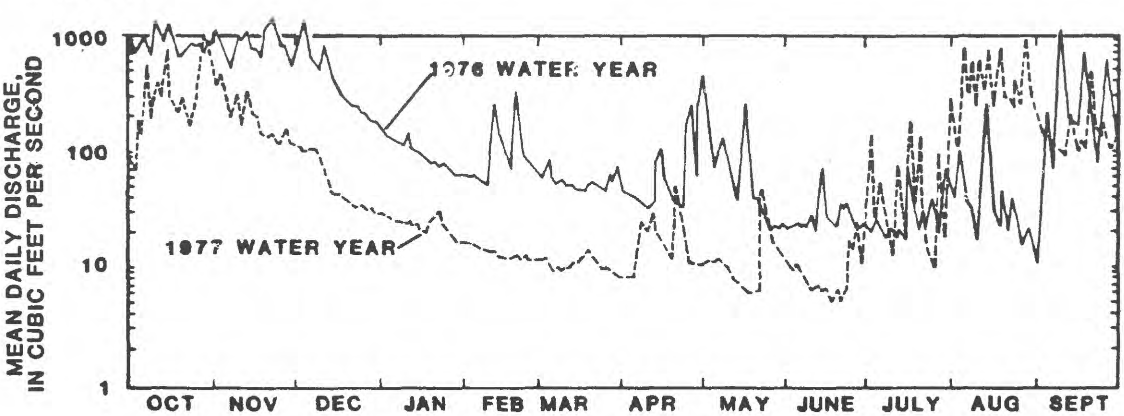



Figure 3.1-2 Typical mean-daily discharge hydrographs for Río Guanajibo near Hormigueros.

Table 3.1-2 Mean-monthly discharges for Río Guanajibo near Hormigueros.

| YEAR | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1973 | * | * | * | 13.8 | 30.8 | 28.9 | 22.7 | 17.5 | 99.2 | 33.2 | 226.00 | 314.00 |
| 1974 | 229.00 | 189.00 | 44.1 | 37.0 | 95.9 | 37.1 | 24.8 | 20.5 | 18.8 | 78.8 | 134.00 | 485.00 |
| 1975 | 358.00 | 951.00 | 293.00 | 57.9 | 39.9 | 54.5 | 31.2 | 43.7 | 52.6 | 165.00 | 395.00 | 2075.0 |
| 1976 | 820.00 | 783.00 | 422.00 | 89.2 | 93.4 | 49.5 | 69.7 | 70.9 | 24.0 | 26.4 | 42.3 | 281.00 |
| 1977 | 352.00 | 228.00 | 56.2 | 24.7 | 13.9 | 10.6 | 16.1 | 12.7 | 9.23 | 53.5 | 368.00 | 145.00 |
| 1978 | 488.00 | 1518.0 | 75.6 | 37.4 | 33.4 | 27.0 | 121.00 | 72.1 | 70.8 | 91.7 | 130.00 | 193.00 |

* NO DATA

## 3.2 Floods

### MOST OF THE AGRICULTURAL AREAS ARE FREQUENTLY INUNDATED

**The Guanajibo Valley has been flooded at least 18 times since 1899. The 1975 flood, the highest of record, inundated most of the valley.**

The Guanajibo Valley is subject to intense and frequent floods. Significant flooding has occurred in the valley at least 18 time since 1899 (Johnson, 1981). The areas inundated by the 1963 and 1975 floods have been documented by Haire (1972) and Johnson (1981). The approximate area affected by the 1975 flood (about 27 $mi^2$) is shown in figure 3.2-1. The highest flood of record in the area occurred on September 16, 1975. The peak discharge of the Río Guanajibo near Hormigueros (station 50138000) during the 1975 flood was about 128,000 $ft^3/s$, with a recurrence interval of about 60 years.The second highest flood occurred in 1899 (table 3.2-1). Other important floods in the valley, as well as the elevation of the water surface at the Highway 360 bridge (formerly Highway 119), are also given in table 3.2-1.

Most of the area in the valley with potential for agricultural development was affected by the flood. Flood depths in the central areas of the valley and study area were as much as 6 feet. Additional information and details about 1975 flood are available in the report by Johnson and from the Caribbean District office of the U.S. Geological Survey.

**Table 3.2-1 Flood peaks of Río Guanajibo at San Germán (Highway 360).**

| Date of flood | Water-surface elevation, feet above mean sea level |
|---|---|
| August 8, 1899 | 140.4 |
| September 13, 1928 | 138.1 |
| August 4, 1945 | 135.5 |
| September 23, 1952 | 136.1 |
| September 5-6, 1954 | 135.8 |
| March 6, 1958 | 132.8 |
| December 3-4, 1960 | 136.4 |
| May 17-18, 1963 | 134.8 |
| July 30, 1963 | 135.1 |
| November 27, 1968 | 129.9 |
| September 16, 1975 | 141.0 |

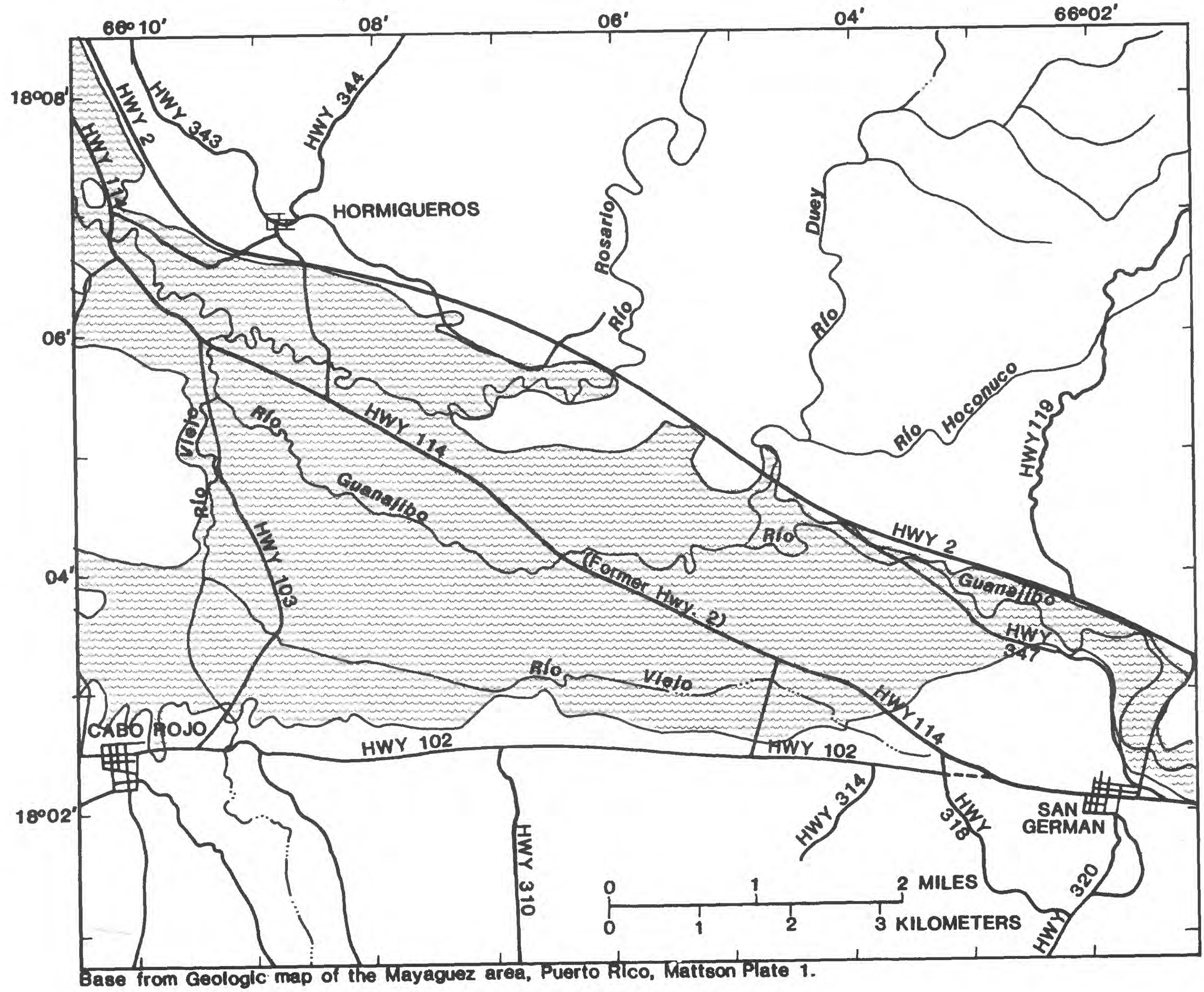



Figure 3.2-1 Approximate area inundated in the lower Rio Guanajibo Valley during the September 16, 1975 flood.

### 3.3 Flow Duration

## STREAMFLOW AT RIO GUANAJIBO NEAR HORMIGUEROS EXCEEDS 14 CUBIC FEET PER SECOND 90 PERCENT OF THE TIME

**Monthly, the 90-percent duration at Río Guanajibo ranges from 10 to 115 cubic feet per second.**

The streamflow at a given point in a basin is an integration of the effects of climate, topography, and geology. Streamflow provides a distribution of runoff in time and magnitude. This distribution can be expressed by means of a flow duration curve. The duration curve is a cumulative frequency curve that indicates the percentage of the time that a particular parameter (in this case, streamflow) has been equaled or exceeded. The curve shows no chronological order and applies only to the period of record for which the data was collected. Flow duration data can be used for comparing flow characteristics of streams. The slope of the curve is a measure of the variability of flow. A steep slope indicates highly variable flow, where as a flat slope indicates more sustained flow possibly from ground and surface-water storage.

A flow duration curve for a particular station is normally based on mean daily discharges for period of record. This curve, referred to as the "period of record curve", provides no insight into seasonal effects on streamflow nor basin changes such as flow regulation. Partial-record curves can be derived to study regulation effects. In this type of analysis, the periods before and after regulation are studied independently. The seasonal variation of streamflow can be studied from partial monthly curves, in which the data for individual months for all the years of record are analyzed.

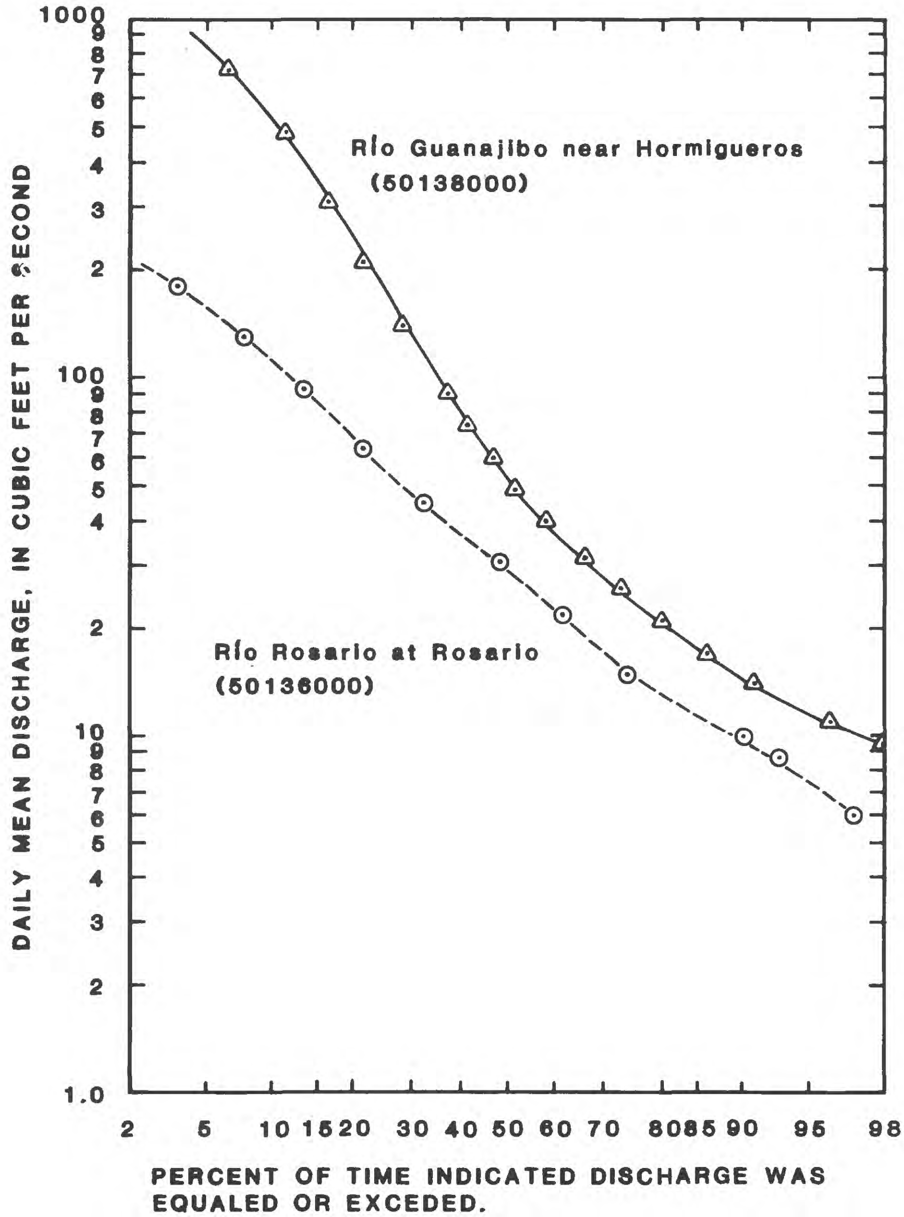



Figure 3.3-1 Flow duration curves for Río Rosario at Rosario and Río Guanajibo near Hormigueros.

## STREAMFLOW AT RIO GUANAJIBO NEAR HORMIGUEROS EXCEEDS 14 CUBIC FEET PER SECOND 90 PERCENT OF THE TIME (Continued)

Streamflow at the Río Rosario at Rosario and Río Guanajibo near Hormigueros are fairly well sustained. At Río Rosario, a mean daily discharge of 9.5 $ft^3/s$ is exceeded 90 percent of the time (fig. 3.3-1). However, on a monthly basis, the 90-percent duration ranges varying from 6.0 $ft^3/s$ in May, to about 40 $ft^3/s$ in October (table 3.3-1).

At Río Guanajibo near Hormigueros a mean-daily discharge of 14 $ft^3/s$ is exceeded 90 percent of the time (fig. 3.3-1). On a monthly basis, the 90-percent duration ranges from 10 $ft^3/s$ in June to about 115 $ft^3/s$ in October and November (table 3.3-2). The wide variation in the duration of monthly-streamflow is due to the marked seasonal fluctuations in precipitation and runoff.

Planning the development and management of the surface-water resources in the Guanajibo Valley will require careful considerations of the flow variability. The seasonal fluctuations in flow, as indicated by the monthly flow-duration data, should be carefully considered in any projected development.

Table 3.3-1 Flow duration at Río Rosario at Rosario

| FLOW, IN CUBIC FEET PER SECOND >= | * PERCENT OF TIME 1961-65, 75-78 | PERCENT OF TIME FLOW WAS EQUALED OR EXCEEDED BY MONTHS, 1961-65, 75-78 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC |
| 0.0 | | | | | | | 100 | | | | | | |
| 2.9 | 100 | | | | | | 98 | | | | | | |
| 4.2 | 99 | | | 100 | 100 | 100 | 95 | | | | | | |
| 6.0 | 97 | 100 | 100 | 94 | 92 | 91 | 92 | | | | | | |
| 8.6 | 93 | 97 | 81 | 80 | 85 | 86 | 87 | 100 | | | | | |
| 10 | 90 | 91 | 78 | 40 | 67 | 73 | 84 | 97 | 100 | | | | 100 |
| 15 | 74 | 90 66 | 52 | 22 | 55 | 58 | 69 | 90 | 95 | 100 | | 100 | 90 |
| 22 | 62 | 50 35 | 18 | 9.7 | 45 | 47 | 55 | 78 | 91 | 97 | 100 | 96 | 71 |
| 31 | 48 | 13 | 5.3 | 7.3 | 25 | 38 | 38 | 58 | 75 | 89 | 95 | 85 | 53 |
| 45 | 32 | 5.6 | 2.2 | 5.2 | 15 | 27 | 17 | 35 | 55 | 72 | 82 | 60 | 21 |
| 64 | 21 | 3.2 | 0.4 | 4.4 | 8.3 | 19 | 11 | 20 | 44 | 50 | 57 | 40 | 8.6 |
| 93 | 13 | 1.6 | | 2.0 | 6.7 | 9.1 | 7.7 | 11 | 30 | 30 | 34 | 24 | 4.7 |
| 130 | 7.4 | 0.4 | | 1.6 | 4.6 | 5.3 | 3.7 | 5.8 | 18 | 20 | 22 | 10 | 3.2 |
| 190 | 3.6 | | | 0.8 | 1.6 | 3.3 | 1.6 | 2.5 | 9.0 | 8.3 | 13 | 5.9 | 1.0 |
| 280 | 1.5 | | | | 0.4 | 1.5 | 1.0 | 0.9 | 5.8 | 3.6 | 4.9 | 1.8 | 0.3 |
| 400 | 0.8 | | | | | 0.7 | 0.3 | 0.3 | 2.5 | 2.3 | 3.1 | 0.3 | 0.3 |
| 580 | 0.3 | | | | | 0.3 | 0.3 | 0.3 | | 1.6 | 0.7 | | |
| 830 | 0.1 | | | | | | | | | 1.0 | | | |

* FLOW WAS EQUALED OR EXCEEDED IN PERIOD OF RECORD
(90 AND 50 PERCENT DURATIONS INDICATED BY LINES ON MONTHLY DATA).

Table 3.3-2 Flow duration at Río Guanajibo near Hormigueros.

| FLOW, IN CUBIC FEET PER SECOND >= | * PERCENT OF TIME 1973-78 | PERCENT OF TIME FLOW WAS EQUALED OR EXCEEDED BY MONTHS, 1973-78 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC |
| 0.0 | | | | | | | | | | | | | |
| 5.0 | 100 | | | 100 | 100 | 100 | 100 | 100 | | | | | |
| 9.3 | 98 | 100 | | 97 | 97 | 94 | 91 | 97 | | 100 | | | |
| 11 | 96 | 96 | 100 | 91 | 94 | 93 | 84 | 97 | 100 | 99 | | | |
| 14 | 91 | 90-90 | 88 | 84 | 82 | 82 | 77 | 95 | 99 | 99 | | | |
| 17 | 86 | 86 | 81 | 78 | 78 | 69 | 70 | 83 | 97 | 99 | | | |
| 21 | 80 | 81 | 76 | 66 | 64 | 54 | 60 | 72 | 92 | 99 | | | |
| 26 | 73 | 73 | 67 | 55 | 53 | 44 | 47 | 65 | 90 | 99 | | | 100 |
| 32 | 66 | 52 | 54 | 48 | 39 | 31 | 37 | 61 | 87 | 99 | | | 98 90 |
| 40 | 58 | 50 45 | 40 | 34 | 25 | 20 | 32 | 53 | 82 | 99 | | | 81 |
| 49 | 51 | 30 | 27 | 18 | 20 | 14 | 28 | 48 | 79 | 99 | | 100 | 70 |
| 60 | 46 | 23 | 17 | 9.1 | 15 | 11 | 22 | 42 | 76 | 98 | 100 | 99 | 62 |
| 74 | 41 | | 12 | 5.9 | 13 | 9.7 | 18 | 32 | 67 | 94 | 98 | 95 | 55 |
| 91 | 37 | 7.6 | 8.9 | 3.8 | 11 | 7.0 | 14 | 26 | 63 | 89 | 93 | 95 | 50 |
| 140 | 28 | | 6.5 | 0.5 | 6.7 | 3.1 | 7.2 | 16 | 50 | 71 | 79 | 83 | 32 |
| 210 | 21 | | 3.6 | | 4.4 | 2.2 | 3.3 | 7.5 | 38 | 51 | 64 | 71 | 24 |
| 310 | 16 | | 1.2 | | 2.6 | 1.6 | 0.6 | 3.2 | 23 | 41 | 46 | 64 | 17 |
| 480 | 11 | | 0.6 | | | 1.1 | | 1.1 | 11 | 30 | 36 | 50 | 8.4 |
| 720 | 6.2 | | | | | | | 0.5 | 5.3 | 17 | 24 | 29 | 4.5 |
| 1100 | 2.6 | | | | | | | | | 5.5 | 7.7 | 21 | 1.2 |
| 1600 | 1.0 | | | | | | | | | 2.7 | 0.5 | 11 | |
| 2500 | 0.4 | | | | | | | | | | | 4.6 | |

* FLOW WAS EQUALED OR EXCEEDED IN PERIOD OF RECORD
(90 AND 50 PERCENT DURATIONS INDICATED BY LINES ON MONTHLY DATA).

## 3.4 Minimum Flows

### 3.4.1 Lower Río Guanajibo

**MONTHLY MINIMUM FLOWS AT RIO GUANAJIBO NEAR HORMIGUEROS SITE RANGE FROM 7.8 TO 58 CUBIC FEET PER SECOND**

**A statistical technique was used to determine frequency curves of the 7-day monthly minimum flows at Río Guanajibo near Hormigueros.**

Minimum flows are an important factor in water-resources planning and management. The 7-day, 10-year minimum flow of a stream is widely used in the design of water works, effluent discharge permits, waste allocation and dilution, and the design of irrigation systems. Normally, the 7-day, 10-year minimum flow at a stream site is computed from daily-discharge records as described by Cobb (1978). A minimum of 10 years of continuous records are required for a reliable computation, but estimates can be made using shorter periods of record.

Streamflow records in the Guanajibo Valley include only 6 years of continuous data (1973-78). However, monthly instantaneous measurements at Río Guanajibo near Hormigueros (station 50138000) are available from 1959-78. The instantaneous measurements and the continuous record were used to develop frequency curves of the 7-day minimum discharge for each month. The technique used for the computations included the following steps:

1. The instantaneous measurements for the 1973-78 continuous record period were plotted on mean daily discharge hydrographs.

2. The 7-day minimum flow period was determined for each month of the 1973-78 records.

3. A correlation was developed between the estimated 7-day monthly minimums and the instantaneous measurements (fig. 3.4.1-1).

4. The correlation was used to estimate the 1959-78, 7-day monthly minimums from the instantaneous monthly discharges.

5. Frequency curves of the 7-day minimum flows were developed for each month of the year (fig. 3.4.1-2).

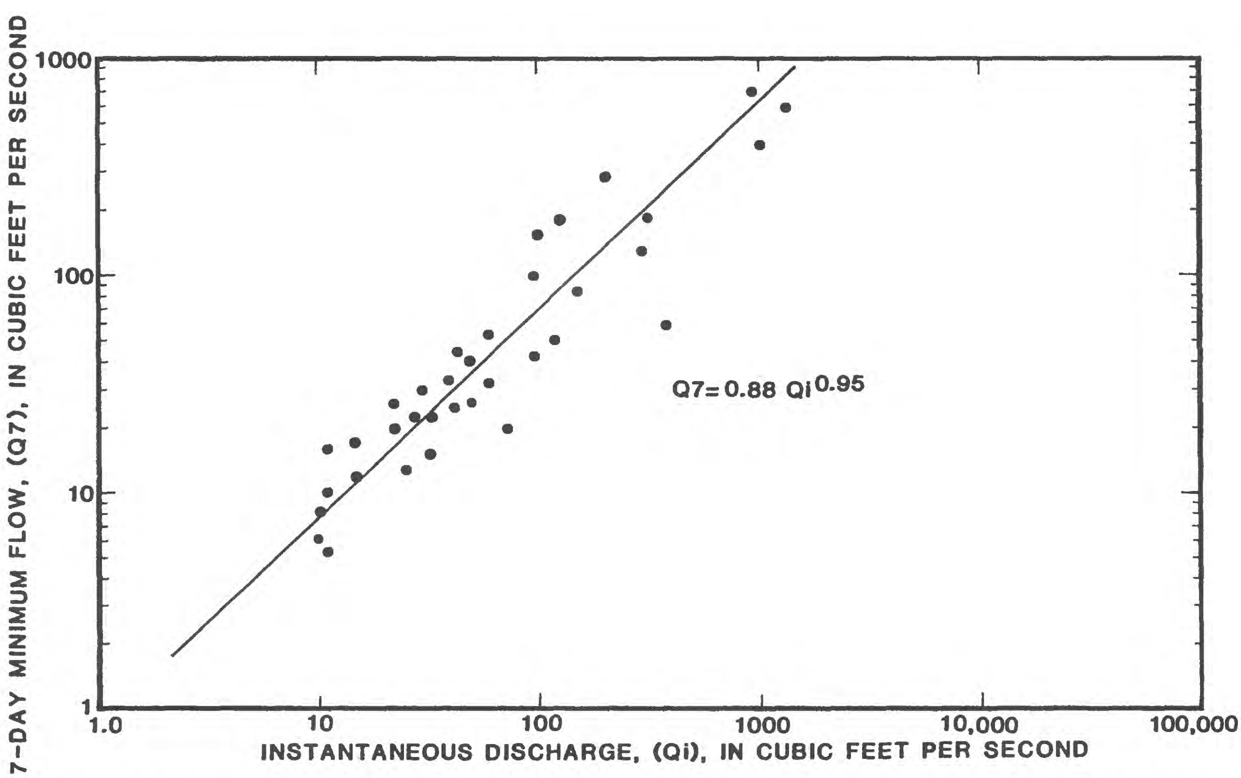



Figure 3.4.1-1 Correlation between 7-day minimum flows and instantaneous discharge at Río Guanajibo near Hormigueros.

Table 3.4.1-1 Minimum flows for Río Guanajibo near Hormigueros (50138000), 1973-78.

| | LOWEST MEAN DAILY DISCHARGE FOR THE INDICATED NUMBER OF CONSECUTIVE DAYS, IN CUBIC FEET PER SECOND | | | | |
|---|---|---|---|---|---|
| MONTH | 1 | 3 | 7 | 14 | 30 |
| JAN | 10 | 10 | 10 | 11 | 14 |
| FEB | 11 | 11 | 12 | 13 | — |
| MAR | 8.1 | 8.6 | 9.2 | 10 | 11 |
| APR | 7.7 | 7.9 | 9.6 | 12 | 16 |
| MAY | 5.4 | 5.6 | 6.2 | 7.1 | 13 |
| JUNE | 5.0 | 5.3 | 5.5 | 6.1 | 9.2 |
| JULY | 7.0 | 8.5 | 10 | 16 | 26 |
| AUG | 10 | 14 | 16 | 23 | 42 |
| SEPT | 10 | 65 | 68 | 78 | 145 |
| OCT | 64 | 67 | 85 | 99 | 231 |
| NOV | 54 | 57 | 63 | 100 | 189 |
| DEC | 30 | 30 | 33 | 35 | 44 |

## MONTHLY MINIMUM FLOWS AT RIO GUANAJIBO NEAR HORMIGUEROS SITE RANGE FROM 7.8 TO 58 CUBIC FEET PER SECOND (Continued)

The 7-day, 10-year monthly minimum flows are represented by the 90 percent probability of being less than in fig. 3.4.1-2. These range from 7.8 $ft^3/s$ during March to 58 $ft^3/s$ during October. Probabilities of being less than 5 to 95 percent are also shown in figure 3.4.1-2. For example, the 7-day minimum flows at the 50 percent probability range from 17 $ft^3/s$ in May to 112 $ft^3/s$ in October.

Minimum flows during different periods of consecutive days are also an important parameter in water-resources planning. Lowest mean daily discharges for 1, 3, 7, 14 and 30 consecutive days for Río Rosario at Rosario and Río Guanajibo near Hormigueros are shown in tables 3.4.1-1 and 3.4.1-2. The data in the tables and in figure 3.4.1-2 can be used to estimate critical periods of water availability at Río Rosario and Río Guanajibo.

**Table 3.4.1-2 Minimum flows for Río Rosario at Rosario (50136000), 1961-65 and 1976-78.**

| | LOWEST MEAN DAILY DISCHARGE FOR THE INDICATED NUMBER OF CONSECUTIVE DAYS, IN CUBIC FEET PER SECOND | | | | |
|---|---|---|---|---|---|
| MONTH | 1 | 3 | 7 | 14 | 30 |
| JAN | 8.2 | 8.2 | 8.3 | 9.3 | 11 |
| FEB | 6.1 | 6.2 | 6.4 | 6.6 | — |
| MAR | 5.2 | 5.5 | 5.8 | 5.9 | 6.2 |
| APR | 4.6 | 4.7 | 4.9 | 6.4 | 6.9 |
| MAY | 4.3 | 4.4 | 4.5 | 4.7 | 6.3 |
| JUNE | 2.4 | 2.6 | 2.7 | 2.9 | 4.5 |
| JULY | 8.5 | 8.9 | 10 | 11 | 16 |
| AUG | 10 | 11 | 13 | 16 | 21 |
| SEPT | 13 | 18 | 21 | 27 | 46 |
| OCT | 22 | 24 | 28 | 38 | 46 |
| NOV | 18 | 19 | 20 | 21 | 28 |
| DEC | 11 | 11 | 12 | 12 | 14 |

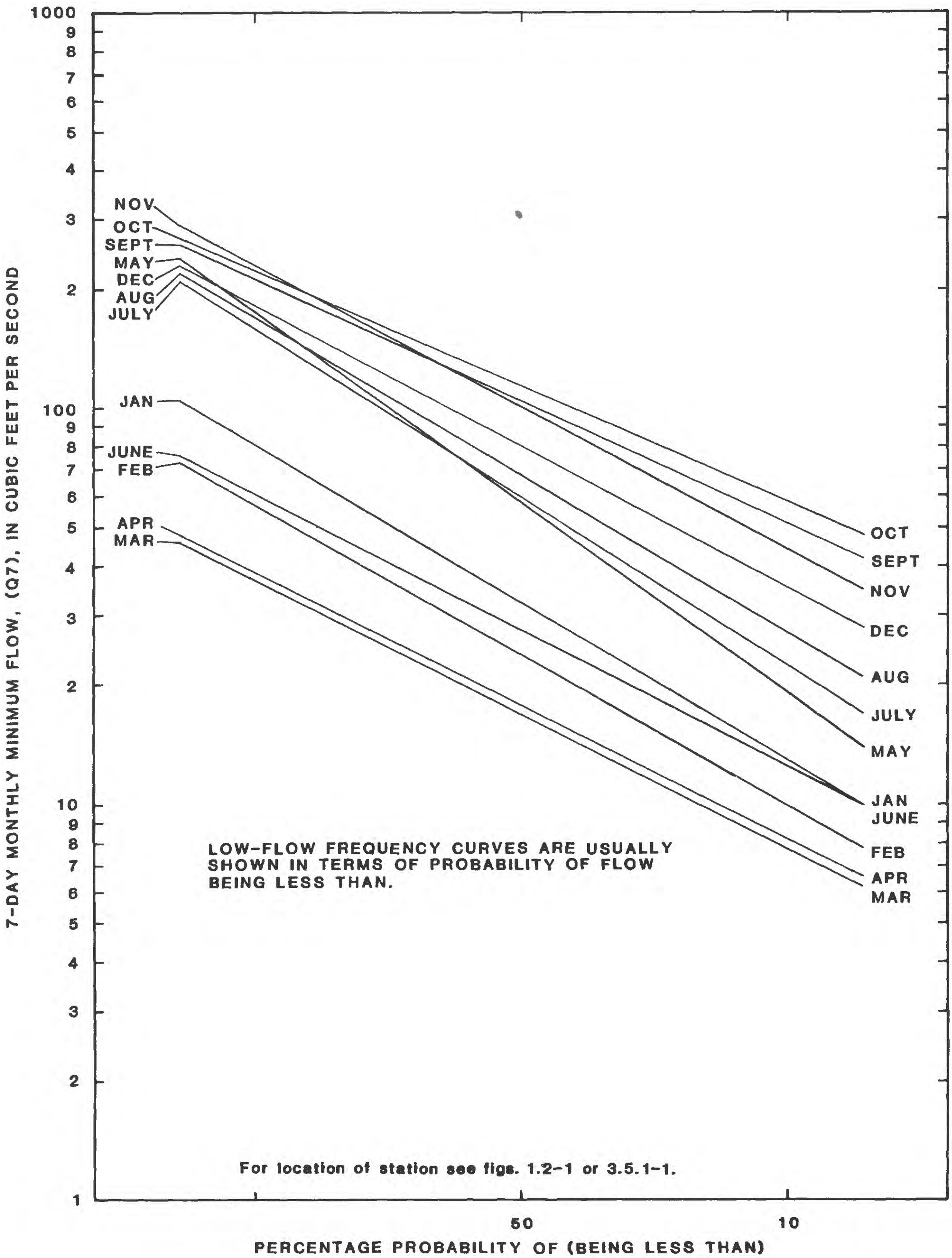



**Figure 3.4.1-2 Generalized frequency curves of 7-day minimum flows at Río Guanajibo near Hormigueros.**

### 3.4.2 Central Río Guanajibo Valley

## 7-DAY, 10-YEAR MONTHLY MINIMUM FLOWS AT RIO GUANAJIBO AT HIGHWAY 114 ARE AS LOW AS 1.7 CUBIC FEET PER SECOND

**Minimum flows at Río Guanajibo at Highway 114 were estimated from downstream records and drainage area adjustments. The 7-day, 10-year monthly minimums range from 1.7 to 33 cubic feet per second.**

Most of the agricultural land in the Guanajibo valley is upstream from the Hormigueros gaging station. As streamflow records at the Hormigueros site are representative of the flow leaving the valley, estimates of the amount of water available for irrigation must be adjusted to reflect flows in the central part of the Guanajibo valley.

Monthly minimum flows at Río Guanajibo at Highway 114 upstream from Río Rosario (station 1351) were estimated from downstream records and drainage area adjustments as follows:

1. Río Rosario mean-daily flows were estimated at the junction with Río Guanajibo. A drainage area ratio was used.

2. Percentage flow contribution of Río Rosario to Río Guanajibo was determined. A comparison of mean-daily flows at both sites was made during the period of occurrence of the 7-day minimum flow at Río Guanajibo near Hormigueros station (50138000).

3. Percentage mean-daily flow contribution was determined for Río Guanajibo upstream from junction. The percentage mean-daily flow contribution of Río Rosario was subtracted from 100.

4. The frequency distribution of the 7-day minimum daily-mean flows for each month at Río Guanajibo at Highway 114 were determined (fig. 3.4.2-1). The upper and lower values of each monthly frequency distribution at the gaging station (fig. 3.4.1-2) were adjusted. Reductions for the ratio of flow contribution and drainage area were applied.

The 7-day monthly minimum flows at a 10 percent probability of being less than at Highway 114 range from 1.7 $ft^3/s$ in March to 33 $ft^3/s$ during October. During the dry season, surface water supplies are very limited in the Central Guanajibo valley.

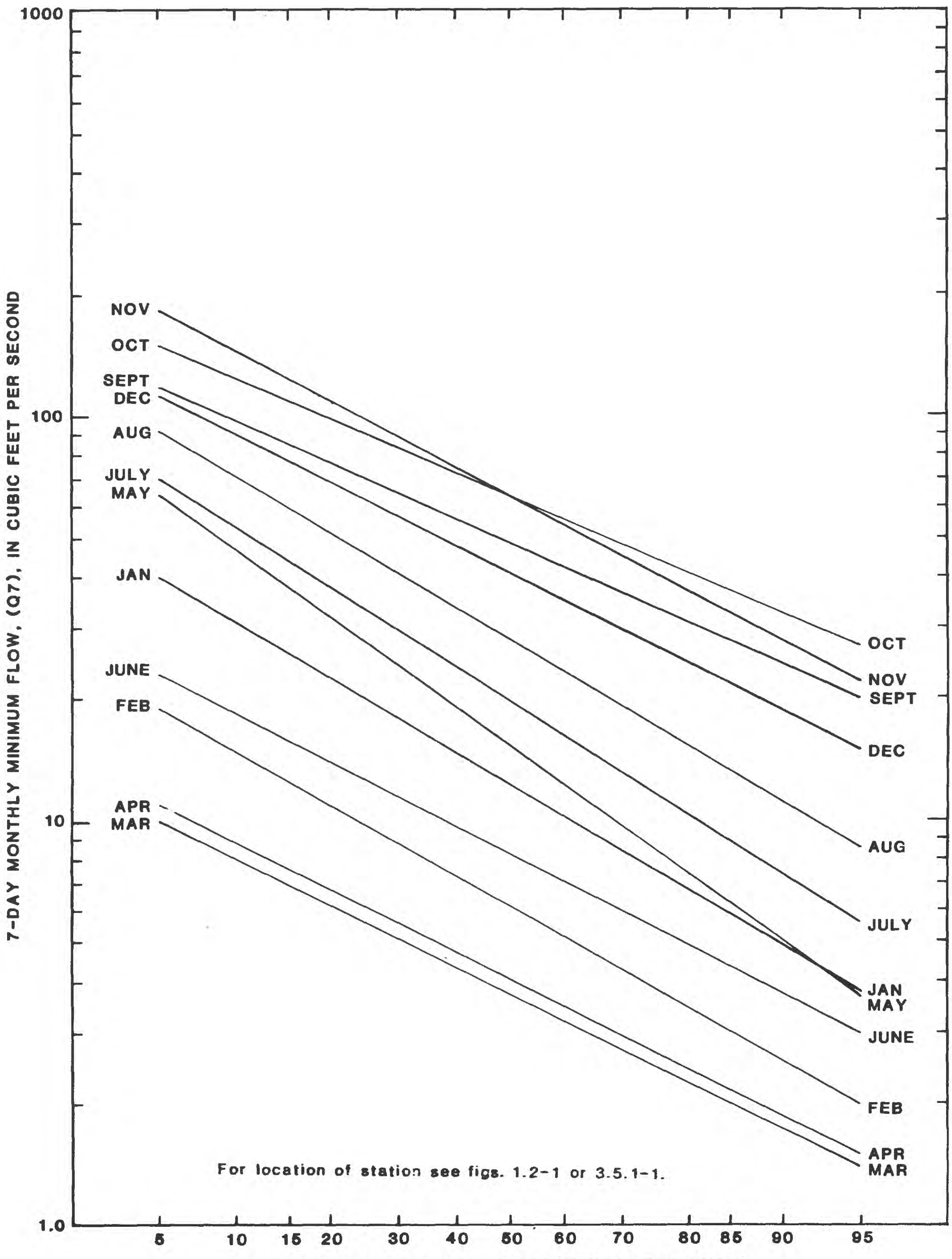



Figure 3.4.2-1 Generalized frequency curves of 7-day monthly minimum flows at Río Guanajibo at Hwy. 114 bridge near San Germán.

## 3.0 SURFACE WATER (Continued)

### 3.5 Water Quality

#### 3.5.1 Chemical and Bacteriological Characteristics

**SURFACE WATERS ARE SUITABLE FOR MOST USES**

**Calcium and bicarbonate are the principal ions. High concentrations of fecal coliform bacteria occur near Hormigueros.**

The chemical quality of the surface waters in the Central Guanajibo Valley makes them suitable for most industrial, domestic, and agricultural uses. Data from streamflow stations at Río Guanajibo near Hormigueros, Río Rosario at Rosario, and Río Guanajibo at San Germán (Figure 3.5.1-1) and (tables 3.5.1-1 to 3.5.1-3), show that the waters are of the calcium-magnesium bicarbonate types and moderately soft. Dissolved solids are relatively low. Analyses of trace elements previously published (U.S. Geological Survey, 1981) do not indicate any significant concentrations of iron, manganese, or any toxic trace metals.

The sanitary quality of the waters in Río Guanajibo indicate that sewage is normally discharged into the stream. Concentration of fecal-coliform bacteria increase markedly between the San Germán and Hormigueros sites (tables 3.5.1-3 and 3.5.1-1). The presence of feces in the stream should be studied further in conjunction with studies of the bilharzia parasite. In agricultural areas, where workers may be in contact with irrigation waters contaminated with the parasite, special precautions are needed to limit exposure.

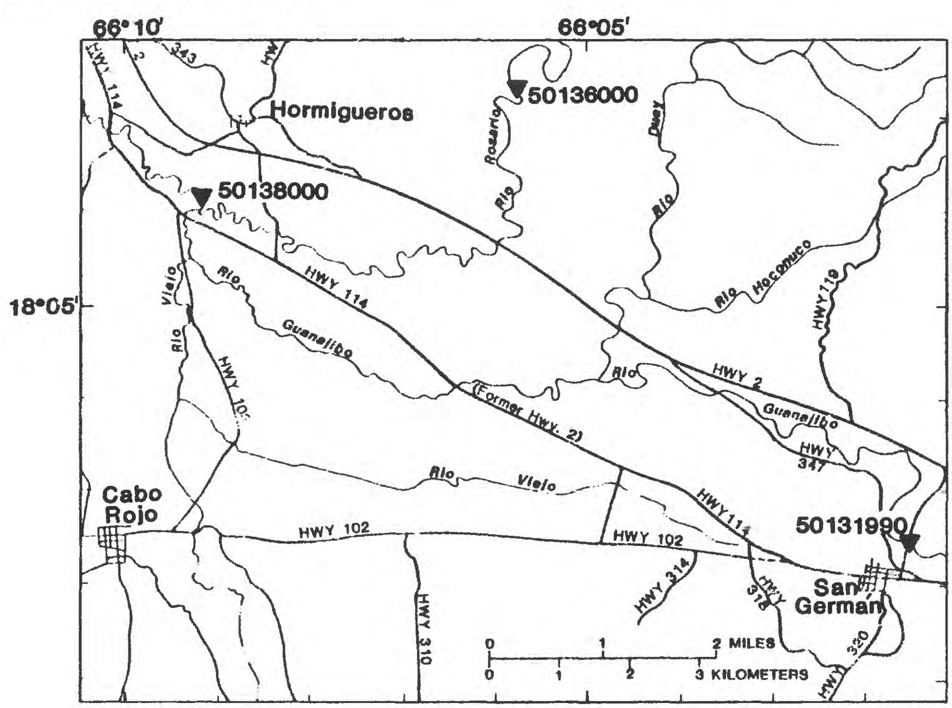



**Figure 3.5.1-1 Water-quality sampling sites.**

Table 3.5.1-1 Selected water-quality characteristics at Río Guanajibo near Hormigueros (50138000).

| PARAMETER | NUMBER OF SAMPLES | MINIMUM | MAXIMUM | MEAN |
|---|---|---|---|---|
| PH | 184 | 6.1 | 8.6 | — |
| SPECIFIC CONDUCTANCE | 184 | 112 | 698 | 400 |
| TEMPERATURE, °C | 190 | 20.5 | 32 | 26 |
| SILICA | 170 | 17 | 46 | 29 |
| CALCIUM | 134 | 10 | 47 | 28 |
| MAGNESIUM | 134 | 8 | 39 | 28 |
| SODIUM | 159 | 0.7 | 36 | 13 |
| BICARBONATE | 179 | 46 | 337 | 218 |
| SULFATE | 170 | 0.8 | 51 | 13 |
| CHLORIDE | 172 | 6.5 | 38 | 14 |
| FLUORIDE | 158 | 0 | 1 | 0.1 |
| DISSOLVED SOLIDS, RESIDUE AT 180°C | 55 | 170 | 331 | 238 |
| TOTAL PHOPHORUS AS PHOSPHORUS | 48 | 0.08 | 2.1 | 0.63 |
| TOTAL COLIFORMS | 48 | 13.000 | 11,600,000 | 3,331,000 |
| FECAL COLIFORMS | 55 | 370 | 2,600,000 | 171,000 |
| FECAL STREPTOCOCCI | 49 | 300 | 700,000 | 59,000 |
| IRON ($Fe^{++}$,$Fe^{+++}$) | 27 | 0 | 1700 | 127 |

Table 3.5.1-2 Selected water-quality characteristics at Río Rosario at Rosario (50136000).

| PARAMETER | NUMBER OF SAMPLES | MINIMUM | MAXIMUM | MEAN |
|---|---|---|---|---|
| PH | 17 | 7.4 | 8.2 | — |
| SPECIFIC CONDUCTANCE | 17 | 224 | 276 | 259 |
| TEMPERATURE,°C | 22 | 20.0 | 30.0 | 23.5 |
| SILICA | 17 | 24 | 30 | 27 |
| CALCIUM | 17 | 19 | 27 | 23 |
| MAGNECIUM | 17 | 14 | 21 | 17 |
| SODIUM | 16 | 0.9 | 13 | 5.8 |
| BICARBONATE | 17 | 126 | 168 | 154 |
| SULFATE | 16 | 0.0 | 16 | 3.7 |
| CHLORIDE | 17 | 5.0 | 7.5 | 6.0 |
| FLUORIDE | 17 | 0.0 | 0.20 | 0.05 |
| DISOLVED SOLIDS, RESIDUE AT 180°C | 17 | 0.0 | 20 | 1.0 |
| IRON | 7 | 132 | 174 | 157 |

Table 3.5.1-3 Selected water-quality Characteristics at Río Guanajibo at Highway 119 at San Germán (50131990).

| PARAMETER | NUMBER OF SAMPLES | MINIMUM | MAXIMUM | MEAN |
|---|---|---|---|---|
| PH | 28 | 7.7 | 8.7 | — |
| SPECIFIC CONDUCTANCE | 28 | 420 | 680 | 517 |
| TEMPERATURE,°C | 28 | 26.0 | 33.0 | 27.0 |
| SILICA | 28 | 30 | 38 | 35 |
| CALCIUM | 7 | 18 | 26 | 23 |
| MAGNECIUM | 7 | 42 | 53 | 49 |
| SODIUM | 28 | 10 | 80 | 17 |
| BICARBONATE | 28 | 234 | 332 | 290 |
| SULFATE | 28 | 13 | 38 | 25 |
| CHLORIDE | 28 | 12 | 120 | 25 |
| FLUORIDE | 22 | 0.1 | 0.3 | 0.1 |
| DISSOLVED SOLIDS, RESIDUE AT 180°C | 5 | 278 | 327 | 311 |
| TOTAL PHOSPHORUS AS PHOSPHORUS | 28 | 0.04 | 0.37 | 0.12 |
| TOTAL COLIFOLMRS | 26 | 300 | 670,000 | 102,000 |
| FECAL COLIFORMS | 7 | 50 | 58,000 | 8900 |
| FECAL STREPTOCOCCI | 7 | 80 | 5500 | 1090 |
| IRON Fe ($Fe^{++}$, $Fe^{+++}$) | 22 | 0 | 910 | 5.5 |

All Values in these tables are in milligrams per liter.
Except ph (Units), Specific conductance (Micromhos per centimeter), and Total coliform, Fecal coliform, and Fecal streptococci bacterias (in colonies per 100 milliliter of sample).

3.0 SURFACE WATER (Continued)

3.5 Water Quality (Continued)

### 3.5.2 Sediment

**LIMITED SEDIMENT DATA AVAILABLE**

**The mean annual suspended-sediment discharge at Río Guanajibo near Hormigueros is about 134,000 tons per year.**

The concentration of suspended sediment affects the suitability of water for domestic, industrial, and agricultural uses. For irrigation, a high suspended-sediment concentration is undesirable, particularly, if the sediment is in the silt-clay particle size-range (less than 0.62 mm).

Sediment data from streams in the Guanajibo valley are very scarce. Miscellaneous suspended-sediment samples have been collected since 1959 at Río Guanajibo near Hormigueros and Río Rosario at Rosario. There are no data on the bedload component of sediment or on the size of the suspended particles. The data collected at Río Rosario are sporadic and inadequate for any significant correlations or estimates.

Data from the samples collected at Río Guanajibo near Hormigueros can be correlated with the instantaneous water discharge (fig. 3.5.2-1). A graphical correlation was developed and used to estimate the mean annual suspended-sediment loads and yields at the site. Techniques described by Miller (1951) were used for the computations. The mean annual suspended-sediment load at the Hormigueros gaging station is about 134,000 tons/year. The suspended-sediment yield at the site is about 1,120 (tons/mi$^2$)/yr.

It is difficult to compare the sediment yield of the Río Guanajibo basin to other sites in Puerto Rico. The only other site on the Island at which long-term suspended-sediment records are available is Río Tanamá near Utuado (50028000). Daily samples are collected at the site and an 11-year average of about 48,000 tons/year has been computed. This is equivalent to a yield of about 2,600 (tons/mi$^2$)/yr, or nearly three-times higher than Río Guanajibo. The Río Tanamá basin has steeper slopes, greater and more intense precipitation, and more agricultural development. Increasing agricultural development in the upper Guanajibo basin should result in higher suspended-sediment yields. Additional data, including particle-size information is needed in the future to determine the possible impact of sediment in irrigation water.

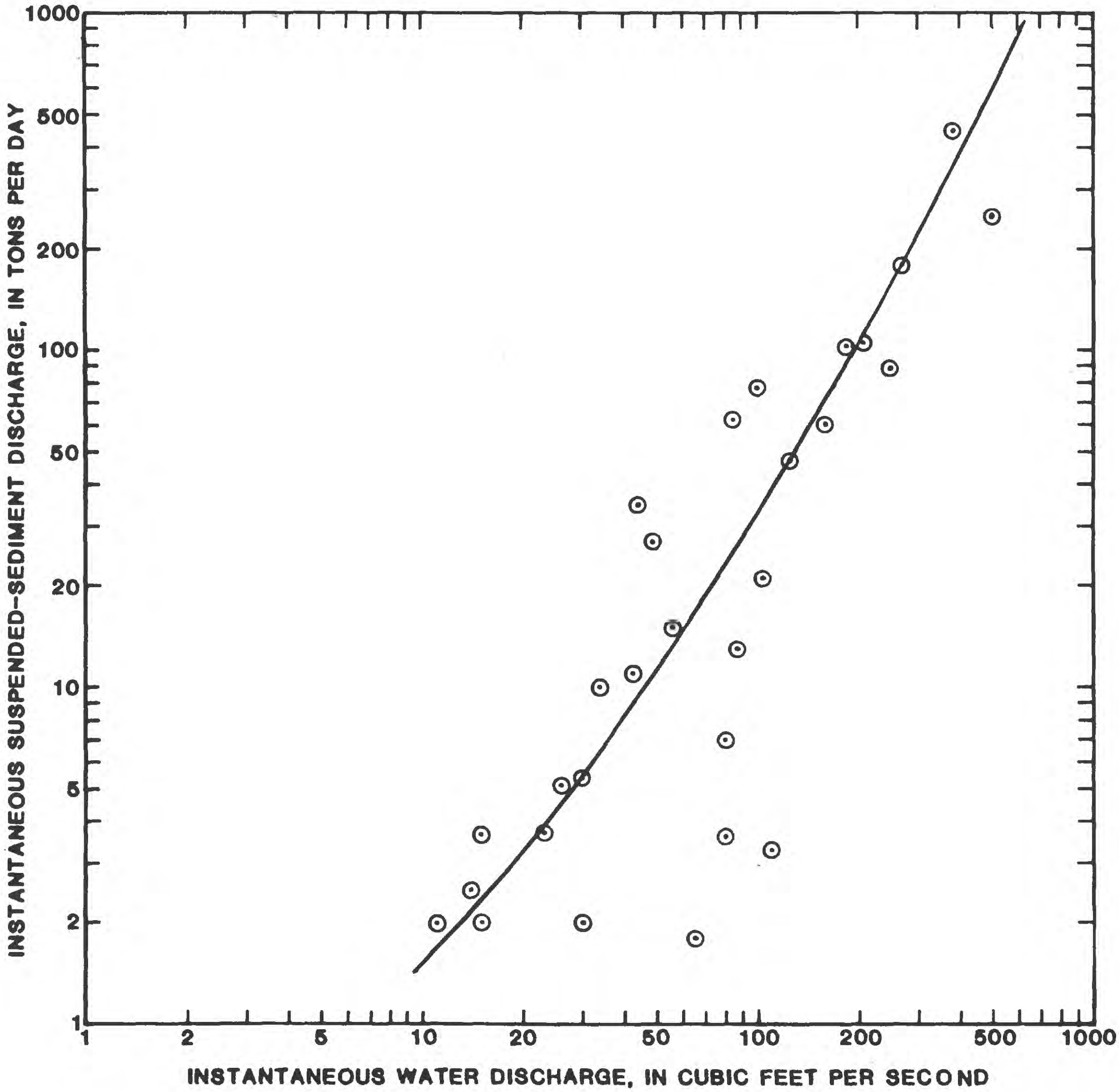



**Figure 3.5.2-1 Graphical correlation between instantaneous water and suspended-sediment discharge at Río Guanajibo near Hormigueros (50138000).**

# 4.0 GROUND WATER

## 4.1 Occurrence and Movement

### FRACTURED ROCKS, LIMESTONE, AND SAND AND GRAVEL DEPOSITS FORM THE PRINCIPAL AQUIFERS

**Water moves through the aquifer from upland areas into the valley and toward the sea.**

Ground water occurs below the valley floor of the study area in fractured and porous limestone and in sand and gravel deposits (fig. 4.1-1). Clay also contains water, but because of its fine-grained nature, it is nearly impermeable and does not readily transmit water. Volcanic and other igneous rocks generally are impermeable, but where these rocks are highly faulted or fractured, they may serve as locally important aquifers. Recharge to the aquifer occurs primarily in the upland areas adjacent to the valley where water as overland flow and streamflow comes in contact with permeable material and infiltrates downward into the aquifer. Rainfall may directly recharge the aquifer in areas where permeable materials extend from the water table to the land surface, but because clay underlies most of the valley floor, most recharge is believed to occur in areas adjacent to the valleys. Water in the aquifer moves down gradient from the higher areas into the valley and then approximately follows the land surface gradient to the coast, where the water discharges to the sea.

Water level measurements from 23 wells were used to construct a water-table contour map of the study area (fig. 4.1-2). In areas where wells are sparse, the water-table gradient was assumed to approximate the land surface gradient. In general, the water-table gradient is about 0.0027 (14 ft/mi). The elevation of the water surface ranges from about 15 ft above mean sea level west of Hormigueros to about 110 ft northwest of San Germán. Depth to water ranges from a few feet or less near streams to about 35 ft at higher elevations around the perimeter of the valley floor.

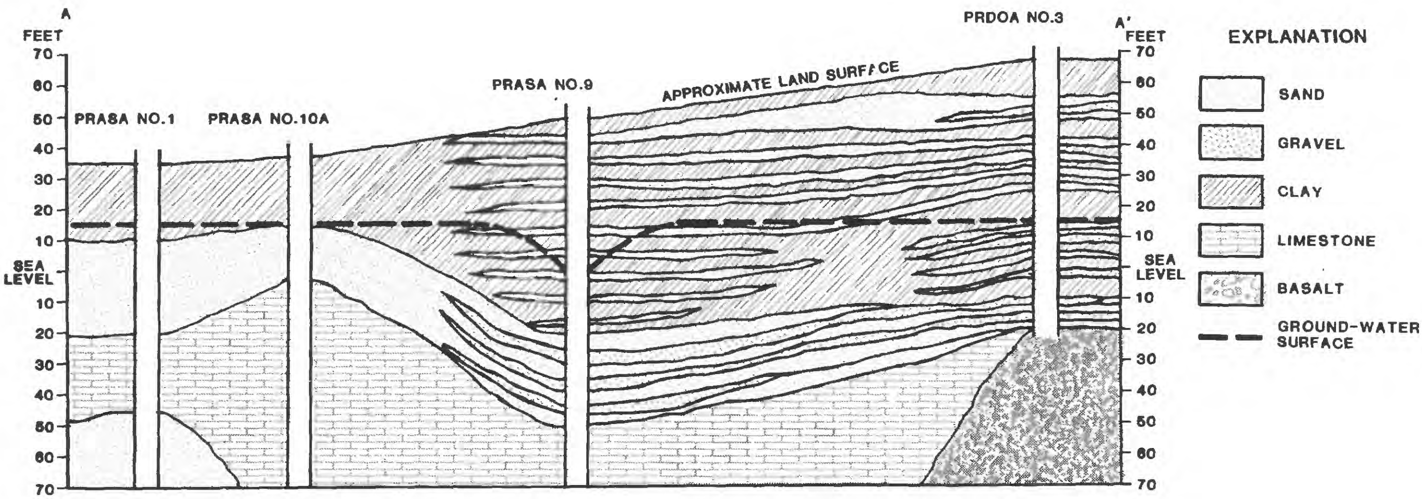
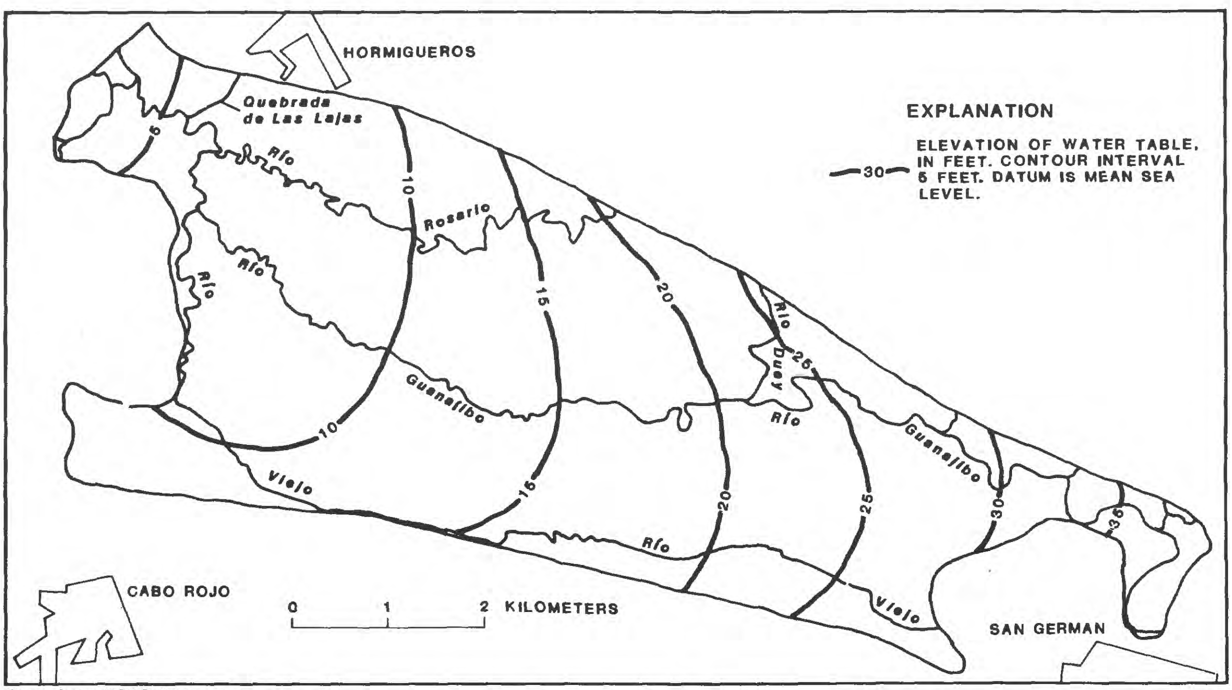



Figure 4.1-1 Generalized occurrence of ground water in the Central Guanajibo Valley.
(See fig. 2.3.2-1 for location of section.)




Base from USGS base map.

Figure 4.1-2 Generalized ground-water elevations in the Central Guanajibo Valley.

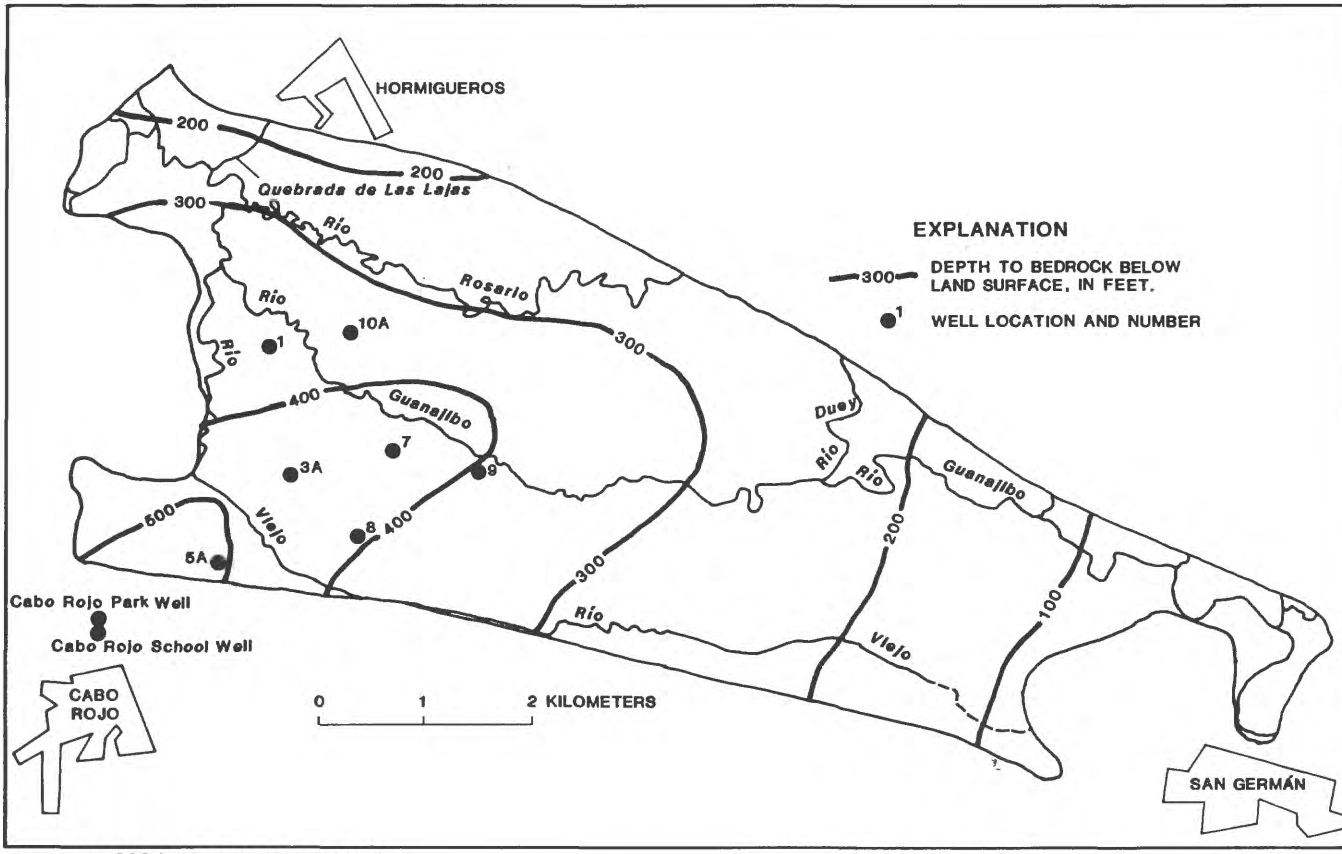
## 4.2 Aquifer Characteristics

### MOST FAVORABLE AQUIFER CHARACTERISTICS ARE IN SOUTHWEST PART OF CENTRAL GUANAJIBO VALLEY

**Specific capacities of well range from 2.4 to 40 (gal/min)/ft, and estimates of transmissivity for the aquifer range from 670 to 11,000 $ft^2/d$.**

The hydrologic characteristics of an aquifer are related directly to the nature and thickness of the water-bearing materials. The most favorable characteristics in the Central Guanajibo Valley coincide with those areas where deposits of permeable limestone, sand, and gravel are thickest. Depth to relatively impermeable bedrock throughout the valley (fig. 4.2-1) was estimated from drillers' logs and from resistivity and seismic profiles. An estimate of the thickness of the aquifer at a given location can be determined by subtracting the depth to water at that location from the depth to bedrock. The nature of the water-bearing rock, including such properties as grain size, degree of sorting, and type and degree of cementing, determine the ability of the aquifer to store and transmit water. The abundance of limestone, sand, and gravel in the west and southwest area of the valley and the relative abundance of clay in the east and north indicate that the hydrologic characteristics of the aquifer are more favorable in the southwest.

Some hydrologic characteristics for the aquifer in the southwest part of the valley can be estimated from well-performance data as reported by drilling reports (table 4.2-1). Maximum test yields at individual wells ranged from 75 to 1,100 gal/min, with specific capacities (discharge per unit drawdown) that ranged from 2.4 to 40 (gal/min)/ft. The hydraulic characteristics, transmissivity and storage coefficient, cannot be computed from the data; however a rough estimate of transmissivity can be made from the specific capacity. The transmissivity of an aquifer refers to the aquifer's capacity to transmit water and is equal to the hydraulic conductivity of the material comprising the aquifer multiplied by the thickness of the aquifer (Heath, 1980, p. 37). The aquifer in the area of the Puerto Rico Aqueduct and Sewer Authority (PRASA) wells is primarily limestone with some sand and gravel, and estimates of the transmissivity of the aquifer in that area range from 670 to 6,000 $ft^2/d$. The principal water-bearing zone in the wells at Cabo Rojo, referred to as "blue rock" by the driller probably is fractured volcanic rock or limestone. The reason for the substantial difference in the performance of the two wells listed in table 4.2-1 is not apparent, but can best be explained by the presence of a higher degree of fracturing at the park well, which would increase the permeability of the rock, the potential well yield, and the transmissivity of the aquifer--11,000 $ft^2/d$ at the park well as compared to 1,600 $ft^2/d$ at the school well.



Base from USGS base map Scale: 1:20,000

Figure 4.2-1 Generalized depth to bedrock in the Central Guanajibo Valley.

Table 4.2-1 Well performance data and estimated aquifer transmissivity values in the Central Guanajibo Valley.

| WELL 1/ ID NO. | DISCHARGE, IN GALLONS PER MINUTE | DRAWDOWN, IN FEET | SPECIFIC CAPACITY, IN GALLONS PER MINUTE PER FOOT | AQUIFER TRANSMISSIVITY, IN FEET SQUARE PER DAY |
|---|---|---|---|---|
| CABO ROJO PARK | 400 | 10.0 | 40 | 11,000 |
| CABO ROJO SCHOOL | 190 | 22.5 | 8.4 | 1600 |
| PRASA NO.1 | 54<br>75 | 6.5<br>31.3 | 8.3<br>2.4 | 670 |
| NO.3A | 260<br>360 | 27.9<br>66.2 | 10.0<br>5.3 | 1700 |
| NO.5A | 410<br>1100 | 11.8<br>59.7 | 34.7<br>18.4 | 6000 |
| NO.7 | 97<br>280 | 16.0<br>57.5 | 6.1<br>4.9 | 1300 |
| NO.8 | 140<br>410 | 10.S<br>72.7 | 13.0<br>5.6 | 2000 |
| NO.9 | 300<br>660 | 13.5<br>45.6 | 22.2<br>14.5 | 5300 |
| NO.10A | 160<br>470 | 11.7<br>40.5 | 15.4<br>11.6 | 2700 |

1/ SEE FIGURE 4.2-1 FOR WELL LOCATIONS.

2/ AQUIFER TRANSMISSIVITY AT INDIVIDUAL WELLS WAS ESTIMATED FROM SPECIFIC CAPACITY.

## 4.0 GROUND WATER (Continued)
### 4.3 Quality of Ground Water

## GROUND WATER IS SUITABLE FOR IRRIGATION

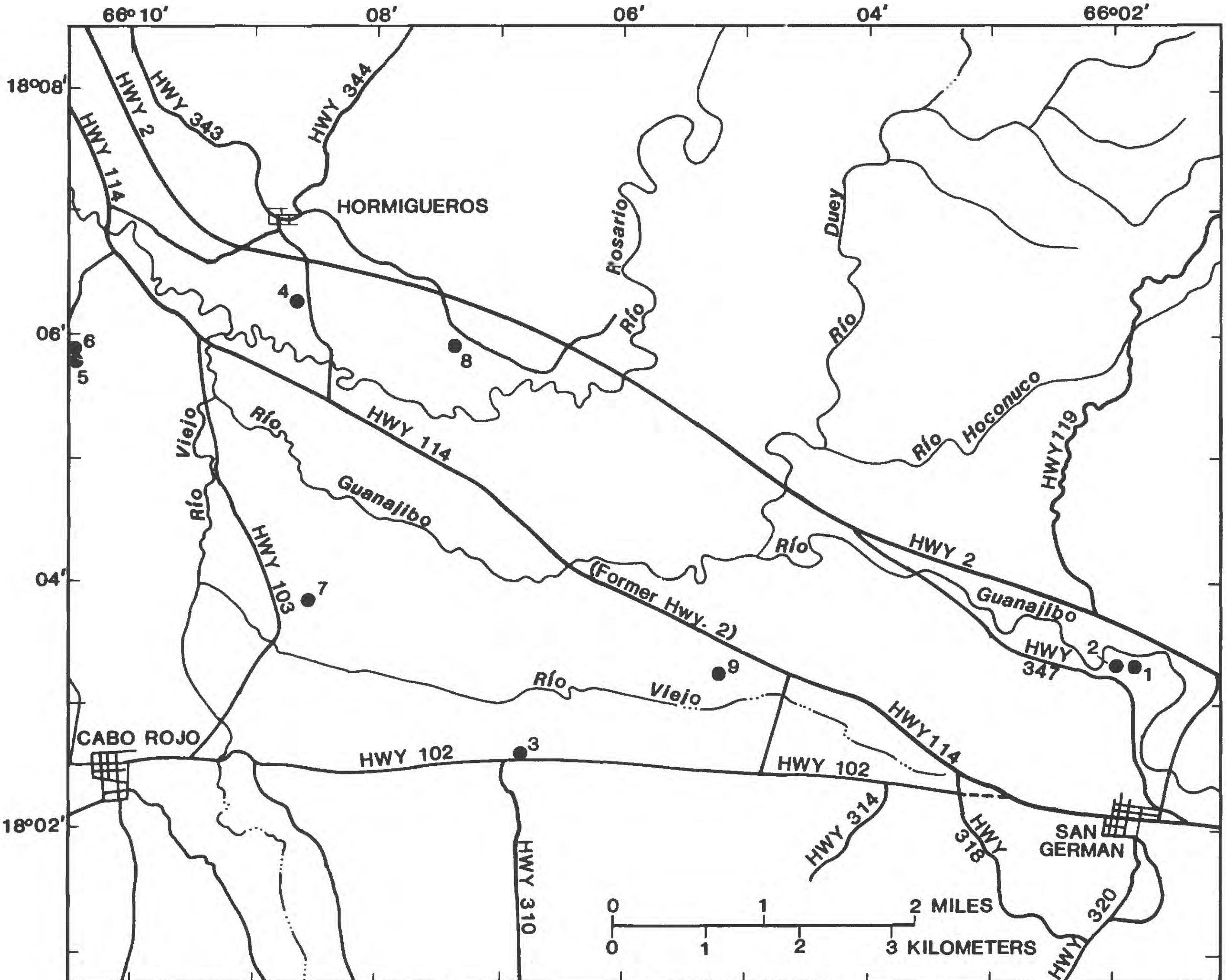
**High sulfate and nitrate concentrations at several wells indicate that additional testing is necessary if water is to be used for domestic supply.**

Calcium, magnesium, and sulfate are the principal ions in ground water in the lower Guanajibo Valley (table 4.3-1). Limited data from 9 wells (fig. 4.3-1) indicate that the water is generally suitable for most purposes including irrigation. There was no evidence of high salinity concentrations. However in 1967, the concentration of nitrate ions in water from well 3 exceeded the recommended standard of 10 mg/L for water supply. The sulfate concentration was also extremely high. In 1980, the sulfate concentration in water from well 2 was also about twice the average for the wells sampled. Both wells (2 and 3) are located downstream from urban areas, suggesting that domestic contamination could be contributing to increase the sulfate and nitrate concentrations in waters from these wells. Additional testing is needed to better characterize the ground waters in the valley.

**Table 4.3-1 Chemical analyses of ground water in the Central Guanajibo Valley.**

| WELL LOCATION NO. | DATE SAMPLED | pH | SPECIFIC CONDUCTANCE | CALCIUM (Ca) | MAGNISIUM (Mg) | SODIUM AND POTASSIUM (Na-K) | BICARBONATE ($HCO_3$) | SULFATE ($SO_4$) | CHLORIDE (Cl) | FIUORIDE (F) | NITRATE ($NO_3$) | PHOSPHATE (P) | HARDNESS AS CaCO3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12-28-61 | 7.6 | — | 24 | 45 | 1.0 | 249 | 16 | 16 | 0.1 | 0.04 | 0.15 | 245 |
| | 06-17-80 | 7.4 | 640 | — | — | — | — | — | 26 | 0.2 | — | — | 410 |
| 2 | 11-9-61 | 7.3 | — | 27 | 44 | 5.0 | 254 | 21 | 21 | 0.2 | 0.6 | 0.2 | 248 |
| | 06-17-60 | 7.6 | 640 | — | — | — | — | 50 | 10 | 0.2 | — | — | 250 |
| 3 | 06-13-67 | 7.9 | 831 | 100 | 37 | | 280 | 133 | 24 | 0.1 | 52 | 0.1 | 400 |
| | 06-17-60 | 7.8 | 690 | — | — | — | — | — | 13 | 0.1 | — | — | 240 |
| 4 | 09-02-59 | 7.5 | — | 127 | 15 | 9.4 | 368 | 22 | 43 | — | 0.9 | — | 380 |
| 5 | 04-26-67 | 7.6 | 692 | 24 | 63 | 26 | 324 | 18 | 34 | 0.2 | 1.5 | 0.2 | 319 |
| 6 | 04-26-67 | 7.6 | 434 | 48 | 1.4 | 20 | 196 | 12 | 33 | 0.2 | — | 0.2 | 178 |
| 7 | — | — | — | — | — | — | 496 | 3.8 | 26 | — | — | 0.2 | — |
| 8 | — | — | — | — | — | — | 304 | 50 | 10 | — | — | 0.2 | — |
| 9 | — | — | — | — | — | — | 292 | 7.6 | 13 | — | — | 0.1 | — |

All results in milligrams per liter, except pH (units) and specific conductance (micromhos per centimeter at 25°C).



Base from Geologic map of the Mayaguez area, Puerto Rico, Mattson Plate 1.

Figure 4.3-1 Water well sampling sites.
(Well numbers are for this report only. Refer to table 4.3-1.)

## 4.4 Areas for Potential Development

### SOUTHWEST PART OF STUDY AREA HAS MOST POTENTIAL FOR FUTURE DEVELOPMENT

**Additional testing and drilling are needed to delineate areas of best potential and to provide for optimal development of the ground-water resources.**

Existing data indicate that the most promising area for ground-water development in the area of this investigation is the already partially developed southwestern part of the valley (fig. 4.4-1). The aquifer in that area consists of thick deposits of porous limestone with some sand and gravel. Test yields reported by the drillers generally were in the average of 280 to 660 gal/min (table 4.2-1), but one well tested at 1,100 gal/min and another at only 54 gal/min. The poor production of the latter well may be explained by its location near the western edge of the valley and so it does not have as thick a limestone sequence as the other wells. Limited well data in the eastern and northern parts of the valley indicate that the aquifer there is composed of clay or sandy clay and gravel, and well yields generally are small. However, the extent of the limestone to the east and north in the study area is not known; consequently an area of unknown potential borders the most favorable area (the southwestern part of the valley). A questionable area is indicated at Cabo Rojo in the extreme southwest, where two wells with dissimilar test performances have been drilled. The yield of the better well was 400 gal/min with a drawdown of 10 ft, and the yield of the other was 190 gal/min with a drawdown of 22 ft. The physical nature of the aquifer is unknown, and the reason for the substantial difference in well performance is conjectural; however, it appears that the Cabo Rojo area should be considered favorable for potential development.

Additional testing and exploratory drilling are needed to establish the areal extent of the potentially favorable area and to evaluate the aquifer at Cabo Rojo. Aquifer testing under controlled conditions at existing and future test wells is needed to determine proper well spacing, optimum well discharge, and the amount of available water in the aquifer. Eventually this will assist in the optimal development of the ground-water resources of the valley.

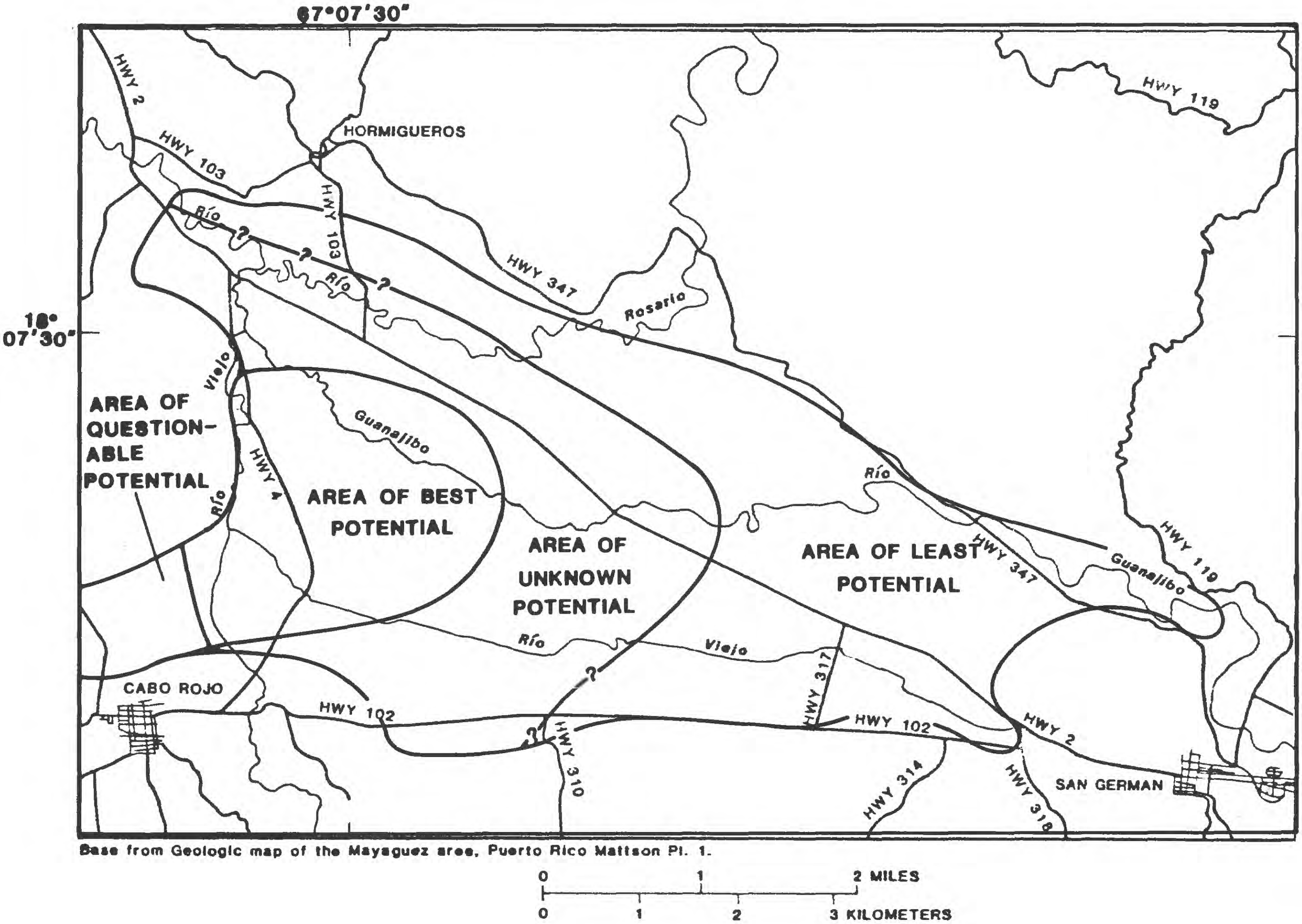



**Figure 4.4-1 Areas of potential ground-water development in the Central Guanajibo Valley.**

## 5.0 CONCLUSIONS

### GROUND WATER CAN BE USED DURING PERIODS OF LOW FLOW TO AUGMENT SURFACE-WATER SUPPLIES

**More testing and exploratory work are needed to accurately assess the aquifer's potential and to plan proper means of development.**

Adequate surface-water supplies of good quality are available for agriculture on an annual basis in the central Guanajibo Valley, but because of seasonal variations in streamflow, the supply is not reliable. The mean-annual discharge of Río Guanajibo near Hormigueros, which, with its tributaries, drains the entire study area, is about 200 $ft^3/s$. Mean-monthly values have ranged from 9.2 to 2,075 $ft^3/s$, and the 7-day, 10-year low flow ranges from 7.8 $ft^3/s$ in March to 58 $ft^3/s$ in October. The dry season generally extends from December or January through April. The valley experiences damaging floods about once every four years, and most of the potential agricultural land on the valley floor is subject to flooding.

Ground water can be used to supplement surface-water supplies during periods of low streamflow. The chemical quality of the ground water is suitable for agriculture, and salt-water intrusion does not appear to pose a problem. The most favorable area for ground-water development apparently is the southwest part of the valley, where test yields of existing wells range between 75 and 1,100 gal/min.

Additional testing is necessary to evaluate the aquifer's potential and to determine the most efficient methods of developing the aquifer. Aquifer tests under controlled conditions are especially needed to evaluate the hydraulic properties of the aquifer, and either test drilling at selected locations or more definitive geophysical exploration is needed to define the northern and eastern extent of the limestone aquifer. The testing and exploration are necessary to evaluate the aquifer in terms of total ground water in storage and ground-water flow into and from the area. The results of the additional work also will assist in the determination of proper methods of developing the aquifer, such as efficient well spacing configurations and optimum yields for wells and pumping centers.

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