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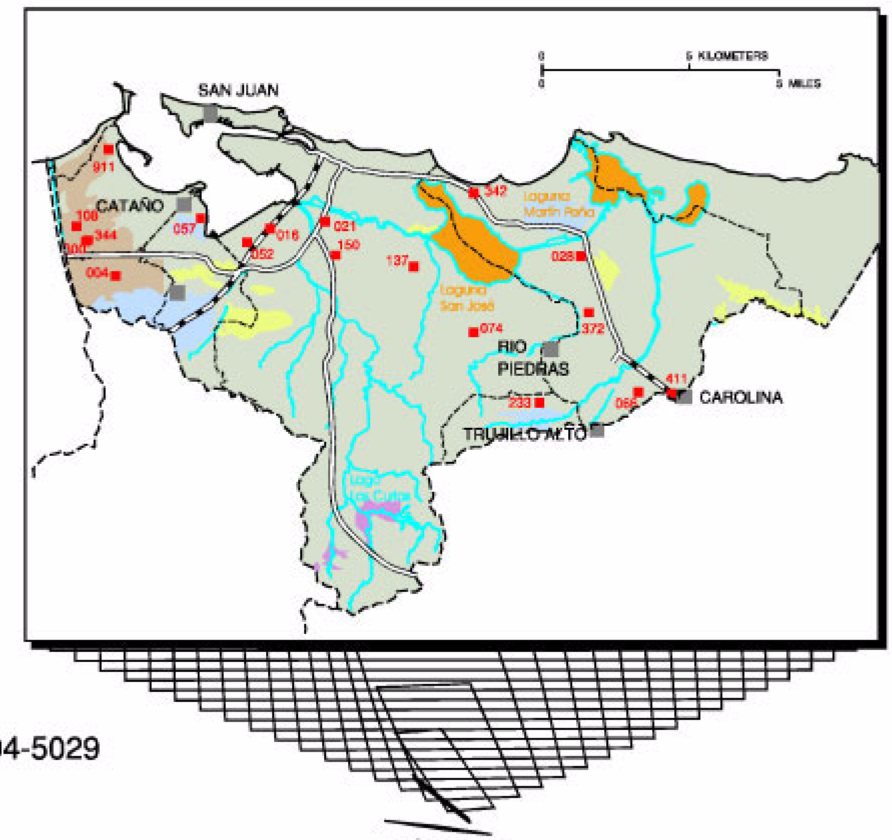
Assessment of Ground-Water Withdrawals at Municipal Industrial Parks in Puerto Rico, 2000



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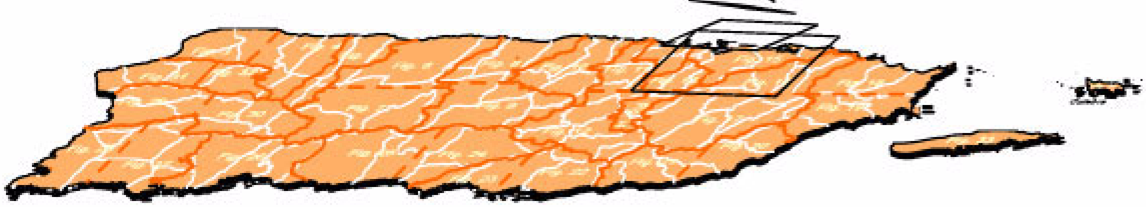

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Prepared in cooperation with the
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY

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By José M. Rodríguez

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Scientific Investigations Report 2004-5029

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Conversion Factors, Datum, and Acronyms

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
foot per year (ft/yr)	0.3048	meter per year (m/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
gallon per day per square mile (gal/d-mi^2)	0.001461	cubic meter per day per square kilometer (m^3/d-km^2)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Specific capacity	
gallon per minute per foot (gal/min-ft)	0.2070	liter per second per meter (L/s-m)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Vertical Datum

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929) - a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called "Sea Level Datum of 1929".

Acronyms used in this report:

GPS	Global Positioning System
NCLA	North Coast Limestone Aquifer
NCLP	North Coast Limestone Province
PRASA	Puerto Rico Aqueduct and Sewer Authority
PRDNER	Puerto Rico Department of Natural and Environmental Resources
PRIDCO	Puerto Rico Industrial Development Company
PWSS	Public Water Supply System
USGS	U.S. Geological Survey

Assessment of Ground-Water Withdrawals at Municipal Industrial Parks in Puerto Rico, 2000

By José M. Rodríguez

Abstract

An assessment of ground-water withdrawals at municipal industrial parks throughout Puerto Rico was conducted to investigate the effect of ground-water usage on nearby surface- and ground-water resources. Water-bearing strata were divided into four generalized hydrogeologic units: (1) fissured aquifers (including karst and non-karst limestone); (2) intergranular aquifers; (3) intergranular aquifers overlying fissured rock units; and (4) strata with local or limited ground-water resources. Approximately 49 percent of the municipal industrial parks are located in areas with local or limited ground-water resources, 29 percent overlie intergranular aquifers, 13 percent overlie fissured aquifers, and 9 percent overlie intergranular units that overlie fissured rock units.

Hydrogeologic data for the generalized hydrogeologic units were compiled from published U.S. Geological Survey reports. Depths to ground water near industrial parks range from approximately 20 to 400 feet in the fissured aquifers, 6 to 65 feet in coastal intergranular aquifers, 3 to 30 feet in intergranular aquifers overlying fissured rock units, and 1 to 100 feet in strata with local or limited ground-water resources. Aquifer transmissivities near industrial parks range from approximately 100,000 feet squared per day in the fissured aquifers to less than 100 feet squared per day in the strata with local or limited ground-water resources.

Well construction data were compiled from published U.S. Geological Survey reports, drillers' logs, and unpublished reports. Specific capacity for wells near industrial parks ranges from approximately 100 gallons per minute per foot of drawdown in the fissured aquifer at Manatí to approximately 0.1 gallon per minute per foot of drawdown in strata with local and limited ground-water resources at Bayamón. Reported well yields near industrial parks ranges from 2,800 gallons per minute in the intergranular aquifer at Santa Isabel to approximately 3 gallons per minute in strata with local and limited ground-water resources at Adjuntas.

Historical ground-water-level data from U.S. Geological Survey observation wells were used to define ground-water levels trends in the vicinity of industrial parks. Areas showing ground-water level declines, and therefore possible aquifer over-development, are located in Barceloneta and Guayama. Rising ground-water levels were noted in the vicinity of industrial parks at Florida, Ponce, and Yauco.

Ground-water withdrawal data were compiled from site visits to the industrial facilities and from information provided by Puerto Rico Department of Natural and Environmental Resources. Total ground-water withdrawal at the municipal industrial parks was estimated to be 1.6 million gallons per day. Most withdrawals were from intergranular coastal aquifers, which accounted for about two thirds of the ground-water withdrawals. Municipal industrial parks with substantial ground-water withdrawals are located in Bayamón, Caguas, Humacao, and Ponce.

Introduction

Municipal industrial parks are designated areas with the industrial infrastructure to support light industrial establishments and are located in every municipio (municipio is generally equivalent to a county in the contiguous United States) in Puerto Rico. There are more than 250 industrial parks in Puerto Rico and 68 of 78 municipalities have more than one industrial park. Approximately 25 of these industrial parks have industries with at least one well. Ground-water withdrawals from these wells may affect other public and private users. To address this issue, the United States Geological Survey (USGS), Caribbean District, in cooperation with the Puerto Rico Industrial Development Company (PRIDCO) designed an investigation to examine if and to what degree ground-water withdrawals from municipal industrial parks impact public-supply water, by either streamflow capture or overdraft of aquifers.

This report presents data on ground-water withdrawals for facilities located in municipal industrial parks. These data were obtained during site visits to the facilities and from records provided by the Puerto Rico Department of Natural and Environmental Resources (PRDNER). The assessment includes industrial parks throughout Puerto Rico and island municipios (fig. 1, see page 30, figures are at the end of report). Site-specific data were collected during calendar year 2000. Hydrogeologic and well data for sites in and around industrial parks were utilized to estimate the effect on ground-water availability, due to ground-water withdrawals from industrial parks. This information will provide water-resource managers with a comprehensive database that will enhance understanding of the ground-water resources. Water-resource planners can use this information in their decision-making process to make informed decisions on further development of ground-water resources.

Methods

This section describes the methodology utilized to collect and present the data obtained during this investigation. The methods are described for the collection and presentation of data on characteristics of the hydrogeologic units, site visits, well characteristics, and ground-water availability.

Aquifer Units

For the purpose of this investigation, water-bearing (producing) strata in Puerto Rico and two island municipios were divided into generalized hydrogeologic units described by Gómez-Gómez (U.S. Geological Survey, unpublished data, 1990). These hydrogeologic units include fissured aquifers including karst and non-karst limestone, intergranular (unlithified clastic) aquifers, intergranular aquifers overlying fissured rock aquifers, and strata with local and limited ground-water resources (inland areas underlain by volcaniclastic, plutonic, and serpentinite rocks; and coastal areas underlain by swamp and marsh deposits). Figure 1 presents an index map of figures 3-34 that show the location of municipal industrial parks and hydrogeologic units.

The fissured aquifers or karst aquifers are principally located along the north coast and some parts of the southwest coast and are constituted by karst and non-karst limestone. Intergranular aquifers include the alluvial valley deposits in the coastal and interior parts of Puerto Rico. The alluvial valley deposits along the coast overlying fissured rock units are hydraulically interconnected and comprise a single aquifer.

The hydrogeologic units with local or limited ground-water resources are primarily composed of volcaniclastic, igneous, and metamorphic rocks. These hydrogeologic units are located chiefly in central Puerto Rico and eastern parts of the north coast. The plutonic intrusive rocks are extensive in the southeast between Caguas and Humacao and also in the center of the island near Utuado and Jayuya, serpentinite rocks are located in the southwest between Yauco and Mayagüez, and swamp and marsh deposits are located in low-lying areas near the coast. The plutonic intrusives and serpentenite rocks are classified as strata with local or limited ground-water resources.

Site Visits

Site visits to industrial parks in 28 municipios were conducted to validate information provided by the PRDNER and to corroborate data in USGS files. During the site visits, well locations were verified utilizing a Global Positioning System (GPS), and well construction, ground-water withdrawal, and ground-water-level data were collected.

Hydrogeologic Characteristics

For each of the hydrogeologic units, the data source is from published USGS reports (table 1). Well data were obtained from USGS and the PRDNER well files, and site visits to selected areas. The hydrogeologic data include the generalized hydrogeologic units, aquifer transmissivity, estimated thickness of the saturated zone, sources of recharge (surface-water or rainfall infiltration), dissolved solids concentrations, and ground-water-level trends within an area.

Table 1. References used to compile hydrogeologic characteristics.

[NCLA, North Coast Limestone Aquifer]

Area	Reference
NCLA (Aguadilla to Camuy)	Rodríguez-Martínez, 1995; Tucci and Martínez, 1995
NCLA (Camuy to Manatí)	Rodríguez-Martínez, 1995; Torres-González and others, 1996; Quiñones-Aponte, 1986a; Torres-González, 1985
NCLA (Manatí to San Juan)	Cherry, 2001; Gómez-Gómez, 1984; Gómez-Gómez and Torres-Sierra, 1988; Rodríguez-Martínez, 1995; Torres-González and Díaz, 1984
Río Grande to Fajardo	Pérez-Blair, 1997
Naguabo to Maunabo	Adolphson and others, 1977; Graves, 1989
Patillas to Ponce	Gómez-Gómez, 1990; McClymonds, 1972; McClymonds and Díaz, 1972; Quiñones-Aponte and others, 1997
Peñuelas to Lajas	Crooks and others, 1968; Graves, 1991; Grossman and others, 1972; Quiñones-Aponte, 1986b
Hormigueros to Rincón	Colón-Dieppa and Quiñones-Márquez, 1985; Díaz and Jordan, 1987
Other	Briggs and Akers, 1965; Gómez-Gómez and others, 2001; Olcott, 1997; Puig and Rodríguez, 1990; Rodríguez-Martínez and others, 2001; Torres-González, 1989

Well Characteristics

Specific capacity is the yield per unit of drawdown in a well, usually expressed as gallons of water per foot of drawdown (gal/min-ft), after a given time has elapsed. Specific capacity of a well varies with the duration of the discharge (Driscoll, 1987). Specific capacities of wells utilized in this study were estimated utilizing data from published USGS reports, drillers' logs and reports, and data accessible in the USGS Ground Water Site Inventory (GWSI) database. The specific-capacity data were used to estimate aquifer transmissivities using methods described by Theis and others (1963). The specific capacity of a well can be used as a basis for estimating the transmissivity of an aquifer; however this estimate is limited because the specific capacity is affected by factors such as diameter of the well, depth to which the well extends into the aquifer, type and amount of perforations in the well casing, and the extent to which the well has been developed (Theis and others, 1963). Transmissivity estimates presented in USGS reports are compiled in this report. Potential well yields were estimated using yields in USGS reports and well construction records. The generalized hydrogeologic units, location of industrial parks, and well locations are archived in a Geographic Information System (GIS) to facilitate future investigations.

Ground-Water Availability

Ground-water levels from 19 observation wells operated by the USGS were used to establish long-term trends. Lowest annual ground-water levels were used to evaluate the ground-water trends. Periods of record for the observation wells ranged from 3 to 16 years. Eight observation wells are located in fissured aquifers and eleven are located in intergranular aquifers.

Ground-water levels showing declining trends may be indicative of depletion of aquifer storage. Conversely, ground-water levels showing rising trends may be indicative of increased aquifer storage. Ground-water levels showing no trend may indicate the ground-water system is in a state of relative equilibrium with little or no change in aquifer storage conditions.

The rate of flow for ground water in one sub-basin with hydrogeologic units that have local or limited ground-water resources was estimated for one inland area where municipal industrial parks are located. The estimated ground-water flow rate was calculated utilizing surface-water low-flow data. The range between the Q-98 and Q-90 low-flow surface-water rates were utilized to approximate the ground-water flow rate for the aquifer within the sub-basin. The Q-98 and Q-90 surface-water flow duration rates for a basin are flow-rate values that are equal to or exceeded 98 to 90 percent of the time, respectively. The use of low-flow values to estimate ground-water flow rate assumes that: (1) ground water in the basin discharges entirely into a stream and its tributaries; and (2) ground-water discharge into the stream and tributaries is restricted to aquifer(s) in the corresponding drainage basin(s).

Some industrial parks are located in areas known to have poor (or no) ground-water availability. In areas where ground-water data are limited, the estimates of ground-water yields are based on data obtained from areas with similar hydrogeologic characteristics. In areas with poor ground-water availability, the proximity (500 feet (ft) or less) of streams to the municipal industrial park was considered as a possible source of ground-water flow to wells. Information presented in this report includes hydrogeologic properties of the aquifer, well characteristics, and availability of fresh or saline water for municipal industrial parks located over alluvial and fissured aquifers, and areas with unreliable public water supply.

Public water-supply systems (PWSS) that may be affected by industrial ground-water withdrawals were identified for this investigation.

Hydrogeologic Characteristics of Aquifers Underlying Industrial Parks

The simplified division of Puerto Rico into generalized hydrogeologic units, defined by Gómez-Gómez (U.S. Geological Survey, unpublished data, 1990) was used to describe the aquifers underlying the industrial parks. A correlation of the geologic units and principal aquifers in Puerto Rico is presented in figure 2. The generalized hydrogeologic units underlying the industrial parks are presented in figures 3 through 34. A general description of the hydrogeological properties of the aquifers within or near the municipal industrial parks is presented in table 2 by municipio in alphabetical order (see page 12).

Fissured Aquifers (non-intergranular)

Generally, fissured aquifers (non-intergranular) consist of karst and non-karst rock units along the north coast of Puerto Rico from Aguadilla to Loíza (figs. 3 through 11) and in southwestern Puerto Rico from Lajas to Ponce (figs. 19 through 22). The North Coast Limestone Province (NCLP) aquifer system, along the north coast, comprises the Upper and Lower Aquifer. The Upper Aquifer contains water mostly under unconfined conditions in the Aymamón and Los Puertos Limestones, primarily as a lens of freshwater north (seaward) of latitude 18º25'00". The Lower Aquifer consists of the Montebello Limestone Member of the Cibao Formation and the Lares Limestone (Rodríguez-Martínez, 1995). The Montebello Limestone Member of the Cibao Formation is important locally as a source of ground water between Río Grande de Arecibo and Río Grande de Manatí. In general, the Lower Aquifer is unconfined south (landward) of latitude 18º24'00" and fully confined north of latitude 18º25’00”, where the Lower Aquifer underlies an unnamed confining unit designated as the upper member of the Cibao Formation (Rodríguez-Martínez, 1995). The San Sebastián Formation constitutes the basal confining unit of the Lower Aquifer. West of the municipality of Arecibo (figs. 1 and 6), the Lower Aquifer is fragmented and heterogeneous with the Montebello Limestone Member of the Cibao Formation and the Lares Limestone grading to the less permeable members of the Cibao Formation and the San Sebastián Formation.

In southwest Puerto Rico, the fissured aquifers are in the Ponce Limestone of Miocene age (along coastal areas) and Upper Cretaceous limestones bordering the Lajas Valley (Graves, 1991) (fig. 20). However, few wells tap these limestone units exclusively. Wells completed in these limestone units receive water from the overlying intergranular deposits.

The potentiometric surface of the Upper Aquifer from Aguadilla to Camuy is generally less than 10 ft above mean sea level (amsl) (Renken and Gómez-Gómez, 1994) (figs. 3 to 5). Locally, this would place the depth to ground water in the range of 100 to 400 ft below land surface (bls). East of Arecibo, the potentiometric surface in the Upper Aquifer is generally not greater than 10 ft amsl, but may have been as much as 20 ft amsl prior to large scale ground-water withdrawals that commenced after 1960 (Gómez-Gómez and Torres-Sierra, 1988; Cherry, 2001)(figs. 6 and 7). The depth to water in the Upper Aquifer ranges from 400 ft bls near Quebradillas to about 40 ft bls near Arecibo (figs. 4 and 6).

The transmissivity of the Upper Aquifer in northwest Puerto Rico varies substantially. Along the north to south extent of the aquifer, the highest transmissivities are found where the freshwater lens is thickest. This exists where streams and wetlands are more distant from the Upper Aquifer recharge sources. Estimates of transmissivity within these areas range from 10,000 to greater than 100,000 feet squared per day (ft^2/d) (Olcott, 1997). Along any north-to-south transect, the transmissivity approaches zero near inland areas where the Upper Aquifer pinches-out against the upper member of the Cibao Formation or volcaniclastic rocks; the transmissivity is less than 10,000 ft^2/d along the coast, where the freshwater lens thins-out. Transmissivity of the Lower Aquifer is greatest in the area within the municipios of Barceloneta and Florida (fig. 8), but does not exceed 3,000 ft^2/d (F. Gómez-Gómez, U.S. Geological Survey, written commun., 2001). Outside this geographic area, transmissivity is generally not greater than 500 ft^2/d (Olcott, 1997). Transmissivity estimates for the fissured aquifers in southwest Puerto Rico are unavailable, because few wells tap these units exclusively.

The Upper Aquifer is absent in some parts of San Juan, and where present, it is very thin and ground-water yields are small (Rodríguez-Martínez, 1995). In the Loíza area, the Upper Aquifer is about 750 ft thick (Rodríguez-Martínez, 1995) (fig. 11 and 32). However, the freshwater portion of the aquifer in the coastal zones of San Juan and Loíza is less than 30 ft thick (Rodríguez-Martínez, 1995) (figs. 11 and 32). The Lower Aquifer in the San Juan area is composed mostly by the Mucarabones Sand, which consists of sandstone and gravel (Rodríguez-Martínez, 1995).

Aquifer transmissivity estimates for the Lower Aquifer, obtained from specific-capacity data near the industrial parks of San Juan, range from 2,000 to 3,000 ft^2/d. Depth to water in the Lower Aquifer near the industrial parks range from about 9 to 18 ft bls in San Juan to about 6 ft bls in Carolina. Depth to water in the Upper Aquifer in Loíza is about 3 ft bls.

Intergranular Aquifers

The intergranular aquifers are present in the alluvial deposits that fill bedrock valleys in the interior and coastal areas of Puerto Rico. Intergranular aquifers of eastern, southern, western, interior, and island municipios of Puerto Rico have distinct hydrogeologic properties, and therefore are discussed separately.

Eastern Puerto Rico

Industrial parks within alluvial valleys are located in eastern Puerto Rico within the municipios of Fajardo, Ceiba, Naguabo, Humacao, Yabucoa, and Maunabo (figs. 12 through 14). The thickness of the alluvial deposits near the industrial parks ranges from approximately 170 ft in Fajardo (industrial park and number, IP-099), 100 ft in Humacao, and about 180 ft in Maunabo (figs. 12 through 14).

The potentiometric surface of the alluvial aquifers near the industrial parks in the Fajardo to Humacao area ranges from 20 to 50 ft amsl (figs. 12 through 14). The potentiometric surface in these alluvial valleys indicate that the direction of the ground-water flow is towards the streams (Adolphson and others, 1977; Graves, 1989; and Perez-Blair, 1997). The depth to water near the industrial parks in the alluvial aquifer ranges from approximately 12 ft bls in Fajardo to 22 ft bls in Humacao.

Transmissivity estimates for the alluvial aquifers range from approximately 100 to 2,500 ft^2/d in Fajardo (Pérez-Blair, 1997), from about 500 to 2,000 ft^2/d in Humacao and Naguabo (Graves, 1989), from 1,000 to 7,000 in Yabucoa (Renken and others, 2002), and from about 1,000 to 8,000 ft^2/d in Maunabo (Adolphson and others, 1977). A transmissivity estimate from specific capacity data from the PRASA Calzada well (fig. 14) near an industrial park in Maunabo is 8,500 ft^2/d, which is consistent with previous estimates.

Western Puerto Rico

The industrial parks located in alluvial valleys in western Puerto Rico are in the municipios of Añasco, Mayagüez, Hormigueros, San Germán, and Sabana Grande (figs. 17, 19, and 20). The potentiometric surface in the Río Guanajibo

Valley near Hormigueros and San Germán is about 7 and 40 ft amsl, respectively (Colón-Dieppa and Quiñones-Márquez, 1985). The potentiometric surface in the Río de Añasco Valley near Añasco is about 15 ft amsl (Díaz and Jordan, 1987). The depth to water near the municipal industrial parks is reported to be about 5 ft bls in Mayagüez and about 25 ft bls in San Germán. According to the Puerto Rico Aqueduct and Sewer Authority (PRASA) Guanajibo well records, the thickness of the alluvial deposits near IP-198 in Sabana Grande is reported to be as much as 105 ft. A transmissivity of 2,800 ft^2/d was estimated from specific capacity data from PRASA Guanajibo well (fig. 20) in Sabana Grande.

Southern Puerto Rico

The South Coastal Plain Alluvial Aquifer (SCPAA), which underlies the municipios from Ponce to Patillas (figs. 22 through 26), includes six alluvial fans that form a continuous alluvial plain (Renken and Gómez, 1994). The potentiometric surface near the industrial parks is less than 10 ft amsl from Santa Isabel to Arroyo, and is about 50 ft amsl in Patillas. The depth to the water table in the alluvial aquifer at these industrial parks from Patillas to Santa Isabel range from 9 to 39 ft bls.

Aquifer transmissivities in the SCPAA near the industrial parks are estimated to be 5,000 ft^2/d in Santa Isabel, from 5,000 to 30,000 ft^2/d in Salinas, and from less than 500 to 5,000 ft^2/d in Guayama (Quiñones-Aponte and others, 1997). In Arroyo and Patillas, the estimated transmissivities in the alluvial aquifer range from less than 2,000 to 25,000 ft^2/d.

The freshwater lens in these aquifers is thickest near Santa Isabel, where the thickness is approximately 400 ft (Renken and others, 2002). Near the industrial parks in Salinas, the freshwater lens thickness ranges from 100 to 260 ft (Renken and others, 2002). The freshwater lens thickness is less than 65 ft in Guayama and Patillas, and approximately 70 ft in Arroyo. Almost all principal streams in the Salinas to Patillas area are intermittent in the upper portions of the alluvial fans. This is related to the high permeability of the deposits along the stream reaches, which are composed of coarse gravel and boulders (Quiñones-Aponte and others, 1997).

Interior Puerto Rico

The principal alluvial valleys in interior Puerto Rico are the Caguas-Juncos valley and the Cayey valley (figs. 29 and 31). The Caguas-Juncos valley includes part of the municipios of Caguas, Gurabo, and Juncos. The potentiometric surface in the Caguas-Juncos alluvial valley near the industrial parks ranges from 160 to 200 ft amsl in the Caguas area and 140 to 170 ft amsl in the Gurabo and Juncos areas (Puig and Rodríguez, 1990). The potentiometric surface indicates that the ground-water flow direction in the Caguas-Juncos valley is generally toward stream channels (Puig and Rodríguez, 1990). The thickness of the alluvial deposits near the industrial areas in Caguas ranges from about 45 to 90 ft (Puig and Rodríguez, 1990). In the Caguas area, the alluvial aquifer is in contact with weathered volcanic bedrock, which may serve as a source of additional ground water. The thickness of the alluvial deposits in the Gurabo and Juncos areas ranges from 50 to approximately 100 ft (Puig and Rodríguez, 1990). Depth to water in the alluvial aquifer ranges from 18 to 36 ft bls near the industrial parks in Caguas, 14 to 39 ft bls near Gurabo and Juncos, and from 28 to 37 ft bls near the industrial areas in Cayey.

The transmissivity of the aquifer near the industrial areas of Caguas is estimated to be less than 500 ft^2/d (Puig and Rodríguez, 1990). Aquifer transmissivities in the alluvial aquifer near industrial parks located in the Gurabo and Juncos areas of the Caguas-Juncos valley were estimated to range from less than 500 to less than 1,000 ft^2/d (Puig and Rodríguez, 1990). In the Cayey alluvial valley, the transmissivity estimates for the aquifer near IP-336 ranges from 1,000 to 5,000 ft^2/d.

Island Municipios

The principal alluvial valley in the offshore municipios is the Esperanza Valley in Isla de Vieques (fig. 33). Thickness of sedimentary deposits in the Esperanza Valley ranges from 0 to 90 ft (Torres-González, 1989). The elevation of the water table ranges from 10 to 100 ft amsl. Transmissivity estimates for the Esperanza Valley ranges from 200 ft^2/d near the eastern boundary of the valley to 2,000 ft^2/d at the west boundary (Torres-González, 1989).

Intergranular Unit Overlying Fissured Rock Unit

The intergranular units overlying fissured rock units are present in the north and south coast, and southwest Puerto Rico. These units have distinct hydrogeologic properties, and therefore, are discussed separately.

North Coast

Alluvial deposits form the aquifers within four valleys along the north coast of Puerto Rico and are an important source of ground water. These alluvial valleys were formed by the Río Grande de Arecibo (fig. 6), Río Grande de Manatí (fig. 7), Río Cibuco (fig. 7), and Río de La Plata (fig. 9). The alluvial deposits overlie and are hydraulically connected to the Aymamón and Aguada Limestones. Beneath the industrial parks in Arecibo, Barceloneta, Vega Baja, and Toa Baja are alluvial deposits that form the hydrogeologic units (figs. 6 through 9). The thickness of the alluvial deposits near the industrial parks is approximately 100 ft in Arecibo (Quiñones-Aponte, 1986a) and Barceloneta, approximately 45 ft in Vega Baja, and approximately 90 ft in Toa Baja (Troester, 1999).

The potentiometric surface in the Río Grande de Arecibo alluvial valley indicates that ground-water flow is towards discharge zones towards the northeast of the valley (Quiñones-Aponte, 1986a) (figs. 6). In the Río Grande de Manatí alluvial valley near Barceloneta, the potentiometric surface indicates that ground-water flow is generally towards the Río Grande de Manatí (Gómez-Gómez, 1984). Depth to water near the industrial areas in the alluvial valleys located along the coastal plain from Arecibo to Toa Baja ranges from 5 ft bls to 13 ft bls (figs. 6 through 9).

The transmissivity estimates for the freshwater section of the alluvial aquifer near the industrial parks are less than 5,000 ft^2/d in Arecibo (Quiñones-Aponte, 1986), less than 10,000 ft^2/d in Barceloneta and Vega Baja (Torres-González and Díaz, 1984), and from 10,000 to 25,000 ft^2/d near Toa Baja (Torres-González and Díaz, 1984). However, the transmissivity estimates for the limestone aquifers underlying the alluvium range from 10,000 to 100,000 ft^2/d (Olcott, 1997).

South Coast

In the Ponce to Juana Díaz area (fig. 22), the intergranular deposits are underlain by the Ponce Limestone near the coast and the Juana Díaz Formation in inland areas (Glover, 1971). The Juana Díaz Formation consists primarily of low permeability clastic deposits and chalk beds. Where saturated, the Juana Díaz Formation contains saline water that is not suitable for human consumption (McClymonds, 1972). The thickness of the alluvial deposits in the Ponce area ranges from approximately 30 to 100 ft near the northern edge of the deposits to greater than 300 ft along the adjacent in coastal areas. Transmissivities of the aquifer range from 1,000 to 10,000 ft^2/d near the industrial parks in Ponce (McClymonds, 1972).

Southwest Puerto Rico

Industrial parks located within alluvial valleys overlying fissured rock are located at Lajas, Guánica, Yauco, Guayanilla, and Peñuelas in southwest Puerto Rico (figs. 19 through 21). The potentiometric surface in the Lajas valley indicates that the principal direction of the ground-water flow is from the foothills towards the center of the valley (Graves, 1991). In the alluvial valleys at Guánica (McClymonds, 1967), Yauco (Quiñones-Aponte, 1986b), Guayanilla (Crooks and others, 1968), and Peñuelas (Grossman and others, 1972) the potentiometric surface indicates a general ground-water flow direction from the upper to lower part of the valleys. The thickness of the alluvial deposits reported near the industrial parks is approximately 70 ft in Lajas (Graves, 1991), 110 ft in Guánica (McClymonds, 1967), 75 ft near the town of Yauco (Quiñones-Aponte, 1986b), 40 ft in Peñuelas (Grossman and others, 1972), and less than 40 ft in Guayanilla (Crooks and others, 1968).

The aquifer transmissivity estimates near the industrial parks in Lajas range from approximately 100 to 8,000 ft^2/d (Graves, 1991), near Guánica approximately 5,000 to 25,000 ft^2/d (McClymonds, 1967), near Yauco approximately 5,000 to 15,000 ft^2/d (Quiñones-Aponte, 1986b), near Guayanilla approximately 1,000 to 5,000 ft^2/d (Crooks and others, 1968), and near Peñuelas less than 500 ft^2/d (Grossman and others, 1972).

In southwest Puerto Rico, streamflow infiltration is the primary source of recharge for the alluvial stream-valley aquifers (Crooks and others, 1968; Quiñones-Aponte, 1986). Mean-annual precipitation in southwest Puerto Rico is low and aquifer recharge from precipitation is insignificant.

Strata with Limited and Local Ground-Water Resources

Strata with limited and local ground-water resources underlie most of the interior and northeastern Puerto Rico. The interior of Puerto Rico is comprised of volcaniclastic, igneous, and metamorphic rocks that form minor aquifers. These rock units are highly faulted and folded (Olcott, 1997) and are composed of tuffaceus siltstone, breccia, andesitic to basaltic rocks, and minor limestone. The volcaniclastic rocks store and transmit water through fractures and secondary openings in areas where precipitation is significant (Olcott, 1997). In the vicinity of streams, well yields may be partially or completely sustained by induced surface-water seepage from streams (Rodríguez-Martínez and others, 2001).

Industrial parks constructed over volcaniclastic, igneous, and metamorphic rocks are located primarily in the municipios of the center of the island from Las Piedras in the east to Rincón in the west (fig. 1). Transmissivity estimates from specific-capacity data for wells near the industrial parks range from 15 to 60 ft^2/d. Depths to water at wells near the industrial parks range from 14 to 70 ft bls.

Igneous intrusive (plutonic) rocks are present in the central and southeast portions of the island. Unless fractured, intrusive rocks are not a ground-water source (Olcott, 1997). Several industrial parks are constructed over plutonic rocks, principally in the municipios in east-central Puerto Rico (Las Piedras and San Lorenzo; fig. 31) and near the center of the island (Ciales and Jayuya; figs. 7 and 27). Depths to water range from 24 to 43 ft bls in industrial parks in Las Piedras and San Lorenzo. Transmissivity values of approximately 50 to 70 ft^2/d were estimated from specific-capacity data for wells at or near industrial parks in Las Piedras and San Lorenzo. In an industrial park in Las Piedras, transmissivity values estimated from specific-capacity data for wells located near a creek ranged from 300 to 400 ft^2/d.

In addition to the hydrogeologic units composed of the volcaniclastic, igneous, and metamorphic rock, the strata with limited and local ground-water resources also include hydrogeologic units consisting of fine-grained alluvial and swamp deposits located within the coastal portions of the municipios of San Juan, Carolina, and Loíza (figs. 11 and 32). Industrial parks located in these municipios overlie the easternmost limit of the North Coast Limestone Aquifer (NCLA).

Well Characteristics

Data on the construction and hydraulic characteristics of wells located within and near municipal industrial parks include the depth, reported yield, and specific capacity. Characteristics for wells at or near the industrial parks are presented alphabetically by municipio in table 3 of this report.

The deepest wells are located in the fissured aquifers at Quebradillas (610 ft), Barceloneta and Manatí (2,000 ft, in the Lower Aquifer). Most productive wells were reported in intergranular aquifers near Santa Isabel (2,800 gallons per minute (gal/min)). Most wells were drilled in industrial parks located in Bayamón and Caguas.

Ground-water withdrawals within industrial parks were estimated to be about 1.6 millions gallons per day (Mgal/day) during the year 2000. The industrial self-supplied ground-water withdrawals during year 2000 were estimated to be 11.2 Mgal/d, excluding withdrawals estimated in this assessment (W.L. Molina, U.S. Geological Survey, written commun., 2001). More than one-half of the ground-water withdrawals at industrial parks were from intergranular units overlying fissured aquifers (fig. 35). Ground-water withdrawals by textile manufacturers within industrial parks accounted for more than one-half of the 1.6 Mgal/d withdrawals (fig. 36).

Ground-water withdrawals at the industrial parks and within a 0.6 mile radius are presented in figure 37. Principal ground-water withdrawal areas are from the fissured aquifers located in Barceloneta and Manatí (fig. 7). For the industrial parks located over the intergranular coastal aquifers, the largest ground-water withdrawals are in Salinas and Guayama (figs. 24 and 25). Principal ground-water withdrawal areas near industrial parks from intergranular in the island’s interior aquifers are located in Cayey (fig. 12) and San Germán (fig. 20). Ponce (fig. 22) and Guánica (fig. 21) are the principal ground-water withdrawal areas for intergranular units overlying fissured aquifers. In Aibonito (fig. 29), ground-water withdrawal is from strata with limited ground-water resources.

Potential Effects of Industrial Ground-Water Withdrawals on Availability of Surface- and Ground-Water Resources

Information concerning industrial ground-water withdrawals near industrial parks and location of PWSS were assembled to assess the potential effects on nearby ground-water users. Additionally, ground-water levels were examined to determine ground-water-level trends. Ground-water-level data from observation wells were examined to determine the following: (a) Are declines in ground-water levels occurring in the area? This may indicate that aquifer storage is being reduced and potentially during drought conditions further ground-water declines may be anticipated; (b) Are rising ground-water levels occurring in the area? This may indicate that aquifer storage is being replenished, which could be due to increase in the recharge rate, decrease in ground-water withdrawals, or a combination of both; and (c) Are there no significant trends? This indicates that the ground-water system is in a state of equilibrium. Additionally, wells located at industrial areas less than 500 ft from perennial streams were considered to have the potential for surface-water capture (table 2).

For the fissured aquifers of the north coast of Puerto Rico, PWSS well locations within 0.6 miles radius of industrial parks were identified in the municipios of Quebradillas, Arecibo, Barceloneta, Florida, and Manatí (figs. 4, 6, and 7). The primary source of water for the urban area of Quebradillas, where IP-111 is located, is surface water. In Barceloneta, Manatí, and Florida the primary source of potable water during year 2000 was from ground water.

Ground-water availability in the NCLA Upper Aquifer is limited. However, in some localities withdrawals have been reduced and water levels are rising. Ground-water levels for selected USGS observation wells (OW) are shown in figure 38. OW-1 through OW-5 (figs. 4 and 6 through 8,) are open to the NCLA Upper Aquifer. OW-1 in Quebradillas shows a generally decreasing trend from 1986 to 1995 of more than 40 ft (fig. 38a). OW-2 through 5 (figs. 6 through 8) are generally stable (figs 38b to 38e). OW-6 through OW-8 (figs. 6, 7, and 11) are open to the NCLA Lower Aquifer. Water levels in OW-6 show a decreasing trend from 1989 to 1995 of approximately 14 ft. A 5- to 12-year period of water-level trends is shown for the Barceloneta and Florida areas (OW-7 and OW-8, figs. 6 and 7), where most withdrawals are from the NCLA Lower Aquifer (figs. 38g and 38h). In Barceloneta, OW-7 shows a decreasing trend from 1988 to 2000 of approximately 80 ft (fig. 38g). In the Florida area, ground-water levels are rising, which could be the result of a reduction in ground-water withdrawals, an increase in recharge, or a combination of both conditions. In the urban areas of Florida, all storm-water runoff is conveyed to the sub-surface by injections wells. The injection of surface water into the aquifer may be a major cause for the rise in ground-water levels (fig. 38h).

In the Manatí area, estimated ground-water withdrawals from the fissured aquifers near IP-84/125, IP-356, and IP-927 (fig. 7) were 1.8 Mgal/d, 0.56 Mgal/d, and 0.54 Mgal/d, respectively, during 2000. These withdrawals were from both PWSS and industrial wells. A recent ground-water flow model developed for the Manatí-Vega Baja area (Cherry, 2001) indicates that ground-water withdrawals in the Coto Sur area in Manatí, which is located about 3,000 ft south of IP-356, have contributed to the decline of heads in the Upper Aquifer by as much as 18 ft through depletion of storage from 1940 to 1995.

In the intergranular aquifers of the east coast, two PWSS are located near an industrial park in Maunabo (fig. 14). About 660,000 gallons per day (gal/d) were reported by PRASA to be withdrawn from two wells located about 2,800 and 3,000 ft from IP-283. Ground-water levels recorded at OW-9 (figs. 12 and 38i) in Fajardo and OW-10 (figs. 14 and 38j) in Maunabo indicate fluctuations of approximately 6 and 4 ft, respectively.

At IP-313 in Humacao (fig. 13), approximately 300,000 gal/d were withdrawn from the intergranular aquifer during 2000 from four industrial wells. A ground-water flow model (Graves, 1989) developed for the Humacao-Naguabo area, simulated the scenario of increasing ground-water withdrawals to 720,000 gal/d by simulating a line of imaginary wells approximately 1,000 ft south of IP-313 and to the north of Río Humacao. The model predicted a ground-water level decline of approximately 7 ft at the imaginary wells and approximately a 1 ft decline near IP-313.

The PWSS located near municipal industrial parks that obtain water from the intergranular aquifer of the south coast were identified in the municipios of Salinas, Guayama, Arroyo, and Patillas (figs. 24 through 26). Ground-water withdrawals were not reported for public supply wells located near industrial parks in Guayama and Patillas. Reported ground-water withdrawals from two PWSS wells near IP-090 in Salinas and two wells near IP-221 in arroyo were 750,000 and 330,000 gal/d, respectively.

Ground-water levels for observation wells in Guayama, Salinas, and Santa Isabel are shown in figures 38k to 38m. Ground-water levels at OW-11 (figs. 25 and 38k) near Guayama show a decline of approximately 1.5 ft per year (ft/yr) from 1991 to 1999. In Santa Isabel, water levels in OW-13 (figs. 24 and 38m), declined about 1.3 ft/yr from 1984 to 1995. A ground-water-level rise of approximately 9 ft was observed between 1998 and 2000. Ground-water levels in OW-12 (figs. 29 and 38 l) in Salinas declined approximately 8 ft from 1991 to 1996. Some of the decline in water levels in these areas may be related to the regional abandonment of the surface-water irrigation system, which was a major source of recharge to the SCPAA (Gómez-Gómez, 1990). The rise in ground-water levels observed after 1996 in OW-11 and OW-12 coincide with rainfall events associated with hurricanes Hortense (September 1996), Georges (September 1998), and Lenny (November 1999).

The PWSS near industrial parks that obtain water from the intergranular aquifer of the southwest and west of Puerto Rico were identified at Hormigueros, Cabo Rojo, San Germán, Sabana Grande, and Guánica (figs. 19 through 21); no industrial self-supplied wells were identified in these industrial parks. Ground-water-levels trends in OW-14 and OW-15 (figs. 19 and 17) in the Hormigueros and Mayagüez areas, respectively, are shown in figures 38n and 38o; no significant trend was noted for the water levels recorded in these wells.

Industrial self-supplied ground water is withdrawn from intergranular aquifers overlying fissured aquifers at IP-937 in Ponce (fig. 22). Approximately 800,000 gal/d were withdrawn during 2000 from two wells located in IP-937. Withdrawals from a PWSS well, located about 2,300 ft south of IP-937, accounted for about 400,000 gal/d. From 1996 to 2000, water-level data from OW-16 (figs. 22 and 38p), which is located about 2,300 ft south east from IP-937, indicate rising ground-water levels of about 2 ft/yr. The sudden fluctuations in ground-water levels in OW-16 coincide with rainfall events related to hurricanes Hortense (September 1996), Georges (September 1998), and Lenny (November 1999).

The water levels in OW-17 (figs. 22 and 38q) near IP-050 in Ponce showed a general water-level increase of about 22 ft from 1994 to 2000. The lowest water level recorded during that period was about 50 ft bls, which is at about mean sea level. However, water-level altitudes near IP-050 were reported to be 20 to 30 ft bmsl (depth to water was about 70 to 80 ft bls) during 1964-65 (McClymonds, 1972).

Ground-water levels in OW-18 and OW-19 near Peñuelas and Yauco (fig. 21) are shown in figures 38r and 38s. Water levels in OW-19 (fig. 38s) located near IP-063 in Yauco, showed a general decline of about 2 ft/yr from 1984 to 1997; however, from 1998 to 2000 the water level increased by about 35 ft. A 4-year period of ground-water-level data for OW-18, located south of IP-213 and IP-406, shows maximum fluctuations of approximately 10 ft.

The PWSS located near industrial parks overlying intergranular aquifers in the interior of Puerto Rico were identified at Ciales, Cayey, Caguas, and Juncos (figs. 7, 29, and 31). No public-supply ground-water withdrawal were reported near these industrial parks. In IP-017 in Caguas, six industrial wells were identified, one of which was not in operation during this study. Estimated ground-water withdrawal from the intergranular aquifer at IP-017 was approximately 173,000 gal/d in 2000. Depth to water at the industrial park for the period of 1986 to 1989 ranged from approximately 29 to 35 ft bls (Puig and Rodríguez, 1990). Depth-to-water at the industrial park in July 1999 was 35 ft bls.

At IP-003 near Bayamón (fig. 10), seven industrial wells were identified, five of which were active during 2000. The estimated ground-water withdrawal rate was 150,000 gal/d. Ground-water altitude during 1986 and 1994 at IP-003 was approximately 60 and 30 ft amsl, respectively.

In strata with local or limited ground-water resources, PWSS were identified near industrial parks in the municipios of Jayuya, Aibonito, and Cidra (figs. 27, 29, and 30). Ground-water withdrawals for public supply were reported by PRASA at Aibonito and Cidra. In the municipio of Cidra, two PWSS wells are located near IP-274 and IP-391. Ground-water withdrawals during 2000 were reported to be 20,000 gal/d at each of these wells. Data obtained during field visits indicate that industrial ground-water withdrawals were approximately 82,000 gal/d at IP-391 near Cidra. The PWSS well located about 1,300 ft from IP-391, and one of the industrial wells are located near unnamed creeks that flow into the water-supply reservoir of Lago de Cidra. However, no long-term discharge records are available for these creeks to determine the influence of ground-water withdrawals on surface-water discharge.

In Aibonito, three PWSS wells located near IP-072 and IP-902 were identified. The distance from these PWSS wells to IP-072, in which an industrial well is located, ranges from 1,300 to 3,000 ft. In addition to the PWSS wells, an institutional-use (hospital) well is located approximately 1,900 ft from the IP-072. Ground-water withdrawals were estimated to be 656,000 gal/d during year 2000. No long-term ground-water-level data are available near these industrial parks.

The ground-water flow in the sub-basin in Aibonito, where industrial parks IP-072 and IP-902 are located, was estimated using low-flow data collected at Río Aibonito (Santiago-Rivera, 1998) (fig. 29).The range between the Q-98 and Q-90 low-flow surface-water rates were utilized as an approximation of the ground-water flow rate for the aquifer within the sub-basin (Gómez-Gómez and others, 2001). The Q-98 and the Q-90 flow were calculated to be 0.8 and 1.7 ft^3/s, respectively. The Q-98 flow and the Q-90 flow normalized values (to remove the effect of drainage basin size) in gallons per day per square mile ($gal/d\text{-}mi^2$) are approximately 80,000 and 169,000 $gal/d\text{-}mi^2$, respectively. Using the normalized Q-98 and Q-90 flow rates and multiplying by the drainage area of the sub-basin in Aibonito (2.8 mi^2), the estimated ground-water flow is between 220,000 to 470,000 gal/d. Reported ground-water withdrawals by PRASA and industries within the basin, where IP-072 and IP-902 are located for the period when low-flow measurements were made (1994 to 1997), range from 111,000 to 466,000 gal/d. The total ground-water withdrawals from wells within the sub-basin, where the municipal industrial parks are located, was 656,000 gal/d during year 2000.

Summary

The U.S. Geological Survey, in cooperation with the Puerto Rico Industrial Development Company, during year 2000 conducted an assessment on the effects of ground-water withdrawals on availability of surface and ground water in and near municipal industrial parks. The location of municipal industrial parks and wells were compiled in digital format utilizing Geographic Information System software to facilitate future investigations. The municipal industrial parks were classified on the basis of the underlying hydrogeologic units. The generalized hydrogeologic units include fissured aquifers, intergranular aquifers, intergranular units overlying fissured aquifers, and strata with limited or local ground-water resources. Most of the industrial parks, 49 percent, are located in areas with local or limited ground-water resources, 29 percent overlie intergranular aquifers, 13 percent overlie fissured aquifers, and 9 percent overlie intergranular unit overlying fissured rock aquifers. Reported well yields near and within industrial parks ranged from 3 to 2,800 gallons per minute. Wells near the industrial parks of Santa Isabel and Guánica, which tap intergranular aquifers, have the highest reported yields. Yields of less than 10 gallons per minute were reported from wells near industrial parks in Adjuntas, Guayama, and Luquillo; these wells tap strata with limited or local ground-water resources. Specific capacities of wells at or near the industrial areas range from 0.1 gallons per minute per foot (gal/min-ft) in the strata with limited or local ground-water resources to 103 gal/min-ft in the fissured aquifers. Deepest wells are located in the fissured aquifer in the north coast. Most wells are at industrial parks in Bayamón and Caguas.

Depths to water at or near industrial parks range from 20 to 400 ft in the fissured rock aquifers, 6 to 65 ft in the coastal intergranular aquifers, 3 to 30 ft in the intergranular aquifers overlying fissured rock units, and from 1 to 100 ft in strata with local or limited ground-water resources. Transmissivities in the vicinity of industrial parks range from approximately 15 ft^2/d in strata with limited or local ground-water resources to 100,000 ft^2/d in the fissured aquifer.

Total ground-water withdrawals during year 2000 within municipal industrial parks in Puerto Rico were estimated at 1.6 million gallons per day. Intergranular coastal aquifers are the principal source of ground-water for municipal industrial parks. Textile manufacturers accounted for half of the total ground-water withdrawals.

Ground-water withdrawals from public water-supply systems were identified near municipal industrial parks in Aibonito, Cidra, and Ponce, in addition to industrial ground-water withdrawals. Other areas with substantial ground-water withdrawals within or near municipal industrial parks are located at Manatí, Caguas, Bayamón, and Humacao. Ground-water-level data indicate levels are declining near industrial parks in Manatí, Barceloneta, Guayama, and Santa Isabel. Data indicate that ground-water levels are rising in Florida, Ponce, and Yauco.

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Table 2. Hydrogeologic properties of aquifers within or near industrial parks in Puerto Rico.

[C, confined; U, unconfined; n.d., no data available; SFC, Potential streamflow capture; RI, Rainfall infiltration; SLLGWR, Strata with local and limited ground resources; NCLA, North Coast Limestone Aquifer; RGAAVA, Río Grande de Añasco Alluvial Valley Aquifer; I/F, Intergranular unit overlying fissured aquifer; SCPAA, South Coastal Plain Alluvial Aquifer; CJVAA, Caguas -Juncos Valley Alluvial Aquifer; CVAA, Cayey Valley Alluvial Aquifer; RESRDAV, Río Espíritu Santo to Río Demajagua Alluvial Valleys; GAA, Guánica Alluvial Valley; GUAA, Guayanilla Alluvial Valley; RGVA, Río Guanajibo Valley Aquifer, HNAA, Humacao-Naguabo Alluvial Aquifer; MAA, Maunabo Alluvial Valley; TAA, Tallaboa Alluvial Aquifer; EAA, Esperanza Alluvial Valley; YVAA, Yabucoa Valley Alluvial Aquifer; YAVAA; Yauco Valley Alluvial Aquifer]

Municipality and industrial park number	Aquifer name	Estimated ground-water withdrawals, in gallons per day (within industrial park or within 0.6 mile radius)	Hydrogeologic properties					
			Generalized hydrogeologic unit	Confined or unconfined (C/U)	Estimated transmissivity range or expected upper limit, in feet squared per day	Depth to water, in feet below land surface	Fresh or saline water	Local aquifer recharge source (potential stream flow capture or rainfall infiltration)
Adjuntas								
145	Unnamed	0	Intergranular	U	<500	n.d.	Fresh	SFC/RI
259	Unnamed	0	Intergranular	U	<500	n.d.	Fresh	SFC/RI
420	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	RI
Aguada								
129	Unnamed	0	SLLGWR	U	<500	n.d.	Fresh	SFC/RI
253	Unnamed	0/120,000	Fissured	U	<500	n.d.	Fresh	RI
Aguadilla								
216	NCLA	0	Fissured	U	5,000-10,000	n.d.	Fresh	RI
266	NCLA	0	Fissured	U	n.d.	n.d.	Fresh	RI
279	NCLA	0	Fissured	U	5,000-10,000	n.d.	Fresh	RI
900	NCLA	0	Fissured	U	5,000-10,000	n.d.	Fresh	RI
901	NCLA	0	Fissured	U	5,000-10,000	n.d.	Fresh	RI
346	NCLA	0	Fissured	U	5,000-10,000	212	Fresh	RI
Aguas Buenas								
094	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
227	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
263	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
273	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
351	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
Aibonito								
238	Volcanic Rocks	0/210,000	SLLGWR	U	<100	15	Fresh	SFC/RI
417	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
902	Unnamed	0	SLLGWR	U	<100	22	Fresh	SFC/RI
072	Unnamed	16,000/430,000	SLLGWR	U	<100	n.d.	Fresh	RI
Añasco								
154	RGAAVA	n.d.	Intergranular	U	<500	20	Fresh	SFC/RI

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			Generalized hydrogeologic unit	Confined or unconfined (C/U)	Estimated transmissivity range or expected upper limit, in feet squared per day	Depth to water, in feet below land surface	Fresh or saline water	Local aquifer recharge source (potential stream flow capture or rainfall infiltration)
Arecibo								
065	NCLA	48,000	Fissured	U	10,000-40,000	125	Fresh	RI
151	NCLA	0	SLLGWR	U	5,000-10,000	3	Saline	RI
280	NCLA	0	I/F	U	<5,000	5	Fresh	RI
350	NCLA	0/480,000	Fissured	C/U	10,000-40,000	40	Fresh	RI
Arroyo								
221	SCPAA	0/330,000	Intergranular	C/U	5,000- 25,000	37	Fresh	RI
295	SCPAA	0	Intergranular	C/U	5,000- 25,000	13	Fresh	RI
354	SCPAA	0	Intergranular	C/U	5,000- 25,000	37	Fresh	RI
383	SCPAA	0	Intergranular	C/U	5,000- 25,000	39	Fresh	RI
Barceloneta								
114	NCLA	n.d.	I/F	C/U	<10,000	13	Fresh	RI
321	NCLA	0/1,200,000	Fissured	C/U	10,000-100,000	300	Fresh	RI
388	NCLA	0	SLLGWR	C/U	1,000-10,000	4	Saline	RI
Barranquitas								
098	Volcanic Rocks	0	SLLGWR	U	<100	100	Fresh	SFC/RI
224	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
Bayamón								
003	Unnamed	150,000/0	SLLGWR	U	100-1,000	25	Fresh	RI
004	NCLA	68,000/0	I/F	U	<500	10	Fresh	RI
Cabo Rojo								
122	Unnamed	0	SLLGWR	U	n.d.	n.d.	Fresh	RI
229	Unnamed	0	Intergranular	U	200-1,000	n.d.	Fresh	RI
298	Unnamed	0	SLLGWR	U	n.d.	n.d.	Fresh	RI

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			Generalized hydrogeologic unit	Confined or unconfined (C/U)	Estimated transmissivity range or expected upper limit, in feet squared per day	Depth to water, in feet below land surface	Fresh or saline water	Local aquifer recharge source (potential stream flow capture or rainfall infiltration)
Caguas								
017/416	CJVAA	173,000/0	Intergranular	U	<500	35	Fresh	RI
068	CJVAA	0/310,000	Intergranular	U	<500	35	Fresh	RI
132	Volcanic Rocks	0	SLLGWR	U	<100	33	Fresh	RI
339	CJVAA	n.d.	Intergranular	U	<500	n.d.	Fresh	RI
112	CJVAA	0	Intergranular	U	<500	18	Fresh	SFC/RI
307	CJVAA	n.d.	Intergranular	U	<500	22	Fresh	SFC/RI
395	CJVAA	0	Intergranular	U	<500	36	Fresh	SFC/RI
Camuy								
169	NCLA	0	Fissured	U	1,000-10,000	200	Fresh	RI
297	NCLA	0	Fissured	U	1,000-10,000	99	Fresh	RI
Canóvanas								
73/246/367	Volcanic Rocks	5,000	SLLGWR	U	<100	12	Fresh	RI
164/191	Volcanic Rocks	18,000	SLLGWR	U	<1,000	17	Fresh	RI
430	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
Carolina								
012	Unnamed	0	SLLGWR	U	<100	20		SFC/RI
028	NCLA	0	SLLGWR	U	n.d.	6	Saline	SFC/RI
066	Unnamed	0	SLLGWR	U	<100	16	Fresh	RI
372	NCLA	0	SLLGWR	U	<500	n.d.	Fresh	RI
342	NCLA	0	SLLGWR	U	n.d.	n.d.	Saline	RI
426	Unnamed	0	SLLGWR	U	<100	26	Fresh	RI
Cataño								
108/300/344	NCLA	0	I/F	U	<500	15	n.d.	RI
911	NCLA	0	SLLGWR	U	n.d.	1	Saline	RI

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Cayey								
009	CVAA	0	Intergranular	U	<500	28	Fresh	RI
143	Volcanic Rocks	0/90,000	SLLGWR	U	<1,000	40	Fresh	SFC/RI
336	CVAA	8,200/698,000	Intergranular	U	1,000-5,000	37	Fresh	RI
Ceiba								
144	Unnamed	0	Intergranular	U	<500	38	Fresh	RI
308	Unnamed	0	Intergranular	U	<500	n.d.	Fresh	RI
421	Unnamed	0	Intergranular	U	<500	13	Fresh	SFC/RI
Ciales								
040	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
170	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
212	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
232	Unnamed	0	Intergranular	U	<5,000	30	Fresh	SFC/RI
310	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
373	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	RI
556	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	RI
Cidra								
163	Unnamed	0	SLLGWR	U	100-200	n.d.	Fresh	RI
274	Unnamed	18,900/20,000	SLLGWR	U	100-200	70	Fresh	RI
391	Unnamed	82,000 / 0	SLLGWR	U	100-200	63	Fresh	SFC/RI
Coamo								
089	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
167	Unnamed	0	Intergranular	U	<500	65	Fresh	SFC/RI
317	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	RI
408	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	RI
Comerío								
124	Unnamed	0	Intergranular	U	<500	30	Fresh	SFC/RI
320	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI

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Corozal								
153	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/ RI
Culebra								
281	Volcanic Rocks	0	SLLGWR	U	n.d.	1	Saline	RI
Dorado								
107	NCLA	0	Fissured	U	500-10,000	n.d.	Saline	RI
128/361	NCLA	0	I/F	U	500-10,000	10	Saline	RI
Fajardo								
018	Volcanic Rocks	0	SLLGWR	U	<500	33	Fresh	RI
023	Volcanic Rocks	0	SLLGWR	U	<100	3	Saline	RI
099	RESRDAV	0	Intergranular	U	100-2,500	12	Fresh	SFC/RI
159	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Saline	RI
172	Volcanic Rocks	0	SLLGWR	U	<100	3	Saline	RI
Florida								
223	NCLA	0/100,000	Fissured	U	500-1,000	180	Fresh	RI
Guánica								
029	GAA	0	SLLGWR	U	<5,000	5	Fresh	RI
141	GAA	0/520,000	I/F	U	20,000-25,000	14	Fresh	RI
207	Unnamed	0	Fissured	U	n.d.	n.d.	n.d.	RI
Guayama								
006	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
165	SCPAA	0	Intergranular	C/U	<500	32	Fresh	RI
381	SCPAA	0/1,400,000	Intergranular	C/U	4,000-5,000	11	Fresh	RI
414	SCPAA	0	Intergranular	C/U	<500	21	Fresh	RI
Guayanilla								
290	GUAA	0	I/F	U	1,000-5,000	20	Fresh	SFC/RI
315	GUAA	0	SLLGWR	U	n.d.	2	Saline	SFC/RI
428	GUAA	0	Intergranular	U	1,000-5,000	30	Fresh	SFC/RI

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Guaynabo								
057	Unnamed	0	SLLGWR	U	n.d.	n.d.	Saline	RI
234	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
331	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
Gurabo								
024	CJVAA	0	Intergranular	U	<500	39	Fresh	SFC/RI
Hatillo								
204	NCLA	0	Fissured	U	1,000-10,000	60	Fresh	RI
919	NCLA	0	Fissured	U	1,000-10,000	20	Fresh	RI
Hormigueros								
211	Volcanic Rocks	0/120,000	SLLGWR	U	<100	18	Fresh	SFC/RI
291/389	Volcanic Rocks	0	SLLGWR	U	<100	28	Fresh	SFC/RI
920	RGVA	0	Intergranular	U	<500	23	Fresh	SFC/RI
Humacao								
140	HNAA	0	Intergranular	U	<500	13	Fresh	RI
278	HNAA	93,000/0	Intergranular	U	500-2,000	22	Fresh	RI
312	HNAA	0	SLLGWR	U	n.d.	1	Saline	RI
313	HNAA	0/300,000	Intergranular	U	500-2,000	6	Fresh	SFC/RI
407	HNAA	0	Intergranular	U	500-2,000	7	Fresh	RI
Isabela								
102	NCLA	0	Fissured	U	<5,000	320	Fresh	RI
921	NCLA	0	Fissured	U	<5,000	370	Fresh	RI
Jayuya								
241	Unnamed	0	Intergranular	U	500-1,000	15	Fresh	SFC/RI
275	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
Juana Díaz								
075/196	SCPAA	0	Intergranular	U	500-1,000	n.d.	Fresh	SFC/RI
384	SCPAA	0	Intergranular	U	500-1,000	18	Fresh	SFC/RI

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Juncos								
010	Volcanic Rocks	0	SLLGWR	U	n.d.	n.d.	Fresh	RI
303	Volcanic Rocks	0	SLLGWR	U	<100	26	Fresh	SFC/RI
394	CJVAA	40,000/0	Intergranular	U	<1,000	14	Fresh	SFC/RI
Lajas								
032	Lajas Valley	0	Intergranular	U	n.d.	n.d.	Saline	RI
209	Lajas Valley	0	I/F	U	<100	30	Fresh	RI
288	Lajas Valley	0	Intergranular	U	<100	n.d.	Fresh	RI
418	Lajas Valley	0	I/F	U	600-8,000	8	Fresh	RI
Lares								
249	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
309	Volcanic Rocks	0	SLLGWR	U	<500	14	Fresh	SFC/RI
Las Marias								
245	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
282	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
Las Piedras								
215	Unnamed	0/8,000	SLLGWR	U	<100	n.d.	Fresh	RI
332	Unnamed	0/47,000	SLLGWR	U	50-400	24	Fresh	SFC/RI
Loíza								
059/147	NCLA	0	SLLGWR	U	n.d.	3	Saline	RI
188/316	NCLA	0	SLLGWR	U	n.d.	2	Saline	RI
Luquillo								
085	RESRDAVA	0	SLLGWR	U	<100	18	Fresh	RI
Manatí								
084/125	NCLA	0/1,820,000	Fissured	C/U	10,000-100,000	66	Fresh	RI
356	NCLA	0/555,000	Fissured	C/U	10,000-100,000	240	Fresh	RI
927	NCLA	0/540,000	Fissured	C/U	10,000-100,000	128	Fresh	RI

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Maricao								
054	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
247/349	Volcanic Rocks	65,000 / 0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
314	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
928	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
Maunabo								
283	MAA	0 / 660,000	Intergranular	U	1,000-8,000	6	Fresh	SFC/RI
304	Unnamed	0	SLLGWR	U	<100	45	Fresh	RI
Mayagüez								
005	Unnamed	0	Intergranular	U	<500	n.d.	n.d.	RI
031	Volcanic Rocks	0	SLLGWR	U	<100	8	Fresh	SFC/RI
036	Unnamed	0	SLLGWR	U	<100	5	Saline	SFC/RI
93/178/214	Unnamed	n.d.	SLLGWR	U	<100	12	n.d.	RI
120/130	Unnamed	n.d.	Intergranular	U	<500	n.d.	Fresh	SFC/RI
193	Volcanic Rocks	n.d.	SLLGWR	U	<100	n.d.	Fresh	RI
231	Volcanic Rocks	0	SLLGWR	U	<100	20	Fresh	SFC/RI
270	Volcanic Rocks	0	SLLGWR	U	<100	5	Fresh	RI
Moca								
219	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
252	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
311	Unnamed	0	Intergranular	U	<500	n.d.	Fresh	SFC/RI
Morovis								
218	NCLA	0	Fissured	U	<500	n.d.	Fresh	SFC/RI
413	NCLA	0	Fissured	U	<500	n.d.	Fresh	RI
Naguabo								
162	HNAA	0	SLLGWR	U	<100	35	Fresh	SFC/RI
243	HNAA	0	Intergranular	U	<500	28	Fresh	SFC/RI
299	Volcanic Rocks	0	SLLGWR	U	n.d.	n.d.	n.d.	RI
932	HNAA	0	SLLGWR	U	<100	42	Fresh	RI

Table 2. Hydrogeologic properties of aquifers within or near industrial parks in Puerto Rico.—Continued

[C, confined; U, unconfined; n.d., no data available; SFC, Potential streamflow capture; RI, Rainfall infiltration; SLLGWR, Strata with local and limited ground resources; NCLA, North Coast Limestone Aquifer; RGAAVA, Río Grande de Añasco Alluvial Valley Aquifer; I/F, Intergranular unit overlying fissured aquifer; SCPAA, South Coastal Plain Alluvial Aquifer; CJVAA, Caguas -Juncos Valley Alluvial Aquifer; CVAA, Cayey Valley Alluvial Aquifer; RESRDAV, Río Espíritu Santo to Río Demajagua Alluvial Valleys; GAA, Guánica Alluvial Valley; GUAA, Guayanilla Alluvial Valley; RGVA, Río Guanajibo Valley Aquifer, HNAA, Humacao-Naguabo Alluvial Aquifer; MAA, Maunabo Alluvial Valley; TAA, Tallaboa Alluvial Aquifer; EAA, Esperanza Alluvial Valley; YVAA, Yabucoa Valley Alluvial Aquifer; YAVAA; Yauco Valley Alluvial Aquifer]

Municipality and industrial park number	Aquifer name	Estimated ground-water withdrawals, in gallons per day (within industrial park or within 0.6 mile radius)	Hydrogeologic properties					
			Generalized hydrogeologic unit	Confined or unconfined (C/U)	Estimated transmissivity range or expected upper limit, in feet squared per day	Depth to water, in feet below land surface	Fresh or saline water	Local aquifer recharge source (potential stream flow capture or rainfall infiltration)
Naranjito								
235	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
294	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
933	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
934	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
Orocovis								
228	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
237	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
284	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
Patillas								
236	SCPAA	0	Intergranular	C/U	2,000	9	Fresh	RI
375	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	RI
Peñuelas								
083	TAA	0	I/F	U	n.d.	n.d.	Saline	RI
213	TAA	0	Intergranular	U	<500	15	Fresh	RI
406	TAA	0	Intergranular	U	<500	15	Fresh	SFC/RI
Ponce								
027	SCPAA	0 / 400,000	I/F	U	5,000-10,000	10	Fresh	SFC/RI
050	SCPAA	0 / 1,800,000	I/F	U	1,000-5,000	29	Fresh	RI
062	SCPAA	n.d.	I/F	U	1,000-5,000	5	Fresh	RI
080	SCPAA	n.d.	I/F	U	1,000-5,000	30	Fresh	RI
086	SCPAA	0	I/F	U	1,000-5,000	n.d.	Fresh	RI
194	SCPAA	0	I/F	U	n.d.	3	Saline	RI
306/410	SCPAA	0	I/F	U	5,000-10,000	16	Fresh	RI
937	SCPAA	800,000 / 400,000	I/F	U	5,000-10,000	19	Fresh	SFC/RI
970	SCPAA	0	I/F	U	n.d.	3	Saline	RI

Table 2. Hydrogeologic properties of aquifers within or near industrial parks in Puerto Rico.—Continued

[C, confined; U, unconfined; n.d., no data available; SFC, Potential streamflow capture; RI, Rainfall infiltration; SLLGWR, Strata with local and limited ground resources; NCLA, North Coast Limestone Aquifer; RGAAVA, Río Grande de Añasco Alluvial Valley Aquifer; I/F, Intergranular unit overlying fissured aquifer; SCPAA, South Coastal Plain Alluvial Aquifer; CJVAA, Caguas -Juncos Valley Alluvial Aquifer; CVAA, Cayey Valley Alluvial Aquifer; RESRDAV, Río Espíritu Santo to Río Demajagua Alluvial Valleys; GAA, Guánica Alluvial Valley; GUAA, Guayanilla Alluvial Valley; RGVA, Río Guanajibo Valley Aquifer, HNAA, Humacao-Naguabo Alluvial Aquifer; MAA, Maunabo Alluvial Valley; TAA, Tallaboa Alluvial Aquifer; EAA, Esperanza Alluvial Valley; YVAA, Yabucoa Valley Alluvial Aquifer; YAVAA; Yauco Valley Alluvial Aquifer]

Municipality and industrial park number	Aquifer name	Estimated ground-water withdrawals, in gallons per day (within industrial park or within 0.6 mile radius)	Hydrogeologic properties					
			Generalized hydrogeologic unit	Confined or unconfined (C/U)	Estimated transmissivity range or expected upper limit, in feet squared per day	Depth to water, in feet below land surface	Fresh or saline water	Local aquifer recharge source (potential stream flow capture or rainfall infiltration)
Quebradillas								
111	NCLA	0/ 180,000	Fissured	U	1,000-5,000	400	Fresh	RI
276	NCLA	0	Fissured	U	1,000-5,000	370	Fresh	RI
400	NCLA	0	Fissured	U	1,000-5,000	400	Fresh	RI
Rincón								
136	Unnamed	0 / 20,000	SLLGWR	U	n.d.	n.d.	Saline	RI
Río Grande								
006	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
020	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
155	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
225	Unnamed	0	SLLGWR	U	n.d.	n.d.	Saline	RI
Sabana Grande								
198/374	RGVA	0/ 90,000	Intergranular	U	<5,000	10	Fresh	SFC/RI
941	RGVA	0	Intergranular	U	<500	n.d.	Fresh	RI
Salinas								
087/226	SCPAA	0 / 30,000	Intergranular	C/U	20,000-30,000	9	Fresh	RI
090	SCPAA	0 / 750,000	Intergranular	C/U	5,000	24	Fresh	RI
San Germán								
049	Volcanic Rocks	0	SLLGWR	U	<100	25	Fresh	RI
264	Volcanic Rocks	0 / 70,000	SLLGWR	U	<100	n.d.	Fresh	RI
412	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
San Juan								
016	NCLA	0	SLLGWR	U	n.d.	n.d.	Saline	RI
021/150	NCLA	0	SLLGWR	U	<5,000	9	n.d.	RI
052	NCLA	0	SLLGWR	U	n.d.	11	Saline	RI
074	Unnamed	0	SLLGWR	U	<500	12	Fresh	RI
137	NCLA	0	SLLGWR	U	n.d.	18	n.d.	RI

Table 2. Hydrogeologic properties of aquifers within or near industrial parks in Puerto Rico.—Continued

[C, confined; U, unconfined; n.d., no data available; SFC, Potential streamflow capture; RI, Rainfall infiltration; SLLGWR, Strata with local and limited ground resources; NCLA, North Coast Limestone Aquifer; RGAAVA, Río Grande de Añasco Alluvial Valley Aquifer; I/F, Intergranular unit overlying fissured aquifer; SCPAA, South Coastal Plain Alluvial Aquifer; CJVAA, Caguas -Juncos Valley Alluvial Aquifer; CVAA, Cayey Valley Alluvial Aquifer; RESRDAV, Río Espíritu Santo to Río Demajagua Alluvial Valleys; GAA, Guánica Alluvial Valley; GUAA, Guayanilla Alluvial Valley; RGVA, Río Guanajibo Valley Aquifer, HNAA, Humacao-Naguabo Alluvial Aquifer; MAA, Maunabo Alluvial Valley; TAA, Tallaboa Alluvial Aquifer; EAA, Esperanza Alluvial Valley; YVAA, Yabucoa Valley Alluvial Aquifer; YAVAA; Yauco Valley Alluvial Aquifer]

Municipality and industrial park number	Aquifer name	Estimated ground-water withdrawals, in gallons per day (within industrial park or within 0.6 mile radius)	Hydrogeologic properties					
			Generalized hydrogeologic unit	Confined or unconfined (C/U)	Estimated transmissivity range or expected upper limit, in feet squared per day	Depth to water, in feet below land surface	Fresh or saline water	Local aquifer recharge source (potential stream flow capture or rainfall infiltration)
San Lorenzo								
019	Volcanic Rocks	0	SLLGWR	U	<100	43	Fresh	SFC/RI
302	Unnamed	0	Intergranular	U	<500	n.d.	Fresh	SFC/RI
335	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
San Sebastián								
104	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
142	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
265	Unnamed	0	Intergranular	U	<100	n.d.	Fresh	SFC/RI
Santa Isabel								
037	SCPAA	0	Intergranular	U	5,000	37	Fresh	RI
076	SCPAA	0	Intergranular	U	5,000	12	Fresh	RI
Toa Alta								
082	NCLA	0	Fissured	U	<500	n.d.	Fresh	SFC/RI
Toa Baja								
217	NCLA	0	I/F	U	10,000-25,000	11	Saline	SFC/RI
Trujillo Alto								
233	Unnamed	0	Intergranular	U	<500	n.d.	Fresh	RI
357	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
957	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
Utuado								
203	Unnamed	0	Intergranular	U	<500	n.d.	Fresh	RI
396	Unnamed	0	Intergranular	U	<500	n.d.	Fresh	SFC/RI
Vega Alta								
260/292	NCLA	0	Fissured	C/U	<10,000	70	Fresh	RI
Vega Baja								
096	NCLA	0	I/F	C/U	10,000-100,000	11	Fresh	RI

Table 2. Hydrogeologic properties of aquifers within or near industrial parks in Puerto Rico.—Continued

[C, confined; U, unconfined; n.d., no data available; SFC, Potential streamflow capture; RI, Rainfall infiltration; SLLGWR, Strata with local and limited ground resources; NCLA, North Coast Limestone Aquifer; RGAAVA, Río Grande de Añasco Alluvial Valley Aquifer; I/F, Intergranular unit overlying fissured aquifer; SCPAA, South Coastal Plain Alluvial Aquifer; CJVAA, Caguas -Juncos Valley Alluvial Aquifer; CVAA, Cayey Valley Alluvial Aquifer; RESRDAV, Río Espíritu Santo to Río Demajagua Alluvial Valleys; GAA, Guánica Alluvial Valley; GUAA, Guayanilla Alluvial Valley; RGVA, Río Guanajibo Valley Aquifer, HNAA, Humacao-Naguabo Alluvial Aquifer; MAA, Maunabo Alluvial Valley; TAA, Tallaboa Alluvial Aquifer; EAA, Esperanza Alluvial Valley; YVAA, Yabucoa Valley Alluvial Aquifer; YAVAA; Yauco Valley Alluvial Aquifer]

Municipality and industrial park number	Aquifer name	Estimated ground-water withdrawals, in gallons per day (within industrial park or within 0.6 mile radius)	Hydrogeologic properties					
			Generalized hydrogeologic unit	Confined or unconfined (C/U)	Estimated transmissivity range or expected upper limit, in feet squared per day	Depth to water, in feet below land surface	Fresh or saline water	Local aquifer recharge source (potential stream flow capture or rainfall infiltration)
Vieques								
156	Unnamed	0	SLLGWR	U	<100	n.d.	n.d.	RI
175	EAA	0	Intergranular	U	200-2,000	4	Fresh	RI
250	Unnamed	0	SLLGWR	U	<100	45	n.d.	RI
318	Unnamed	0	SLLGWR	U	<100	n.d.	n.d.	RI
403	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	n.d.	RI
Villalba								
148	Unnamed	0	Intergranular	U	<500	n.d.	Fresh	RI
262	Unnamed	0	Intergranular	U	<500	n.d.	Fresh	RI
285	Unnamed	0	Intergranular	U	<500	32	Fresh	SFC/RI
Yabucoa								
042	Unnamed	0	SLLGWR	U	<100	15	Fresh	SFC/RI
242	Unnamed	0	SLLGWR	U	<100	n.d.	Fresh	SFC/RI
425	YVAA	0	Intergranular	U	<500	30	Fresh	RI
Yauco								
063	YAVAA	0	Intergranular	U	<100	10	Fresh	SFC/RI
067	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
097	Volcanic Rocks	0	SLLGWR	U	<100	n.d.	Fresh	RI
271	YAVAA	0	Intergranular	U	10,000-15,000	16	Fresh	SFC/RI
393	Volcanic Rocks	0	SLLGWR	U	<100	30	Fresh	RI

Table 3. Characteristics of wells near industrial parks in Puerto Rico.

[n.d., no data; if two numbers are separated by a dash (for example 55-129) numbers indicate range of data for more than one well]

Municipio and industrial park number	Depth below land surface (feet)	Yield (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)	Duration of well test (hours)
Adjuntas				
145, 259	47	3	n.d.	n.d.
Aguada				
253	n.d.	14	n.d.	n.d.
Aguadilla				
346	270	100-105	48	24
Aguas Buenas				
273	55-129	n.d.	0.31	7
Aibonito				
72, 902	126-240	60-100	n.d.	n.d.
238, 417	110-140	250-300	6.25	14
Añasco				
154	n.d.	n.d.	n.d.	n.d.
Arecibo				
65	114	14-35	n.d.	n.d.
280	61	500	n.d.	n.d.
350	320	500	n.d.	n.d.
Arroyo				
221	120	450	n.d.	n.d.
295	130	240	n.d.	n.d.
383	74-75	140-175	3.9	10
Barceloneta				
114	83-150	100	n.d.	n.d.
321	300-450	500-600	n.d.	n.d.
321	1001-2000	160	n.d.	n.d.
Barranquitas				
78	225-310	15-25	n.d.	n.d.
Bayamón				
3	300-500	40-60	0.1-3.4	24
4	90-150	50-500	1.3	n.d.
Cabo Rojo				
229	n.d.	n.d.	n.d.	n.d.
Caguas				
17	355-580	35-64	0.26-0.46	72
68	546	60	0.47	8
112	87	n.d.	n.d.	n.d.
307	n.d.	95	2.8	24
Camuy				
169, 297	140	100	n.d.	n.d.
Canóvanas				
73	100	n.d.	n.d.	n.d.
164, 191	150-305	10-60	4.5	24

Table 3. Characteristics of wells near industrial parks in Puerto Rico.—Continued

[n.d., no data; if two numbers are separated by a dash (for example 55-129) numbers indicate range of data for more than one well]

Municipio and industrial park number	Depth below land surface (feet)	Yield (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)	Duration of well test (hours)
Carolina				
12	60-300	30-60	0.64-1.63	24
28	90-160	55-200	n.d.	n.d.
66	71-302	100	n.d.	n.d.
411	100	100	2.32	24
Cataño				
108, 344	97-116	50-100	2.2	24
911	130-230	200-800	n.d.	n.d.
Cayey				
9	167-170	75-108	3.3	24
143	140-176	150-224	9.7-15	24
336	307-400	107-150	3.34-21.7	24
Ceiba				
144, 308	27	25	n.d.	n.d.
421	29	40	n.d.	n.d.
Ciales				
232	67-200	70-180	22-38	24
Cidra				
274	367-465	40-90	0.73	48
391	305-500	20-110	0.28-1.34	22
Coamo				
167, 408	40-350	n.d.	n.d.	n.d.
Comerío				
124	100	60	1.2	24
Corozal				
153	n.d.	n.d.	n.d.	n.d.
Culebra				
281	n.d.	n.d.	n.d.	n.d.
Dorado				
128, 361	60	100	n.d.	n.d.
Fajardo				
99	23-34	n.d.	n.d.	n.d.
Florida				
223	200-400	60-200	11	n.d.
Guánica				
141	114-150	200-1,700	15-105	24
207	4	n.d.	n.d.	n.d.
Guayama				
6	70	7	0.17	n.d.
165	105	165	7.2	n.d.
381	100-150	250-650	2.7-7.7	6
Guayanilla				
290, 315	170-200	1,100-1,500	50	24
428	120-150	350-1,200	n.d.	n.d.

Table 3. Characteristics of wells near industrial parks in Puerto Rico.—Continued

[n.d., no data; if two numbers are separated by a dash (for example 55-129) numbers indicate range of data for more than one well]

Municipio and industrial park number	Depth below land surface (feet)	Yield (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)	Duration of well test (hours)
Guaynabo				
057, 234, 331	n.d.	n.d.	n.d.	n.d.
Gurabo				
024	n.d.	n.d.	n.d.	n.d.
Hatillo				
919	30	n.d.	n.d.	n.d.
Hormigueros				
211, 920	106	400	n.d.	n.d.
Humacao				
140	84-140		1.5-2	2
278	150	200	5.2	16
313, 407	297	45-115	1.15	n.d.
Isabela				
102, 921	n.d.	n.d.	n.d.	n.d.
Jayuya				
241	75-120	47-85	1.2-2.4	44
Juana Díaz				
384	100	300	n.d.	n.d.
Juncos				
303	52-110	14-75	n.d.	n.d.
394	485	55	0.63	24
Lajas				
209, 418	97-140	258-500	6-25	n.d.
Lares				
249	n.d.	n.d.	n.d.	n.d.
309	80	22	4.16	8
Las Marias				
245, 282	n.d.	n.d.	n.d.	n.d.
Las Piedras				
215, 332	500-507	30-80	0.19- 2.60	24
332	305-505	29-75	0.17-2.20	24
Loíza				
059, 147	125	35	n.d.	n.d.
Luquillo				
85	50-60	5-22	2.4	24
Manatí				
84/125	200	1,400	103	n.d.
356	191-307	200-700	22-35	n.d.
356	2000	1,000	n.d.	n.d.
927	210	50	n.d.	n.d.
Maricao				
349	135	70-260	n.d.	n.d.
Maunabo				
283	100-120	700	41	36

Table 3. Characteristics of wells near industrial parks in Puerto Rico.—Continued

[n.d., no data; if two numbers are separated by a dash (for example 55-129) numbers indicate range of data for more than one well]

Municipio and industrial park number	Depth below land surface (feet)	Yield (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)	Duration of well test (hours)
Moca				
2219, 252, 311	n.d.	n.d.	n.d.	n.d.
Mayagüez				
31	53-250	42-52	1.6	24
36	100-156	74-255	7.3-10.5	8
93, 178, 214	55-156	20	n.d.	15
231	42-104	108-450	3.5	9
270	43-130	31-100	0.7	n.d.
120, 130	n.d.	n.d.	n.d.	n.d.
193	130	16	1.2	n.d.
Morovis				
218, 413	n.d.	n.d.	n.d.	n.d.
Naguabo				
162, 243, 299, 932	n.d.	n.d.	n.d.	n.d.
Naranjito				
235, 294, 933, 934	n.d.	n.d.	n.d.	n.d.
Orocovis				
228, 237, 284	n.d.	n.d.	n.d.	n.d.
Patillas				
236, 375	90-230	100-258	5.4	24
Peñuelas				
406	107-126	20-65	0.3-2.4	8
213	120-150	700	23	10
Ponce				
27	60-185	50-1,500	2.5-115	24
50, 51	165-505	250-1,500	28-60	24
62	105-167	100-600	10-16	24
80	65	50	n.d.	n.d.
86	200	250	10	24
306	80-100	35-500	0.55-10	24
324	140-202	16-650	6.4-28	53
415	185-215	150-400	n.d.	n.d.
937	115-150	430	23-36	24
Quebradillas				
11, 276, 400	580-610	130-144	n.d.	n.d.
Rincón				
136	90-153	250	n.d.	n.d.
Río Grande				
6, 20, 155, 225	n.d.	n.d.	n.d.	n.d.
Sabana Grande				
198, 374, 941	125	514	15	n.d.
Salinas				
87, 226	60-154	200-1,300	n.d.	n.d.
90	80-152	156-1,450	13-29	24

Table 3. Characteristics of wells near industrial parks in Puerto Rico.—Continued

[n.d., no data; if two numbers are separated by a dash (for example 55-129) numbers indicate range of data for more than one well]

Municipio and industrial park number	Depth below land surface (feet)	Yield (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)	Duration of well test (hours)
San German				
264, 412	73-100	45-273	n.d.	n.d.
San Juan				
7, 21, 150	70-146	75-150	13.5-20	13
22	405	240	7	24
52	33-126	25-160	45	n.d.
137	90-200	50-1,200	15-18	n.d.
San Lorenzo				
109	350	30	0.36	24
San Sebastián				
142	300	n.d.	n.d.	n.d.
Santa Isabel				
76	165-250	1,000-2,800	5.4	12
37	75-140	40-100	4.6-16.7	n.d.
Toa Alta				
82	n.d.	n.d.	n.d.	n.d.
Toa Baja				
217	n.d.	n.d.	n.d.	n.d.
Trujillo Alto				
233, 357, 957	n.d.	n.d.	n.d.	n.d.
Utuado				
203, 396	n.d.	n.d.	n.d.	n.d.
Vega Alta				
206, 292	120-220	180-300	3.6-4	24
Vega Baja				
96	128-360	400-500	73	n.d.
Vieques				
250	42-60	25-45	n.d.	n.d.
175	35-45	20-30	n.d.	n.d.
Villalba				
148, 262, 285	n.d.	n.d.	n.d.	n.d.
Yabucoa				
425	n.d.	n.d.	n.d.	n.d.
Yauco				
63, 271	82-100	80-1,050	11-25	47

Figures

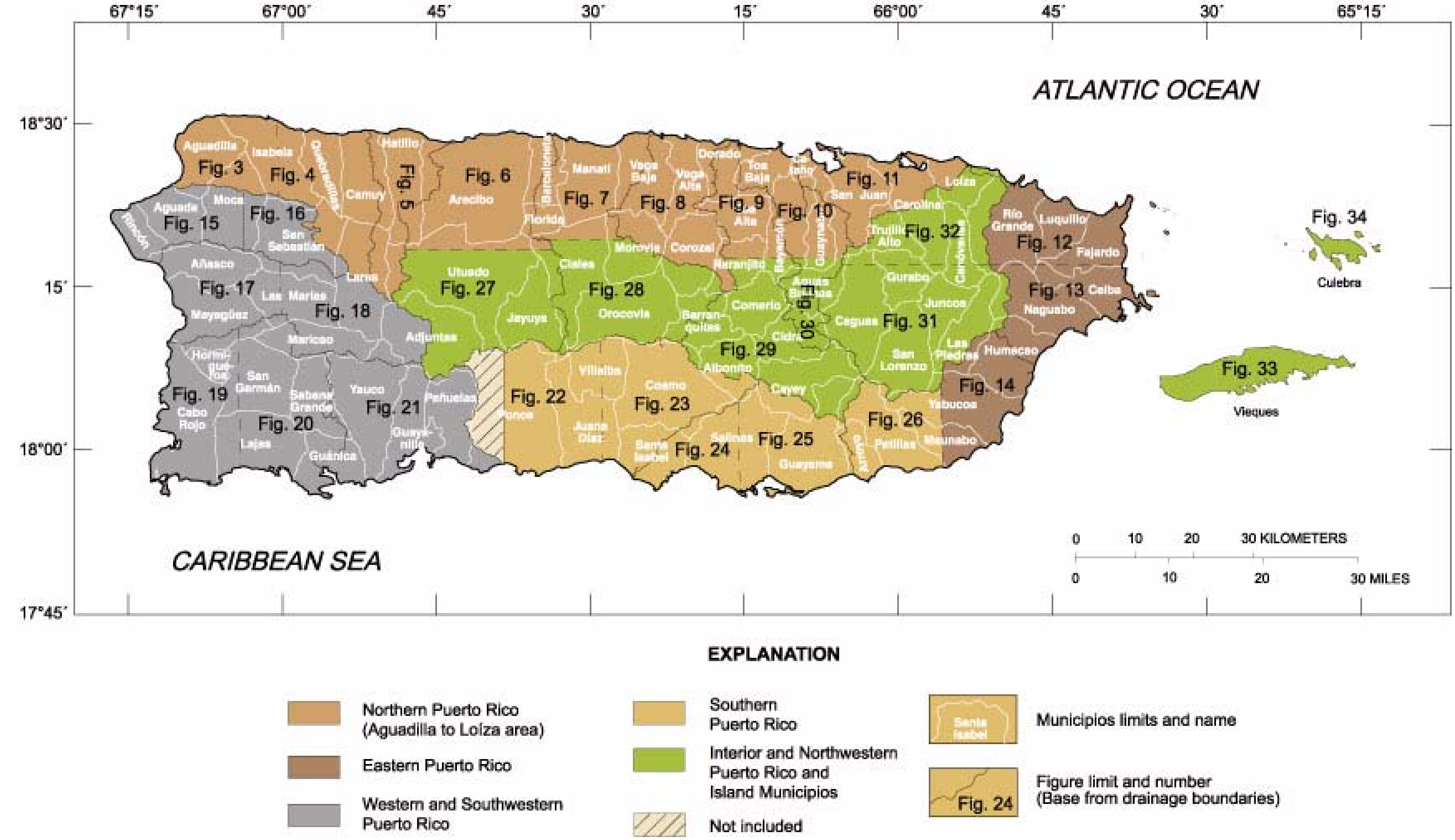
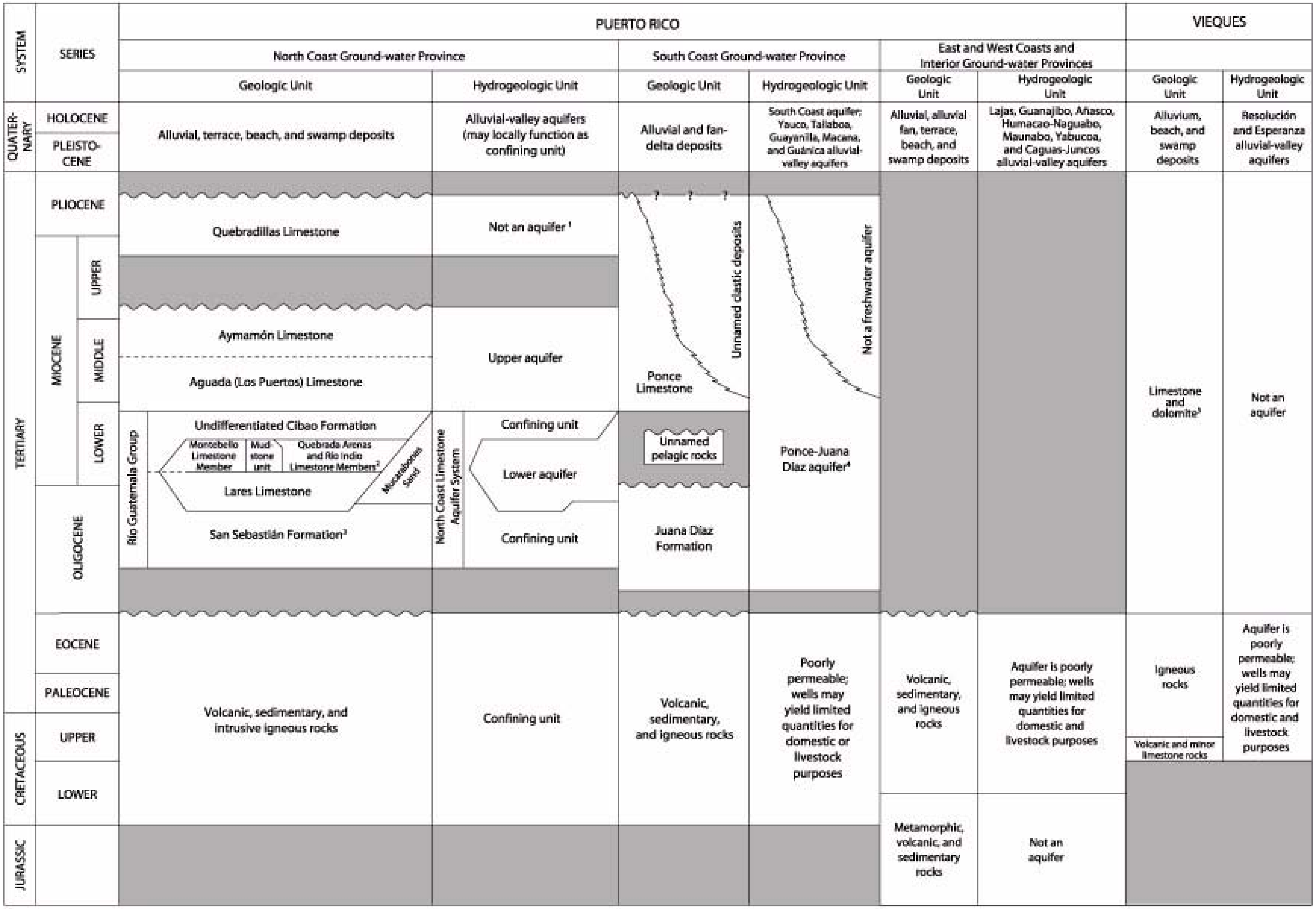


Figure 1. Index of maps for figures 3 through 34.



¹ Mostly or entirely unsaturated.

² Quebrada Arenas and Rio Indio Limestone Members of the Cibao Formation may function as confining unit in downdip areas.

³ San Sebastián Formation contains some conglomeratic and sandy deposits in updip areas that may function as part of the lower aquifer.

⁴ Juana Díaz Formation clastic beds are poorly permeable. Juana Díaz Formation and Ponce Limestone yield fresh water locally, mostly where they are adjacent to or underlie stream-valley alluvial aquifers. Clastic beds equivalent to the Ponce Limestone are deeply buried and contains saline water.

⁵ There are no data available to evaluate water-bearing characteristics.

Figure 2. Correlation of geologic and hydrogeologic units of Puerto Rico (modified from Olcott, 1997).

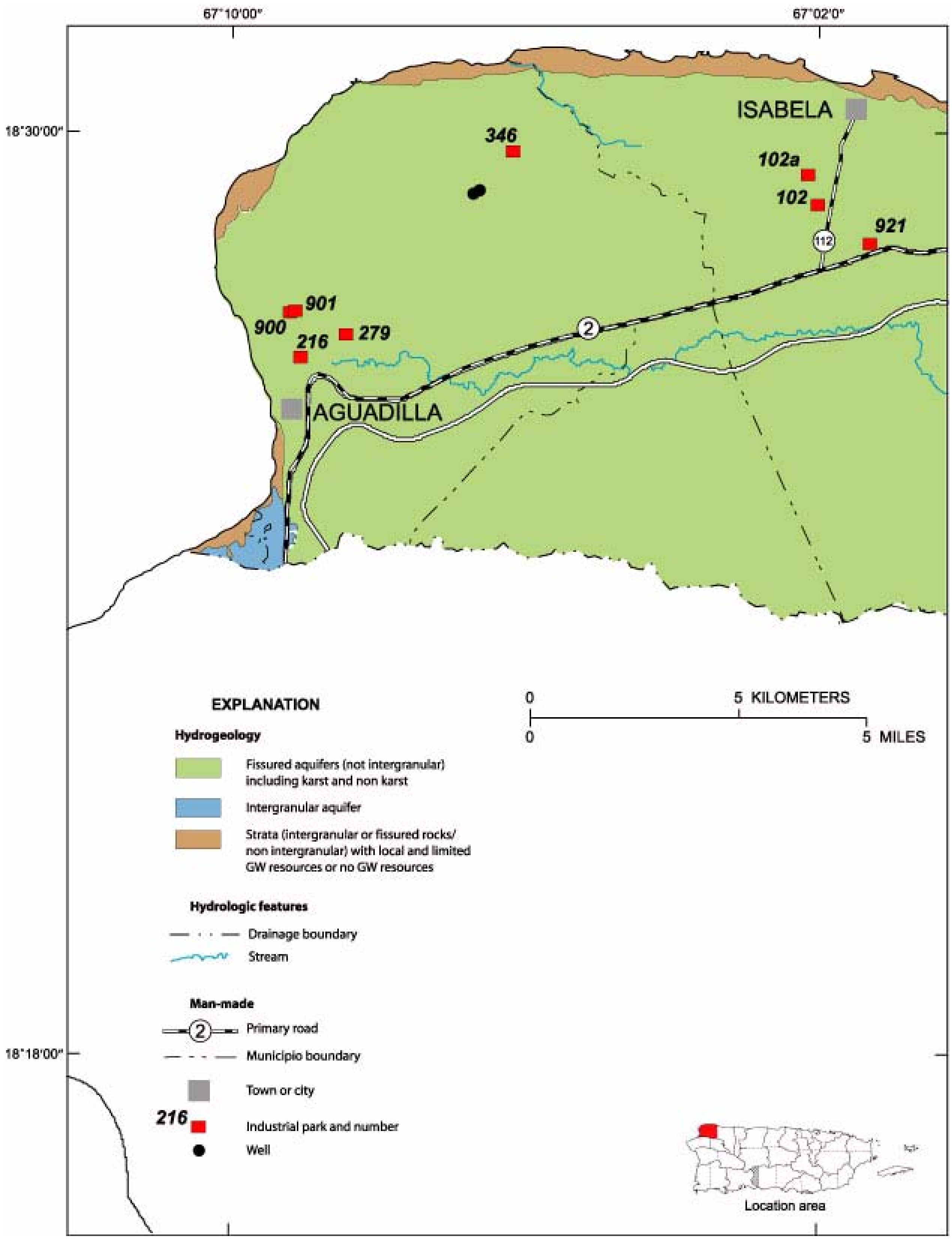


Figure 3. Map showing hydrogeologic units and location of municipal industrial parks near Aguadilla and Isabela, Puerto Rico.

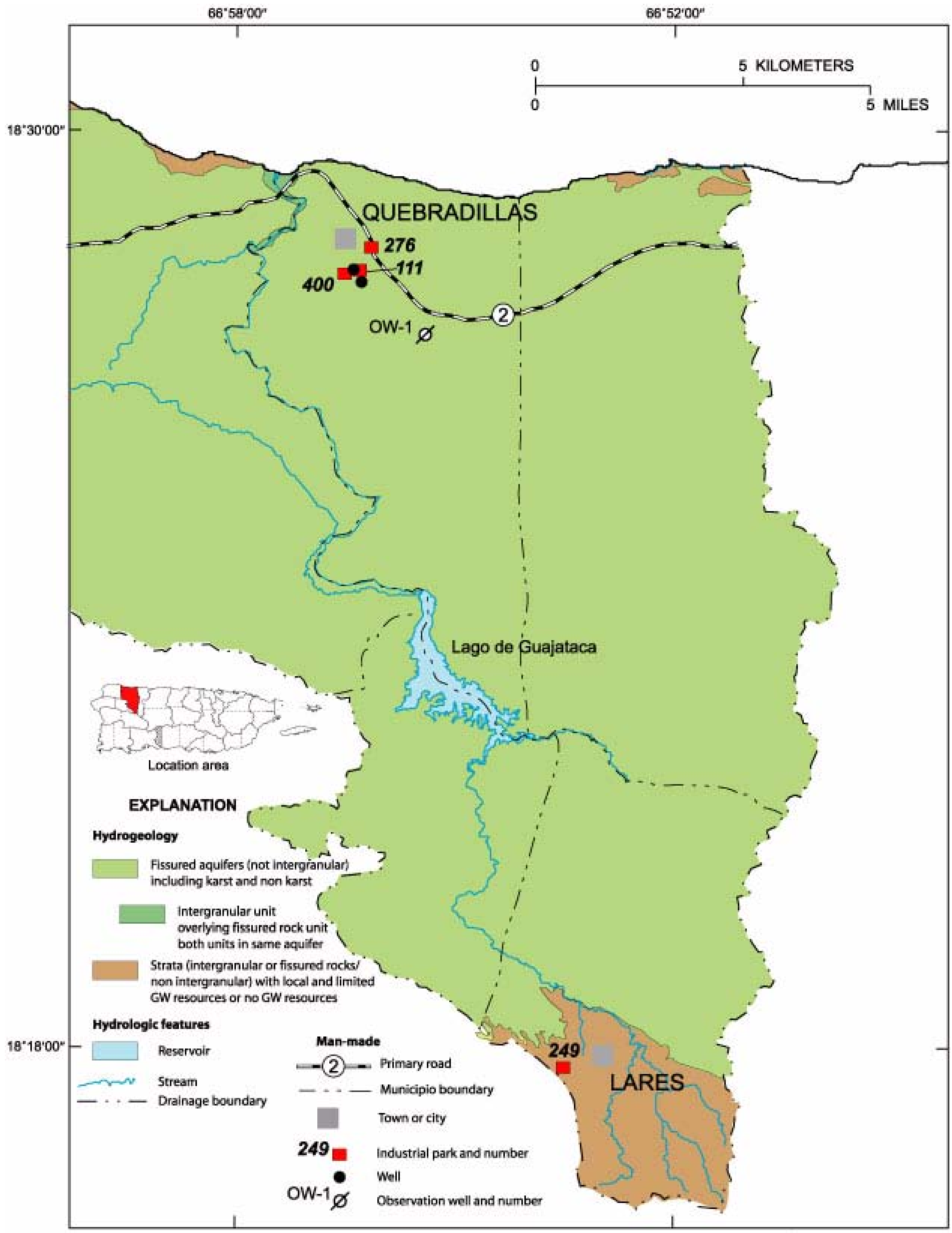


Figure 4. Map showing hydrogeologic units and location of municipal industrial parks near Quebradillas and Lares, Puerto Rico.

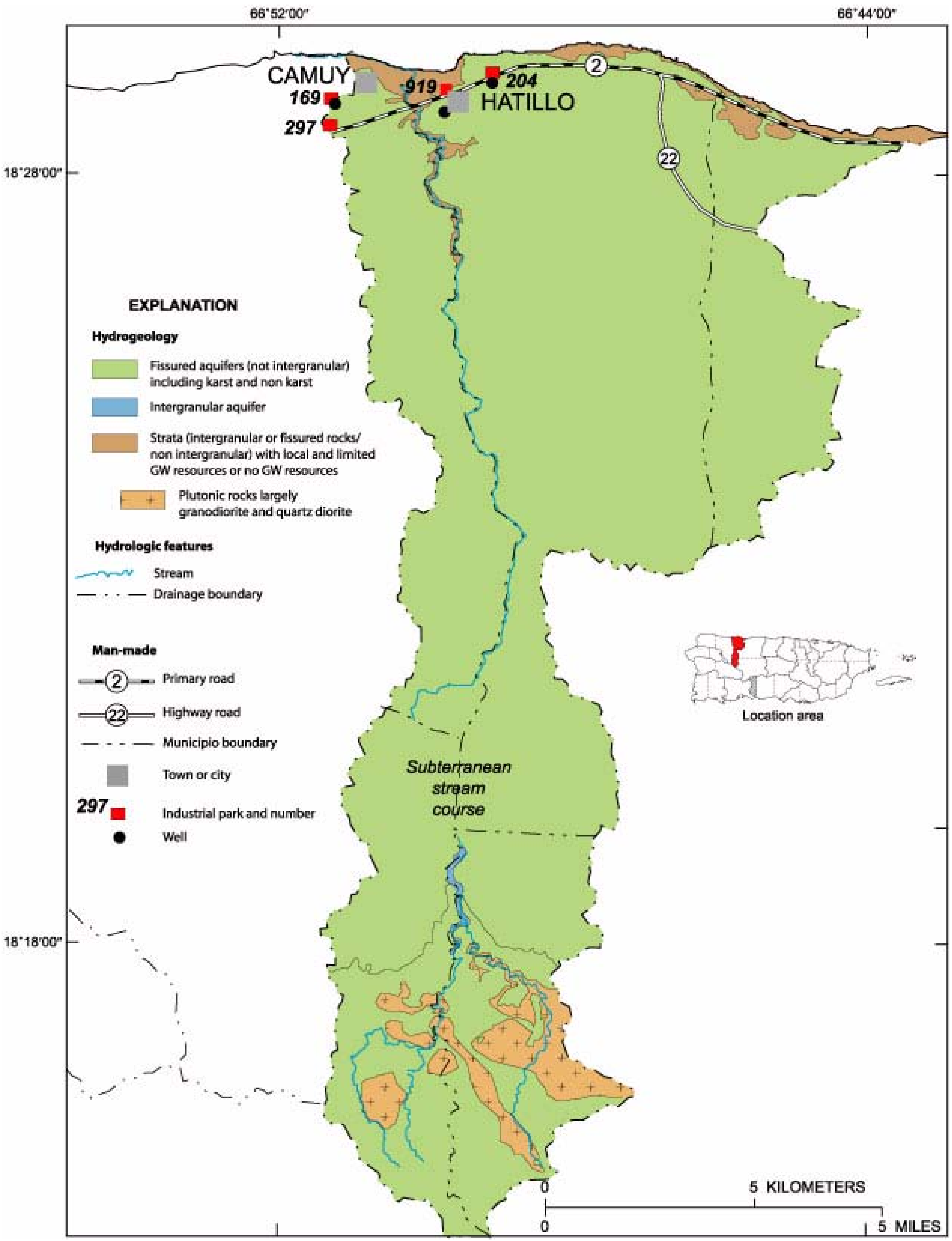


Figure 5. Map showing hydrogeologic units and location of municipal industrial parks near Camuy and Hatillo, Puerto Rico.

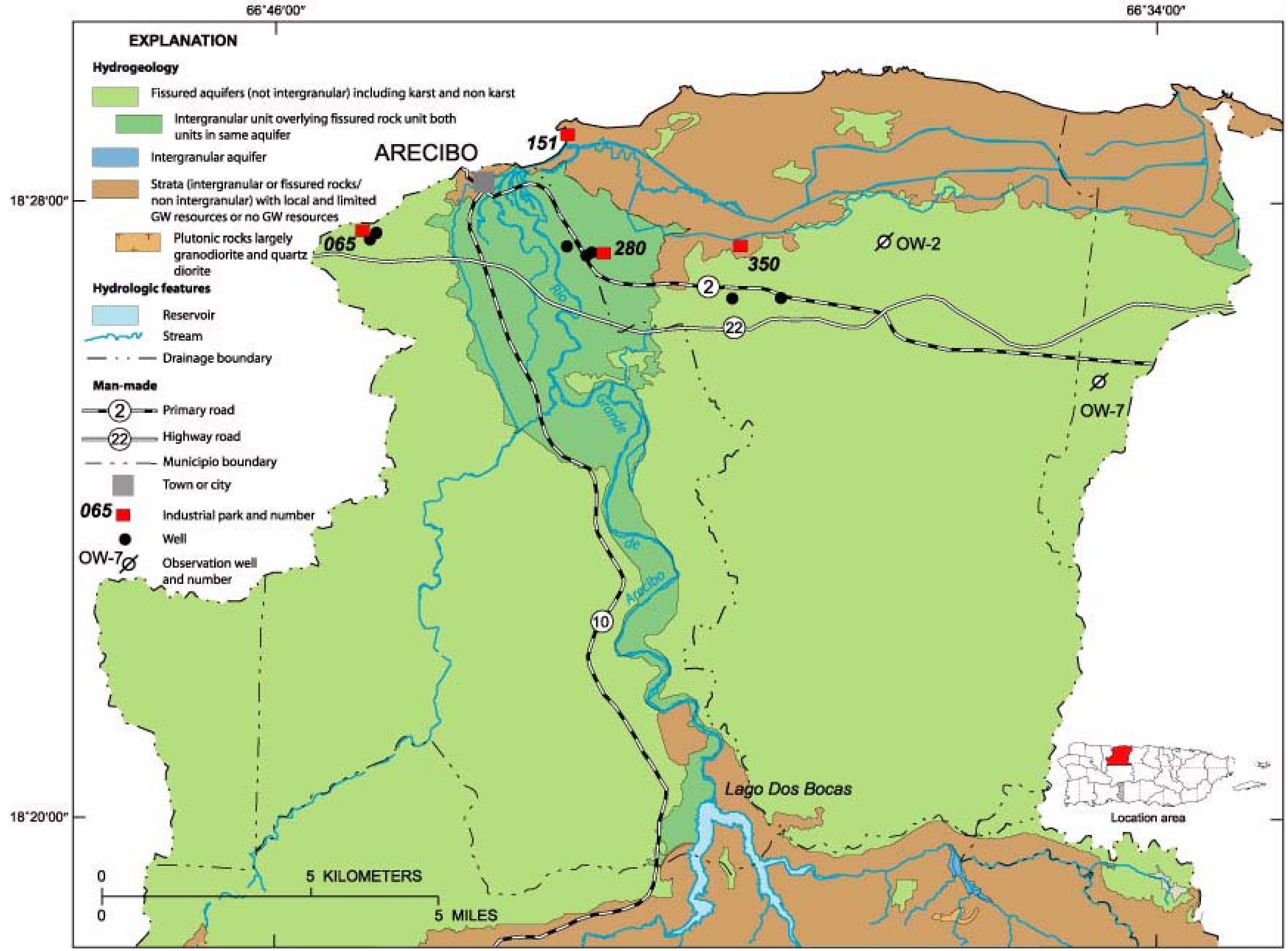


Figure 6. Map showing hydrogeologic units and location of municipal industrial parks near Arecibo, Puerto Rico.

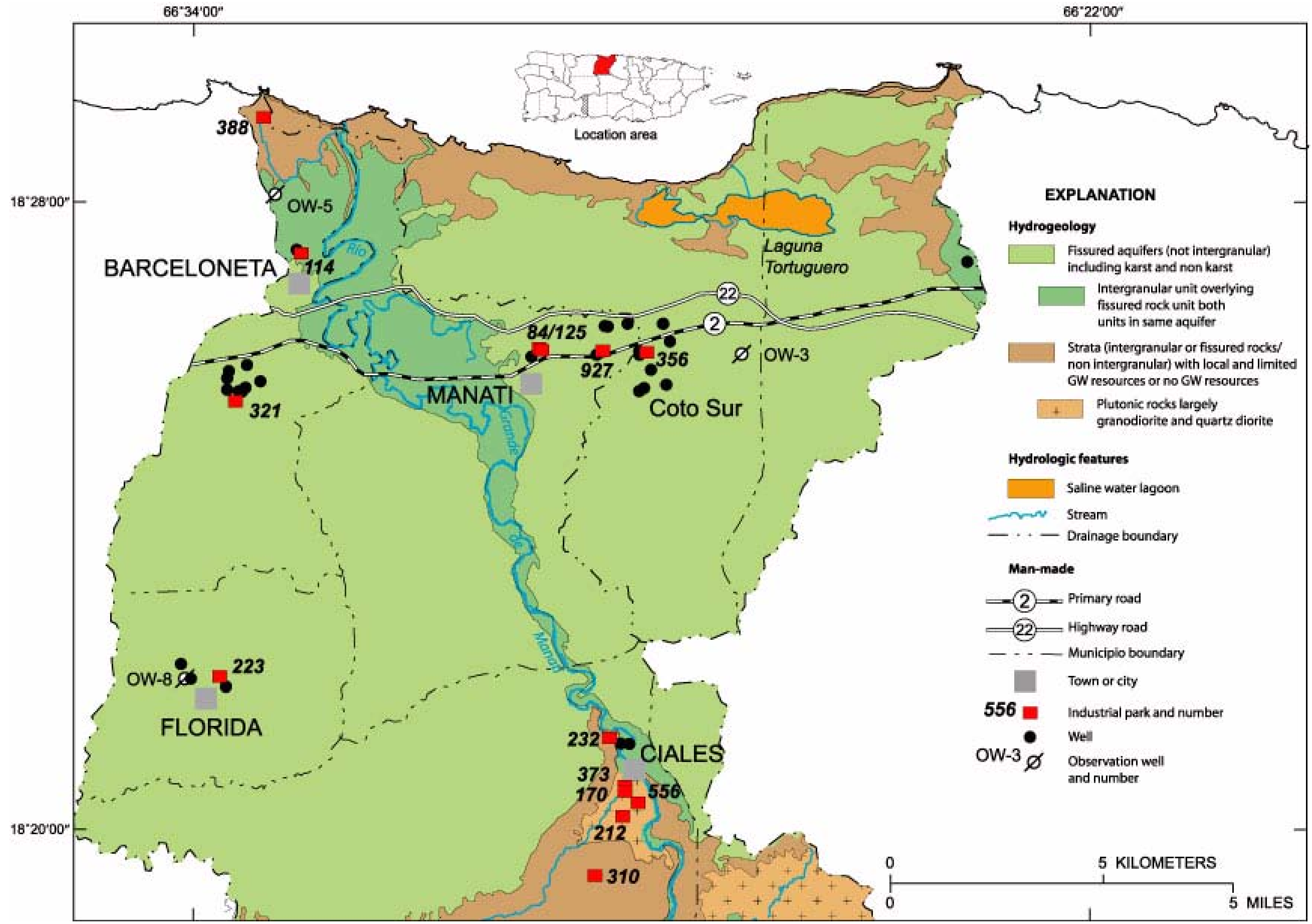


Figure 7. Map showing hydrogeologic units and location of municipal industrial parks near Barceloneta, Manatí, Florida, and Ciales, Puerto Rico.

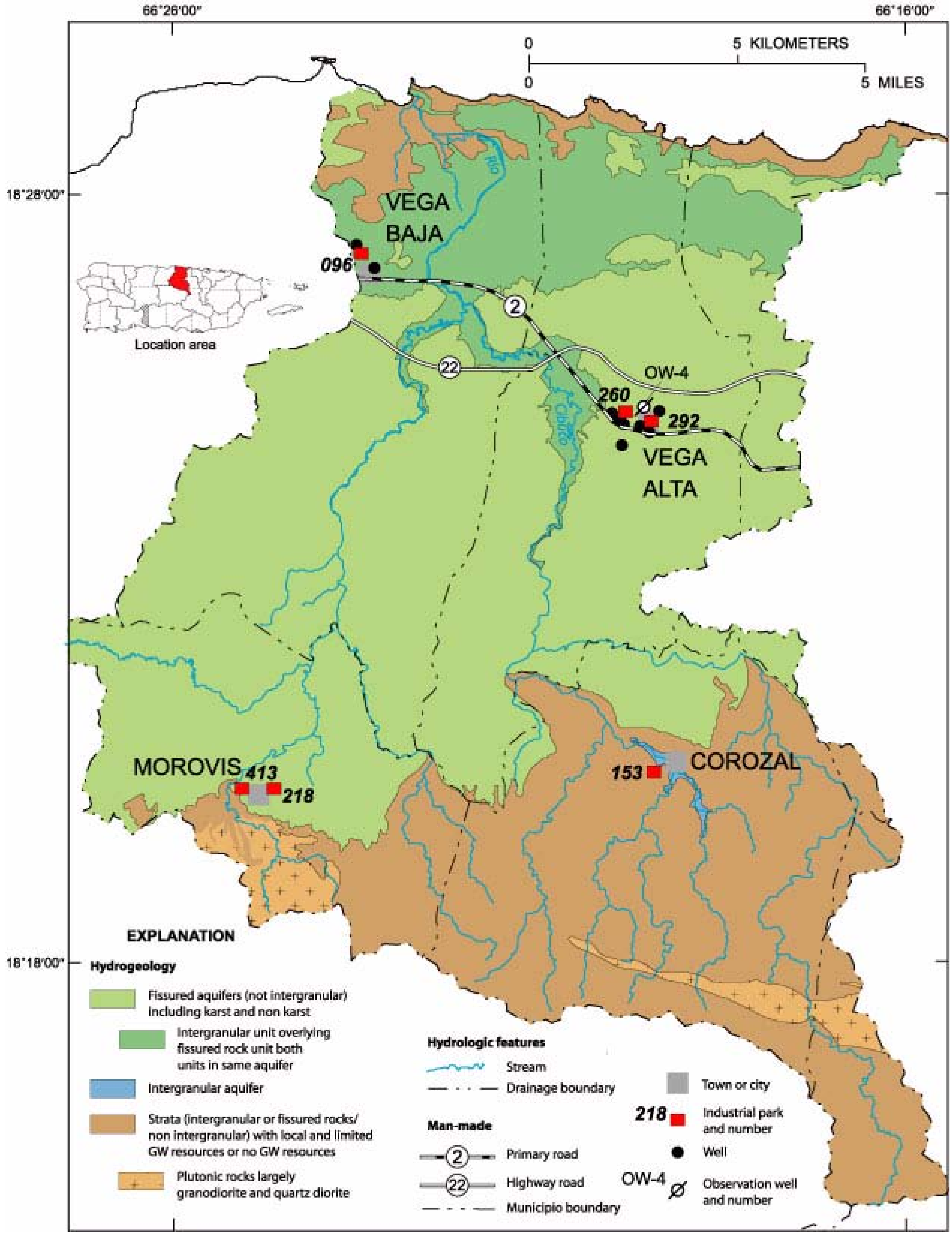


Figure 8. Map showing hydrogeologic units and location of municipal industrial parks near Vega Baja, Vega Alta, Morovis, and Corozal, Puerto Rico.

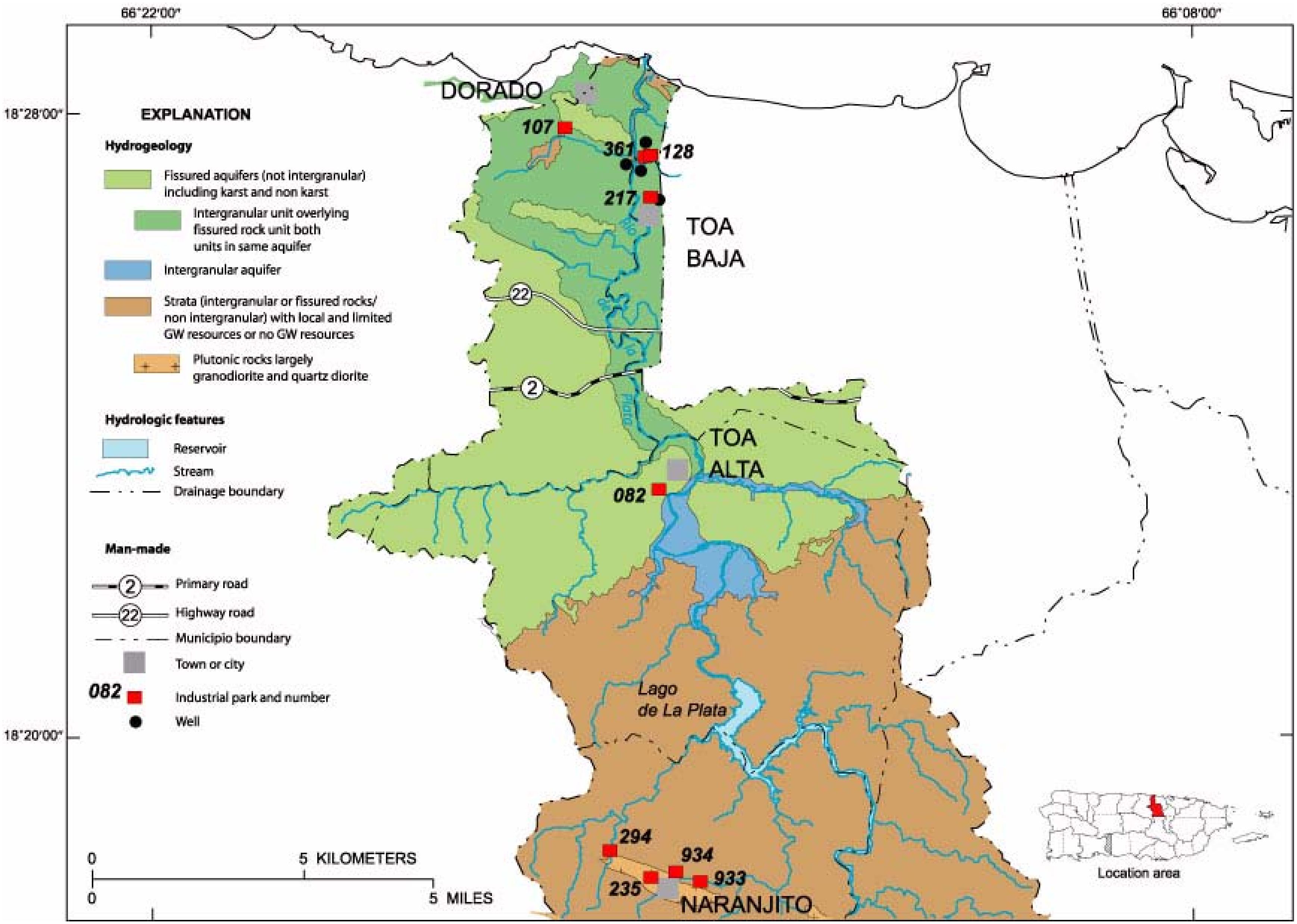


Figure 9. Map showing hydrogeologic units and location of municipal industrial parks near Dorado, Toa Baja, Toa Alta, and Naranjito, Puerto Rico.

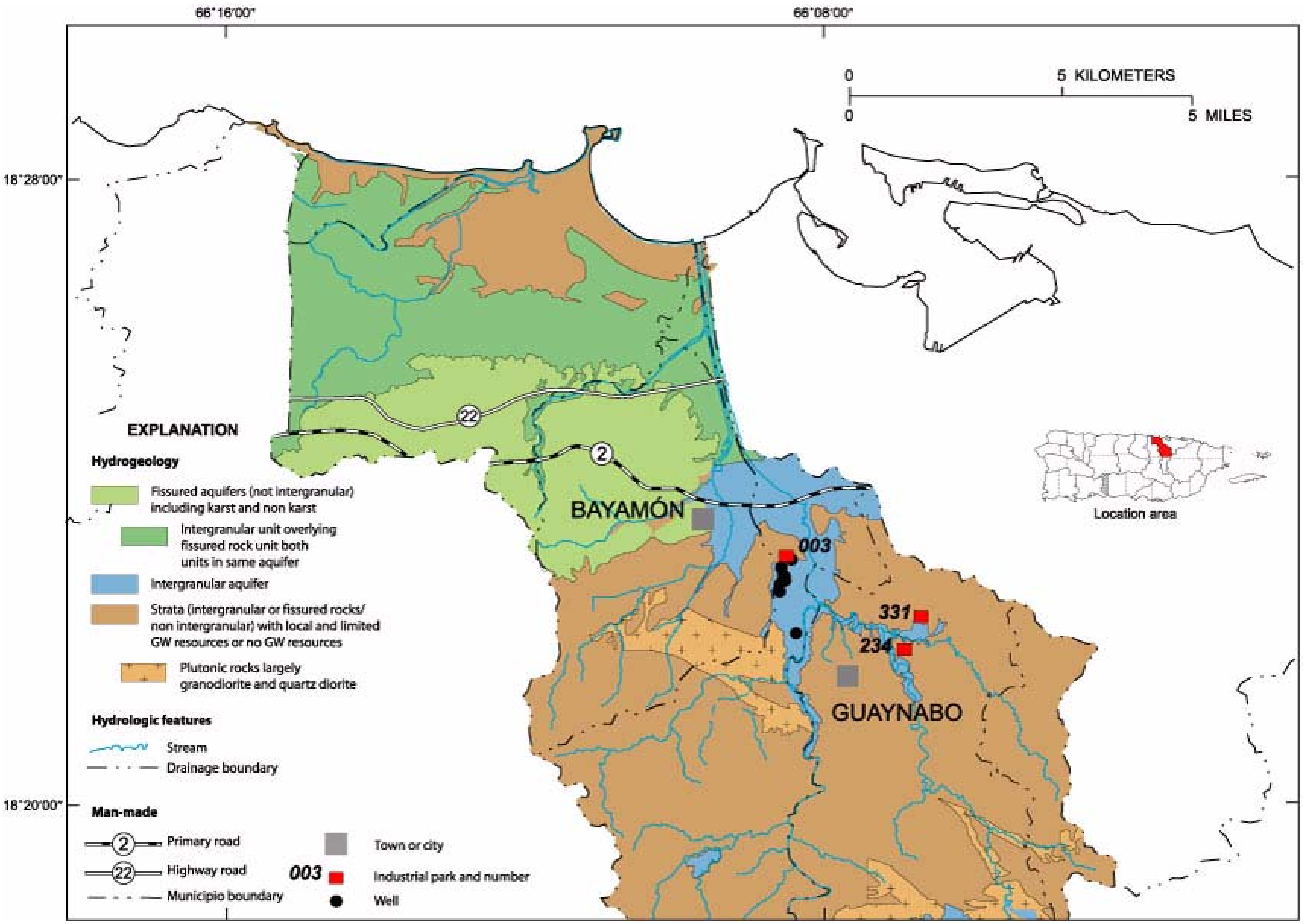


Figure 10. Map showing hydrogeologic units and location of municipal industrial parks near Bayamón and Guaynabo, Puerto Rico.

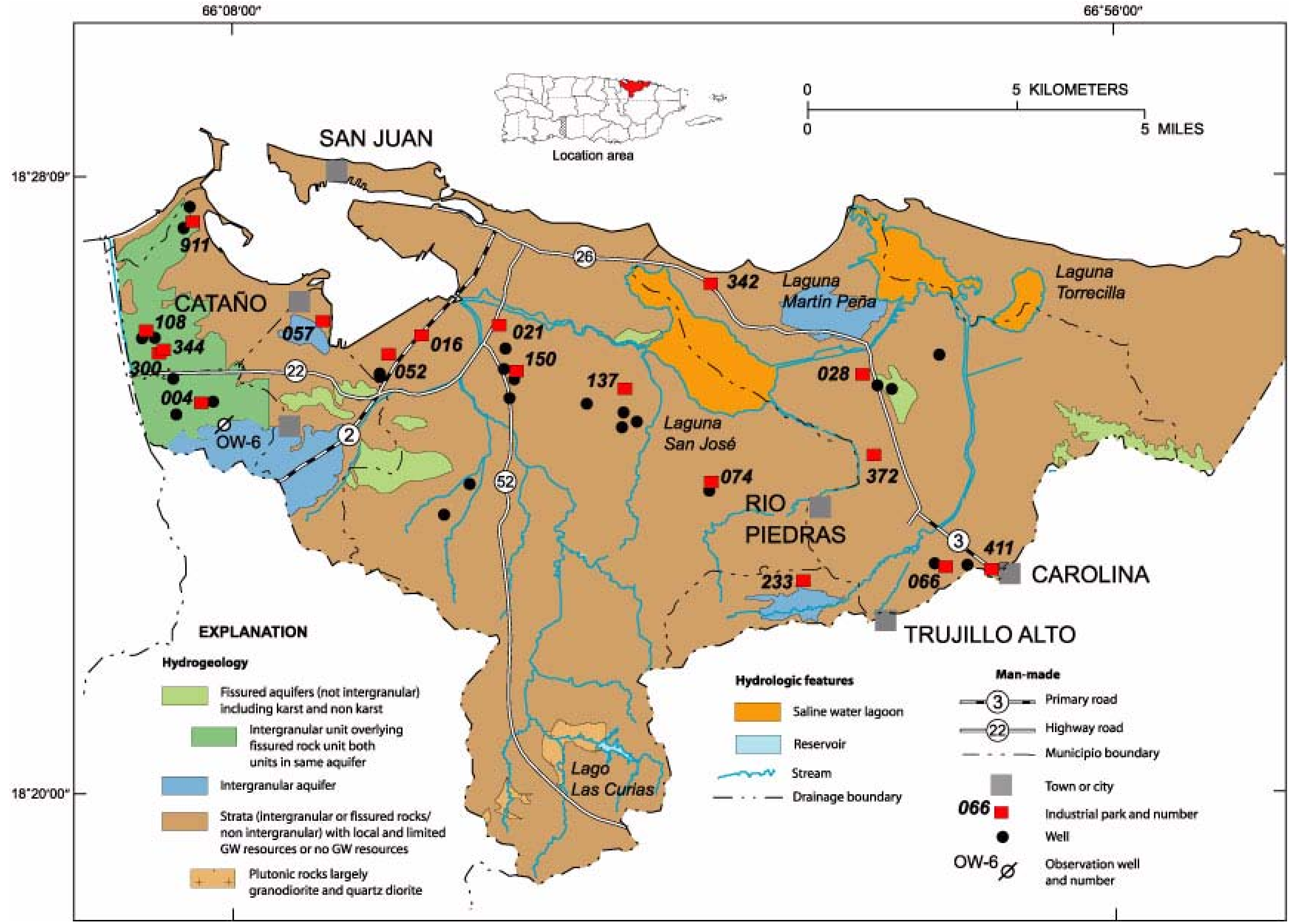


Figure 11. Map showing hydrogeologic units and location of municipal industrial parks near Cataño, San Juan, and Carolina, Puerto Rico.

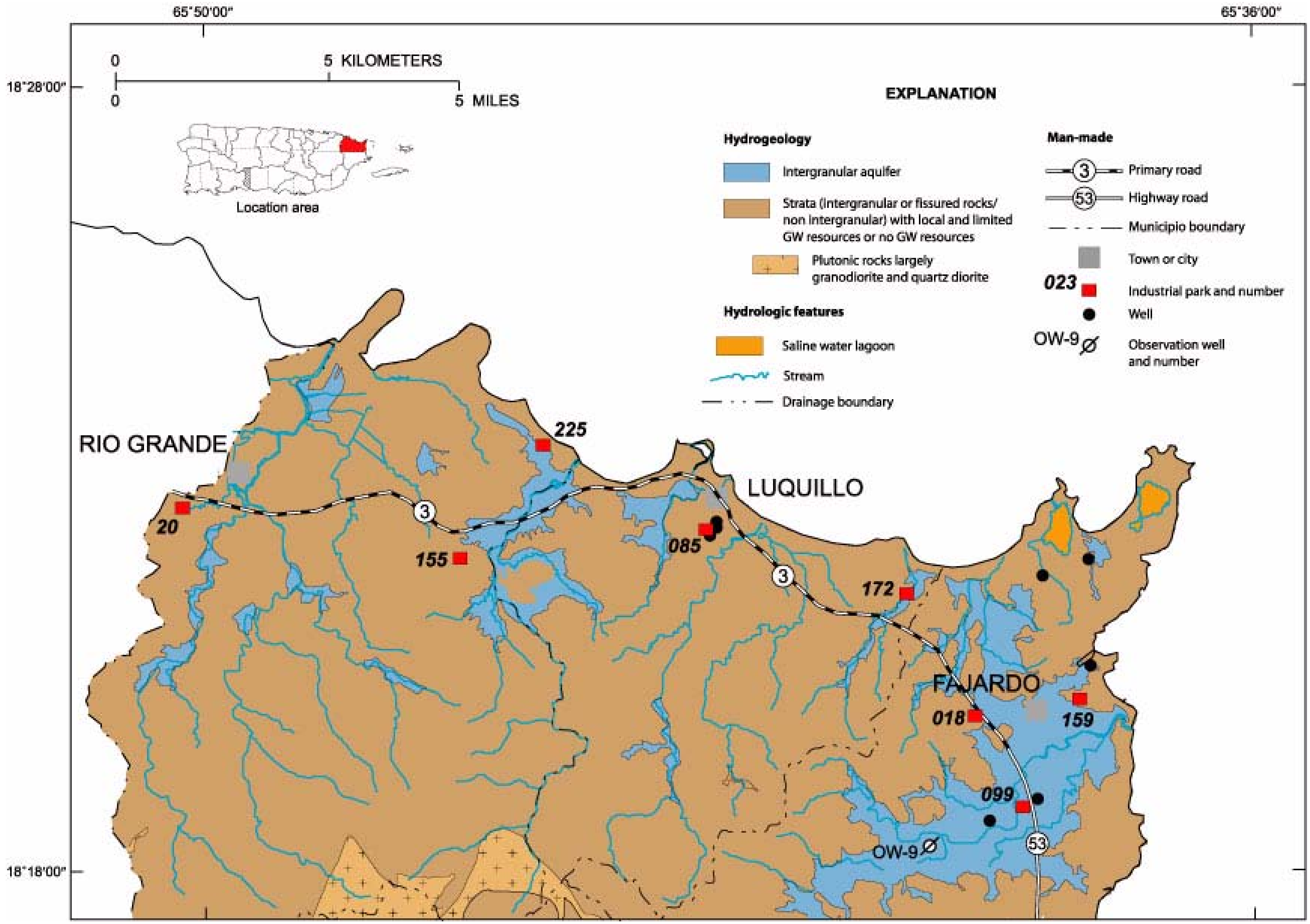


Figure 12. Map showing hydrogeologic units and location of municipal industrial parks near Río Grande, Luquillo, and Fajardo, Puerto Rico

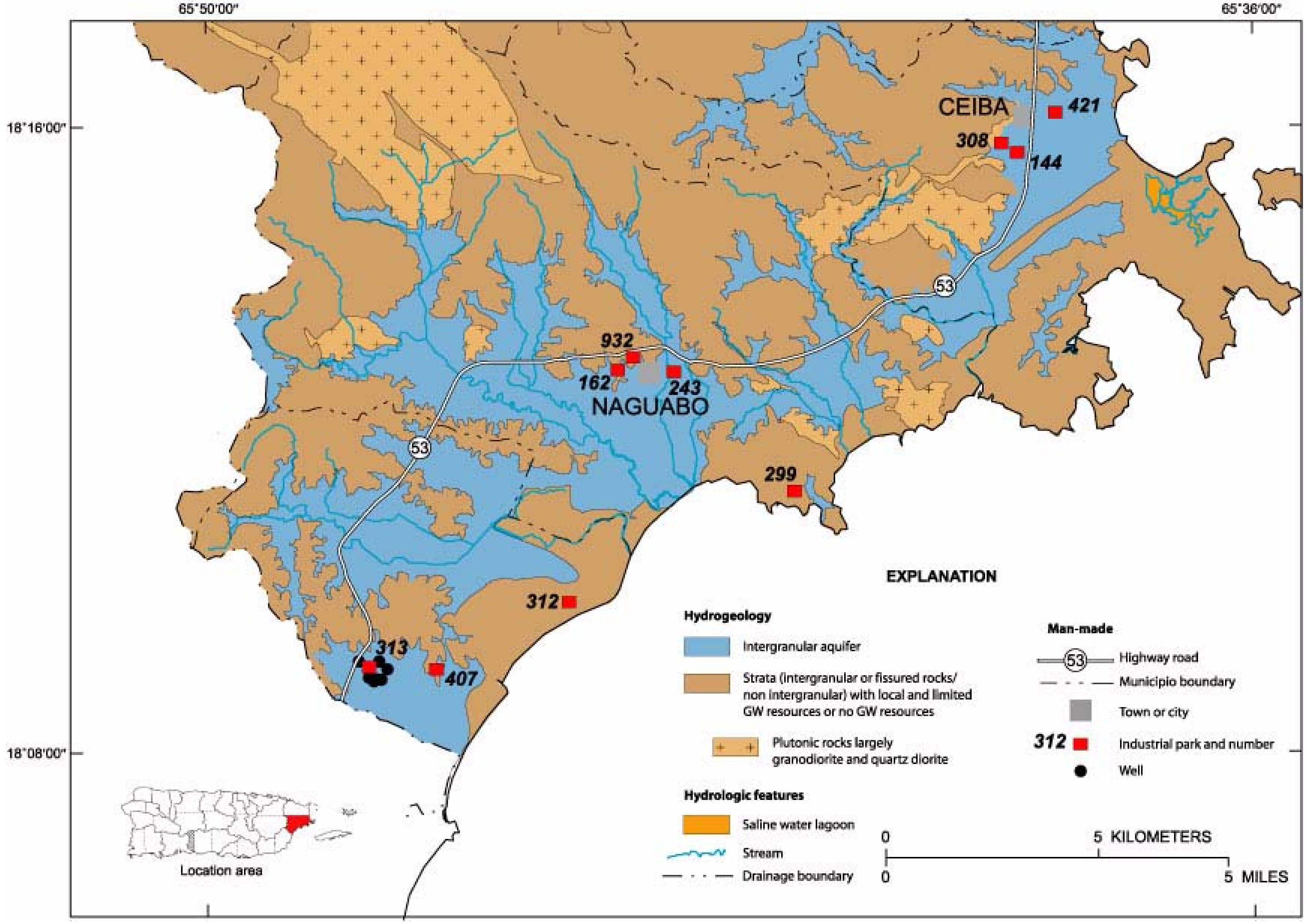


Figure 13. Map showing hydrogeologic units and location of municipal industrial parks near Ceiba and Naguabo, Puerto Rico.

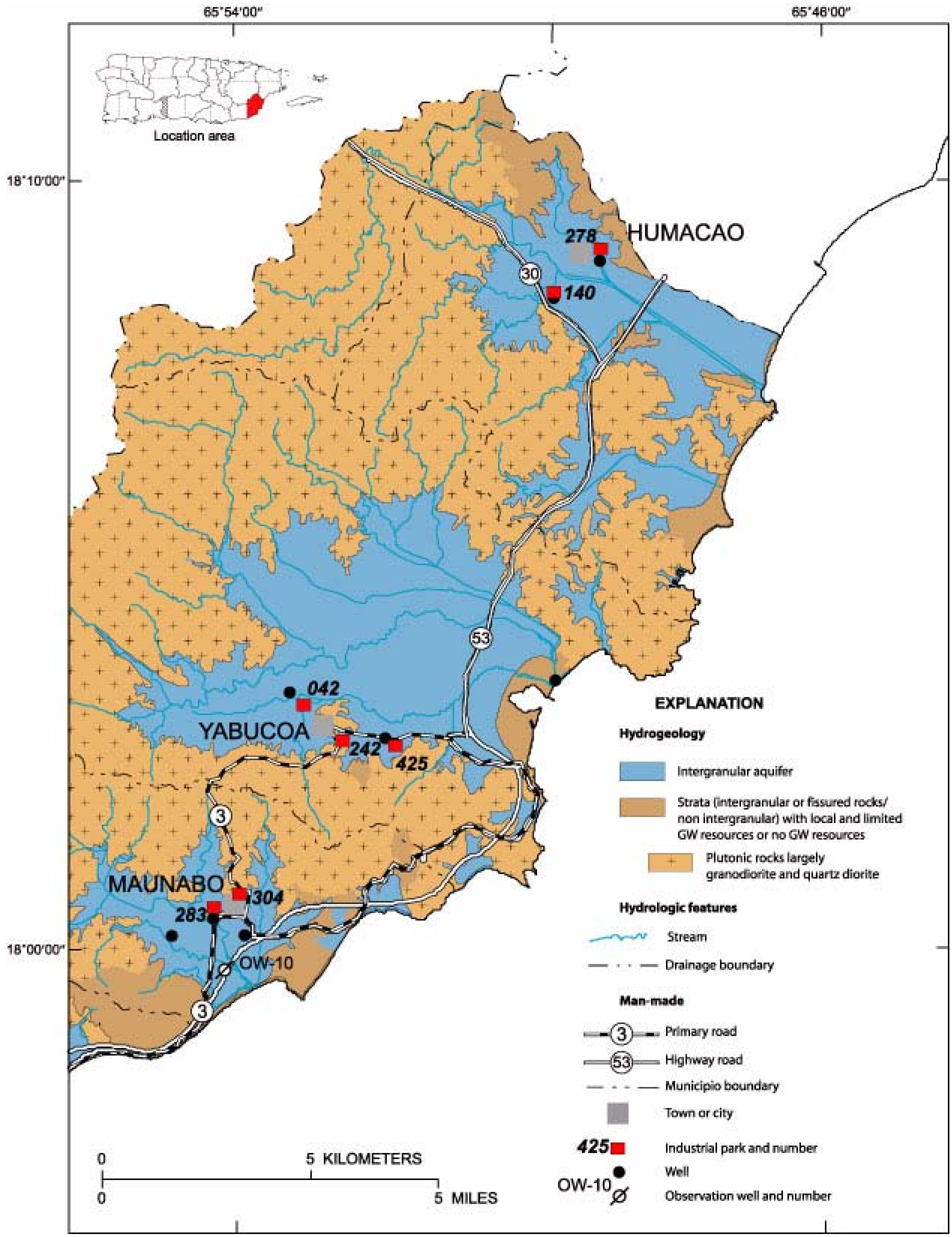


Figure 14. Map showing hydrogeologic units and location of municipal industrial parks near Humacao, Yabucoa, and Maunabo, Puerto Rico.

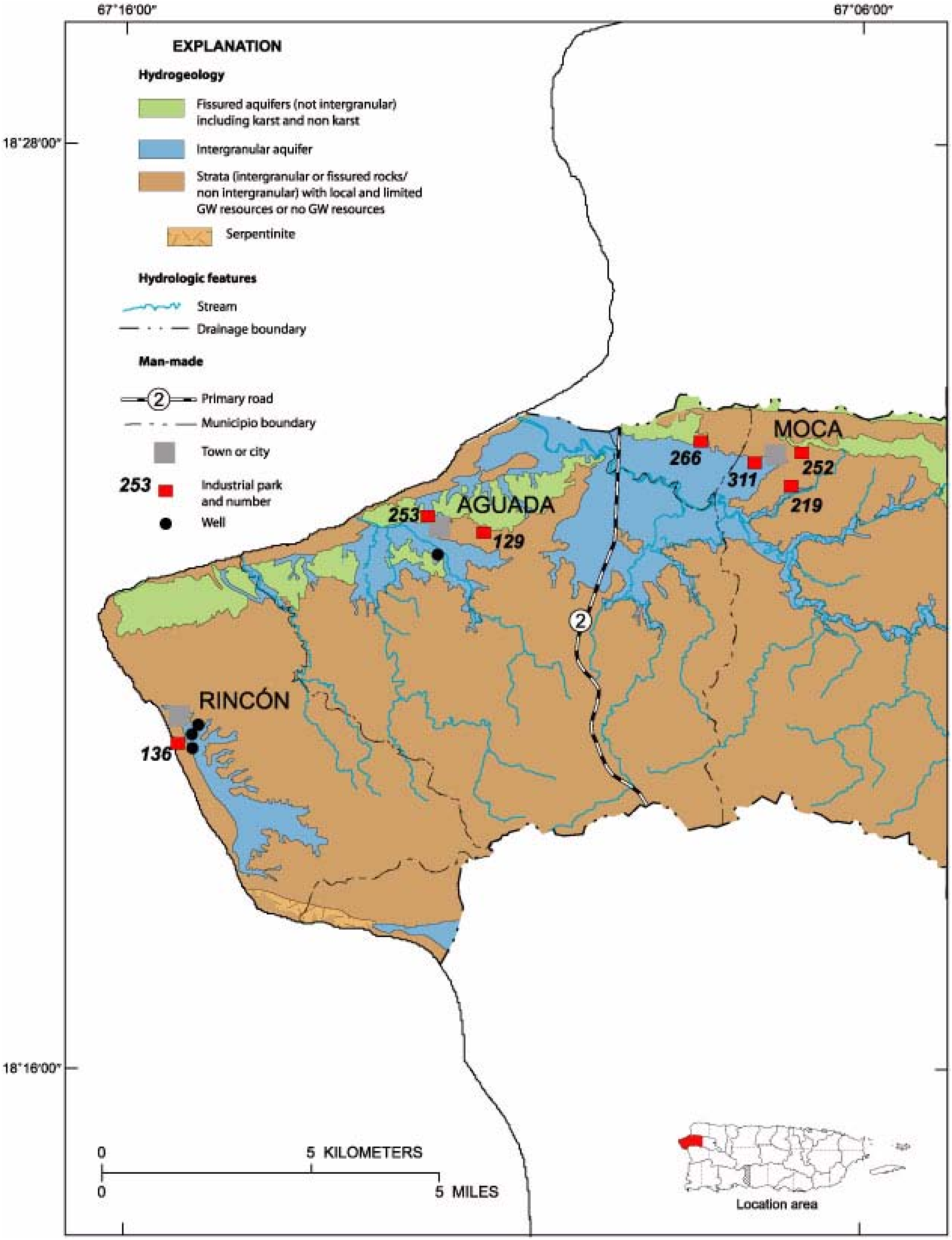


Figure 15. Map showing hydrogeologic units and location of municipal industrial parks near Rincón, Aguada, and Moca, Puerto Rico.

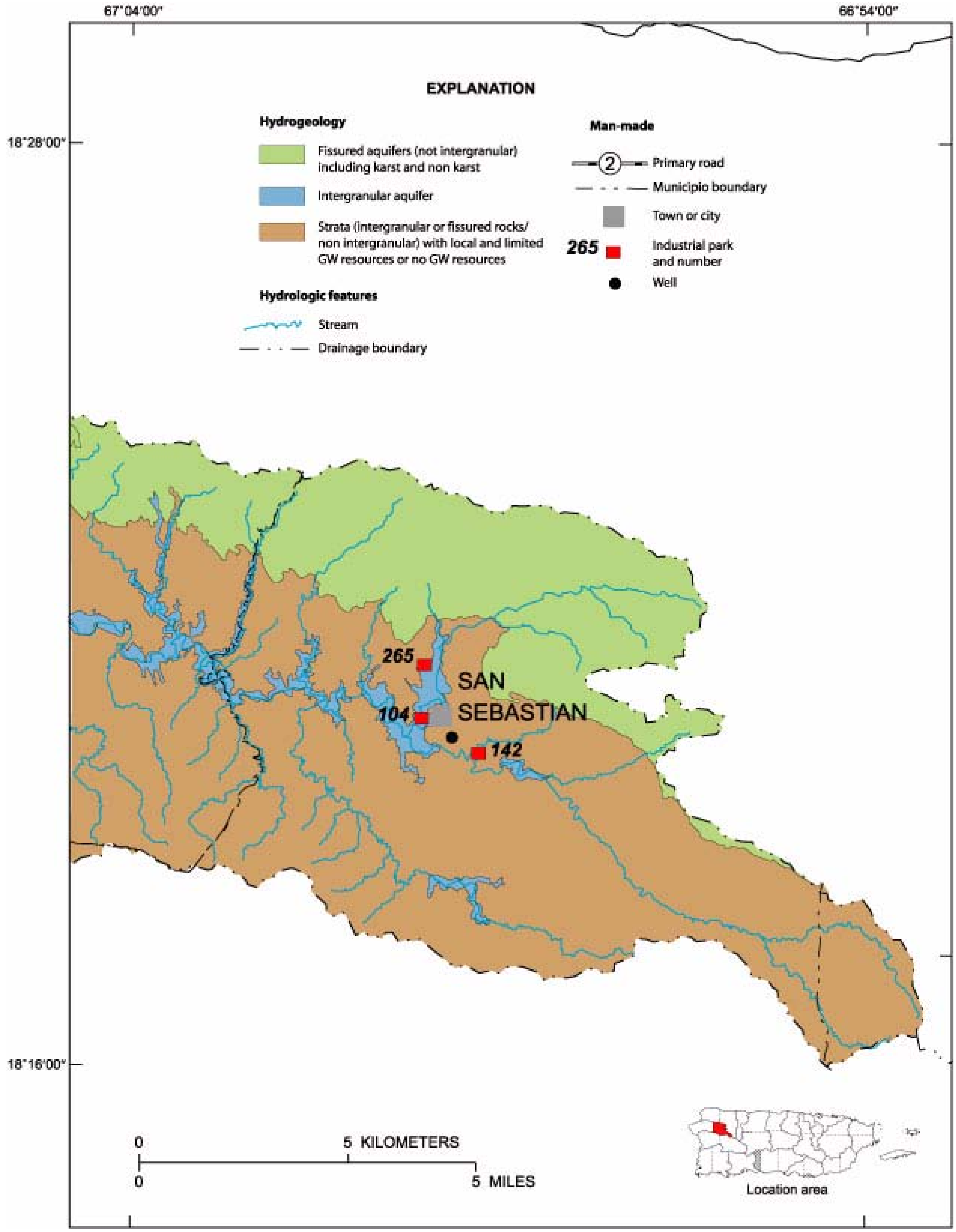


Figure 16. Map showing hydrogeologic units and location of municipal industrial parks near San Sebastián, Puerto Rico.

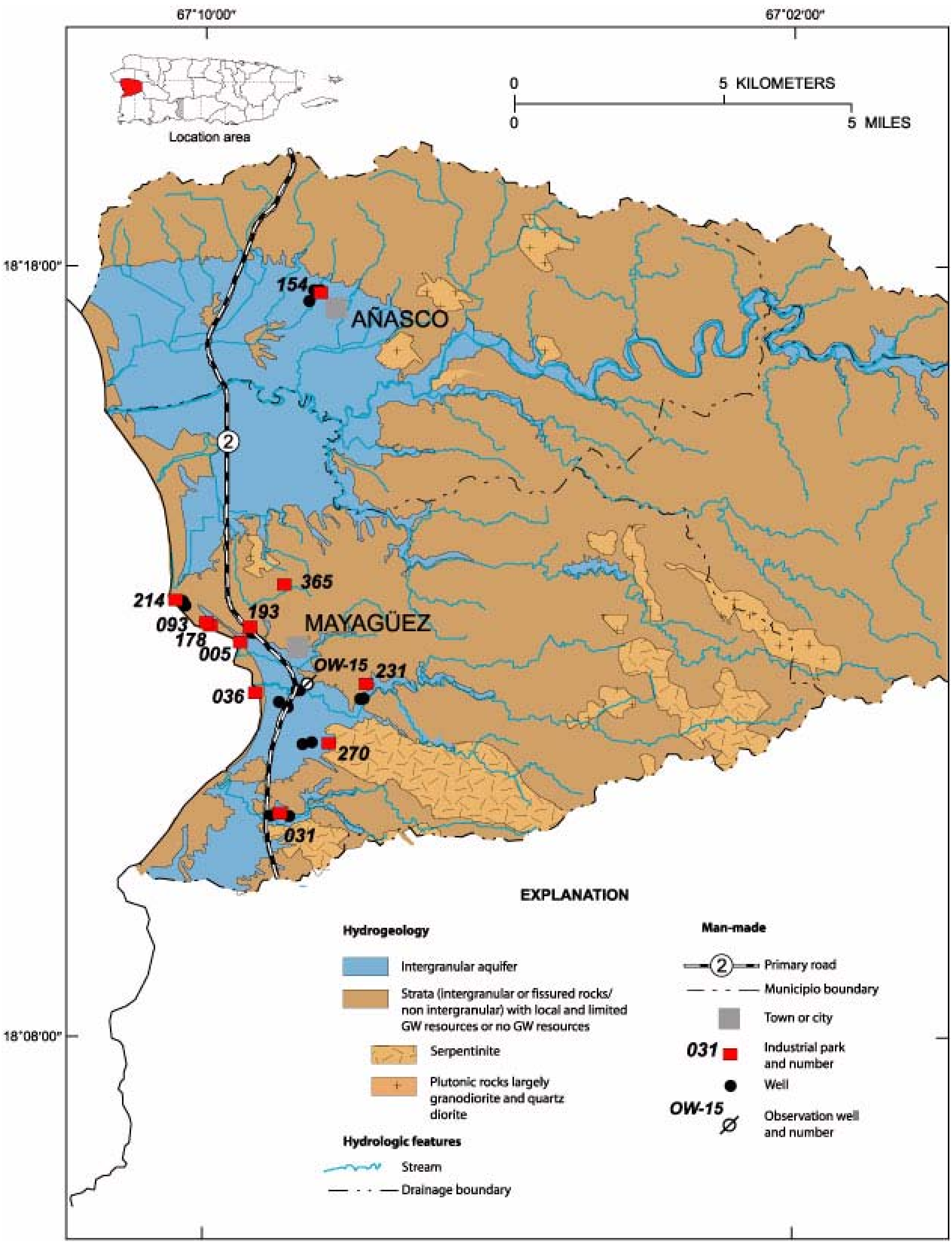


Figure 17. Map showing hydrogeologic units and location of municipal industrial parks near Mayagüez and Añasco, Puerto Rico.

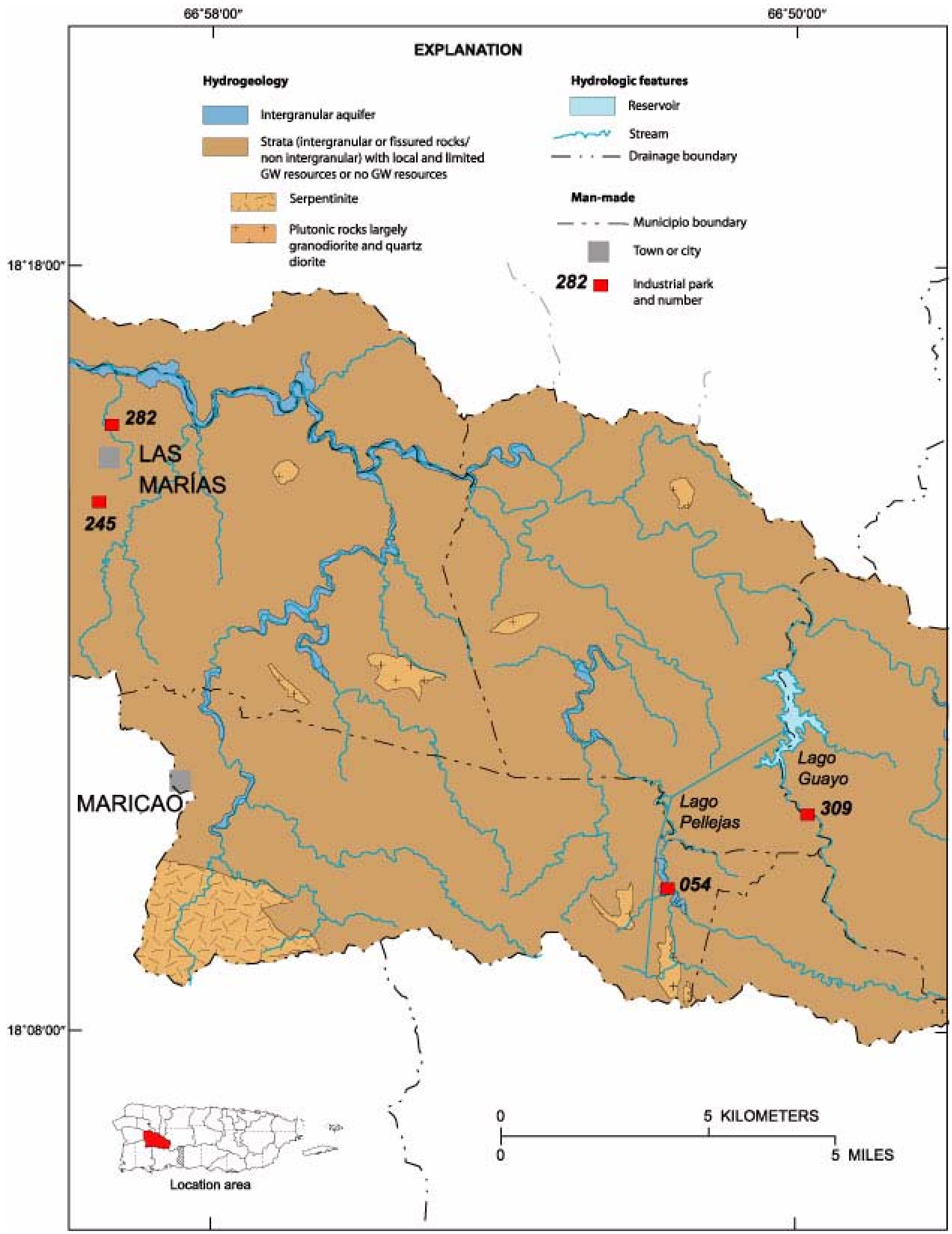


Figure 18. Map showing hydrogeologic units and location of municipal industrial parks near Las Marías, Puerto Rico.

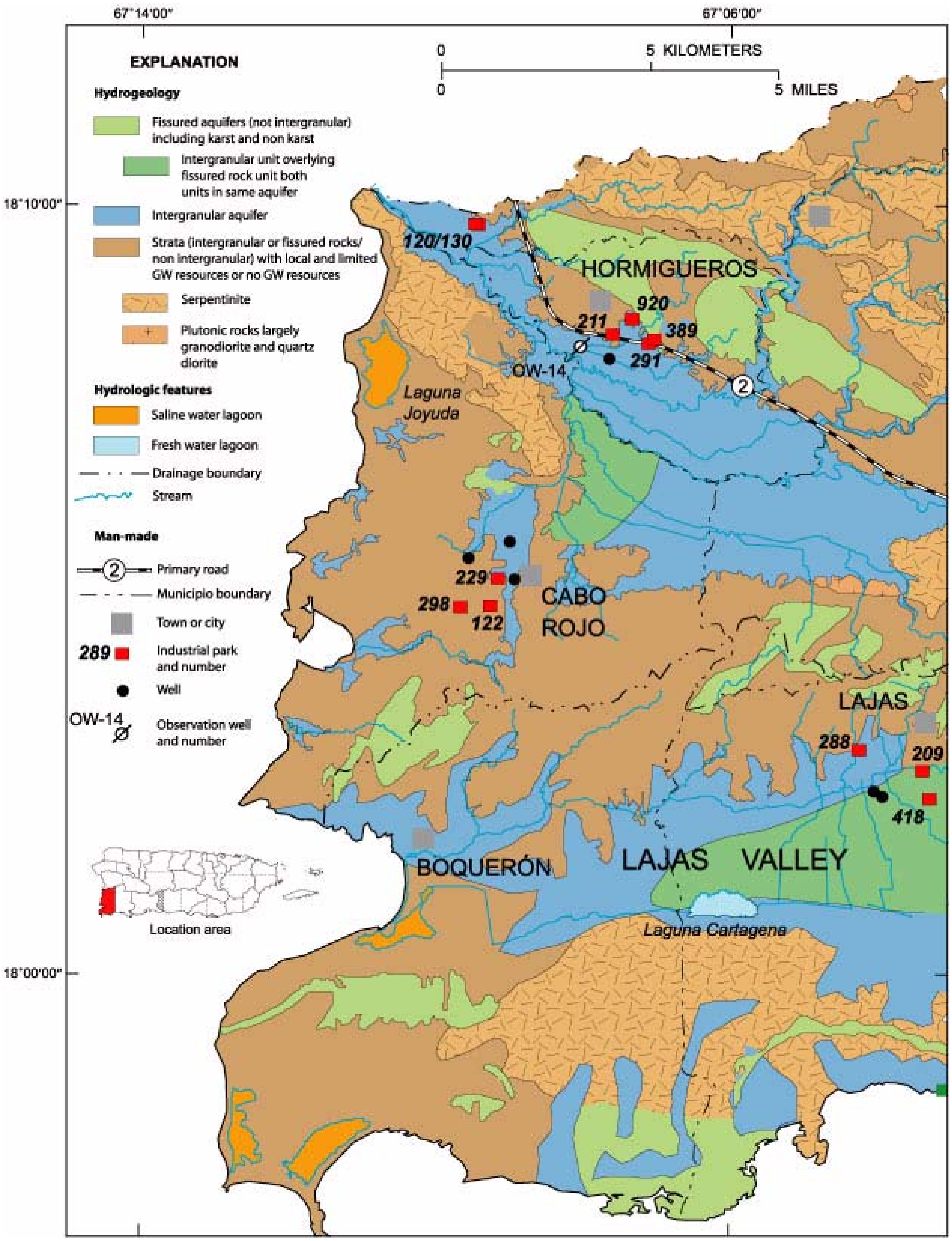


Figure 19. Map showing hydrogeologic units and location of municipal industrial parks near Hormigueros, Lajas, and Cabo Rojo, Puerto Rico.

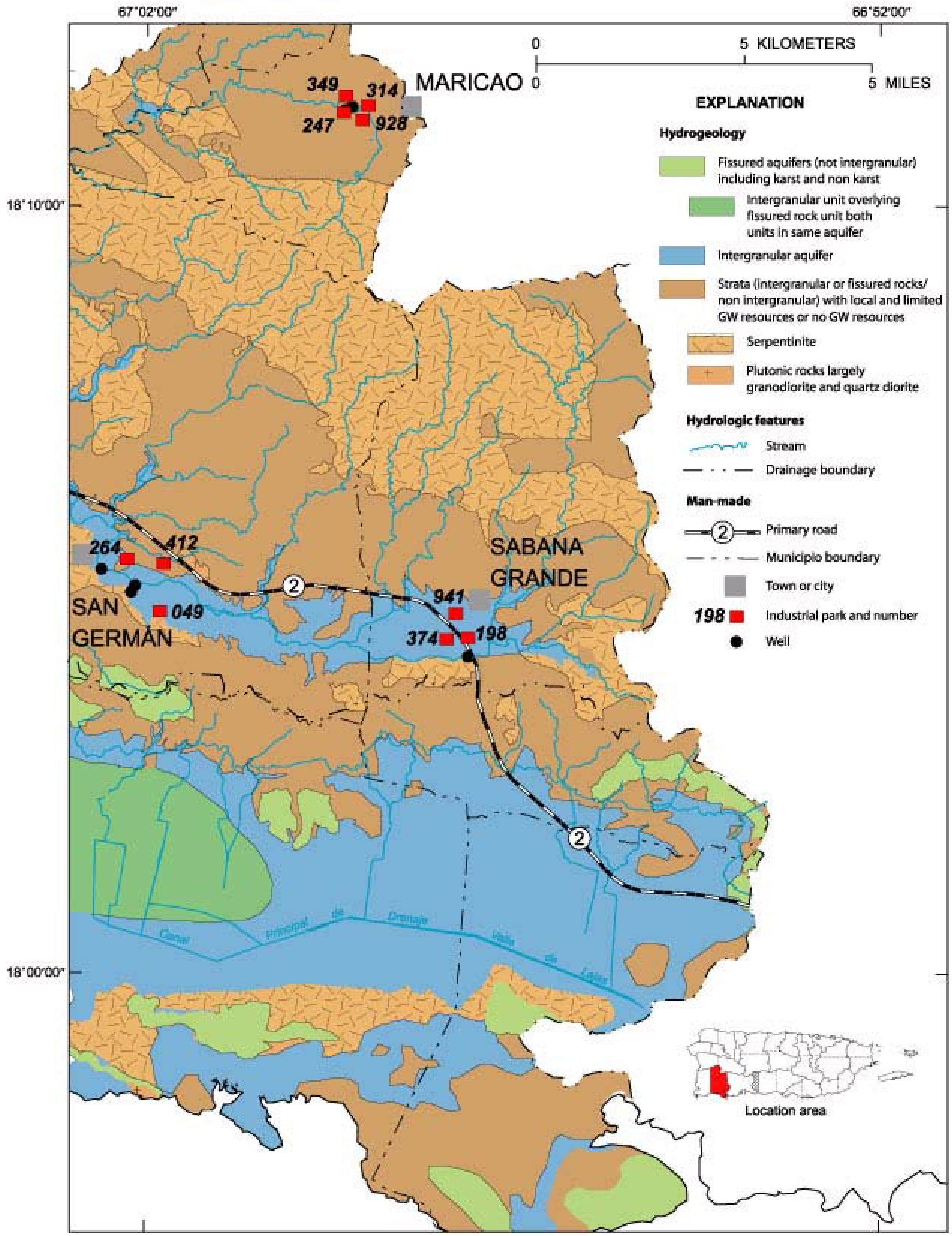


Figure 20. Map showing hydrogeologic units and location of municipal industrial parks near Maricao, Sabana Grande, and San Germán, Puerto Rico.

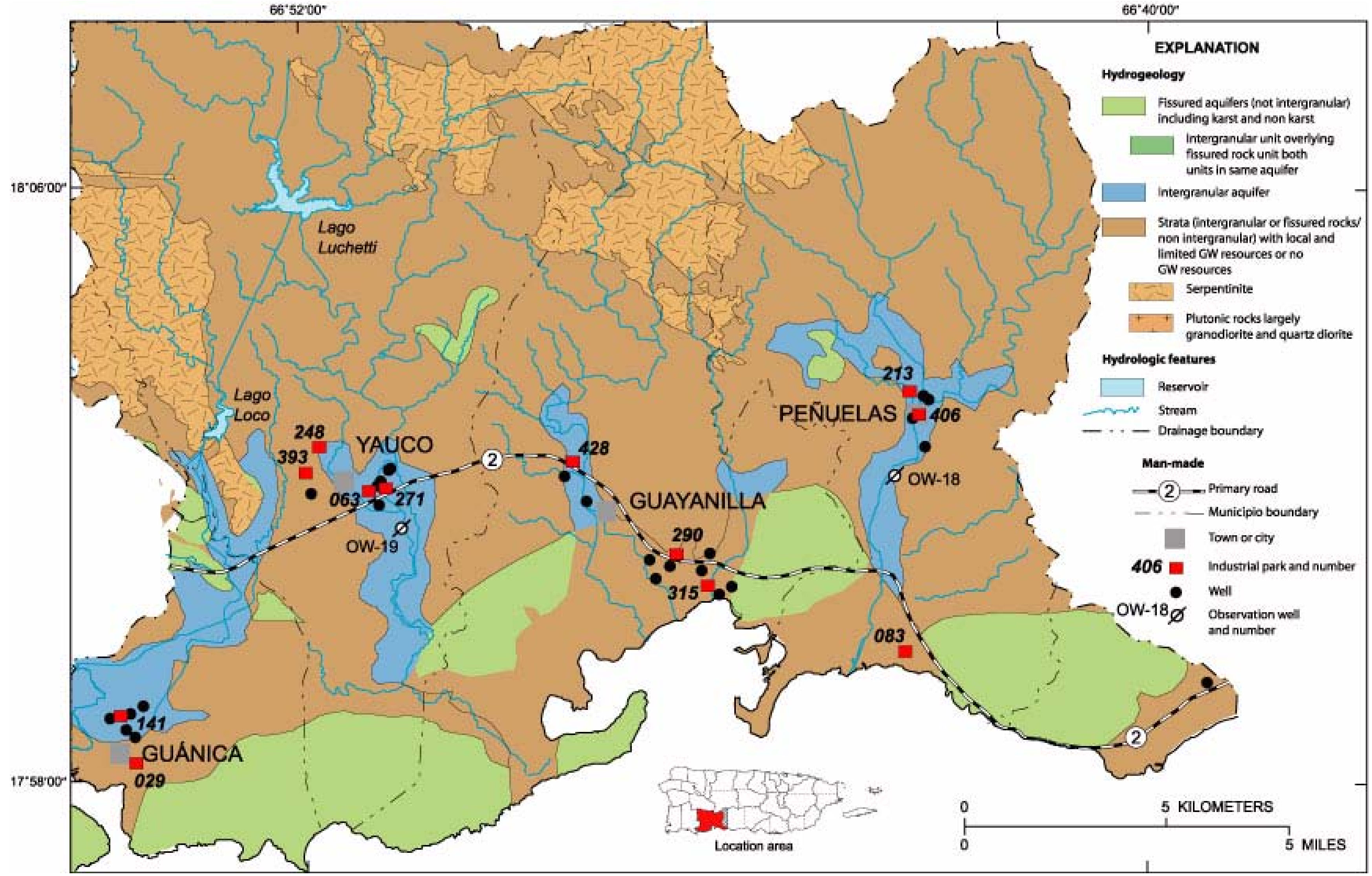


Figure 21. Map showing hydrogeologic units and location of municipal industrial parks near Peñuelas, Guayanilla, Yauco, and Guánica, Puerto Rico.

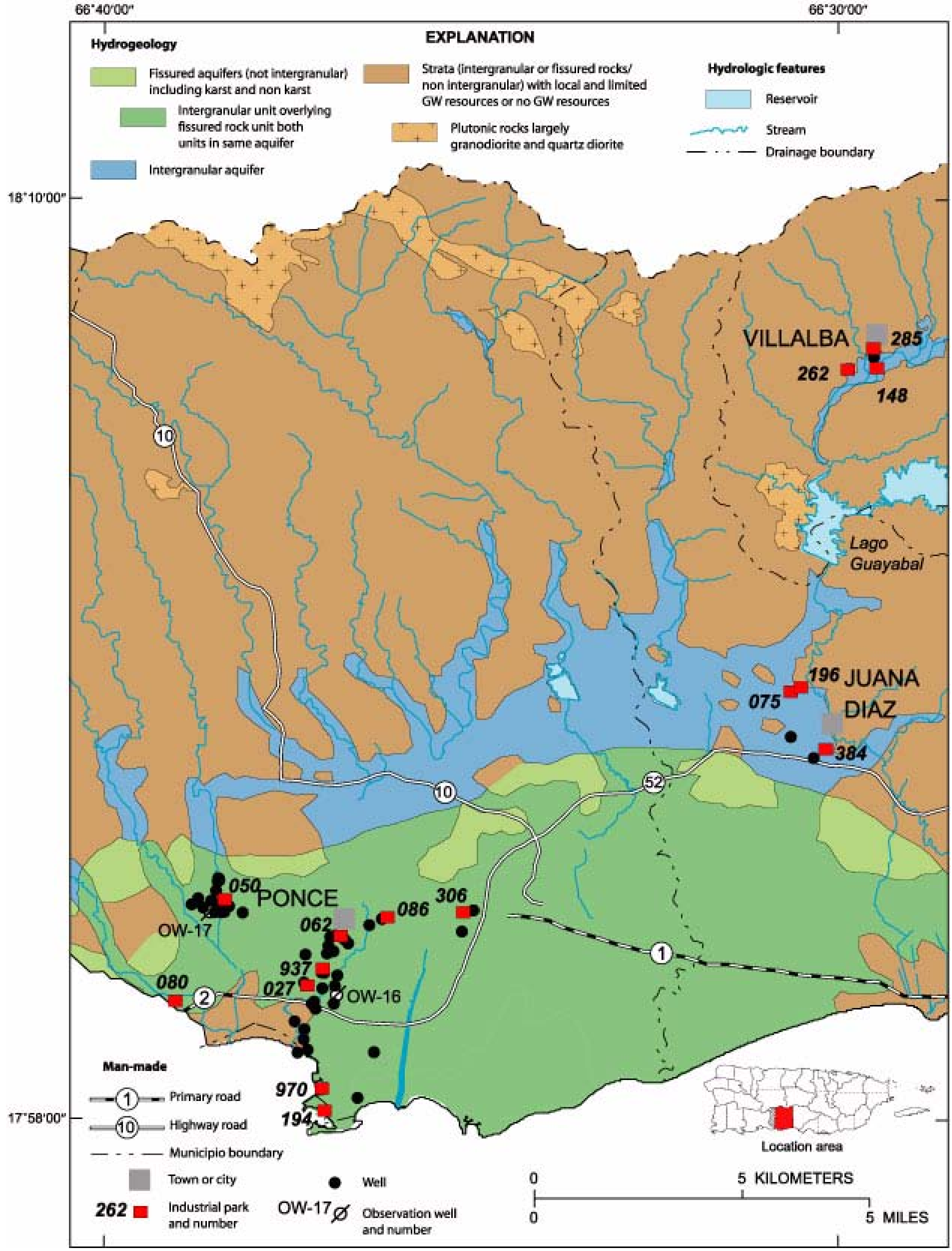


Figure 22. Map showing hydrogeologic units and location of municipal industrial parks near Villalba, Juana Díaz, and Ponce, Puerto Rico.

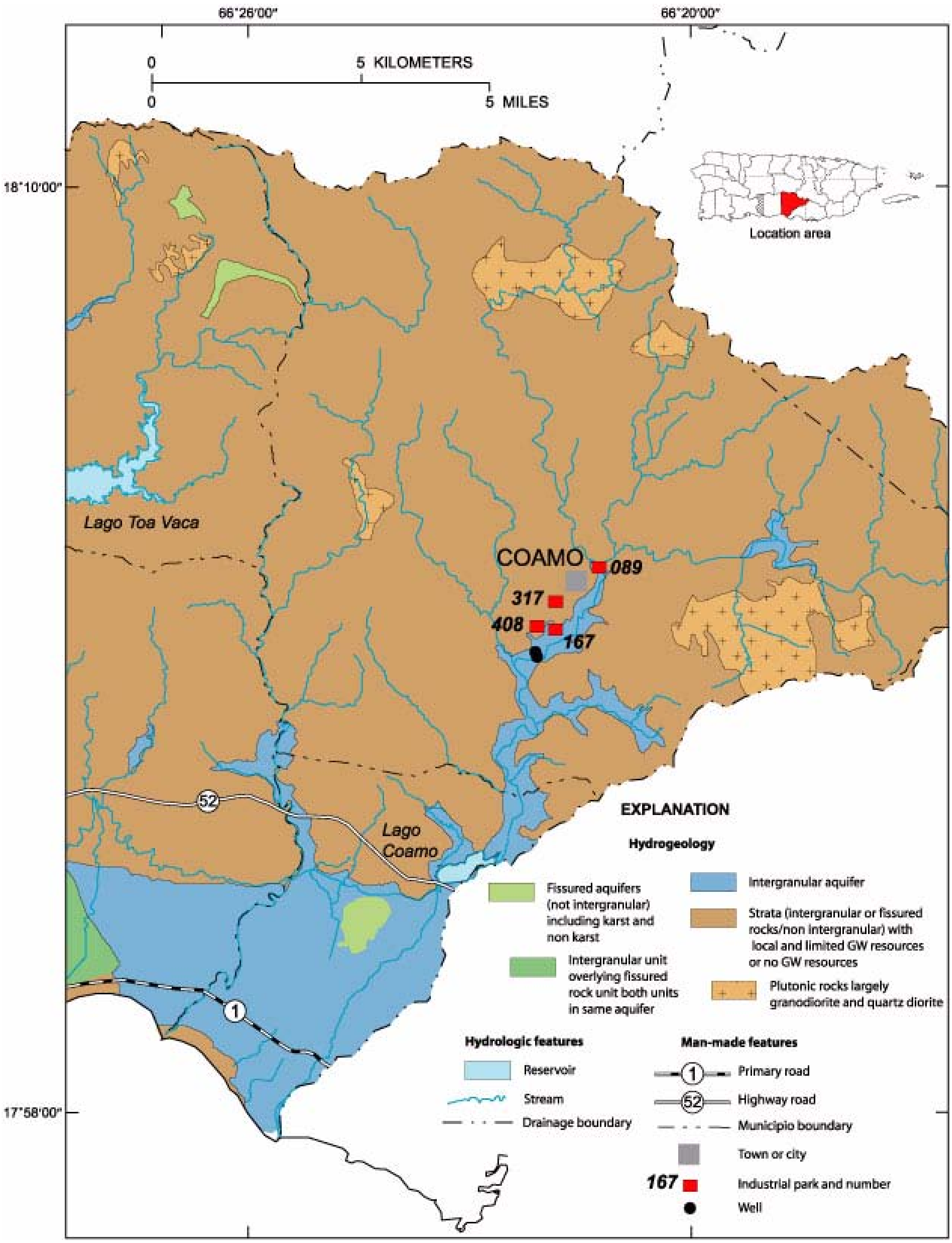


Figure 23. Map showing hydrogeologic units and location of municipal industrial parks near Coamo, Puerto Rico.

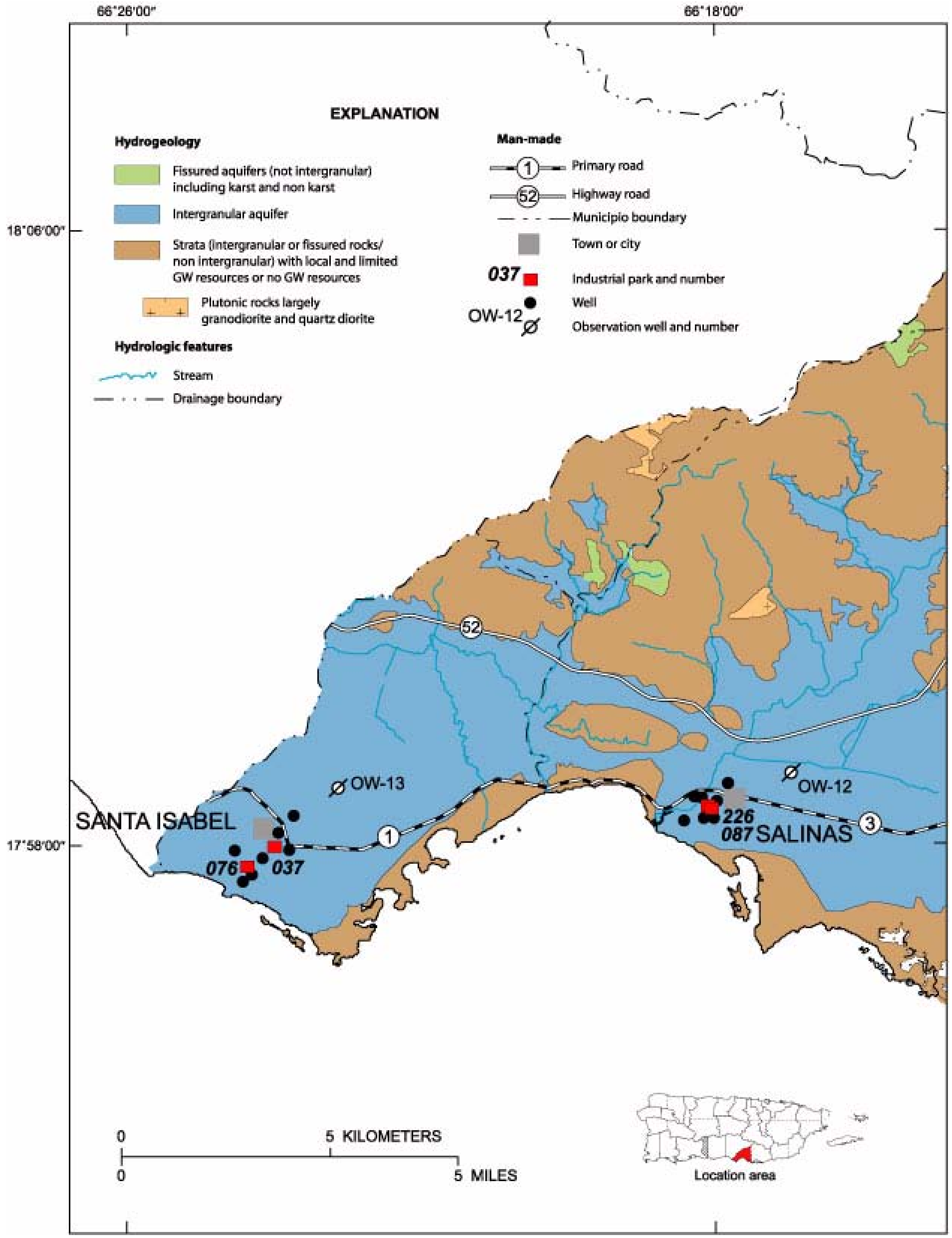


Figure 24. Map showing hydrogeologic units and location of municipal industrial parks near Salinas and Santa Isabel, Puerto Rico.

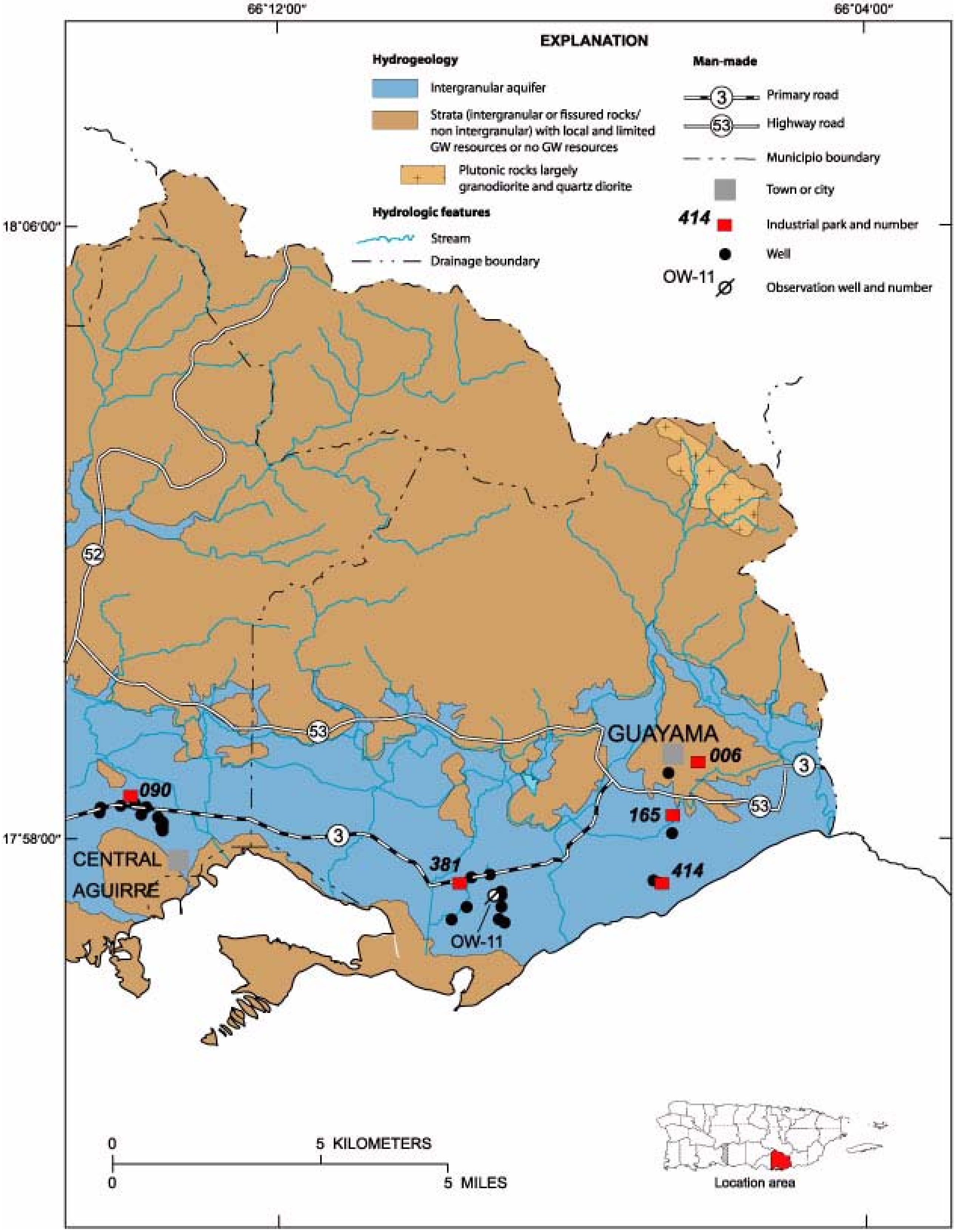


Figure 25. Map showing hydrogeologic units and location of municipal industrial parks near Guayama, Puerto Rico.

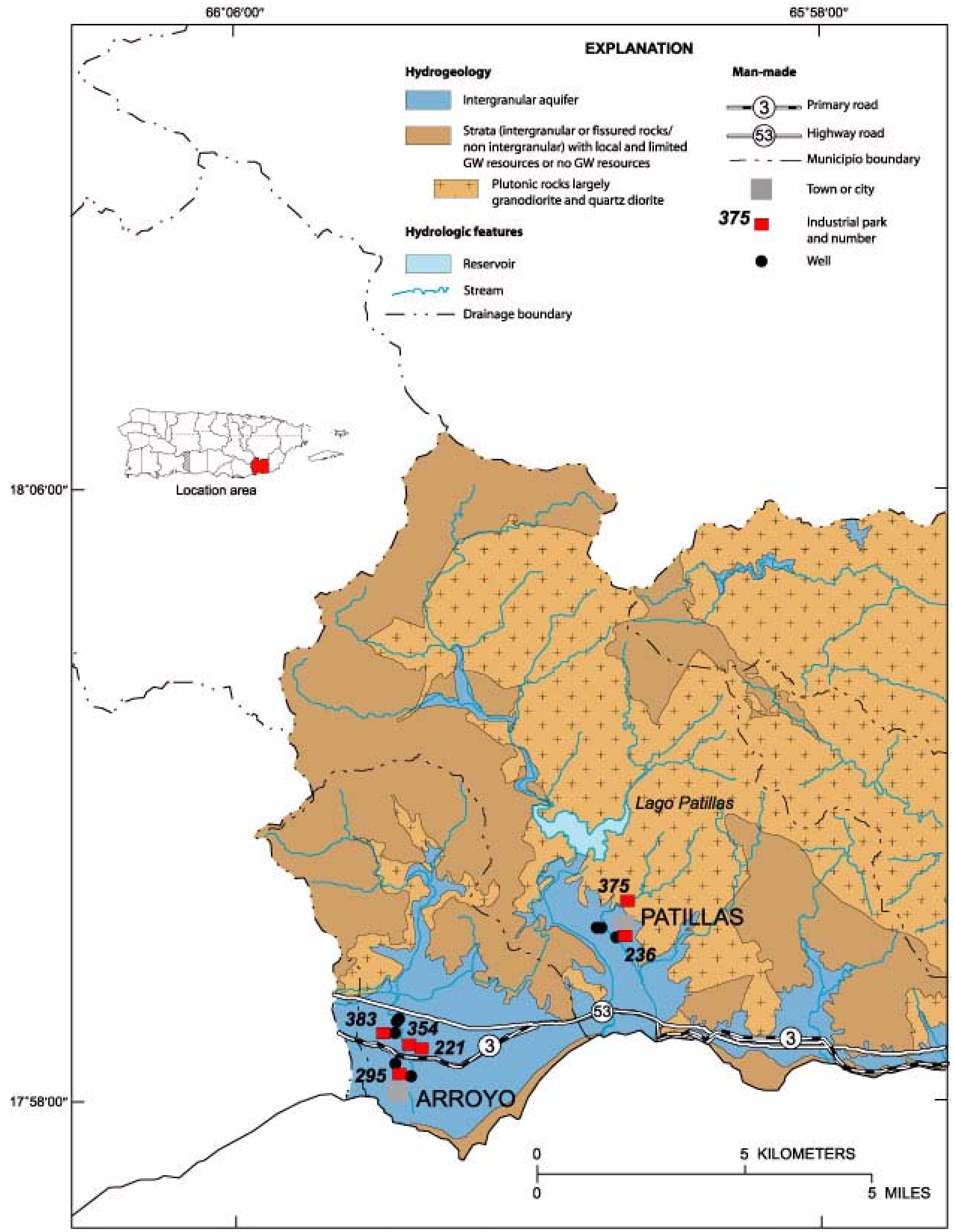


Figure 26. Map showing hydrogeologic units and location of municipal industrial parks near Patillas and Arroyo, Puerto Rico.

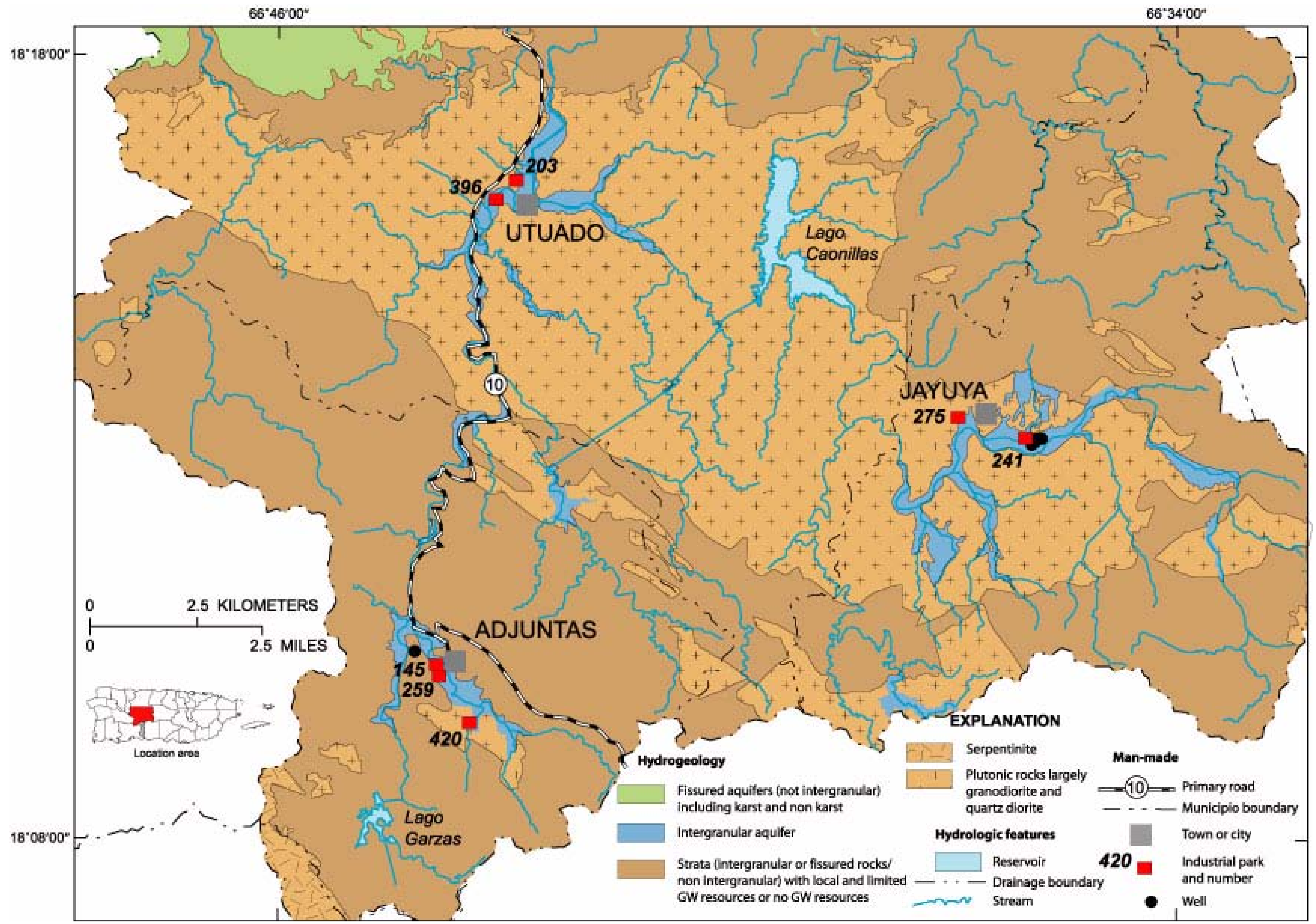


Figure 27. Map showing hydrogeologic units and location of municipal industrial parks near Utuado, Adjuntas, and Jayuya, Puerto Rico.

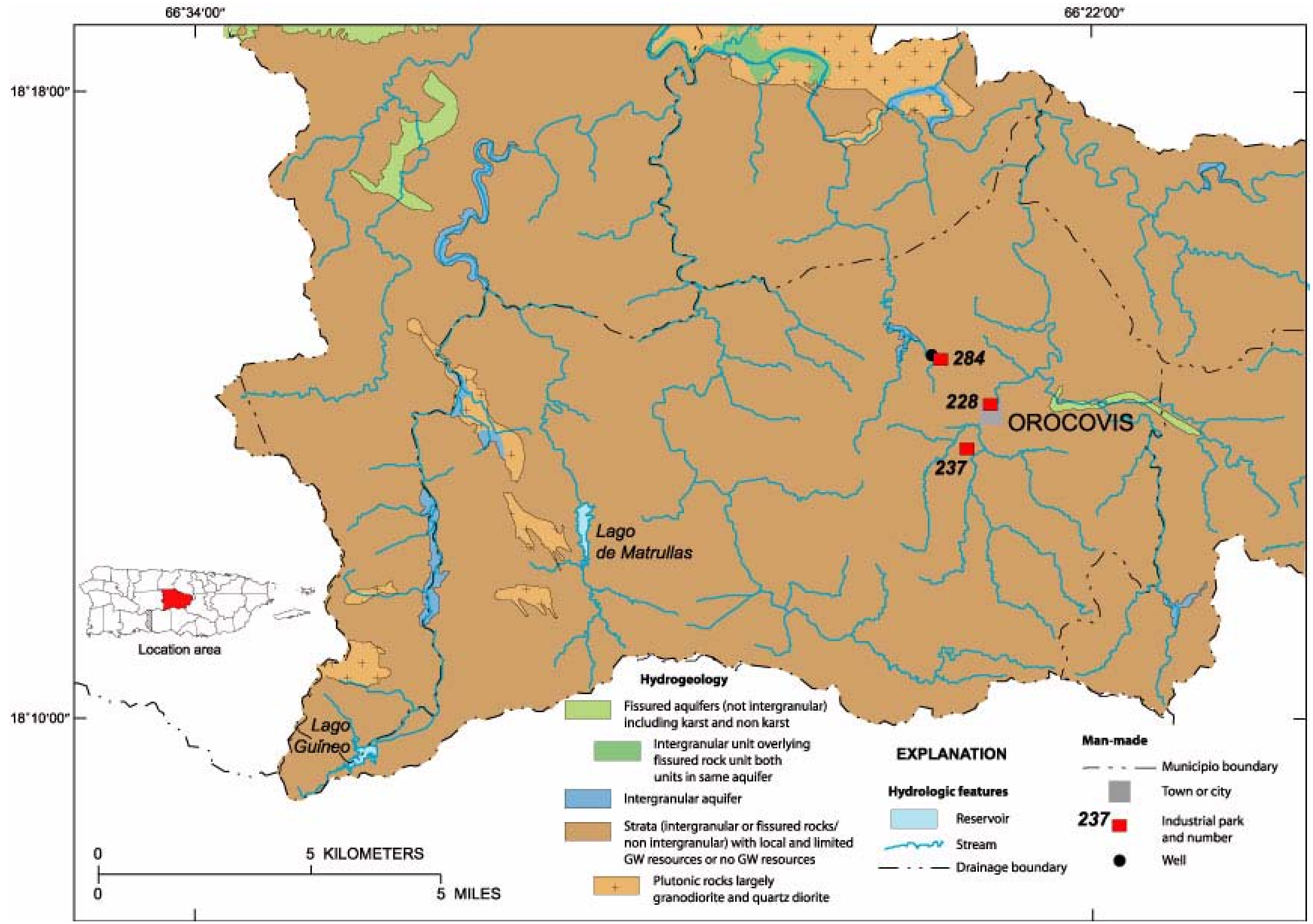


Figure 28. Map showing hydrogeologic units and location of municipal industrial parks near Orocovis, Puerto Rico.

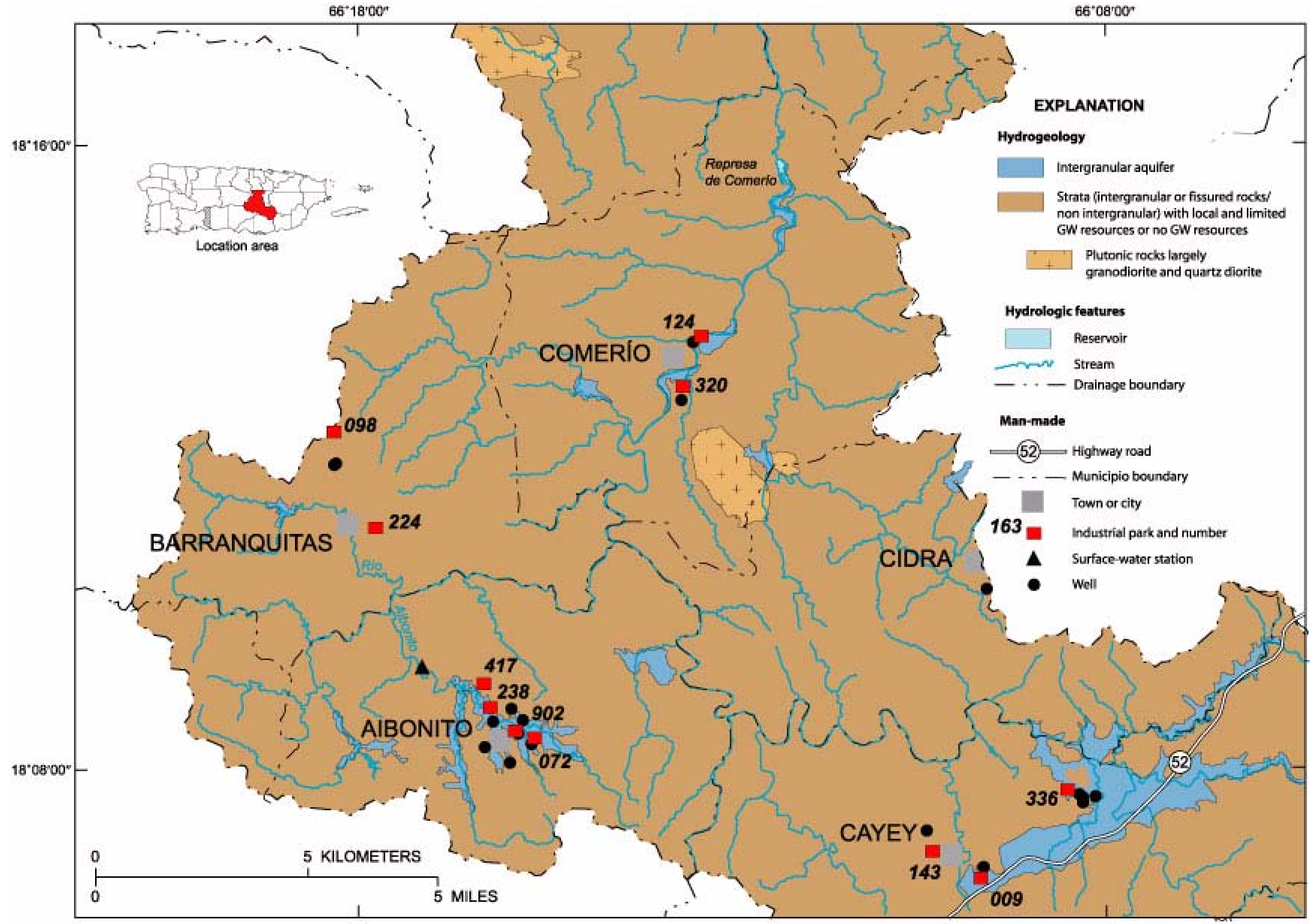


Figure 29. Map showing hydrogeologic units and location of municipal industrial parks near Barranquitas, Comerío, Aibonito, and Cayey, Puerto Rico.

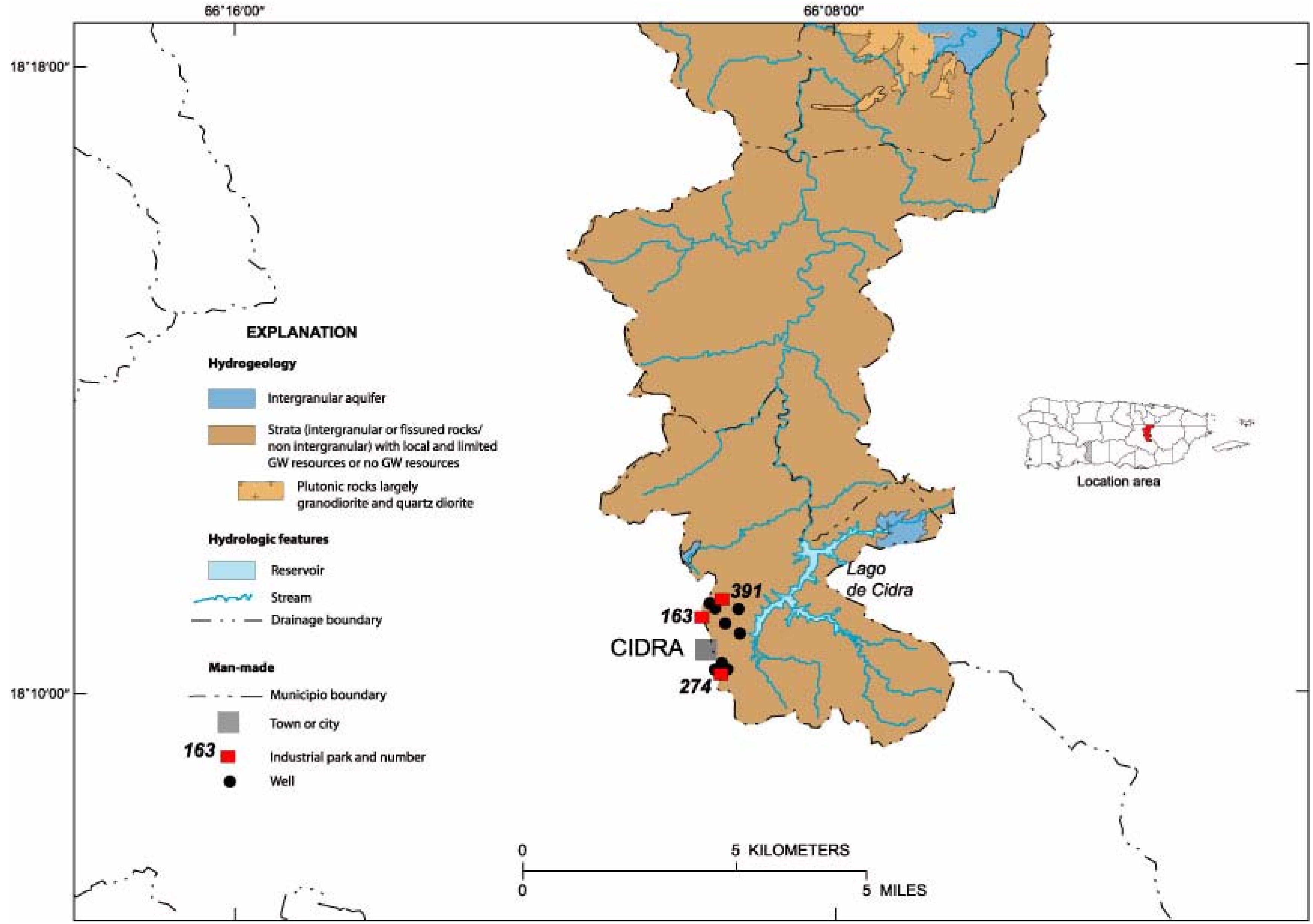


Figure 30. Map showing hydrogeologic units and location of municipal industrial parks near Cidra, Puerto Rico.

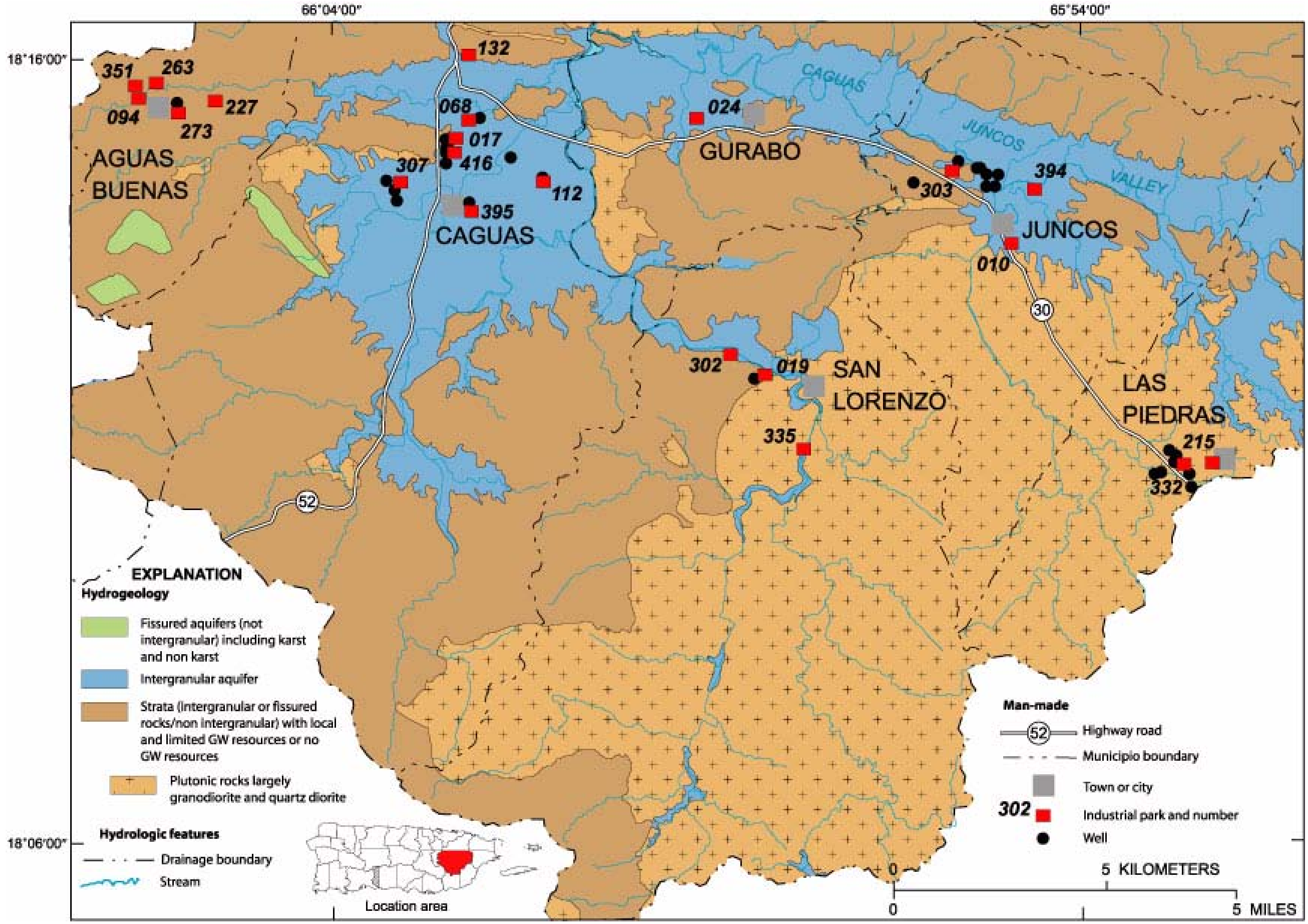


Figure 31. Map showing hydrogeologic units and location of municipal industrial parks near Aguas Buenas, Caguas, Gurabo, Juncos, San Lorenzo, and Las Piedras, Puerto Rico.

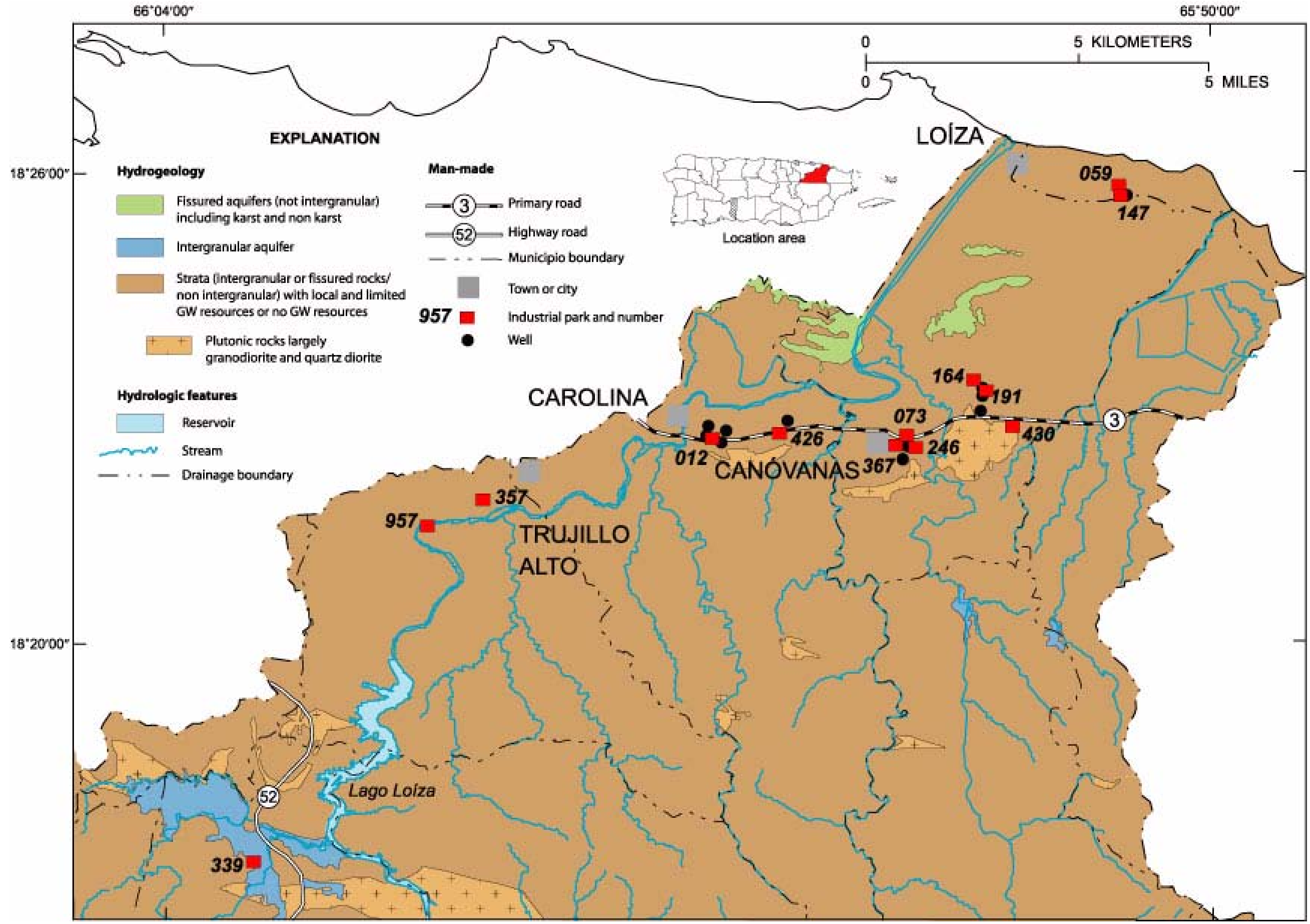


Figure 32. Map showing hydrogeologic units and location of municipal industrial parks near Trujillo Alto, Canóvanas, and Loíza, Puerto Rico.

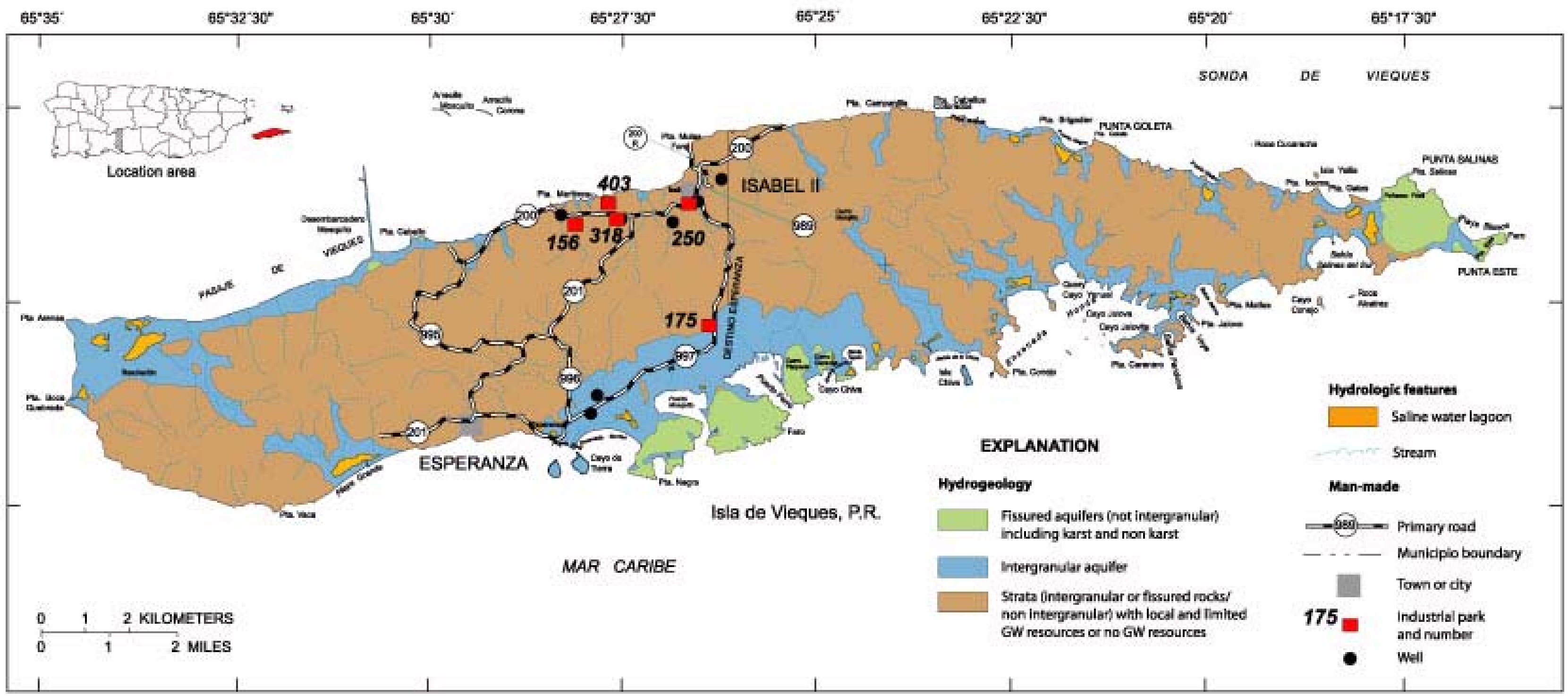


Figure 33. Map showing hydrogeologic units and location of municipal industrial parks near Vieques, Puerto Rico.

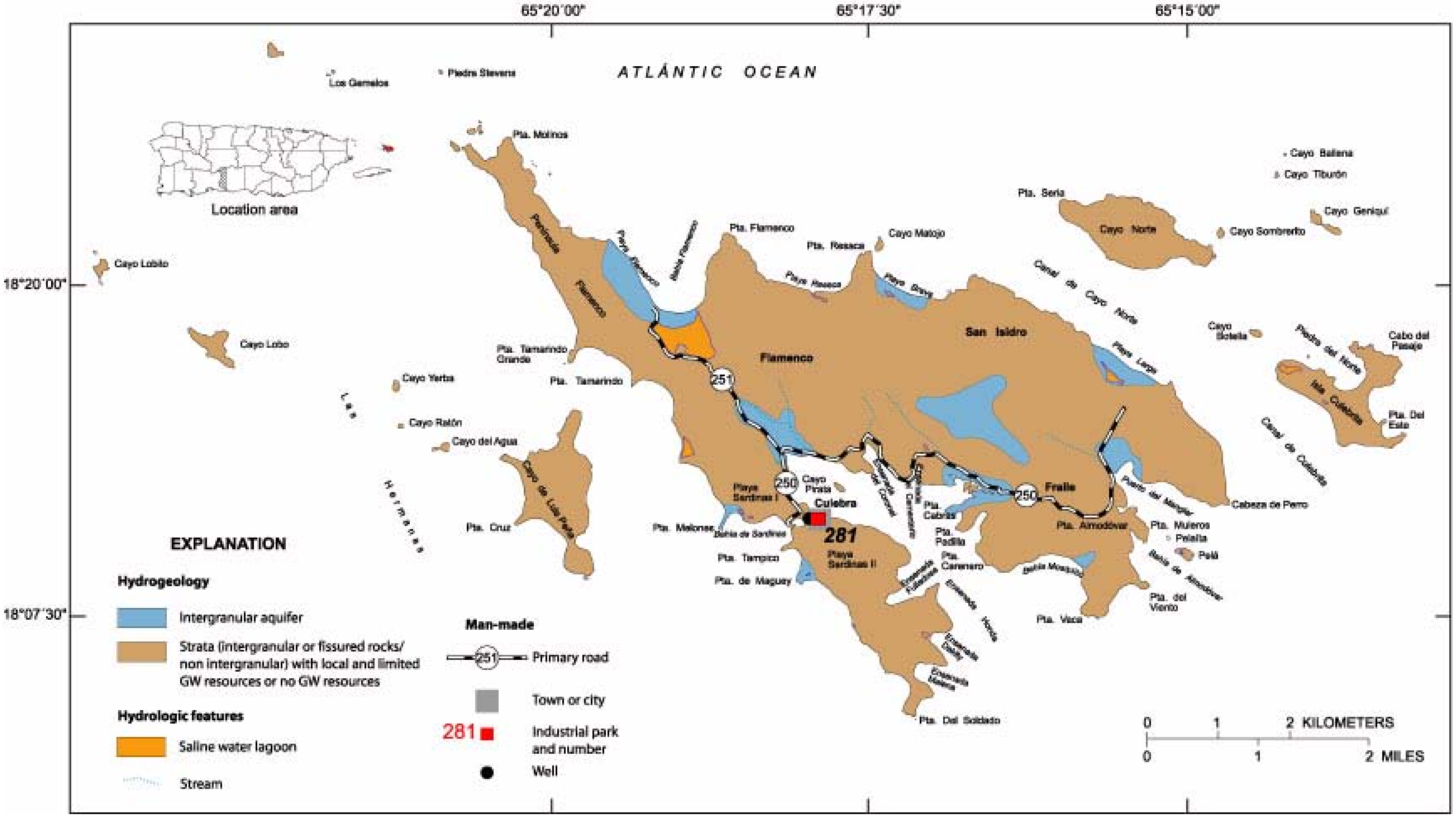


Figure 34. Map showing hydrogeologic units and location of municipal industrial parks near Culebra, Puerto Rico.

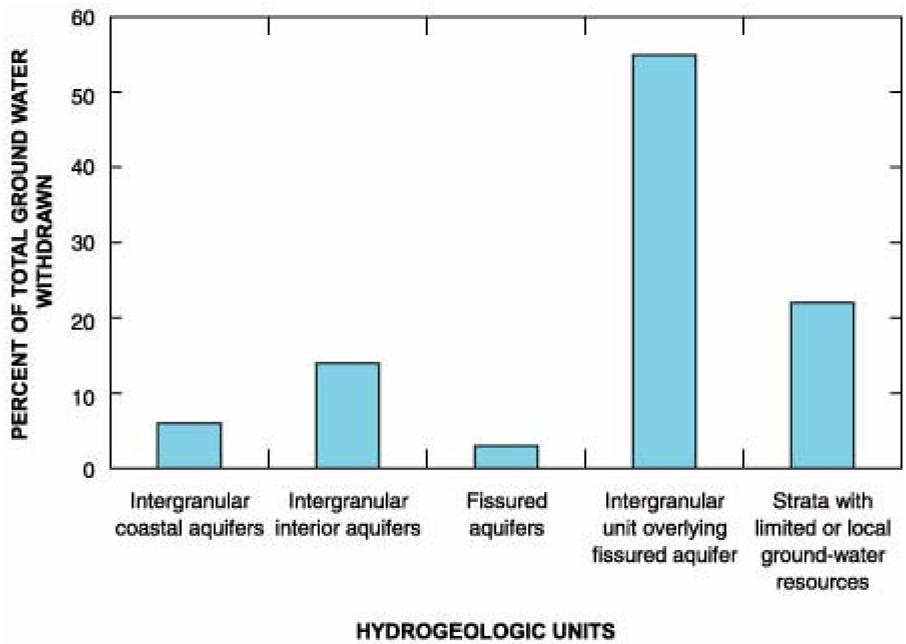


Figure 35. Graph showing ground-water withdrawals at Puerto Rico industrial parks by hydrogeologic unit.

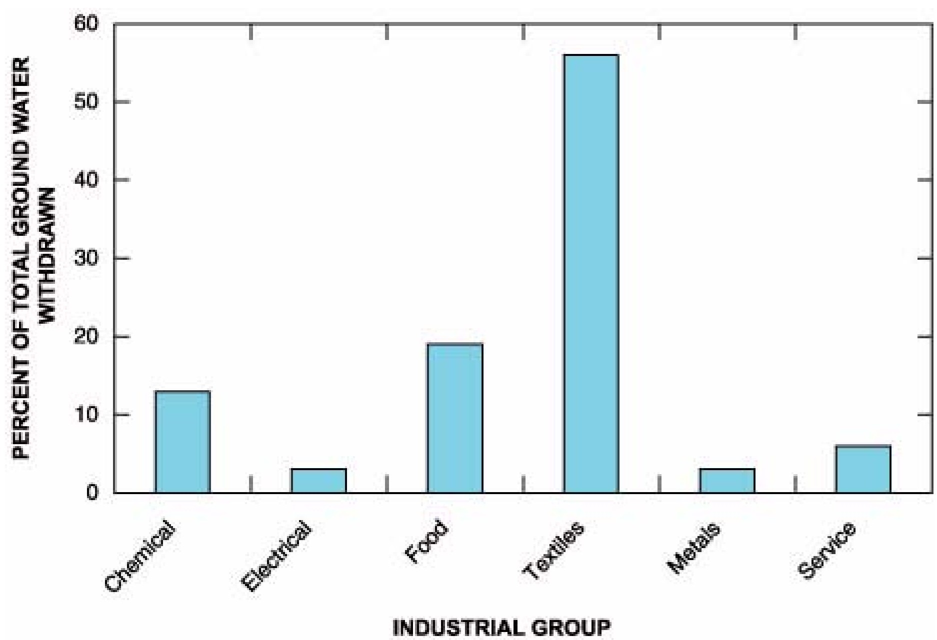


Figure 36. Graph showing ground-water withdrawals at Puerto Rico industrial parks by industrial group.

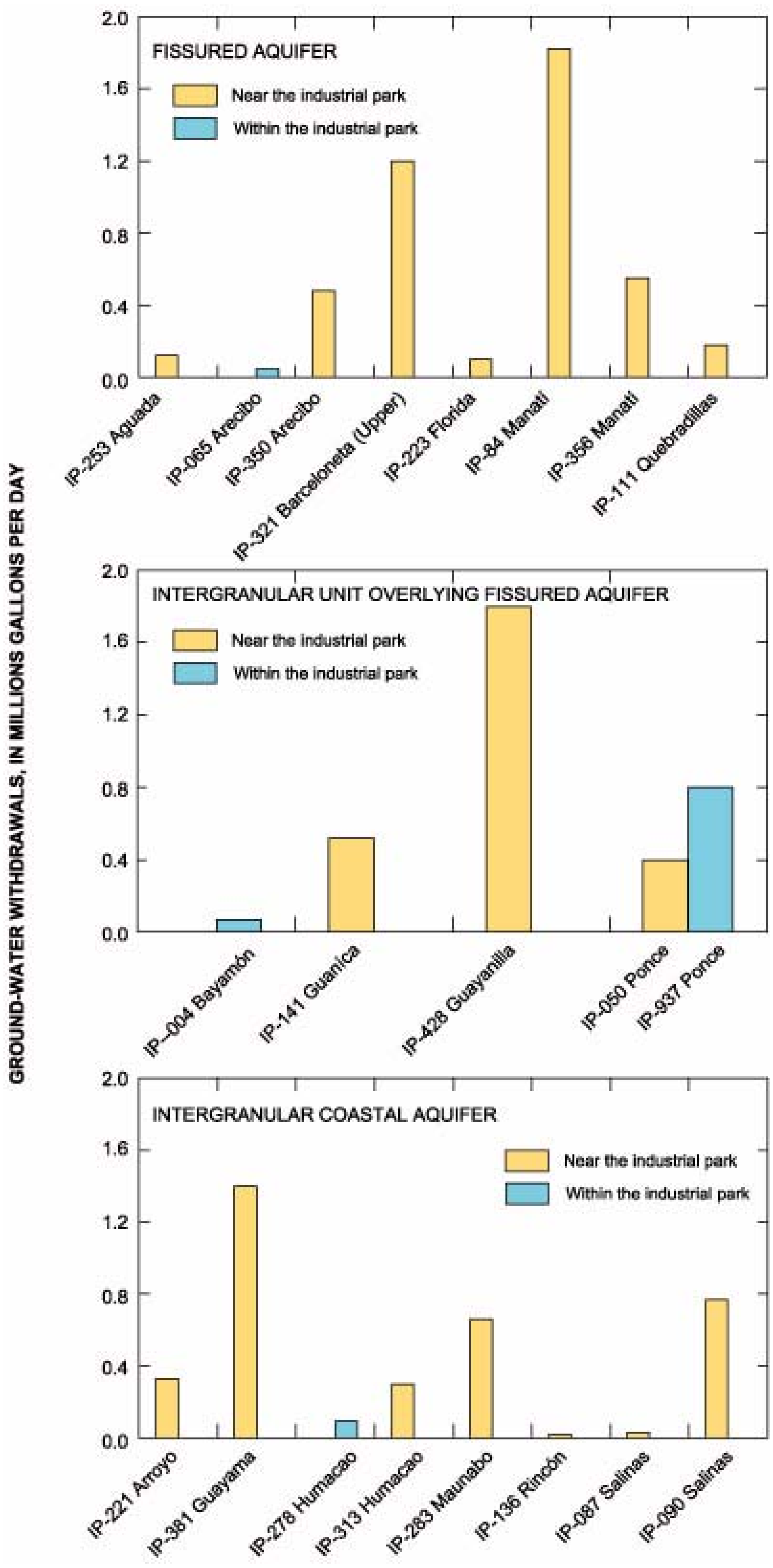


Figure 37. Graphs showing ground-water withdrawals within or near municipal industrial parks by hydrogeologic unit.

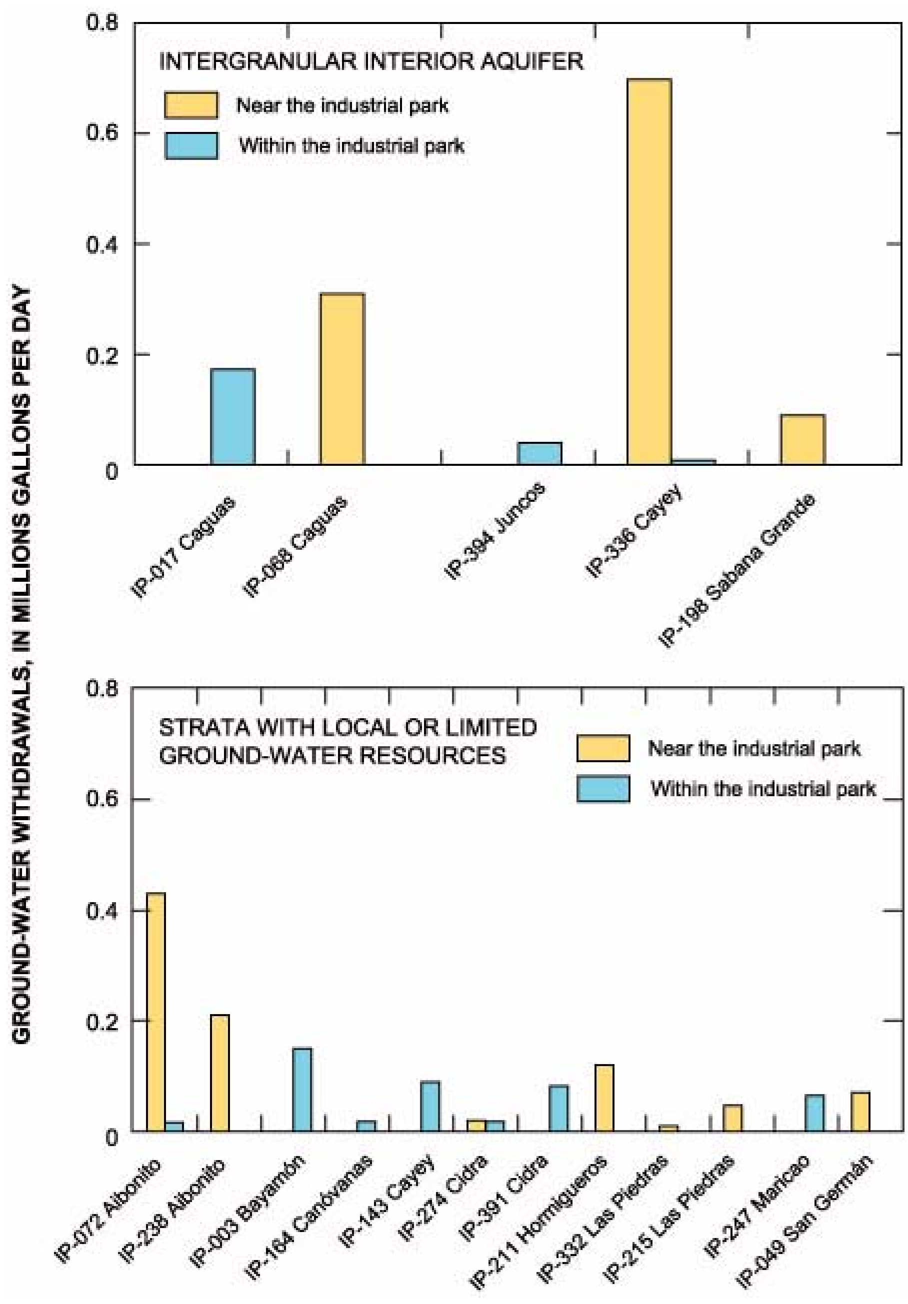


Figure 37. Graphs showing ground-water withdrawals within or near municipal industrial parks by hydrogeologic unit.—Continued

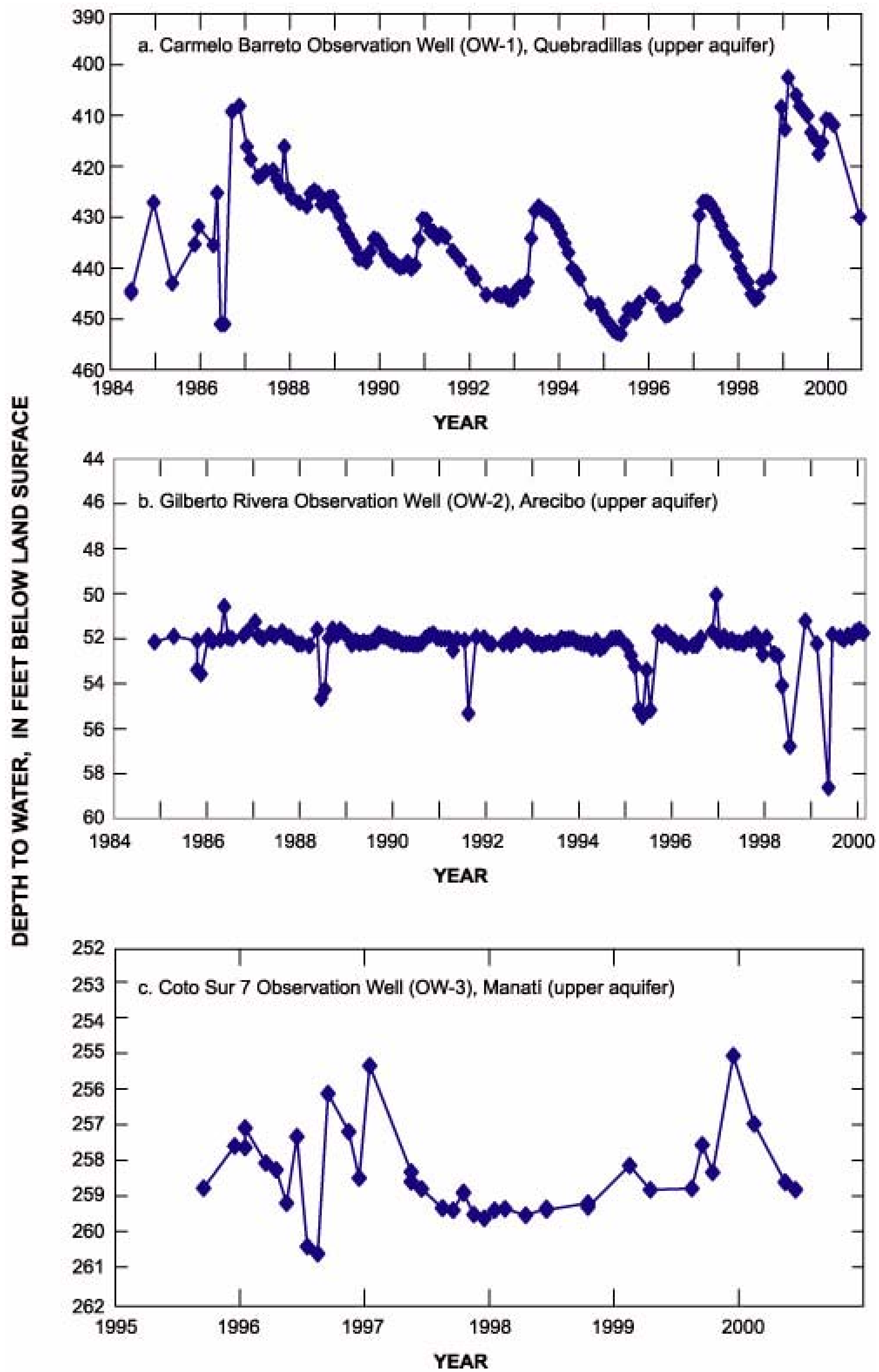


Figure 38. Graphs showing ground-water levels at selected observation wells in Puerto Rico.

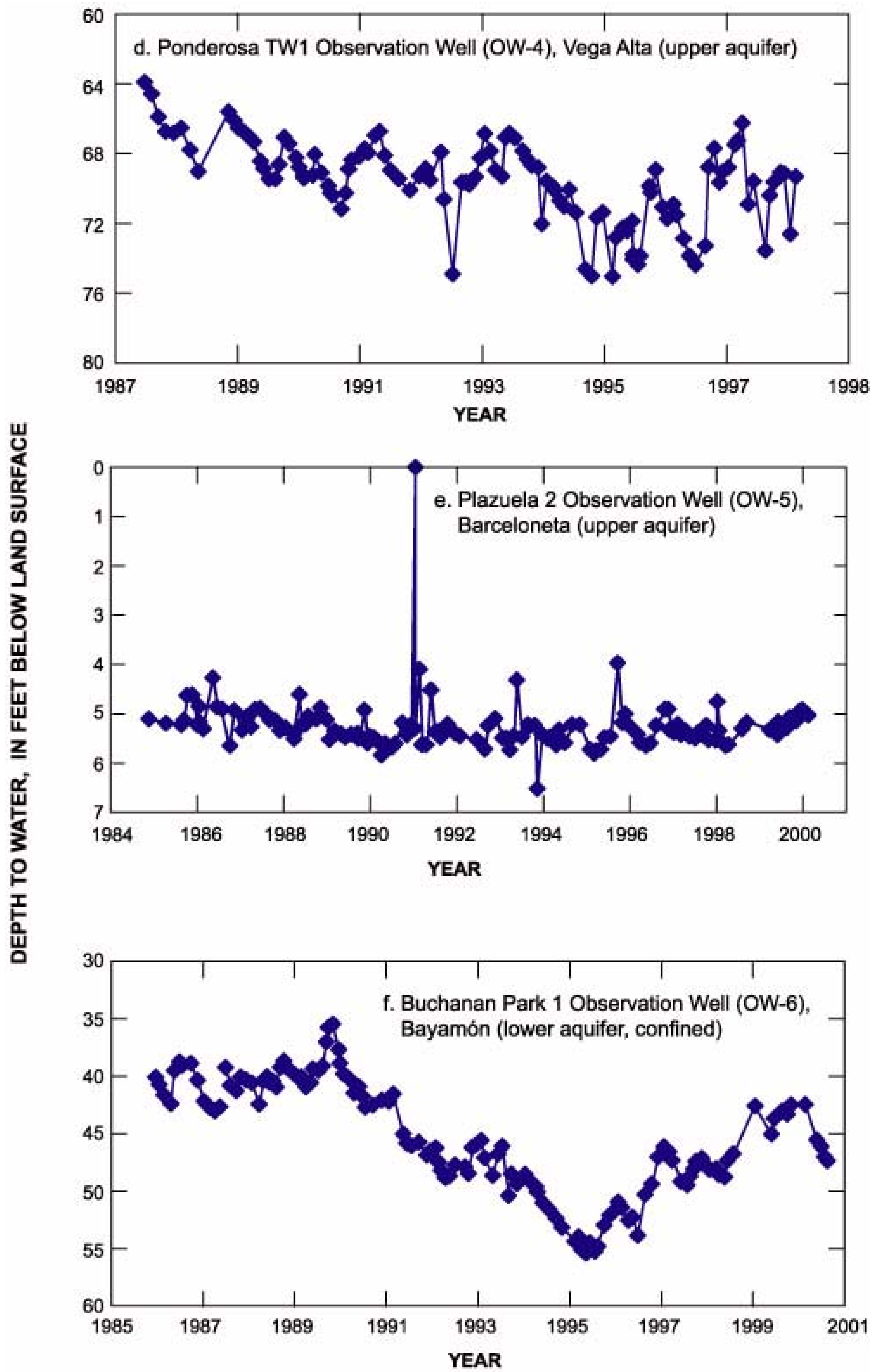


Figure 38. Graphs showing ground-water levels at selected observation wells in Puerto Rico.—Continued

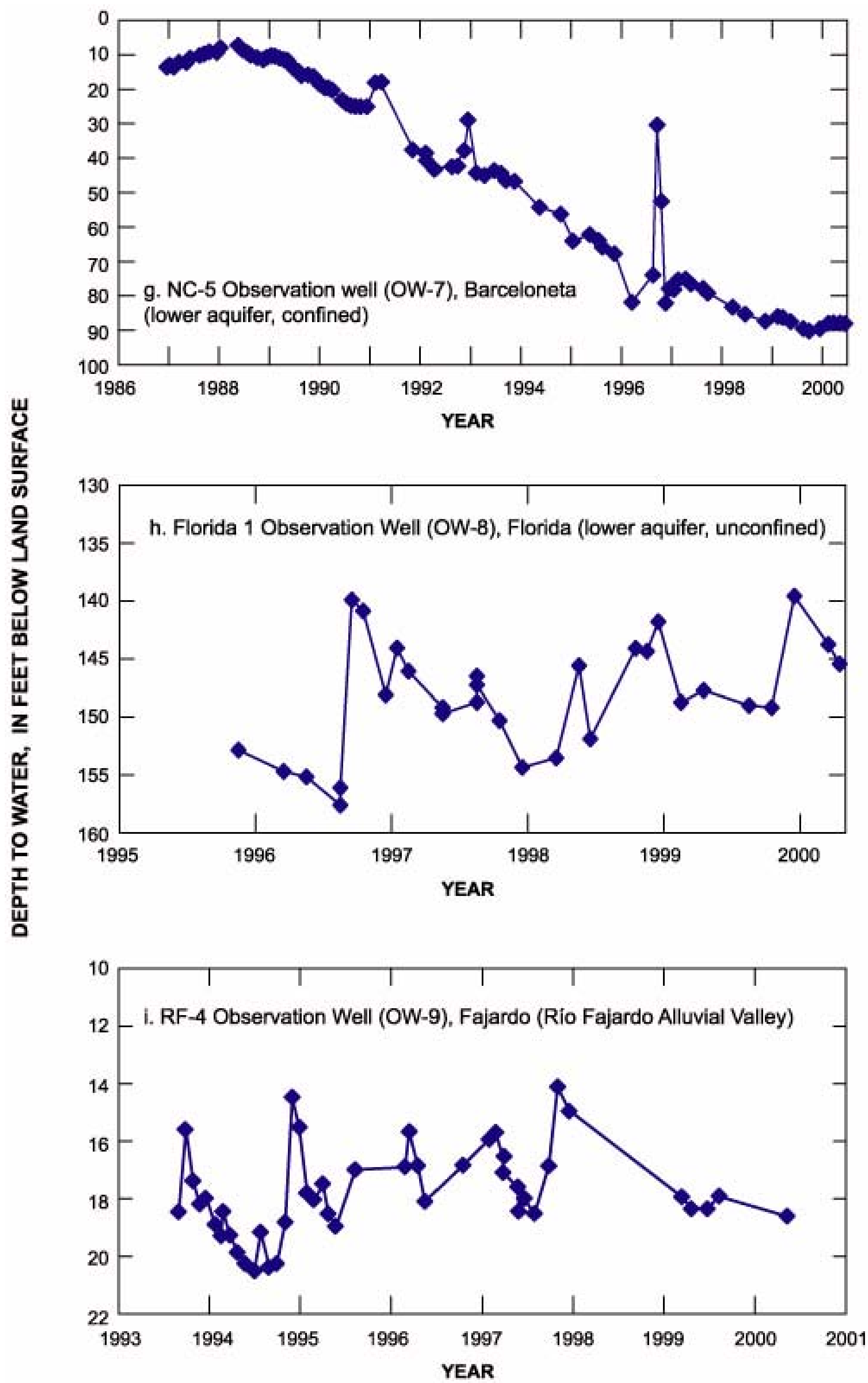


Figure 38. Graphs showing ground-water levels at selected observation wells in Puerto Rico.—Continued

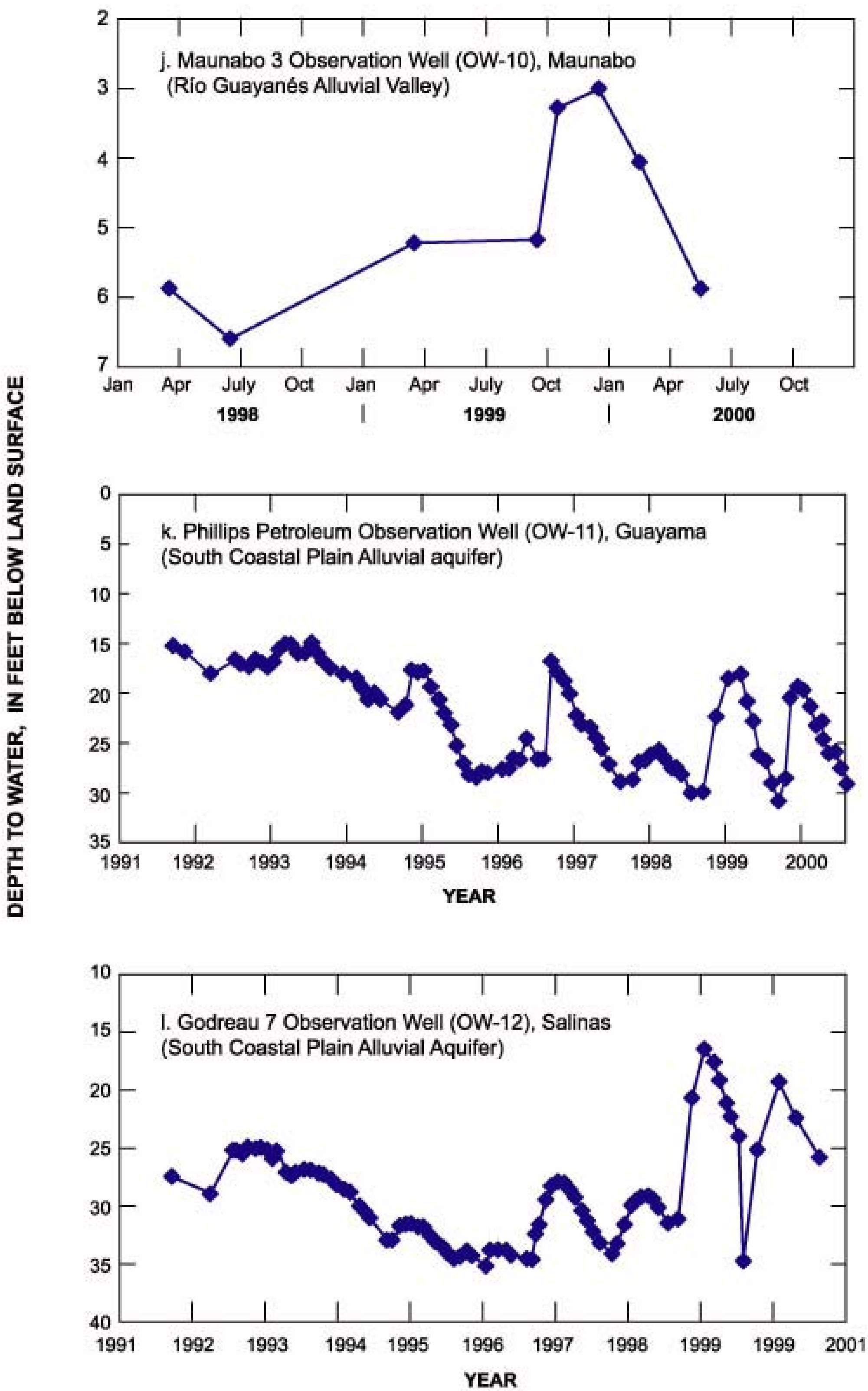


Figure 38. Graphs showing ground-water levels at selected observation wells in Puerto Rico.—Continued

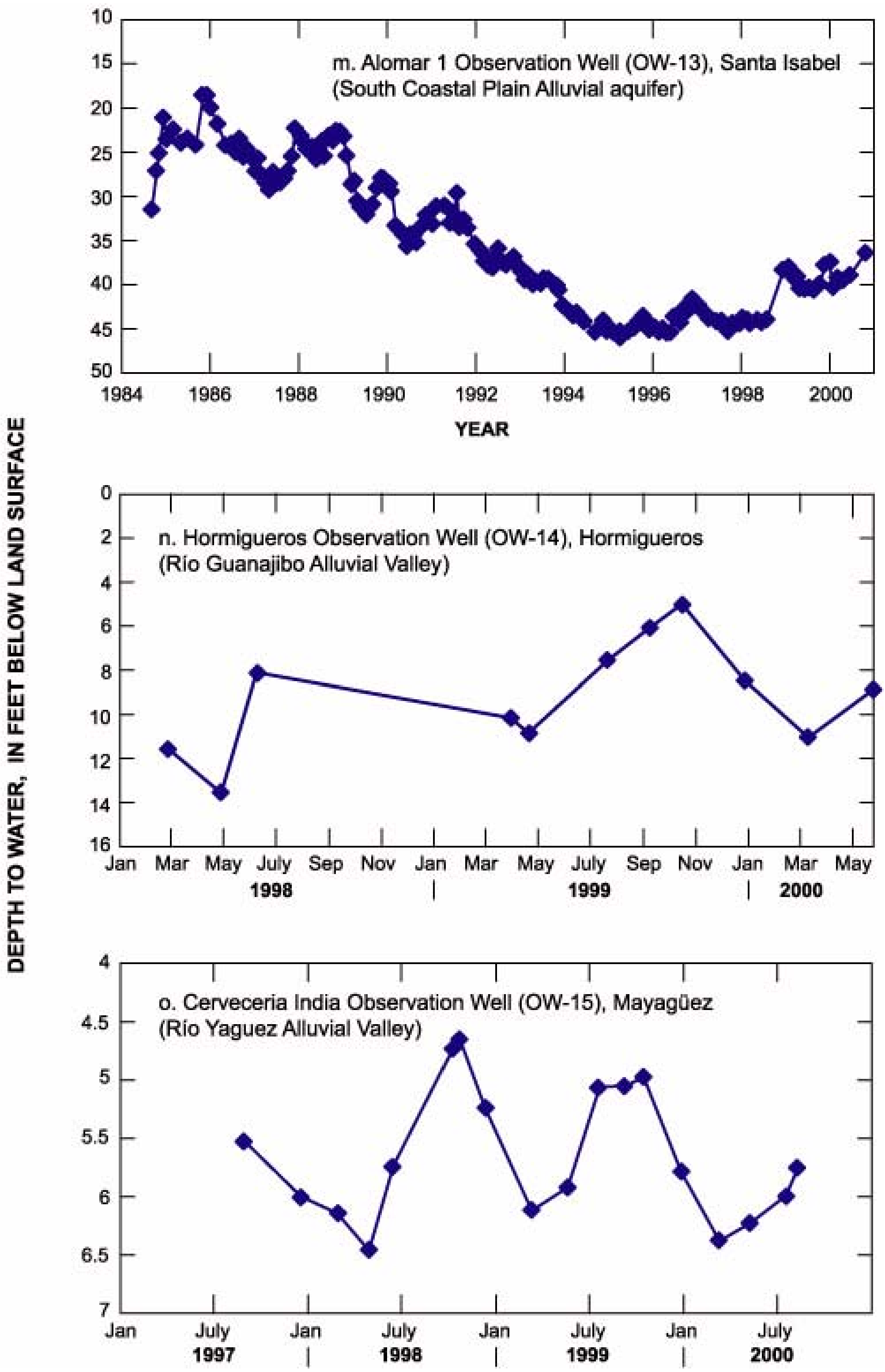


Figure 38. Graphs showing ground-water levels at selected observation wells in Puerto Rico.—Continued

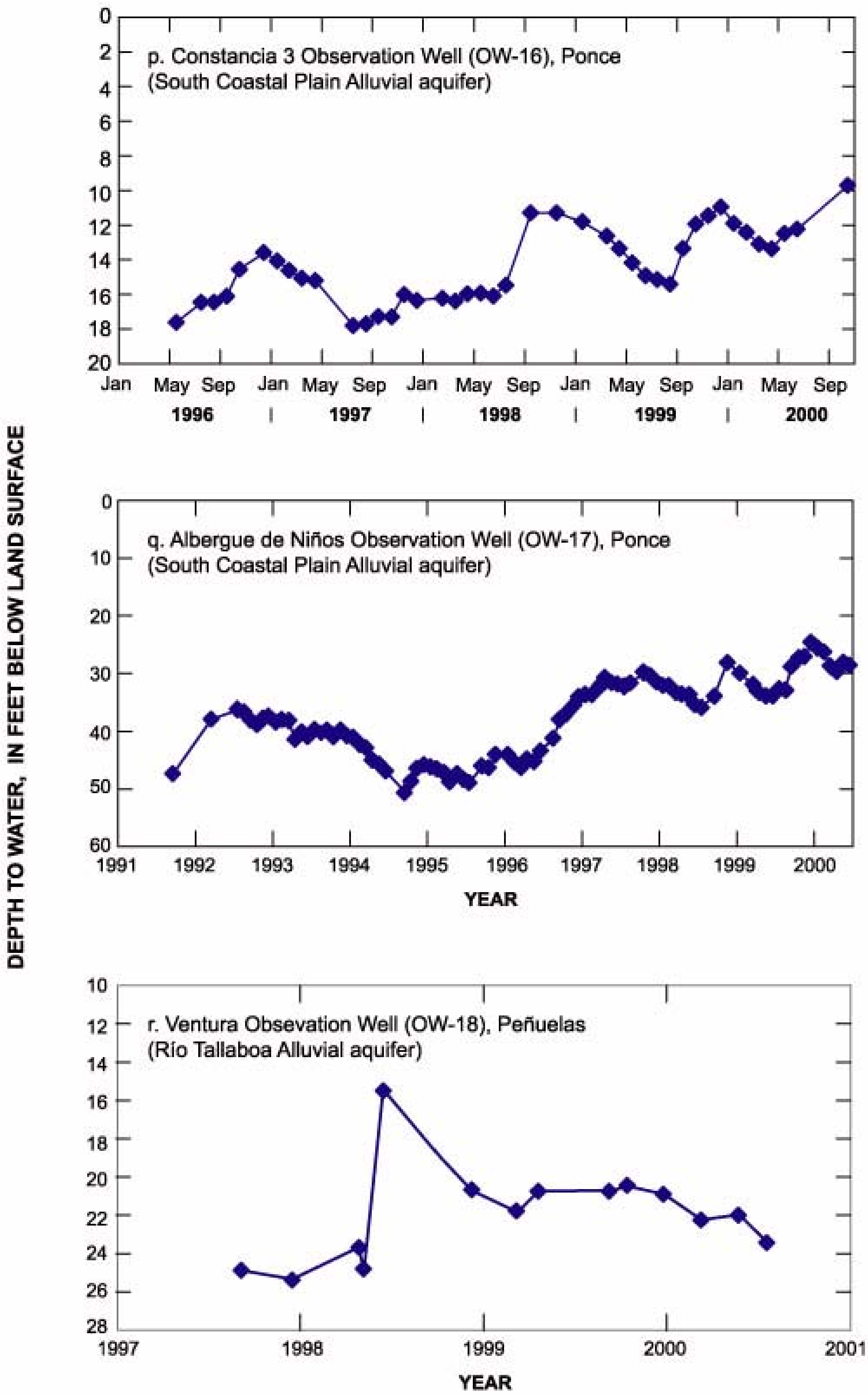


Figure 38. Graphs showing ground-water levels at selected observation wells in Puerto Rico.—Continued

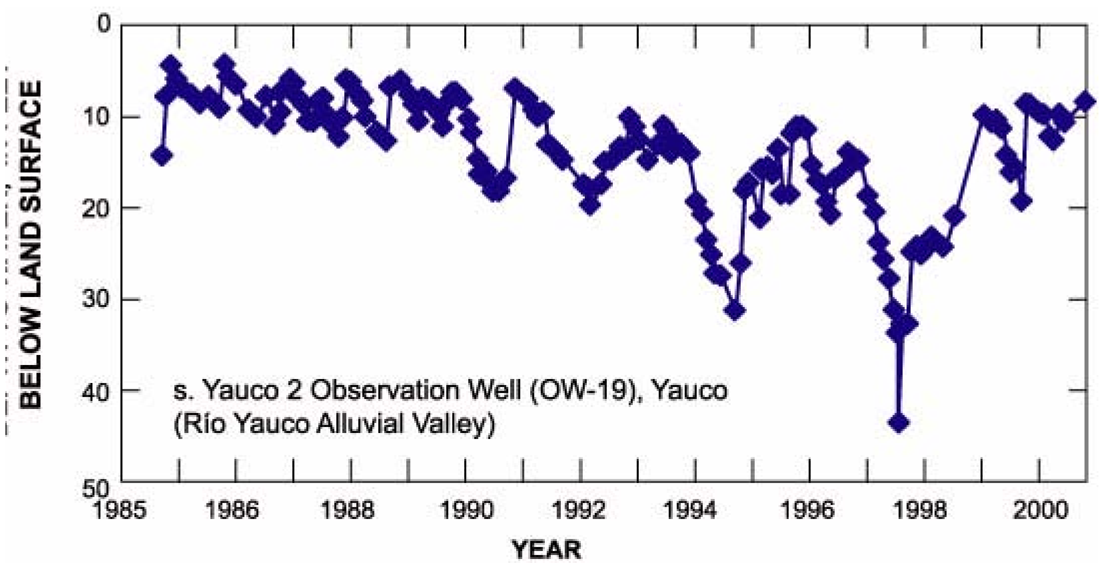


Figure 38. Graphs showing ground-water levels at selected observation wells in Puerto Rico.—Continued

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