GEOHYDROLOGIC DESCRIPTIONS OF SELECTED SOLID-WASTE DISPOSAL SITES IN PUERTO RICO

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Open-file Report 81-490

Prepared in cooperation with the
ENVIRONMENTAL QUALITY BOARD OF PUERTO RICO

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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By Arturo Torres-González and Fernando Gómez-Gómez

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UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

Dallas L. Peck, Director

For additional information write to:

U.S. Geological Survey
Water Resources Division
G.P.O. Box 4424
San Juan, Puerto Rico 00936

CONTENTS

Page

Abstract..... 1

Introduction..... 1

Water-quality methods and procedures..... 2

Parameters and methodology..... 2

Significance of selected parameters..... 5

Results..... 7

References..... 136

Appendix..... 139

ILLUSTRATIONS

Figure 1. Map of the solid-waste disposal sites studied in this report..... 4

2. Site 1, Aguada disposal at Barrio Asomante..... 9

3. Site 2, Aguadilla disposal at Barrio Caimital Abajo..... 12

4. Site 3, Aguas Buenas disposal at Barrio Sumidero..... 14

5. Site 4, Aibonito disposal at Barrio Robles..... 17

6. Site 5, Añasco disposal at Barrio Marías..... 20

7. Site 6, Barceloneta disposal at Barrio Florida Afuera.... 22

8. Site 7, Barranquitas disposal at Barrio Helechal..... 24

9. Site 8, Bayamón disposal at Barrio Buena Vista..... 27

10. Site 9, Cabo Rojo disposal at Barrio Boquerón..... 30

11. Site 10, Caguas disposal at Barrio Turabo..... 32

12. Site 11, Camuy disposal at Barrio Piedra Gorda..... 35

13. Site 12, Carolina disposal at Barrio Hoyo Mulas..... 37

14. Site 13, Cayey disposal at Barrio Beatriz..... 39

15. Site 14, Ceiba disposal at Barrio Río Abajo..... 42

Page

Figure 16. Site 15, Ciales disposal at Barrio Hato Viejo..... 45

17. Site 16, Cidra disposal at Barrio Rincón..... 47

18. Site 17, Corozal disposal at Barrio Cuchillas..... 50

19. Site 18, Fajardo disposal at Barrio Demajagua..... 52

20. Site 19, Guánica disposal at Barrio Ciénaga..... 55

21. Site 20, Guayama disposal at Barrio Palmas..... 57

22. Site 21, Guayama disposal (old) at Barrio Jobos..... 60

23. Site 22, Guaynabo disposal at Barrio Mamey..... 62

24. Site 23, Gurabo disposal at Barrio Rincón..... 65

25. Site 24, Hatillo disposal at Barrio Buena Vista..... 68

26. Site 25, Humacao disposal at Barrio Buena Vista..... 70

27. Site 26, Isabela disposal at Barrio Arenales Altos..... 73

28. Site 27, Jayuya disposal at Barrio Saliente..... 75

29. Site 28, Juncos disposal at Barrio Ceiba Norte..... 78

30. Site 29, Lajas disposal (new) at Barrio Llanos..... 81

31. Site 30, Lajas disposal (old) at Barrio Palmarejo..... 83

32. Site 31, Manatí disposal at Barrio Coto Sur..... 85

33. Site 32, Maricao disposal at Barrio Maricao Afuera..... 87

34. Site 33, Maunabo disposal at Barrio Palo Seco..... 90

35. Site 34, Mayaguez disposal at Barrio Sabanetas..... 92

36. Site 35, Naguabo disposal at Barrio Mariana..... 95

37. Site 36, Naranjito disposal at Barrio Anones..... 98

38. Site 37, Orocovis disposal at Barrio Saltos..... 101

39. Site 38, Quebradillas disposal at Barrio Cacao..... 104

40. Site 39, Rincón disposal at Barrio Pueblo..... 106

Page

Figure 41. Site 40, Río Grande disposal at Barrio Jiménez..... 108

42. Site 41, Sabana Grande disposal at Barrio Torre..... 110

43. Site 42, Salinas disposal at Barrio Aguirre..... 112

44. Site 43, San Germán disposal at Barrio Sabana Grande Abajo..... 114

45. Site 44, San Lorenzo disposal at Barrio Quebrada..... 117

46. Site 45, San Sebastián disposal at Barrio Culebrinas..... 120

47. Site 46, Santa Isabel disposal at Barrio Boca Velázquez.. 123

48. Site 47, Utuado disposal at Barrio Arenas..... 126

49. Site 48, Vega Baja disposal at Barrio Río Abajo..... 129

50. Site 49, Vega Baja disposal (proposed) at Barrio Cibuco.. 131

51. Site 50, Villalba disposal at Barrio Hato Puerco Arriba.. 133

TABLES

Table 1. List of solid-waste disposal sites..... 3

2. Water-quality data Aguada, Puerto Rico..... 11

3. Water-quality data Aguas Buenas, Puerto Rico..... 16

4. Water-quality data Aibonito, Puerto Rico..... 19

5. Water-quality data Barranquitas, Puerto Rico..... 26

6. Water-quality data Bayamón, Puerto Rico..... 29

7. Water-quality data Caguas, Puerto Rico..... 34

8. Water-quality data Cayey, Puerto Rico..... 41

9. Water-quality data Ceiba, Puerto Rico..... 44

10. Water-quality data Cidra, Puerto Rico..... 49

11. Water-quality data Fajardo, Puerto Rico..... 54

12. Water-quality data Guayama, Puerto Rico..... 59

TABLES--Continued

		Page
Table 13.	Water-quality data, Guaynabo, Puerto Rico.....	64
14.	Water-quality data, Gurabo, Puerto Rico.....	67
15.	Water-quality data, Humacao, Puerto Rico.....	72
16.	Water-quality data, Jayuya, Puerto Rico.....	77
17.	Water-quality data, Juncos, Puerto Rico.....	80
18.	Water-quality data, Maricao, Puerto Rico.....	89
19.	Water-quality data, Mayaguez, Puerto Rico.....	94
20.	Water-quality data, Naguabo, Puerto Rico.....	97
21.	Water-quality data, Naranjito, Puerto Rico.....	100
22.	Water-quality data, Orocovis, Puerto Rico.....	103
23.	Water-quality data, San Germán, Puerto Rico.....	116
24.	Water-quality data, San Lorenzo, Puerto Rico	119
25.	Water-quality data, San Sebastián, Puerto Rico.....	122
26.	Water-quality data, Santa Isabel, Puerto Rico.....	125
27.	Water-quality data, Utuado, Puerto Rico.....	128
28.	Water-quality data, Villalba, Puerto Rico.....	135

GEOHYDROLOGIC DESCRIPTIONS OF SELECTED SOLID-WASTE DISPOSAL SITES IN PUERTO RICO

by

Arturo Torres-González and Fernando Gómez-Gómez

ABSTRACT

Fifty solid-waste disposal sites in Puerto Rico were examined in 1977 and ranked according to their potential for degradation of the water resources. Twenty-five of the sites show significant leachate pollution potential. The cover material at 21 sites is relatively permeable and offers insignificant attenuation to leachates. Thirty-six sites are adjacent to streams and nine of these are located in headwater areas. Rainfall is abundant and at 40 of the sites exceeds 1,500 millimeters per year.

General description of the 50 disposal sites are given with their geohydrologic setting. Baseline data consisting of specific conductance, pH, temperature, dissolved oxygen, and common ions were obtained at many of the sites. Such information provides a technical basis for assessing future effects of those solid-waste disposal sites on the quality of water resources.

INTRODUCTION

In 1977, under the auspices of the Islandwide 208 Project, the U.S. Geological Survey made a reconnaissance of 50 selected solid-waste disposal sites. The objective of the reconnaissance was to provide the Division of Solid Waste (DSW) of the Puerto Rico Environmental Quality Board (EQB) and the Islandwide 208 Project with a generalized description of the geology and hydrology of the sites. Although general in nature, the information provides sufficient detail for the DSW to rank the sites as to potential for degradation of the water resources.

Prior to 1977, little information was available on the disposal sites on the island with the exception of a reconnaissance made by the Survey in 1975 in cooperation with DSW on six sites (Gómez-Gómez, 1979).

The completion of this reconnaissance provides the necessary information to enable DSW to determine which sites would require closer monitoring of operations. Additionally, the Islandwide 208 Project receives information which would aid in the 208 Project's responsibility to improve or maintain the quality of the island's water resources.

Some general findings of this solid-waste disposal site reconnaissance are that many of the sites:

1. Seem to have developed without a detailed description and plans that outline the steps to be taken to provide for the safe, efficient disposal of the quantities and types of solid wastes that are expected to be received.

2. Have not been provided with diversion of upland drainage.

3. Do not minimize the water that can infiltrate the soil cover

(a) by grading and sloping the daily and final cover to allow for runoff, and

(b) by suitable compacting of the cover material, thus decreasing its permeability.

4. Evidence exposed refuse and junk along lower gradient of fill zone and at many sites creeks are littered by such wastes.

The solid-waste disposal sites studied in this report are shown in figure 1 and listed in table 1.

Water Quality Methods and Procedures

Water samples were collected from 26 of the sites shown on table 1. Chemical and physical analyses of the samples were made in accordance with methods and procedures described by Brown and others (1970), and the American Public Health Association (1975).

Parameters and Methodology

The parameters selected for determinations include those that can be related to chemicals which may be leached from solid-waste disposal sites. The parameters measured and the methodology employed were as follows:

1. Physical parameters		
a. Temperature		
b. Specific conductance	Instrumental (field)	
c. Discharge	Estimated (field)	
2. Chemical parameters		
a. Common ions (calcium, magnesium, sodium, pottassium, sulfate, chloride, fluoride)	Standard procedures (laboratory)	
(bicarbonate, carbonate)	Standard procedures (field)	
b. pH	Instrumental (field)	
c. Dissolved oxygen (DO)	Winkler procedure (field)	

Table 1.--Solid-waste disposal sites.

Number	Sites	Number	Sites
*1	Aguada	26	Isabela
2	Aguadilla	*27	Jayuya
*3	Aguas Buenas	*28	Juncos
*4	Aibonito	29	Lajas (new)
5	Añasco	30	Lajas (old)
6	Barceloneta	31	Manatí
*7	Barranquitas	*32	Maricao
*8	Bayamón (old)	33	Maunabo
9	Cabo Rojo	*34	Mayaguez
*10	Caguas	*35	Naguabo
11	Camuy	*36	Naranjito (proposed)
12	Carolina	*37	Orocovis
*13	Cayey	38	Quebradillas
*14	Ceiba	39	Rincón
15	Ciales	40	Río Grande
16	Cidra	41	Sabana Grande
17	Corozal	42	Salinas
*18	Fajardo	*43	San Germán
19	Guánica	*44	San Lorenzo
*20	Guayama (new)	*45	San Sebastián
21	Guayama (old)	*46	Santa Isabel
*22	Guaynabo	*47	Utuado
*23	Gurabo	48	Vega Baja (new)
24	Hatillo	49	Vega Baja (old)
*25	Humacao	*50	Villalba

*Sites at which water samples were collected for chemical and physical analyses.

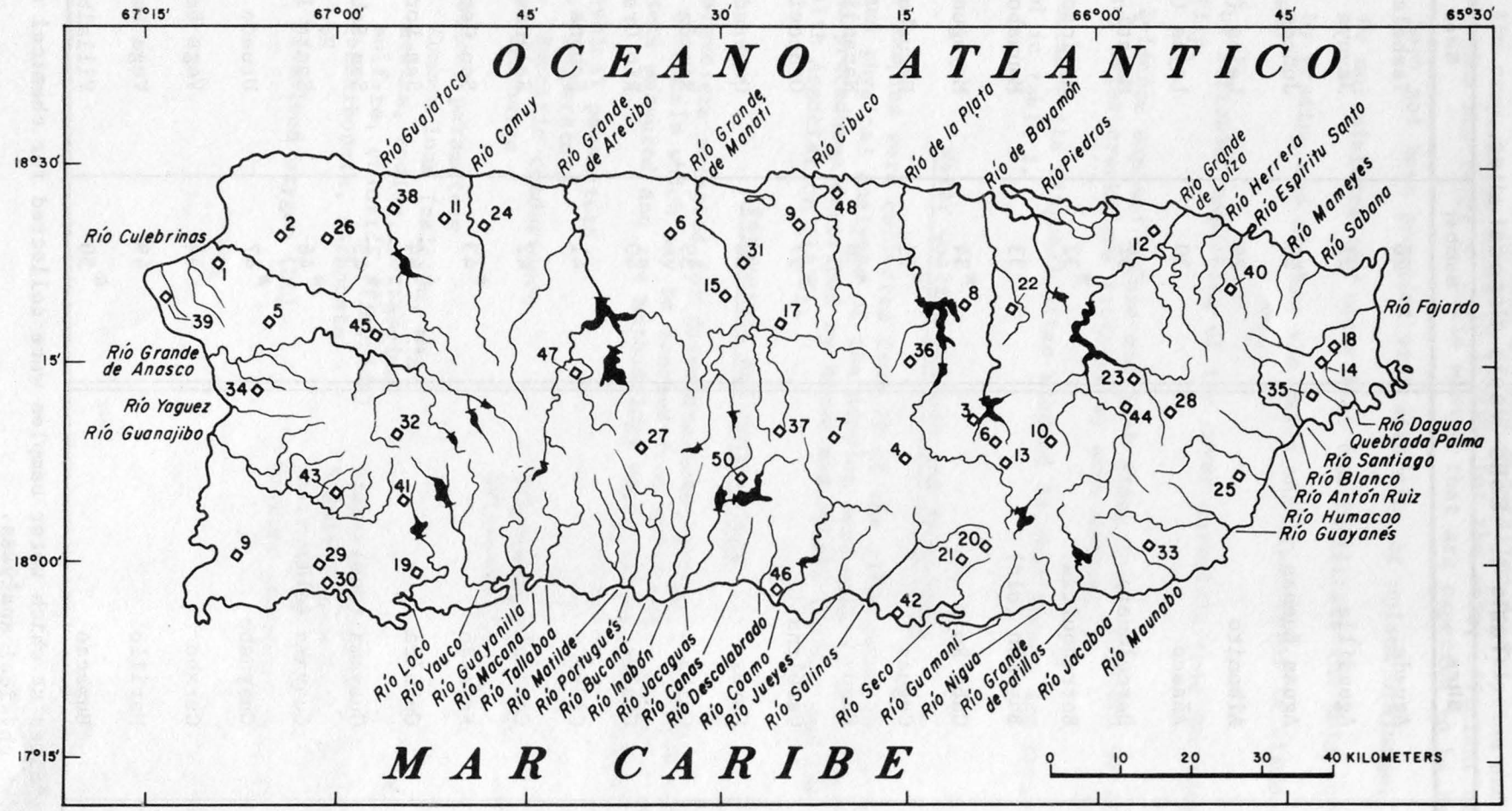


Figure 1.--Solid-waste disposal sites studied in this report.

Significance of Selected Parameters

Some of the parameters sampled have special significance in terms of surface and ground-water pollution. The most important and their significance are (Hem, J.D., 1971):

1. Bicarbonate (HCO_3-).--Carbon dioxide which is dissolved in waters usually appears in chemical analyses as bicarbonate. Carbon dioxide released from biological oxidation is capable of producing low pH if minerals that act as proton acceptors are scarce. Due to the presence of calcite in almost all natural waters and soils, equilibrium conditions control pH to about 6. At such value the main species of dissolved carbon dioxide is HCO_3-.

2. Calcium (Ca).--In most natural waters calcium is the principal cation. It is an essential constituent of igneous-rock minerals. Some calcium is to be expected in waters which have been in contact with igneous or metamorphic rocks, but in low concentrations. It is more commonly present in sedimentary rock, especially in the carbonates. Its solubility in water is essentially controlled by the carbon dioxide partial pressure. Calcium and magnesium are the major contributors to hardness in natural waters.

3. Chloride (Cl-).--Chloride is present in most surface streams but its concentration is usually less than sulfate or bicarbonate. Chloride ions do not significantly enter into oxidation or reduction reactions, form no important solute complexes, do not form salts of low solubility, are not significantly adsorbed on mineral surfaces and play few vital biochemical roles. The circulation of chloride ions in the hydrologic cycle is largely through physical processes. Investigations have shown that chloride ions moved with water through most soils tested with less retardation or loss than any of the other tracers tested including tritium. However, the behavior should not be expected where movement is through compacted clay or shale. Human activities might be a major factor in chloride circulation.

4. Dissolved oxygen (DO).--Dissolved oxygen as the concentration of oxygen present in water in its uncombined form, O_2. Oxygen is essential for the higher forms of aquatic life and the oxidation of organic matter in water. Low DO values are indicative of stressed systems subject to high organic loading or respiration. It is recommended that the minimum DO concentration should not be lower than the seasonal natural minimum (National Academy of Sciences, 1972).

5. Magnesium (Mg).--In most natural waters magnesium is present in concentrations much lower than calcium. Its abundance in rocks is substantially below that of calcium. It is typically a constituent in mineral species such as montmorillonite and serpentine. In carbonates such as dolomite it is present in equal amounts with calcium and in the solution process equal amounts of the two ions will dissolve. Water that is near or above saturation may lose some calcite by precipitation, so that the water attains a concentration of Mg greater than that of Ca.

6. pH.--pH is a measure of the hydrogen-ion concentration, or more precisely, its activity. Most waters in Puerto Rico are slightly basic (pH greater than 7.0 units) ranging from 6.8 to 8.6 units. Toxic pH values depend on the specific conditions. It is recommended (National Academy of Sciences, 1972) that the normal range for a given freshwater environment should not vary by more than 0.5 pH units.

7. Potassium (K).--Potassium is present in silicate rock minerals such as the feldspars, the micas, and the feldspathoid leucite. The potassium feldspars are very resistant to attack by water, but presumably are altered to silica, clay, and K+ ions by the same process as other feldspars but only more slowly. Potassium exhibits a strong tendency to be reincorporated into solid weathering products, especially certain clay minerals. Concentrations of potassium more than a few tenths of milligrams per liter are decidedly unusual except in water with very high dissolved solids concentrations or in water from hot springs.

8. Sodium (Na).--Sodium is the most common member of the alkali-metals. In igneous rock it is slightly more abundant than potassium, but in sediments sodium is much less abundant. There are no important precipitation reactions that can retain low sodium concentrations in water in the way that carbonates precipitate calcium. Sodium is retained by adsorption on mineral surfaces when a high proportion of sodium to divalent cations exists, especially by those minerals with high cation exchange capacities such as clays.

9. Specific conductance.--Specific conductance measures the ability of a solution to conduct an electric current. Its value increases with increasing concentration of ions in solution. Thus its value may be related to the concentration of dissolved solids. Unpolluted streams in Puerto Rico seldom exceed a specific conductance value of 400 umho/cm.

10. Sulfate (SO_4^{-2}).--Sulfate is not a major constituent of the earth's outer crust, but is widely distributed in reduced form both in igneous and sedimentary rocks as metallic sulfides. During weathering processes sulfide in contact with aerated waters yields the sulfate ion which is carried off. Sulfur is one of the main building blocks of proteins. During anoxic decomposition sulfide is produced but may be bonded with metallic ions, which are very insoluble.

RESULTS

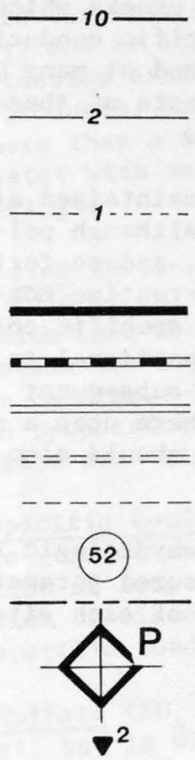
Within the limitations of this study, water samples were collected upstream and downstream of sites where leachate contamination was suspected. Among the sites surveyed, 25 showed significant leachate pollution potential. The cover material in 21 of the sites is relatively permeable and offers insignificant attenuation to leached substances. Twenty-seven of the sites are less than 10 years old. Although leachate production at many sites was not detected, a potential still exists due to the young age of the fill. Cases have been reported where landfills, many years after being abandoned, continued producing leachate. Many of the sites (36) are adjacent to streams or creeks which serve as drainage features. Baseline data consisting of specific conductance, pH, temperature, dissolved oxygen and common ions were obtained at many of these. Such information is valuable in assessing future effects of these solid-waste disposal sites on the quality of water resources.

It is essential that a long-term monitoring program be maintained at these sites even if these are abandoned for such purposes. Although pollutants leached may include toxic metals, phenols, pathogens, and so forth, such detailed sampling and analyses may not be feasible on a routine monitoring program. A more practical approach is to maintain a specific conductance record. Since specific conductance is directly proportional to dissolved solids (ionic concentration), a steady increase of subsequent samplings at a station may indicate leachate contamination where upon a more detailed analysis can be made. A routine monitoring program should also include discharge measurements for comparability of results.

General descriptions of the 50 selected sites, their geohydrologic setting, and tabulated results of the field- and laboratory-measured parameters follow. A more detailed description of the geologic setting of each site appears in Appendix I.

EXPLANATION

FOR FIGURES 2 THRU 51



TOPOGRAPHIC CONTOUR --Shows elevation of land surface in meters. Contour interval varies from 5, 10, 20, 50, and 100 meters. Datum is mean sea level.

INTERMEDIATE TOPOGRAPHIC CONTOUR -- Shows elevation of land surface in meters. Contour interval 2,3, and 4 meters. Datum is mean sea level.

SUPPLEMENTARY TOPOGRAPHIC CONTOUR -- Shows elevation of land surface in meters. Contour interval 1 meter. Datum is mean sea level.

HARD SURFACE, HEAVY-DUTY ROAD

HARD SURFACE, MEDIUM-DUTY ROAD

IMPROVED LIGHT-DUTY ROAD

UNIMPROVED DIRT ROAD

TRAIL

HIGHWAY NUMBER

MUNICIPIO OR BARRIO BOUNDARY

SOLID WASTE DISPOSAL SITE -- Shows location of site. Large P next to some sites means proposed sites.

SAMPLING SITE AND NUMBER

Base map used in figures 2 to 51 are from USGS topographic maps, scale 1:20,000, dated 1958-72.

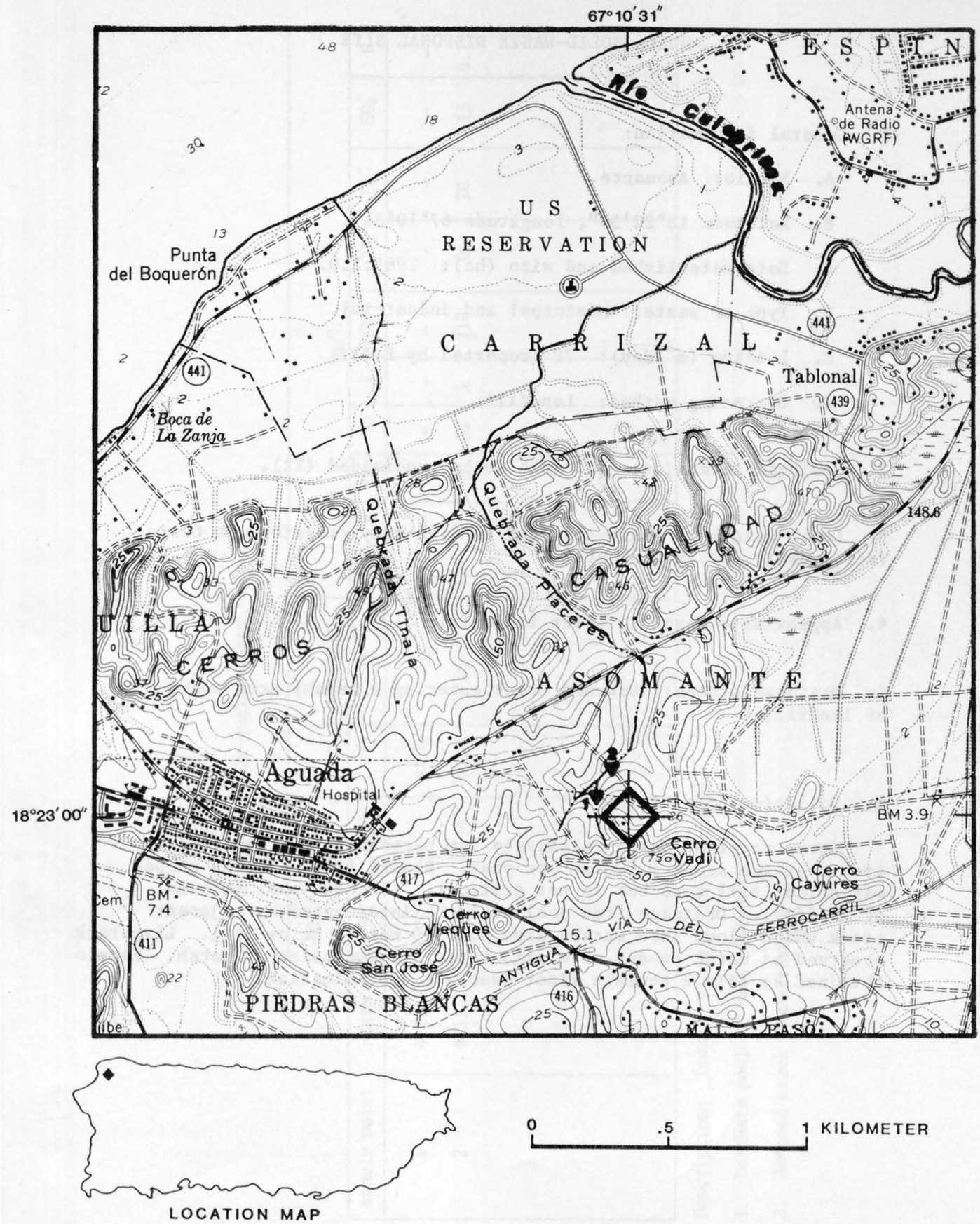


Figure 2.--Aguada solid-waste disposal site at Asomante.

AGUADA SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Asomante.

   B. Latitude 18°22'56", longitude 67°10'31".

   C. Date established and size (ha): 1965;2.0.

   D. Type of waste: Municipal and industrial.

   E. Loading (m^3/day): 78 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Volcanic rocks, undivided (Tt).

3. Cover material: Dark-gray and reddish-gray claystone on Cerro Vadi, mostly deeply weathered.

4. Approximate depth to water table (m): 10-15.

5. Drainage stream: Unnamed creek entering a marshy area north of landfill.

6. Pollution potential:

Cover material has a relatively low permeability. Rainfall in area averages about 1,500 mm per year. Runoff from adjacent slopes may affect fill zone but is not critical. Leachate pool at base of landfill. Drainage from pool could be intercepted by adjacent creek which flows into marshy area some 40 meters below fill. Livestock observed at marsh on day of visit, horse seen watering at marsh. Sample obtained at site 2 reveals minor leachate contamination.

Table 2.--Water-quality data - Aguada

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	4-11-78	1100		27.0	=	-	-	-	-	-	-	-	-	-	-
2	4-11-78	550	7.6	23.0	<1	5.8	68	10	32	1	318	0	20	15	0.1

Description: (sample point(s) shown on map)

1. Leachate pool at base of landfill.

2. Unnamed creek downstream of fill.

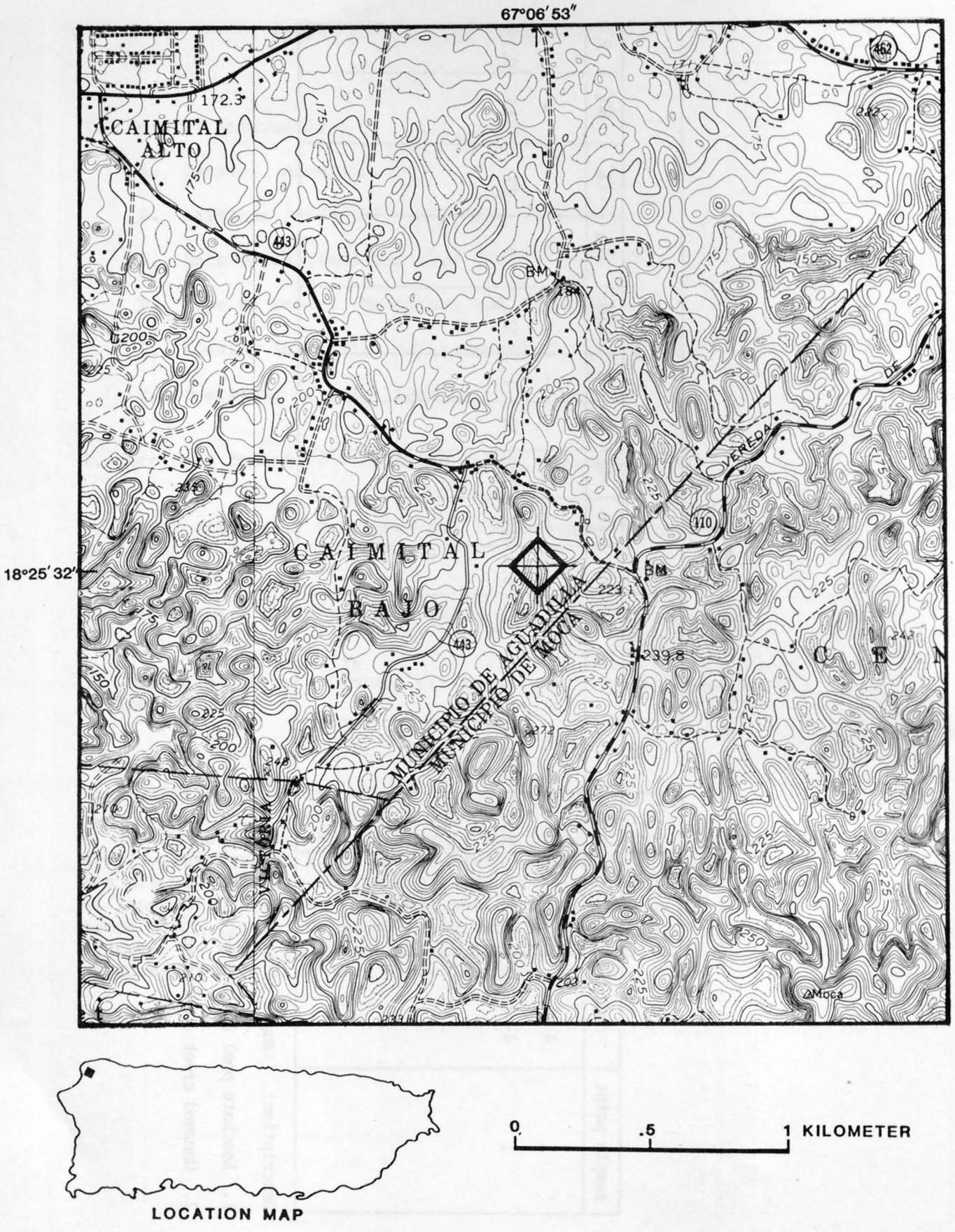


Figure 3.--Aguadilla solid-waste disposal site at Caimital Abajo.

AGUADILLA SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Caimital Bajo.

   B. Latitude 18°25'32", longitude 67°06'53".

   C. Date established and size (ha): 1970;3.9.

   D. Type of waste: Municipal and industrial.

   E. Loading (m^3/day): 185 (reported by EQB).

   F. Operating method: Burning dump and landfill.

2. Geologic formation: Aguada Limestone (Ta): Upper member.

3. Cover material: Limestone fragments; cover material also trucked in (crushed limestone).

4. Approximate depth to water table (m): More than 100 to regional water table; local perched conditions might exist.

5. Drainage stream: No surface stream nearby. Sinkhole used for solid-waste disposal.

6. Pollution potential:

   Cover material highly permeable to leached substances and offers negligible attenuation. Rainfall in area averages about 1,780 mm per year. All rainfall within fill zone will drain toward adjacent sinkhole.

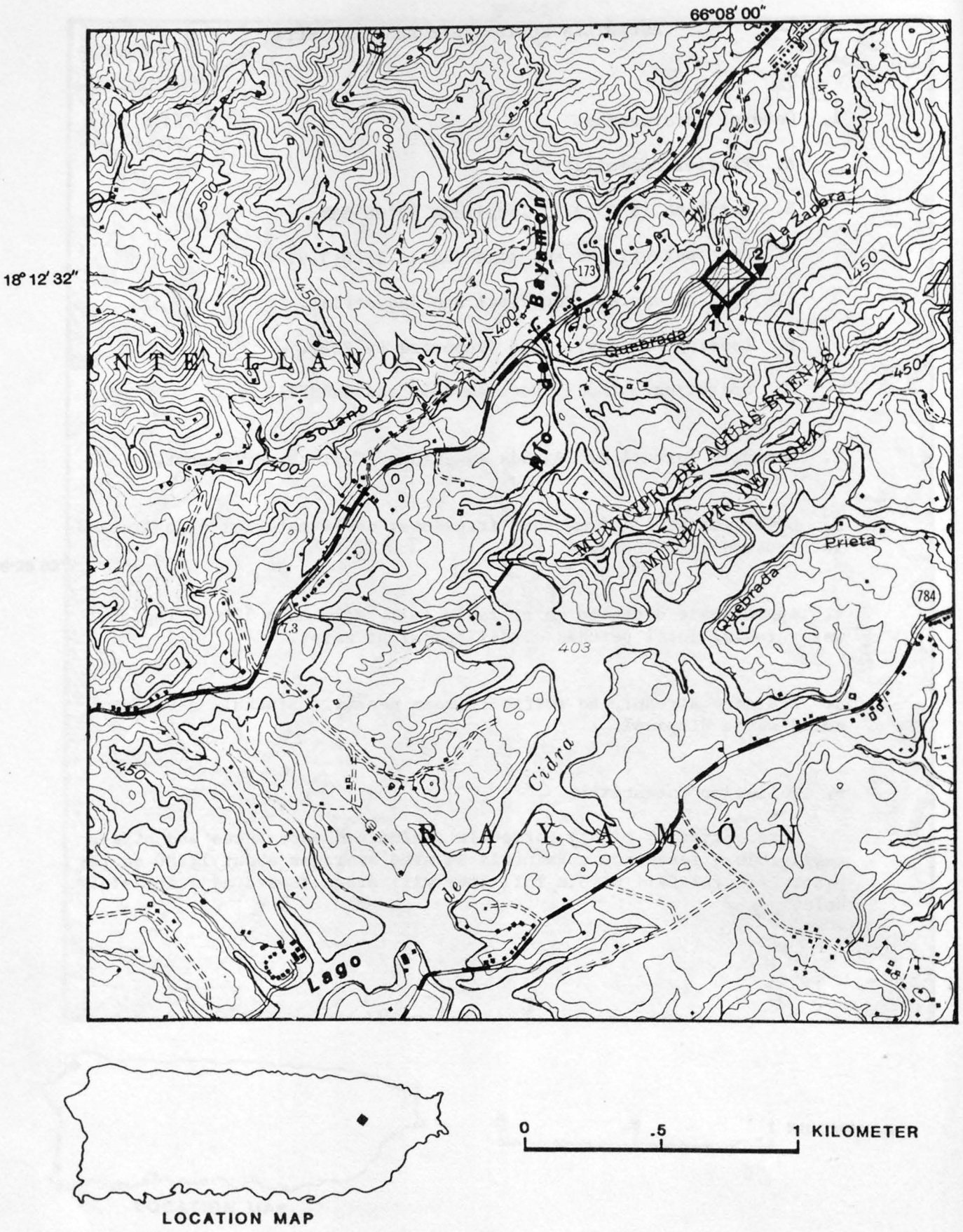


Figure 4.--Aguas Buenas solid-waste disposal site at Sumidero.

AGUAS BUENAS SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Sumidero.

   B. Latitude 18°12'32", longitude 66°08'50".

   C. Date established and size (ha): 1973;78.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 98 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Tkhv, Tkhd, and Kka. Metamorphic rock (Tkhv), Intrusive rock (Tkhd), Aguas Buenas Limestone Member (Kka).

3. Cover material: Gray sandy soil used for cover. Siltstone and stratified claystone outcrops.

4. Approximate depth to water table (m): 10.

5. Drainage stream: Adjacent to Quebrada La Zapera, a tributary of Río de Bayamón.

6. Pollution potential:

Cover material adequate if properly applied. Rainfall in area averages 1,650 mm per year. Runoff from adjacent slopes intercepted by service road into fill zone. Junk and other exposed garbage visible along edge of fill and within Quebrada La Zapera. No indication of leachate effects on creek, but this had a relatively high flow when visited.

Table 3.--Water-quality data - Aguas Buenas

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	2-8-78	165	6.6	20.5	225	8.0	30	3.2	13	1.8	72	0	17	4.8	0.0
2	2-8-78	160	-	20.3	-	-	-	-	-	-	-	-	-	-	-

Description: (sample point(s) shown on map)

1. At creek, downstream of fill.

2. At creek, upstream of fill.

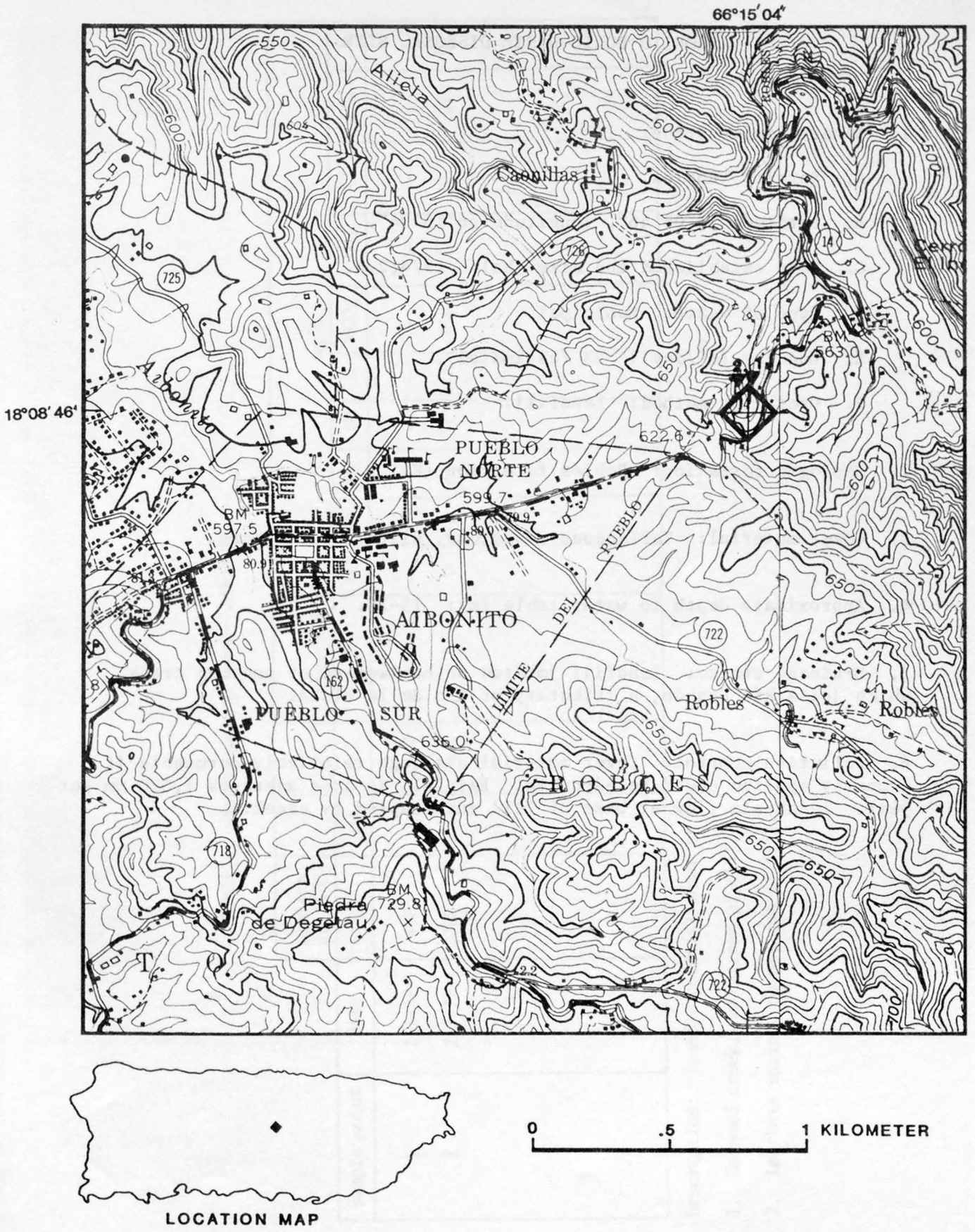


Figure 5.--Aibonito solid-waste disposal site at Robles.

AIBONITO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Robles.

   B. Latitude 18°08'46", longitude 66°15'04".

   C. Date established and size (ha): 1974;2.4.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 83 (estimated).

   F. Operating method: Landfill.

2. Geologic formation: Robles formation (Kr).

3. Cover material: Tuffaceous sandstone, siltstone, breccia.

4. Approximate depth to water table (m): 15-20.

5. Drainage stream: Landfill located on headwaters of unnamed creek which joins Río Usabón, a tributary of Río de la Plata.

6. Pollution control: Cover material although relatively permeable if properly applied could be adequate. Rainfall in area averages 1,320 mm per year. Leacheate flow at base of fill intercepted by creek.

Table 4.--Water-quality data - Aibonito

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	2-7-78	480	-	24.0	-	-	-	-	-	-	-	-	-	-	-
2	2-7-78	700	7.3	23.5	1	0	91	24	37	1.3	396	0	38	27	0.2

Description: (sample point(s) shown on map)

1. Unnamed creek, downstream of fill.

2. Leachate spring, downstream of fill.

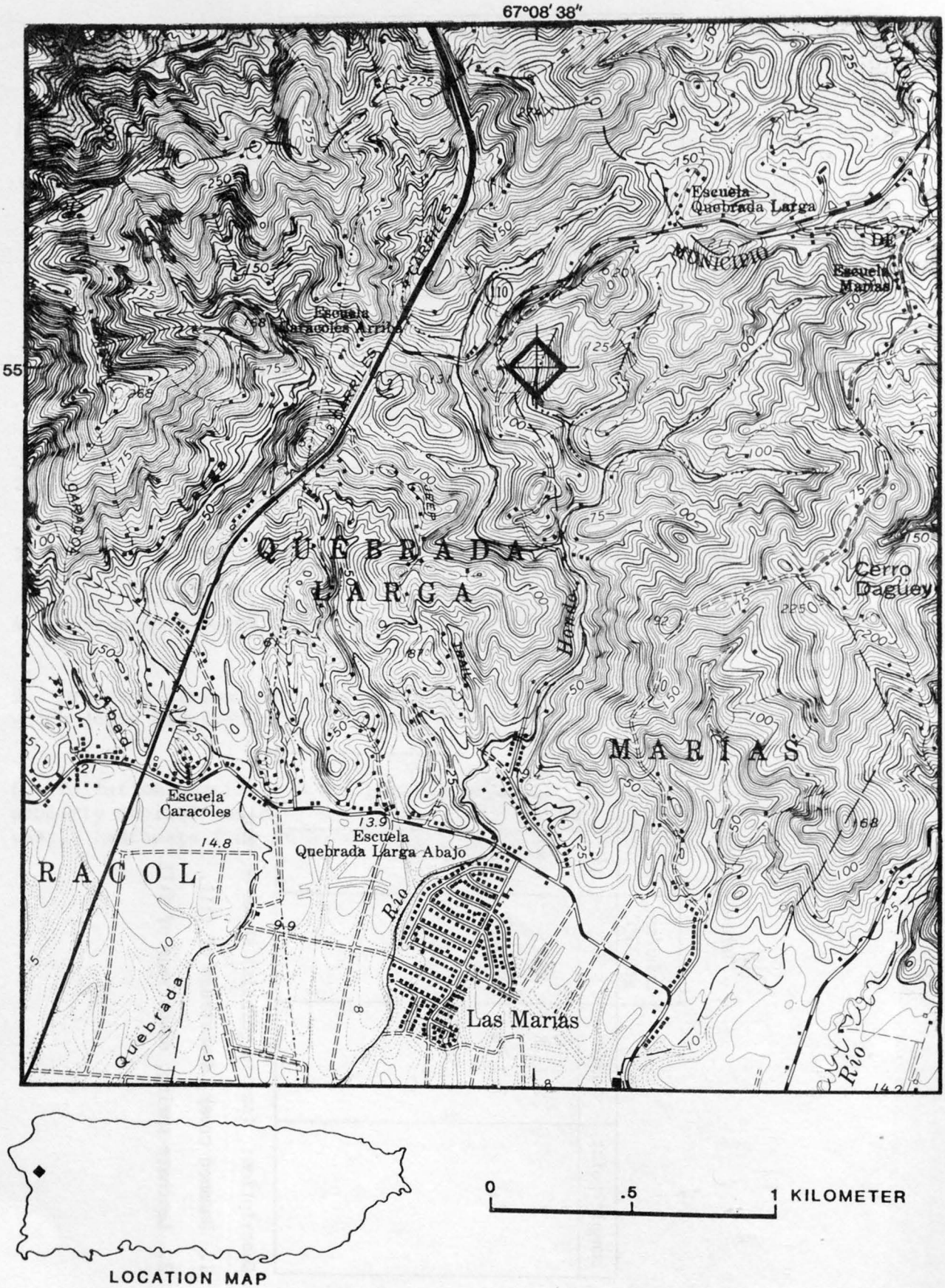


Figure 6.--Añasco solid-waste disposal site at Marías.

AÑASCO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Marías.

   B. Latitude 18°18'55", longitude 67°08'38".

   C. Date established and size (ha): unknown; 7.9.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 49 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Volcanic rocks, undivided (Tks).

3. Cover material: Brown to yellow clay mixed with coarse, loose material.

4. Approximate depth to water table (m): 20-30.

5. Drainage stream: Intermittent unnamed creek runs through landfill site.

6. Pollution potential:

Cover material is relatively permeable and offers insignificant attenuation to leached substances. Rainfall in area averages 2,150 mm per year. Runoff from adjacent slopes not diverted from fill zone. Under such circumstances leachate production could occur and affect unnamed creek whose headwater has been occupied partly by fill zone. When visited creek was dry, but streambed was littered with junk and garbage.

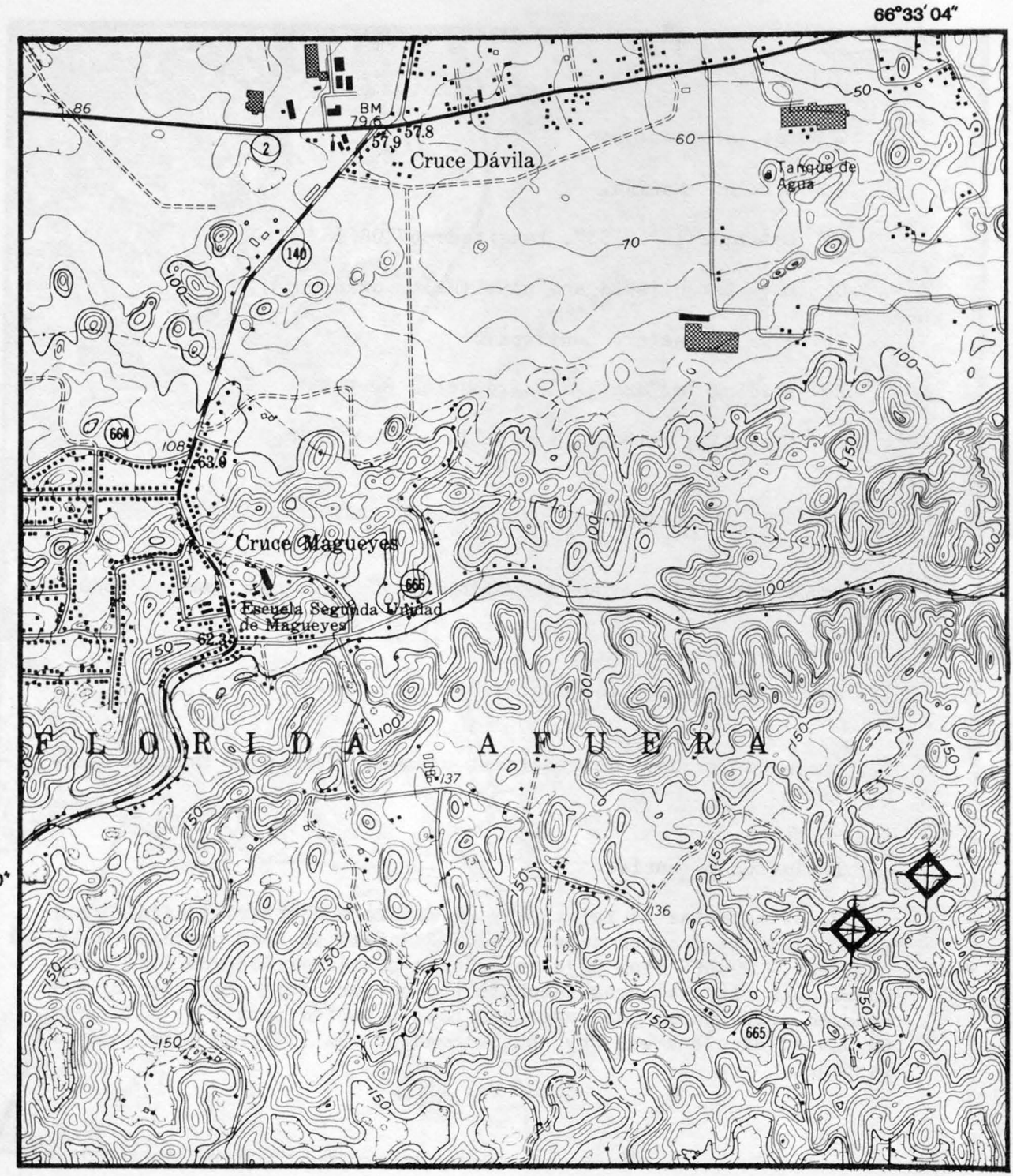


Figure 7.--Barceloneta solid-waste disposal site at Florida Afuera.

BARCELONETA SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Florida Afuera.

   B. Latitude 18°24'30", longitude 66°33'04".

   C. Date established and size (ha): 1973; 7.9.

   D. Type of waste: Municipal; industrial.

   E. Loading (m^3/day): 110 (reported by EQB).

   F. Operating method: Landfill and trench.

2. Geologic formation: Blanket deposits (Qtb), Aguada Limestone (Ta), and Aymamón Limestone (Tay).

3. Cover material: Reddish-brown sandy clay.

4. Approximate depth to water table (m): 60-90 to regional water table. Local perched conditions might exist.

5. Drainage stream: No surface stream nearby. Sinkholes used as solid-waste disposal sites.

6. Pollution potential:

   Cover material used in trench method of disposal consists of relatively impermeable blanket deposits. Rainfall in area averages 1,780 mm per year. Runoff from area flows into sinkholes.

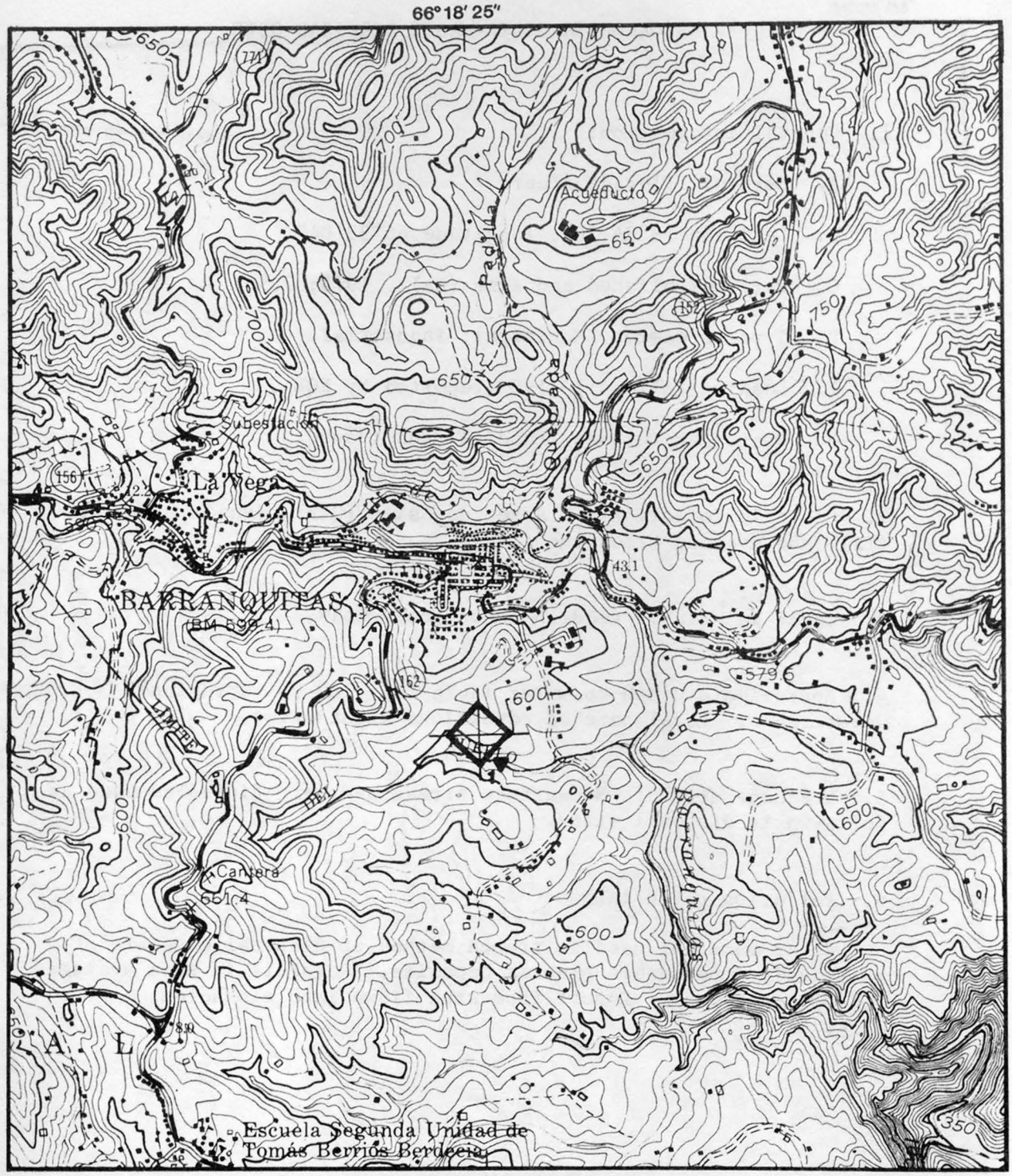


Figure 8.--Barranquitas solid-waste disposal site at Helechal.

BARRANQUITAS SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Helechal.

   B. Latitude 18°11'00", longitude 66°18'25".

   C. Date established and size (ha): 1965; 7.9.

   D. Type of waste: Municipal.

   E. Loading (m^3/day) 99 (estimated).

   F. Operating method: Landfill.

2. Geologic formation: Robles Formation (Kr).

3. Cover material: Light-brown tuffaceous siltstone.

4. Approximate depth to water table (m): 10.

5. Drainage stream: On south side of landfill an unnamed creek flows toward Río de Barranquitas, a tributary of Río Usabón.

6. Pollution potential:

Cover material if properly compacted is adequate. Rainfall in area averages 1,520 mm per year. Runoff from adjacent slopes not diverted from fill zone. Under such circumstances leachate production could occur and affect unnamed creek flowing along edge of fill. When visited, creek did not show the effects of leachate contamination, but was littered with junk and garbage.

Table 5.--Water-quality data - Barranquitas

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	2-7-78	240	6.9	21.0	2	8.2	14	12	18	2.3	94	0	27	.15	0.1

Description: (sample point(s) shown on map)

1. Unnamed creek below fill.

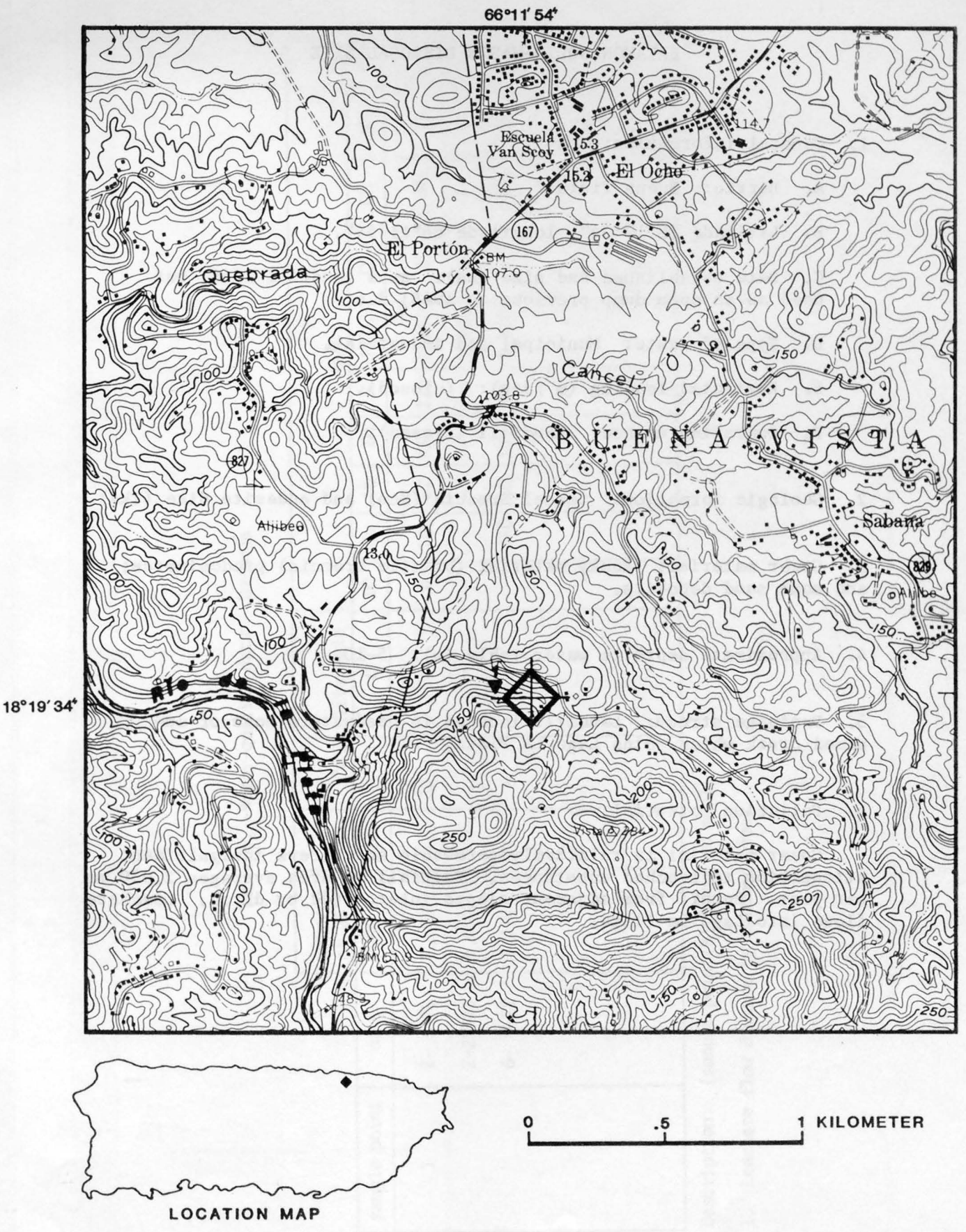


Figure 9.--Bayamón solid-waste disposal site at Buena Vista.

BAYAMON SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Buena Vista.

   B. Latitude 18°19'34", longitude 66°11'54".

   C. Date established and size (ha): as a landfill 1968, but used as an open dump previous to 1968; 8.6.

   D. Type of waste: Municipal and industrial.

   E. Estimated loading (m^3/day): (closed).

   F. Operating method: Landfill (closed).

2. Geologic formation: Cancel Breccia (Kcn) and andesite dike (Tka).

3. Cover material: Rocky material (brittle breccia) predominates; and some sand deposits.

4. Approximate depth to water table (m): 5-10.

5. Drainage stream: Landfill located in headwaters zone of unnamed creek which joins Lago La Plata.

6. Pollution potential:

Cover material is relatively permeable and offers insignificant attenuation to leached substances. Rainfall in area averages 2,030 mm per year. Runoff from adjacent slopes intercepted by ditch. Leachate flows into Lago La Plata.

Table 6.--Water-quality data - Bayamón

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	2- 6-78	7,500	7.5	32.0	4	0	100	62	930	220	1,860	0	1,900	21	0.2
	2-27-75	6,600	7.8	-	-	-	-	-	-	-	1,880	0	-	-	-
	6- 8-72	3,470	7.7	-	-	-	480	120	180	15	1,820	-	340	50	1.0

Description: (sample point(s) shown on map)

1. Leachate flow drained by unnamed creek.

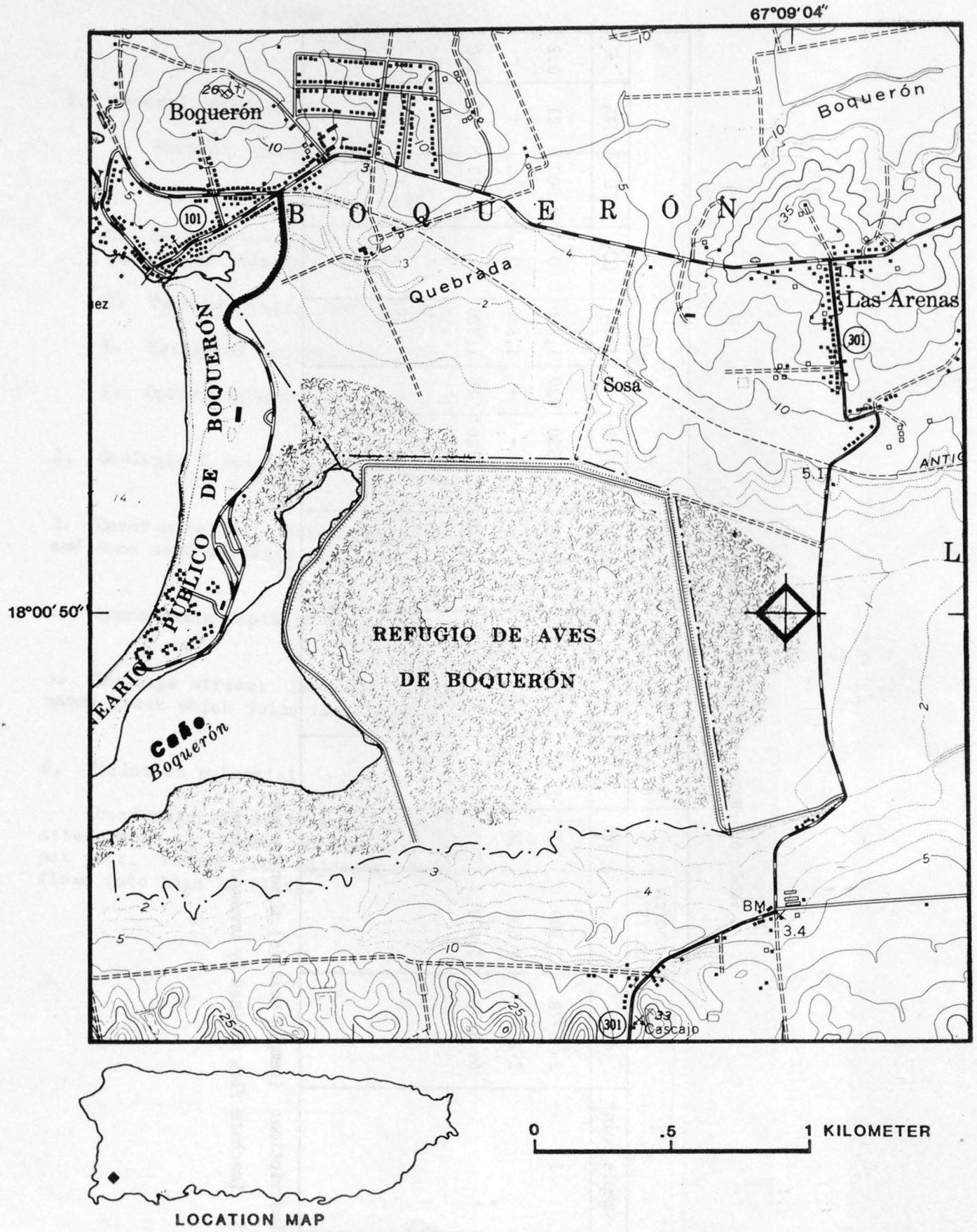


Figure 10.--Cabo Rojo solid-waste disposal site at Boquerón.

CABO ROJO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Boquerón.

   B. Latitude 18°00'50", longitude 67°09'04".

   C. Date established and size (ha): 1969; 3.9.

   D. Type of waste: Municipal and industrial.

   E. Loading (m^3/day): 89 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Swamp and marsh deposits (Qs).

3. Cover material: Tuffaceous breccia, very loose material found at site.

4. Approximate depth to water table (m): Within mangrove wetlands zone.

5. Drainage stream: Mangrove wetlands zone of Caño Boquerón.

6. Pollution potenial:

Cover material adequate for site due to low rainfall incidence which averages 1,015 mm per year. Runoff into adjacent mangrove swamp may occur only during intensive rainstorms.

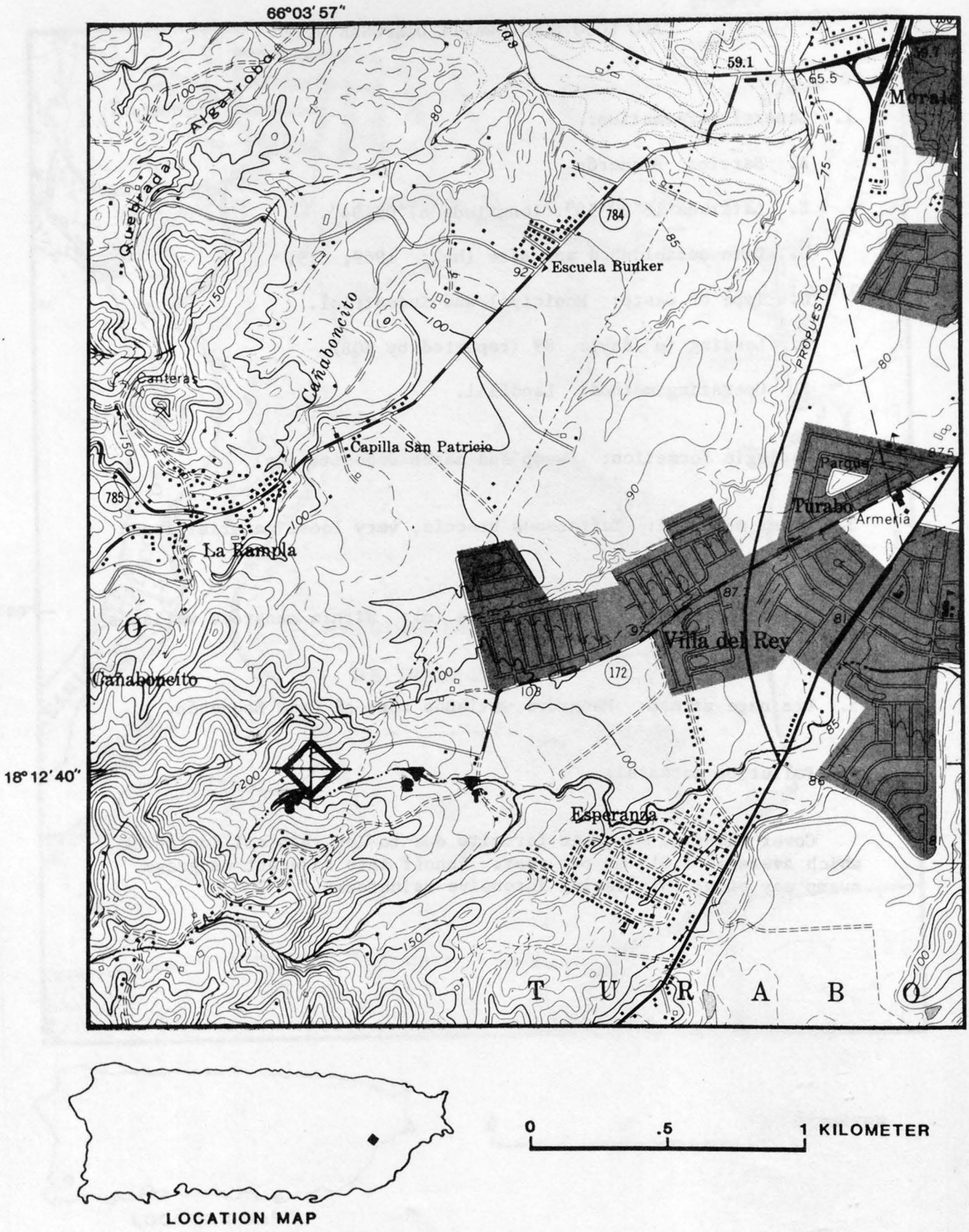


Figure 11.--Caguas solid-waste disposal site at Turabo.

CAGUAS SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Turabo.

   B. Latitude 18°12'40", longitude 66°03'57".

   C. Date established and size (ha): 1953; 7.9.

   D. Type of waste: Municipal and industrial.

   E. Loading (m^3/day): 600 (estimated).

   F. Operating method: Landfill.

2. Geologic formation: Upper Cretaceous volcanic rocks (KL).

3. Cover material: Andesitic tuff, shale, stratified ash and tuff.

4. Approximate depth to water table (m): 15-20.

5. Drainage stream: Unnamed creek flowing on south side, toward Río Turabo.

6. Pollution potential:

Cover material relatively impermeable if properly utilized (sufficient compaction, appropriate refuse-to-soil ratio and sufficient slope to enhance runoff from filled zone). Rainfall in area averages about 1,900 mm per year. Leachate flow at base of fill and through local ground-water system. Adjacent unnamed creek affected by leachate and refuse. Livestock utilize creek for watering.

Table 7.--Water-quality data - Caguas

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	2- 7-78	1,350	-	19.5	12	-	-	-	-	-	-	-	-	-	-
2	2- 7-78	1,200	7.3	22.0	12	7.6	-	-	-	-	270	0	-	-	-
	5-24-76	850	7.7	26.0	1.8	6.8	43	30	67	6.5	207	0	130	44	-
3	5-24-76	430	7.0	25.0	1.8	5.0	32	24	24	2.2	207	0	35	24	-

Description: (sample point(s) shown on map)

1. At creek, downstream of sample point 2.
2. At creek, downstream of fill.
3. At creek, above fill.

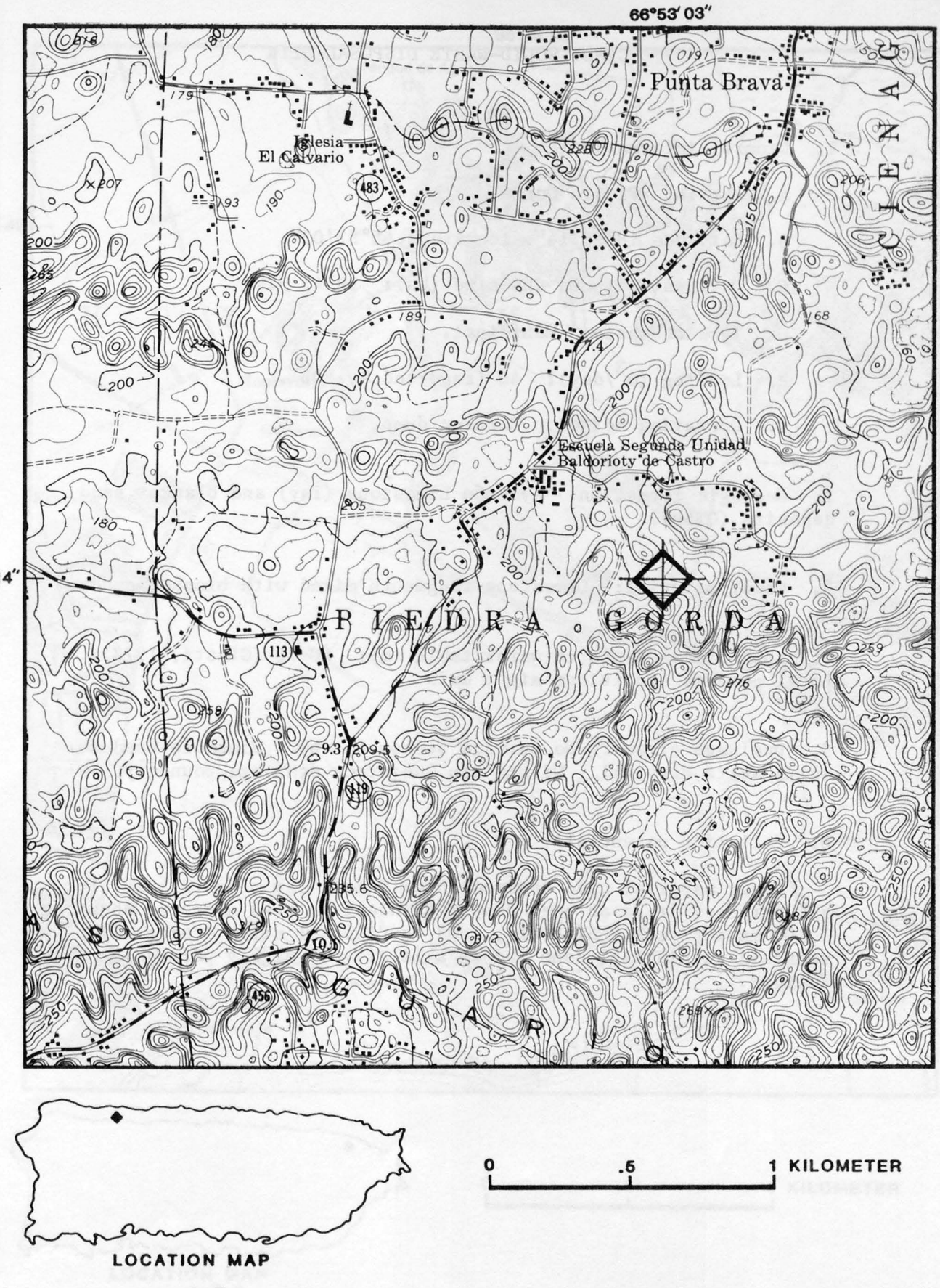


Figure 12.--Camuy solid-waste disposal site at Piedra Gorda.

CAMUY SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Piedra Gorda.

   B. Latitude 18°25'14", longitude 66°53'03".

   C. Date established and size (ha): 1954; 3.9.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 40 (reported by EQB).

   F. Operating method: Burning dump.

2. Geologic formation: Aymamón Limestone (Tay) and blanket sand deposits (QTbs).

3. Cover material: Limestone fragments mixed with blanket sands.

4. Approximate depth to water table (m): 60-70 (Giusti, 1978). Local perched conditions might exist.

5. Drainage stream: No surface stream nearby. Sinkhole used for solid waste disposal. Within Río Guajataca drainage boundary.

6. Pollution potential:

   Cover material used applied in extremely low proportions. For all purposes it is an open dump. Rainfall in area averages about 1,400 mm per year. Sinkhole, used as disposal site, drains all rainfall within fill zone and is a relatively highly permeable feature.

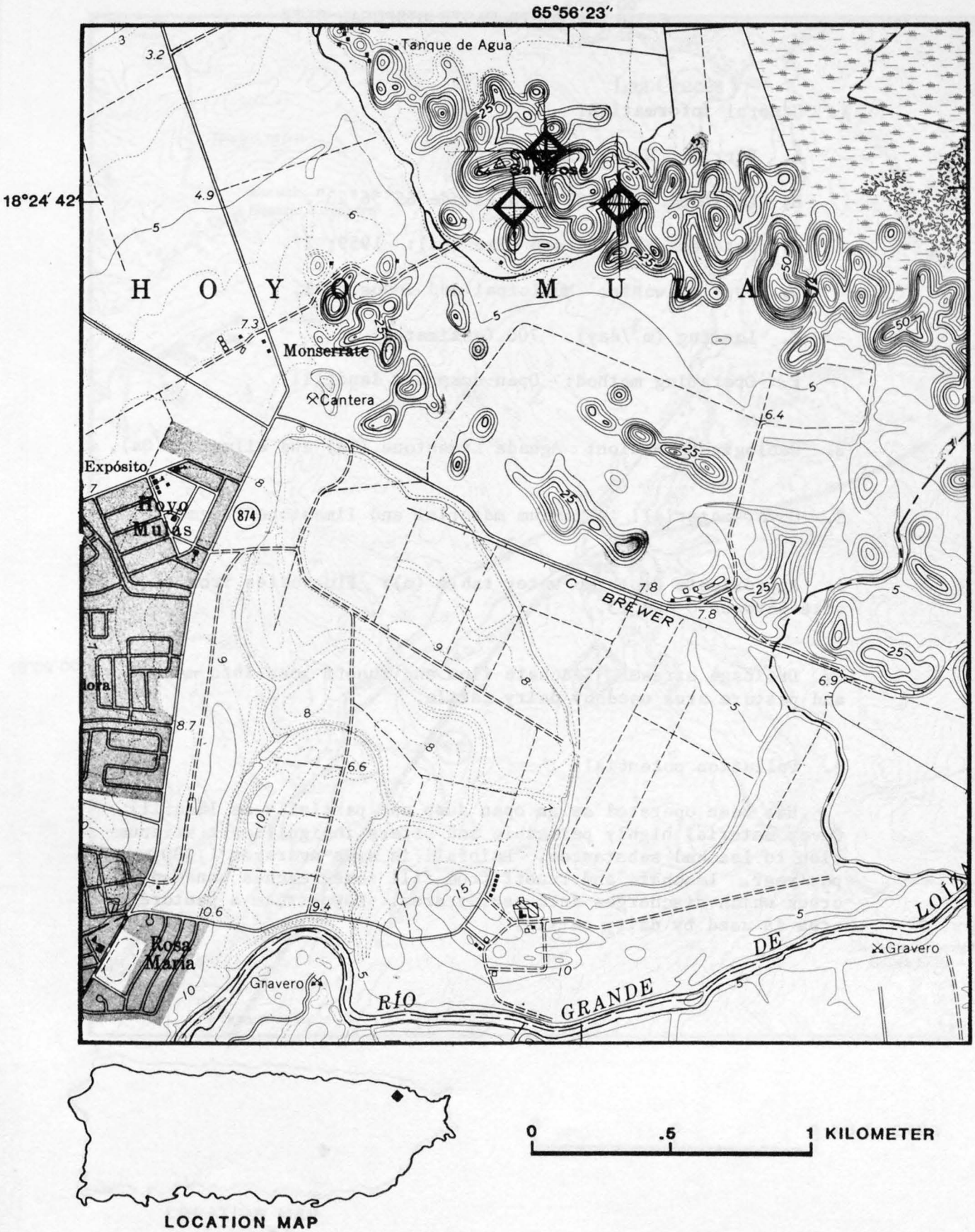


Figure 13.--Carolina solid-waste disposal site at Hoyo Mulas.

CAROLINA SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Hoyo Mulas.

   B. Latitude 18°24'39", longitude 65°56'23".

   C. Date established and size (ha): 1959; 27.

   D. Type of waste: Municipal and industrial.

   E. Loading (m^3/day): 700 (estimated).

   F. Operating method: Open dump and landfill.

2. Geologic formation: Aguada Limestone (Ta) and alluvium (Qa).

3. Cover material: Alluvium material and limestone fragments.

4. Approximate depth to water table (m): Fluctuates from site to site between 0 and 15.

5. Drainage stream: Leachate flow and runoff goes into marsh and pasture area used by dairy cattle.

6. Pollution potential:

Has been operated as an open dump and partially as landfill. Cover material highly permeable and offers insignificant attenuation to leached substances. Rainfall in area averages 1,900 mm per year. Leachate and runoff from fill zone reaches unnamed creek which discharges into nearby area. Downstream a pasture area is used by dairy cattle.

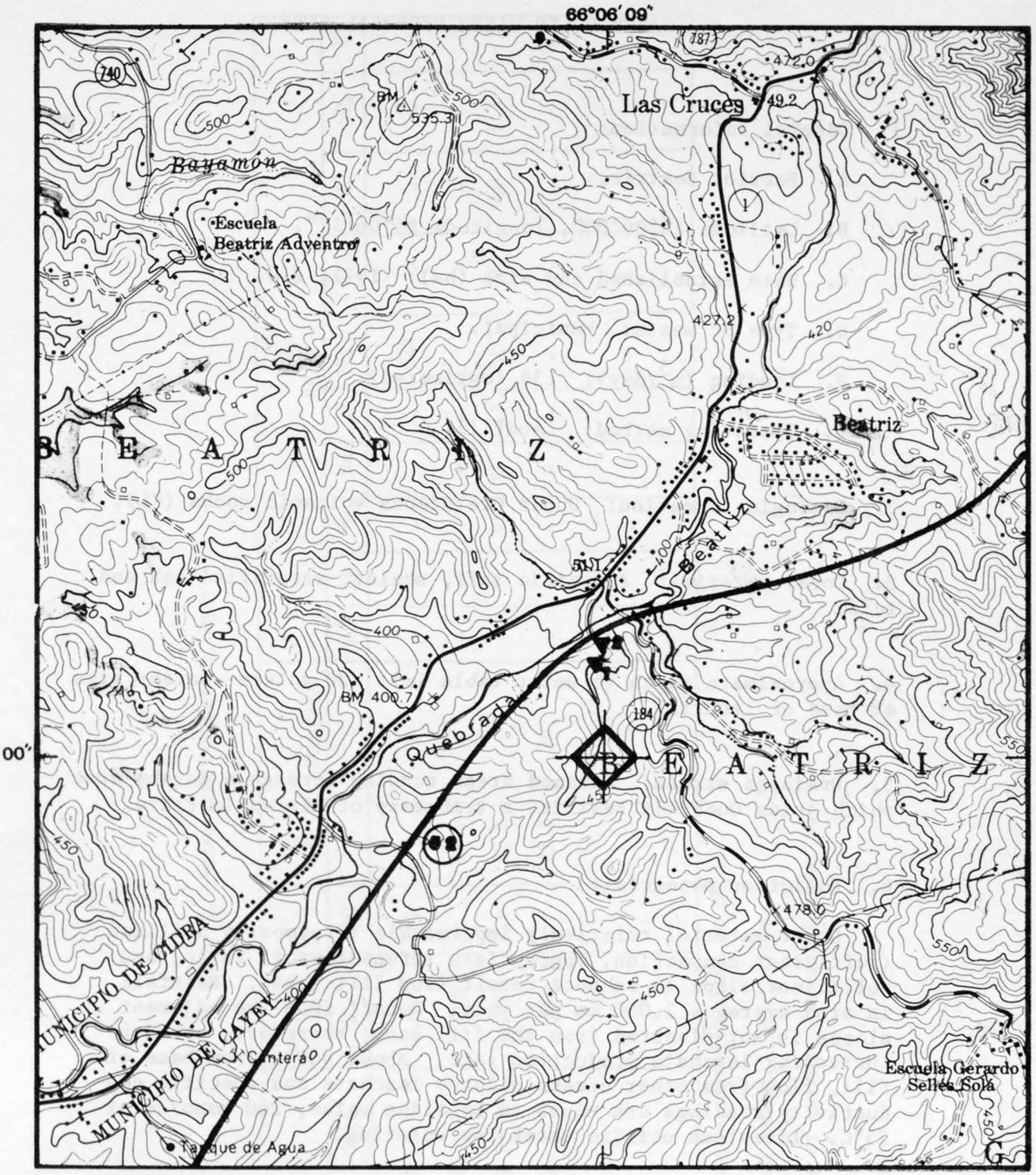


Figure 14.--Cayey solid-waste disposal site at Beatriz.

CAYEY SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Beatriz.

   B. Latitude 18°09'00", longitude 66°06'12".

   C. Date established and size (ha): 1971; 2.0.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 139 (estimated).

   F. Operating method: Landfill.

2. Geologic formation: Upper Cretaceous volcanic rocks (KL).

3. Cover material: Andesitic tuff, shales, stratified ash and tuff.

4. Approximate depth to water table (m): 20 meters--marshy area at base of landfill.

5. Drainage stream: Unnamed creek running through a marshy area which joins Quebrada Beatriz, a tributary of Río de la Plata.

6. Pollution potential:

Cover material relatively impermeable if properly utilized (sufficient compaction, appropriate refuse-to-soil ratio, and sufficient slope to enhance runoff from fill zone). Rainfall in area averages 2,000 mm per year. Runoff from the adjacent slopes is not diverted from the fill zone; therefore, could be increasing leachate production rate. About 400 m from base of fill, flow from other creeks dilutes leachate and specific conductivity readings are equal to baseline value, 240 umho/cm at 25°C. Livestock utilize creek for watering.

Table 8.--Water-quality data - Cayey

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	2- 8-79	1,668	7.1	-	-	-	-	-	-	-	428	-	-	-	-
	2- 7-78	800	-	24.0	-	-	-	-	-	-	-	-	-	-	-
	5-28-76	700	7.0	22.0	-	0	33	30	57	17	317	0	86	5.1	-
2	2- 7-78	240	-	22.3	20	-	-	-	-	-	-	-	-	-	-

Description: (sample point(s) shown on map)

1. At marsh below landfill, north side.

2. Upstream side of culvert, beneath Highway 52.

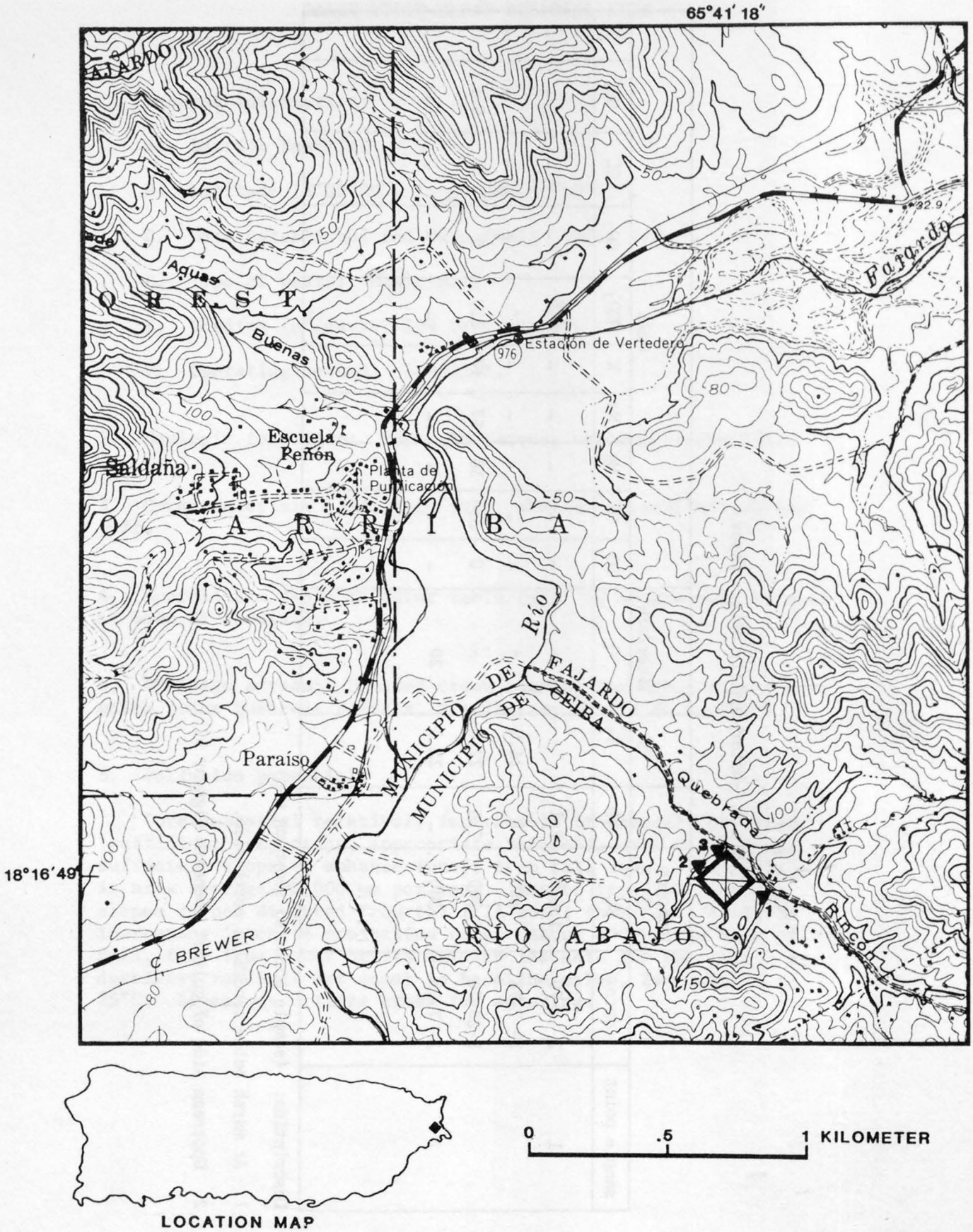


Figure 15.--Ceiba solid-waste disposal site at Río Abajo.

1. General information:

   A. Barrio: Río Abajo.

   B. Latitude 18°16'49", longitude 65°41'18".

   C. Date established and size (ha): 1977: 4.7.

   D. Type of waste: Municipal.

   E. Loading (m^3/day); 73 (reported by EQB).

   F. Operating method: Landfill (area and trench methods).

2. Geologic formation: Lava tuff (Kl).

3. Cover material: Red to brown clayish soil.

4. Approximate depth to water table (m): 10-15.

5. Drainage stream: Unnamed creek--marshy area on southeast side of landfill. Within Río Fajardo drainage boundary.

6. Pollution potential:

Cover material relatively impermeable if properly utilized (sufficient compaction, appropriate refuse-to-soil ratio; good ditch maintenance to continue diverting runoff from adjacent slope and sufficient slope to enhance runoff from filled zone). Rainfall in area averages about 2,000 mm per year.

Within a marshy area below fill, indications exist (odor, red stains) of intermittent leachate flow. At time of visit, water quality of adjacent streams appeared not to be affected by leachate.

Table 9.--Water-quality data - Ceiba

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	5-2-78	245	6.5	25.5	1	5.4	14	7.3	18	1.1	92	0	22	5.5	0.1
2	5-2-78	190		26.5	-	-	-	-	-	-	-	-	-	-	-
3	5-2-78.	190		27.0	-	-	-	-	-	-	-	-	-	-	-

Description: (sample point(s) shown on map)

1. At creek southeast side of fill.
2. Artificial channel north and upstream of fill.
3. Artificial channel downstream of fill.

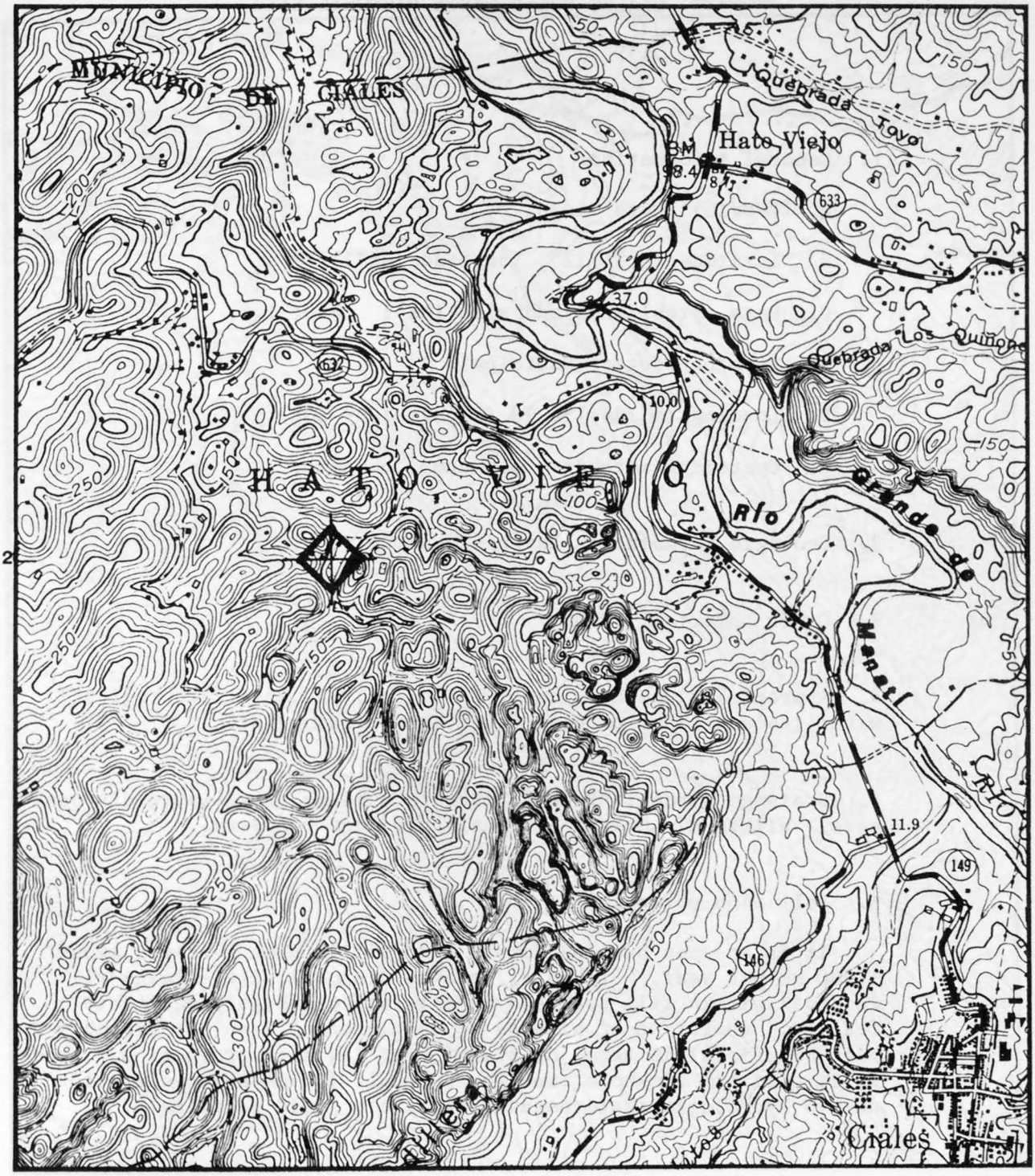


Figure 16.--Ciales solid-waste disposal site at Hato Viejo.

CIALES SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Hato Viejo.

   B. Latitude 18°21'12", longitude 66°29'17".

   C. Date established and size (ha): 1950; 1.6.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 73 (reported by EQB).

   F. Operating method: Open dump, burning.

2. Geologic formation: Lares Limestone (TL).

3. Cover material: None.

4. Approximate depth to water table (m): 50 meters to regional water table. Local perched conditions might exist.

5. Drainage stream: None. Sinkhole used as solid-waste disposal site. Within Río Grande de Manatí drainage boundary.

6. Pollution potential:

It is an open burning dump. Rainfall in area averages about 1,900 mm per year. Sinkhole, used as disposal site, drains all rainfall within fill zone and is a relatively highly permeable feature. Operation of site as an open burning dump has probably been beneficial in terms of diminishing leachate production. Landfilling within sinkhole zone would result in leachate generation due to hydrologic features and relatively humid subclimate.

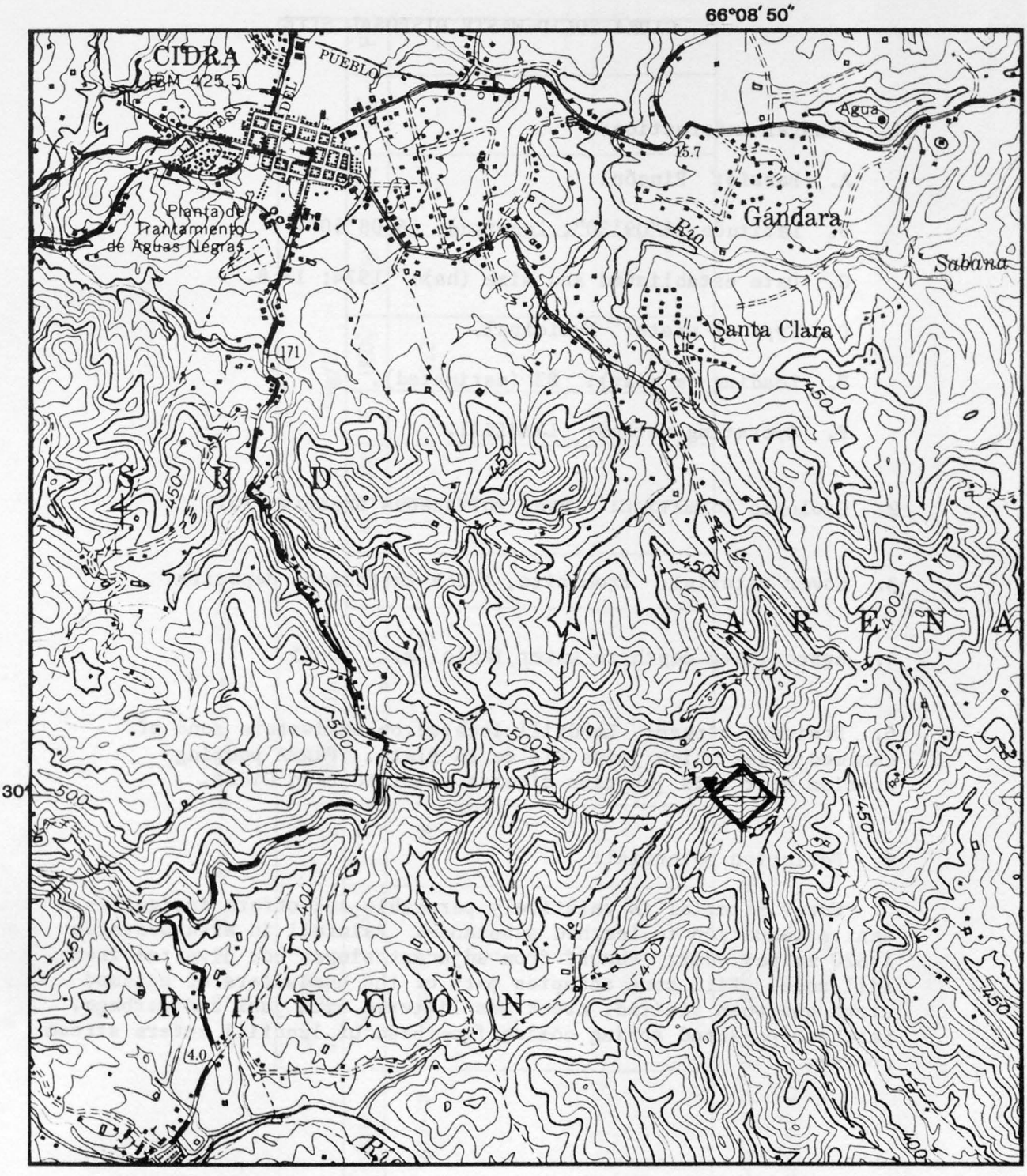


Figure 17.--Cidra solid-waste disposal site at Rincón.

CIDRA SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Rincón.

   B. Latitude 18°09'30", longitude 66°08'50".

   C. Date established and size (ha): 1974; 13.8.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 83 (estimated).

   F. Operating method: Landfill.

2. Geologic formation: Lava, tuffaceous breccia (KJ).

3. Cover material: From site, thick tuffaceous deposits.

4. Approximate depth to water table (m): 20-25.

5. Drainage stream: Landfill located on headwaters zone of unnamed creek which joins Río de La Plata. PRASA pumping station near this junction diverts water to Lago Cidra.

6. Pollution potential:

Cover material is relatively permeable and offers insignificant attenuation to leached substance. Rainfall in area averages 1,520 mm per year. Runoff from adjacent slopes not diverted from fill zone. Fill zone occupies part of the headwaters of unnamed creek and when visited, creek was littered with junk and garbage. Leachate-polluted spring coming from base of landfill enters stream course.

Table 10.--Water-quality data - Cidra

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	5-2-78	1,450	6.5	26	<1	0	-	-	-	-	522	0	-	-	-

Description: (sample point(s) shown on map)

1. Spring at base of fill.

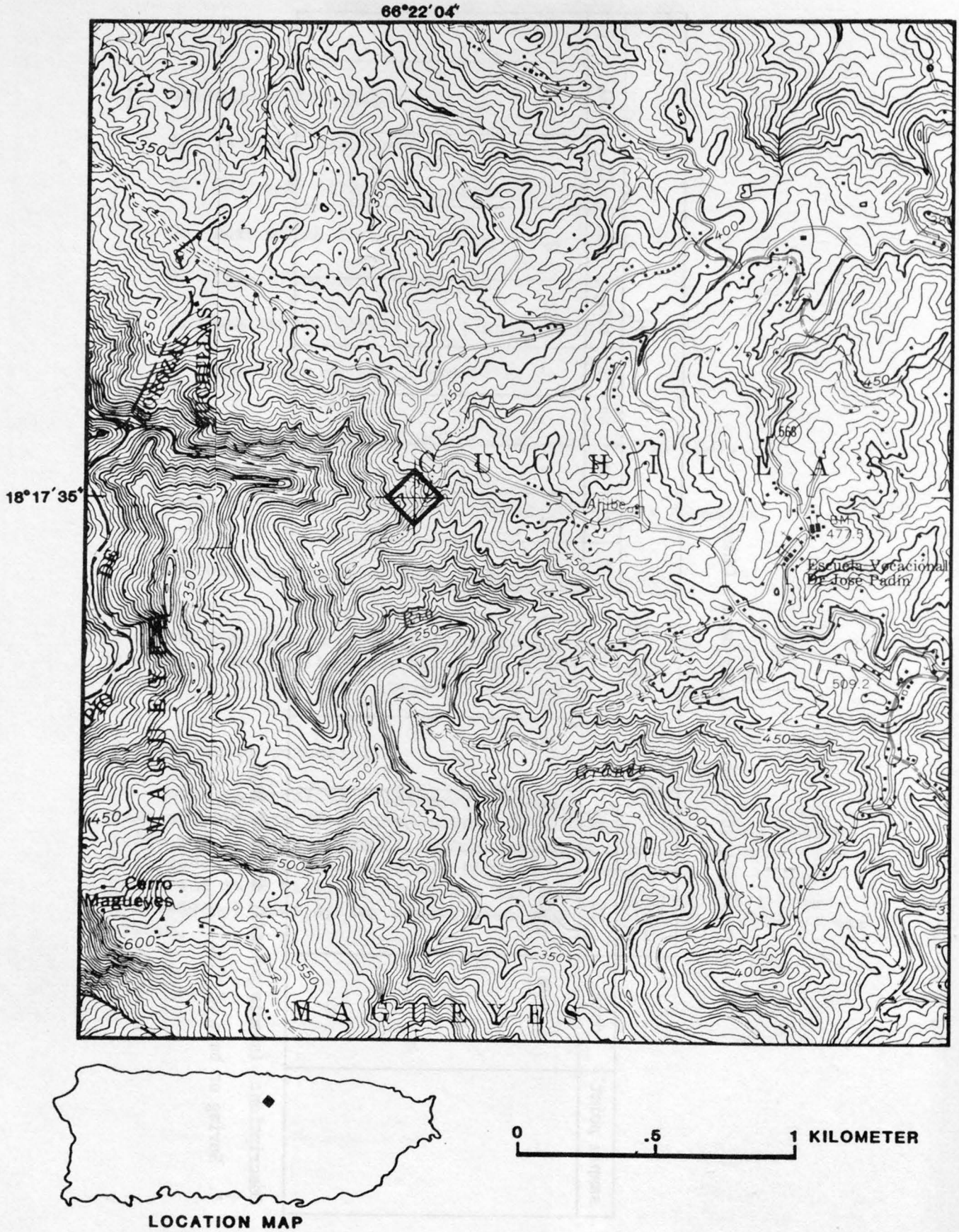


Figure 18.--Corozal solid-waste disposal site at Cuchillas.

COROZAL SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Cuchillas.

   B. Latitude 18°17'35", longitude 66°22'04".

   C. Date established and size (ha): 1957; 1.6.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): (Closed).

   F. Operating method: Open dump (closed).

2. Geologic formation: Avispa Formation (Ka).

3. Cover material: Tuffaceous sandstone and siltstone.

4. Approximate depth to water table (m): More than 100 to regional water table.

5. Drainage stream: On steep ravine above and east of Río Grande de Manatí.

6. Pollution potential:

The site's location on a steep ravine and within an area where annual mean precipitation is aobut 2,160 mm has contributed to dispersion of refuse. Vegetation has completely covered the site, leaving very little evidence that this was previously an open dump. Pollution potential from this closed dump is apparently negligible.

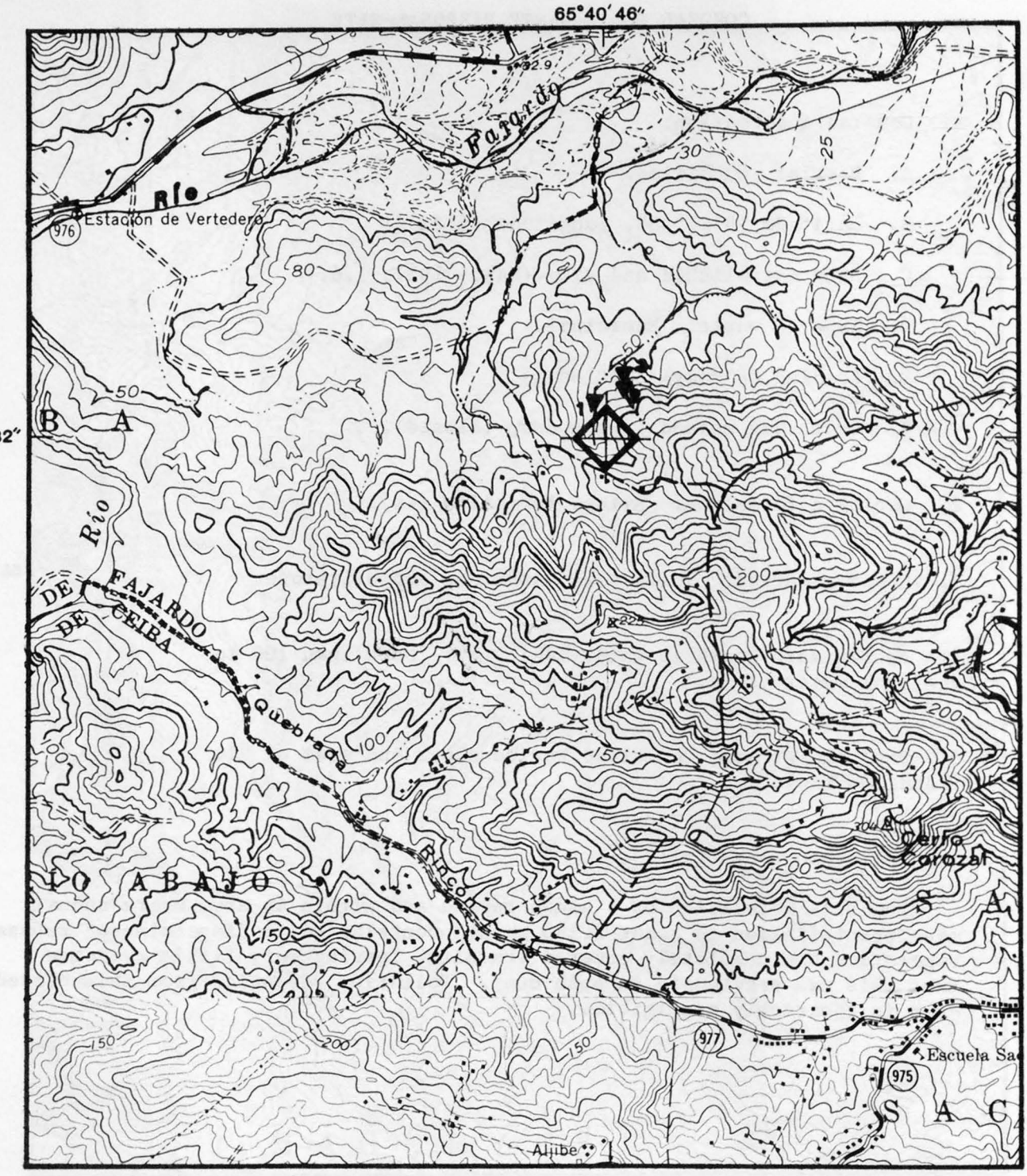


Figure 19.--Fajardo solid-waste disposal site at Demajagua.

FAJARDO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Demajagua.

   B. Latitude 18°17'32", longitude 65°40'46".

   C. Date established and size (ha): 1974; 7.9.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 95 (estimated).

   F. Operating method: Landfill.

2. Geologic formation: Lava tuff (Kl).

3. Cover material: Red to brown clayey soils.

4. Approximate depth to water table (m): 15-20.

5. Drainage stream: Unnamed creek flowing toward Río Fajardo.

6. Pollution potential:

Cover material relatively impermeable if properly utilized (sufficient compaction, appropriate refuse-to-soil ratio, sufficient slope to enhance runoff from filled zone and good drain maintenance to continue diverting runoff from adjacent slopes). When visited, unnamed creek was littered with junk and garbage. Rainfall in area averages about 2,000 mm per year.

Leachate contamination of creek is minimal. Inspection of site indicates an exceedingly high ratio of soil to refuse being used. At such rate, site cover material may not last for its projected use period (10 years). This may result in future use of insufficient cover material and deterioration of adjacent stream water quality. Water in stream used for livestock watering at adjacent farms.

Table 11.--Water-quality data - Fajardo

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	1-3-78	270	-	26.5	±100	-	-	-	-	-	-	-	-	-	-
2	1-3-78	185	-	23.0	±100	-	-	-	-	-	-	-	-	-	-
3	1-3-78	220	7.3	23.5	±200	8.0	14	7.8	23	2.1	88	0	27	8.2	0.1

Description: (sample point(s) shown on map)

1. At creek downstream of fill.

2. At creek downstream and east of fill.

3. Downstream of junction between the two creeks.

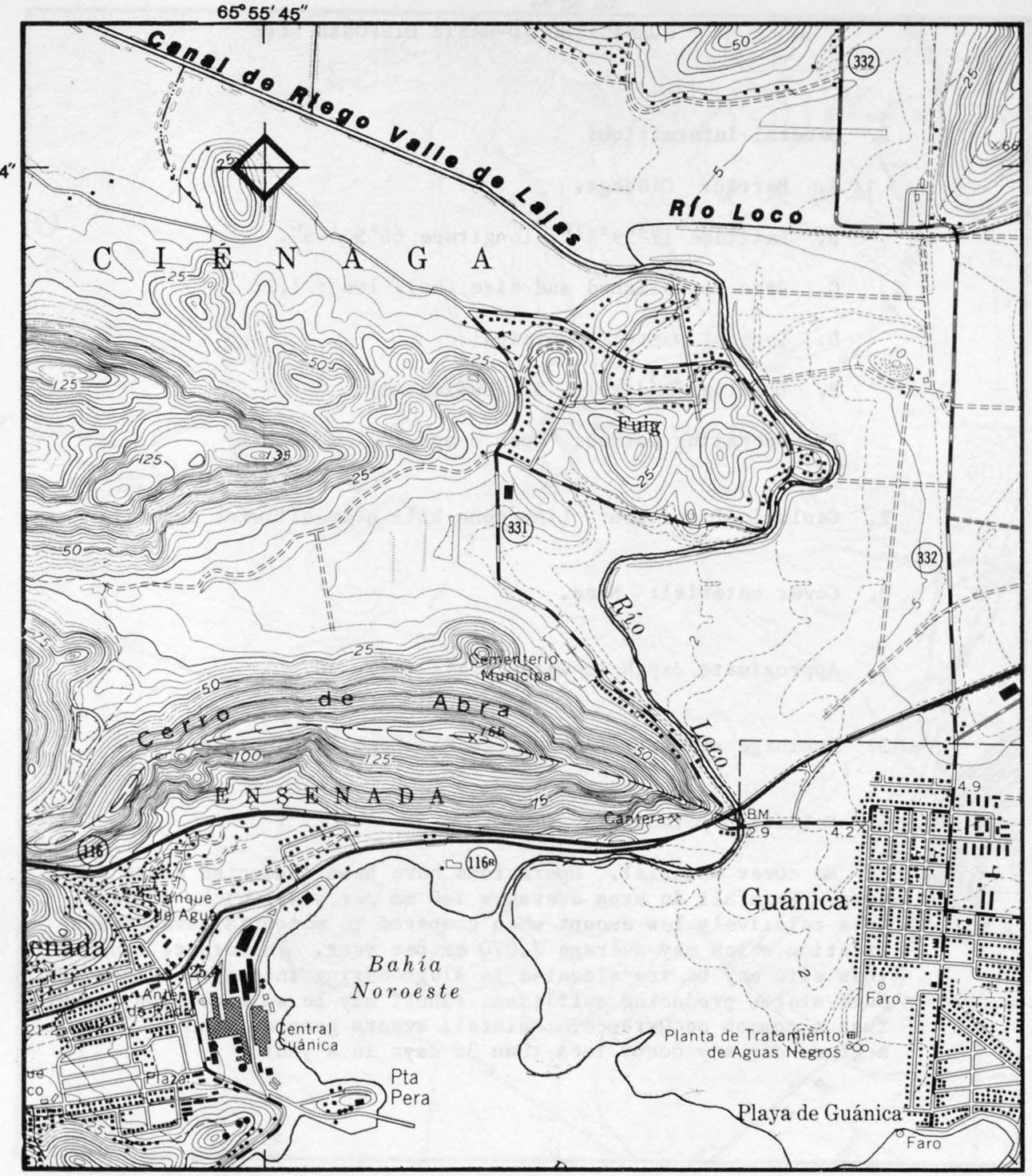


Figure 20.--Guánica solid-waste disposal site at Ciénega.

GUANICA SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Ciénaga.

   B. Latitude 17°59'44", longitude 66°55'45".

   C. Date established and size (ha): 1965; 1.2.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 51 (estimated).

   F. Operating method: Open dump.

2. Geologic formation: Limestone hill near alluvial deposit.

3. Cover material: None.

4. Approximate depth to water table (m): 10.

5. Drainage stream: Adjacent to Río Loco flood-plain.

6. Pollution potential:

No cover material. Operations have been conducted as an open dump. Rainfall in area averages 760 mm per year which, in fact, is a relatively low amount when compared to potential evapotranspiration which may average 2,070 mm per year. Pollutants from this site may be translocated in slugs during intensive rainstorms. Such storms producing sufficient runoff may be an exception rather than a common occurrence. Rainfall events greater than 12.7 mm on a given day may occur less than 36 days in a year.

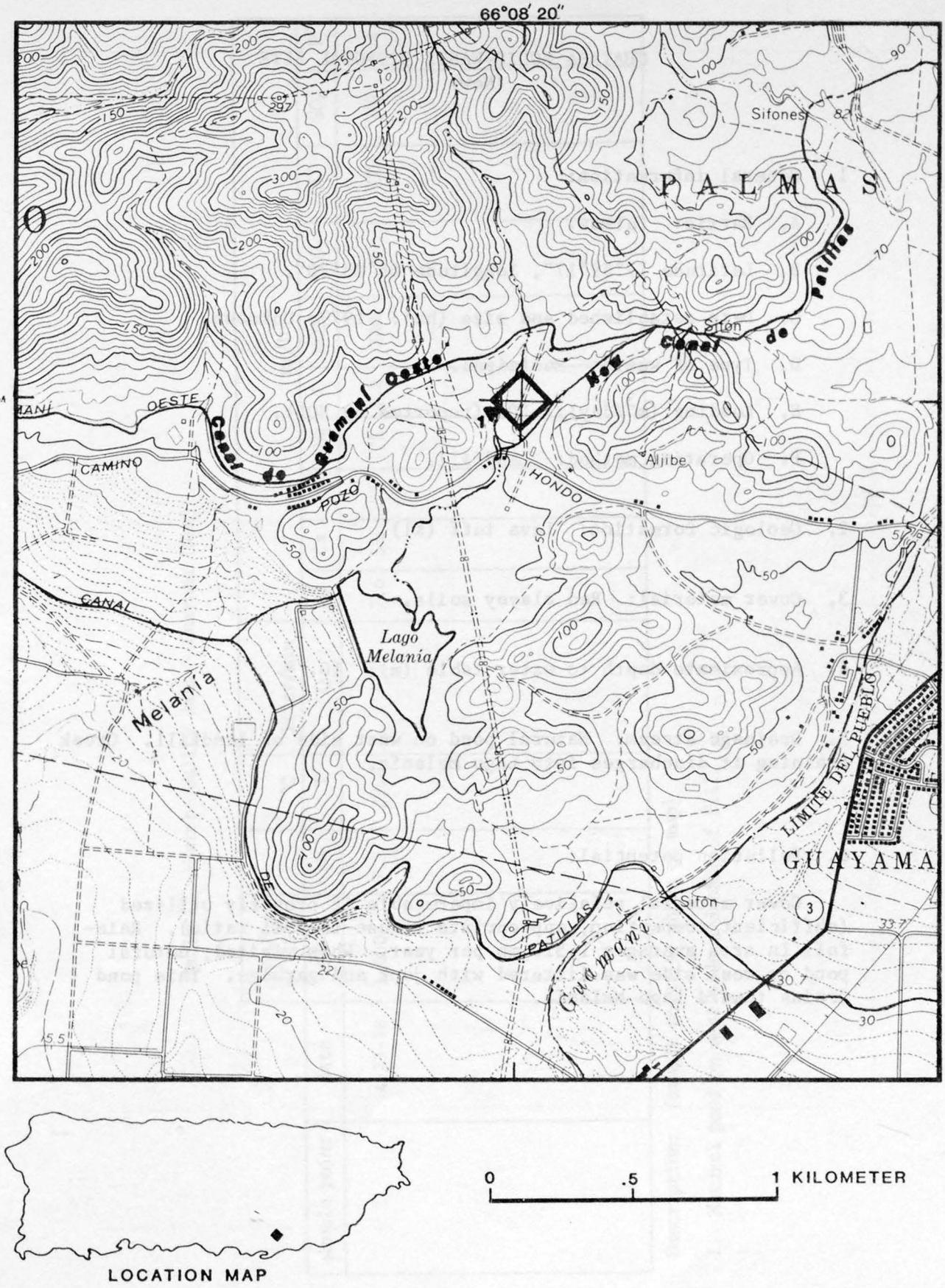


Figure 21.--Guayama solid-waste disposal site at Palmas, (new landfill).

GUAYAMA SOLID-WASTE DISPOSAL SITE
(New)

1. General information:

   A. Barrio: Palmas.

   B. Latitude 17°59'17", longitude 66°08'20".

   C. Date established and size (ha): 1977; Unknown.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 105 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Lava tuff (Kl).

3. Cover material: Red clayey soils.

4. Approximate depth to water table (m): 10.

5. Drainage stream: Natural pond on west side of landfill. Creek draining it discharges into Lago Melanía.

6. Pollution potential:

Cover material relatively impermeable if properly utilized (sufficient compaction, appropriate refuse-to-soil ratio). Rainfall in area averages 1,520 mm per year. When visited, natural pond on west side was littered with junk and garbage. This pond drains toward Lago Melanía.

Table 12.--Water-quality data - Guayama (New)

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	4-27-78	1,000	7.5	29.0	-	7.6	55	33	75	1.8	380	0	77	39	0.4

Description: (sample point(s) shown on map)

1. Natural pond on west side and base of fill.

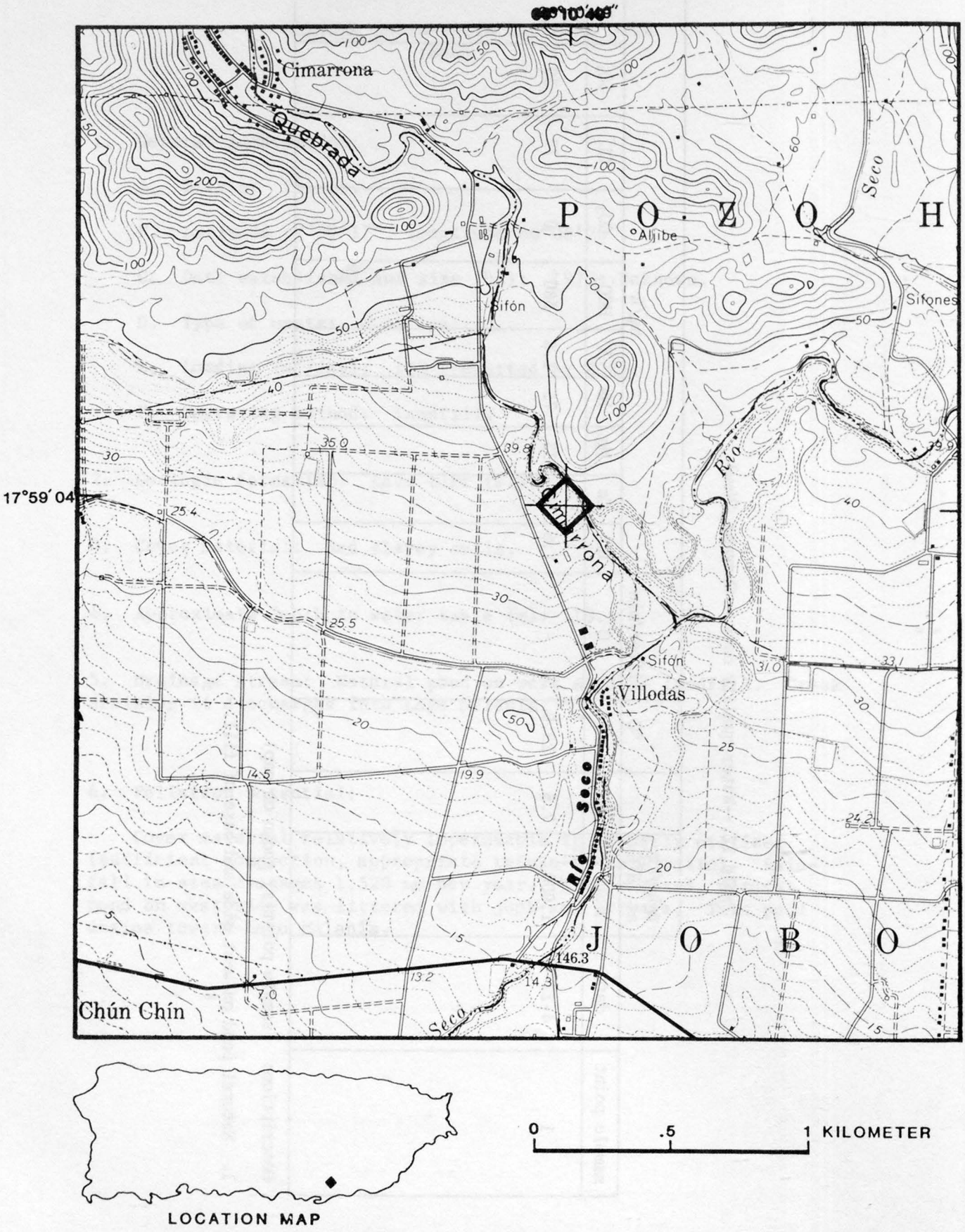


Figure 22.--Guayama solid-waste disposal site at Jobos, (old landfill).

GUAYAMA SOLID-WASTE DISPOSAL SITE
(Old)

1. General information:

   A. Barrio: Jobos.

   B. Latitude 17°59'04", longitude 66°10'49".

   C. Date established and size (ha): 1968; 2.0.

   D. Type of waste: Municipal and industrial.

   E. Loading (m^3/day): Closed.

   F. Operating method: Burning dump (closed).

2. Geologic formation: Alluvial deposits (Qa).

3. Cover material: None.

4. Approximate depth to water table (m): 10.

5. Drainage stream: Intermittent creek, Quebrada Cimarrona, runs adjacent to site.

6. Pollution potential:

No cover material, open dump. Closed in 1977. Rainfall in area averages 1,400 mm per year. When visited, intermittent Quebrada Cimarrona was littered with junk and garbage.

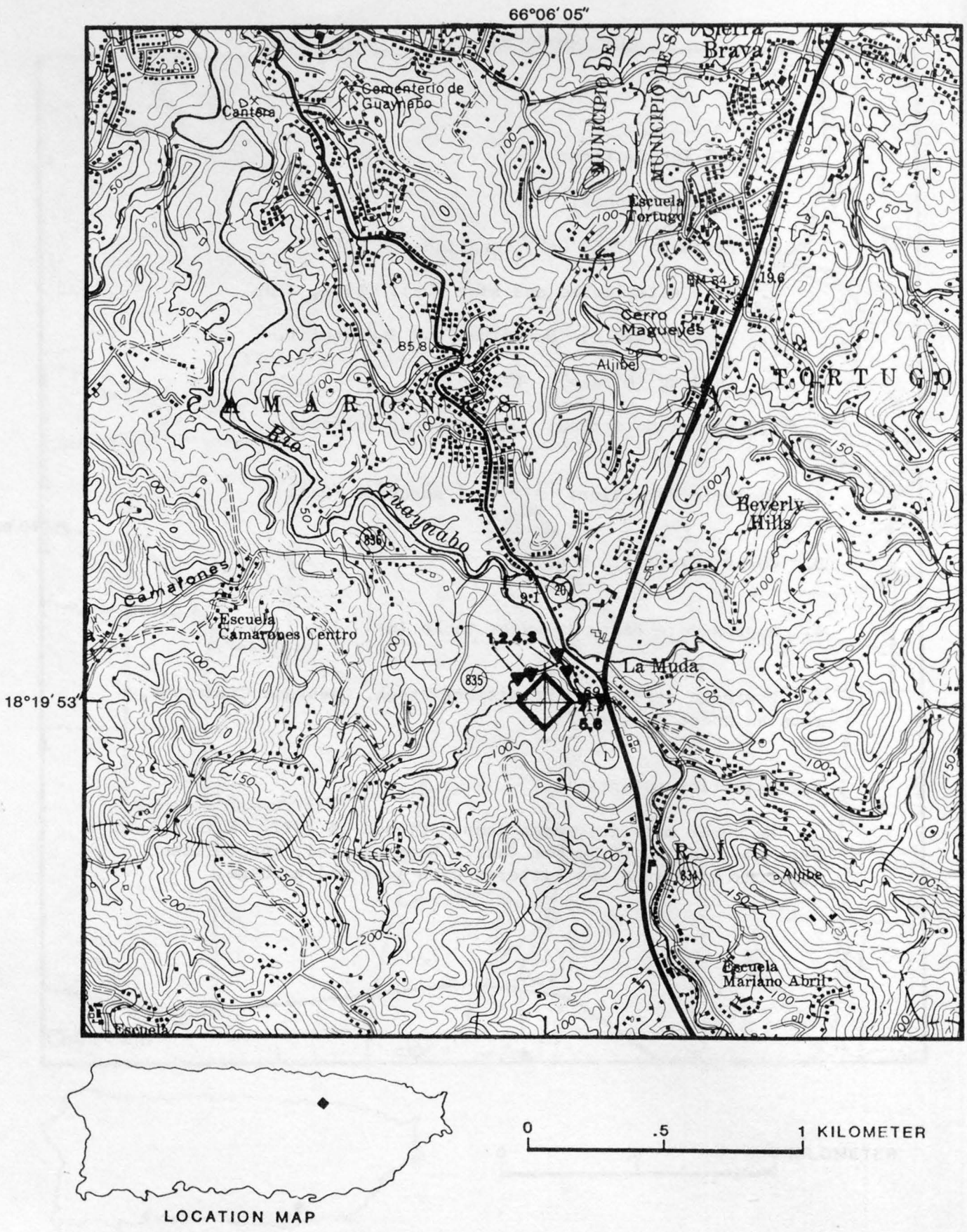


Figure 23.--Guaynabo solid-waste disposal site at Mamey.

GUAYNABO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Mamey.

   B. Latitude 18°19'05", longitude 66°06'05".

   C. Date established and size (ha): 1965; 22.

   D. Type of waste: Municipal and industrial.

   E. Loading (m^3/day): 285 (estimated).

   F. Operating method: Landfill and open dump.

2. Geologic formation: Camarones Sandstone (Kc) and quartz diorite (Tkd).

3. Cover material: Some loose pebble conglomerate and shale.

4. Approximate depth to water table (m): 10-15.

5. Drainage stream: Río Guaynabo drains two unnamed creeks adjacent to landfill and polluted with leachate.

6. Pollution potential:

Cover material relatively highly permeable and offers insignificant attenuation to leached substances. Rainfall in area averages 2,150 mm per year. Runoff from adjacent slopes and fill zone intercepted by local creeks, drained by Río Guaynabo, and highly polluted with leachate. When visited, all three of these (two creeks and the river) were littered with junk and garbage.

Table 13.--Water-quality data - Guaynabo

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	5-3-78	1,500		30.0	-	-	-	-	-	-	-	-	-	-	-
2	5-3-78	6,000		32.5	-	-	-	-	-	-	-	-	-	-	-
3	5-3-78	1,000		30.0	-	-	-	-	-	-	-	-	-	-	-
4	5-3-78	800		30.0	-	-	-	-	-	-	-	-	-	-	-
5	5-3-78	3,300		30.0	-	-	-	-	-	-	-	-	-	-	-
6	5-3-78	280		30.0	-	-	-	-	-	-	-	-	-	-	-

Description: (sample point(s) shown on map)

1. Unnamed creek on north side of fill.
2. Unnamed creek downstream from site 1.
3. At Río Guaynabo, downstream of fill.
4. At Río Guaynabo upstream from site 3.
5. Unnamed creek on south side of fill.
6. At Río Guaynabo upstream of fill.

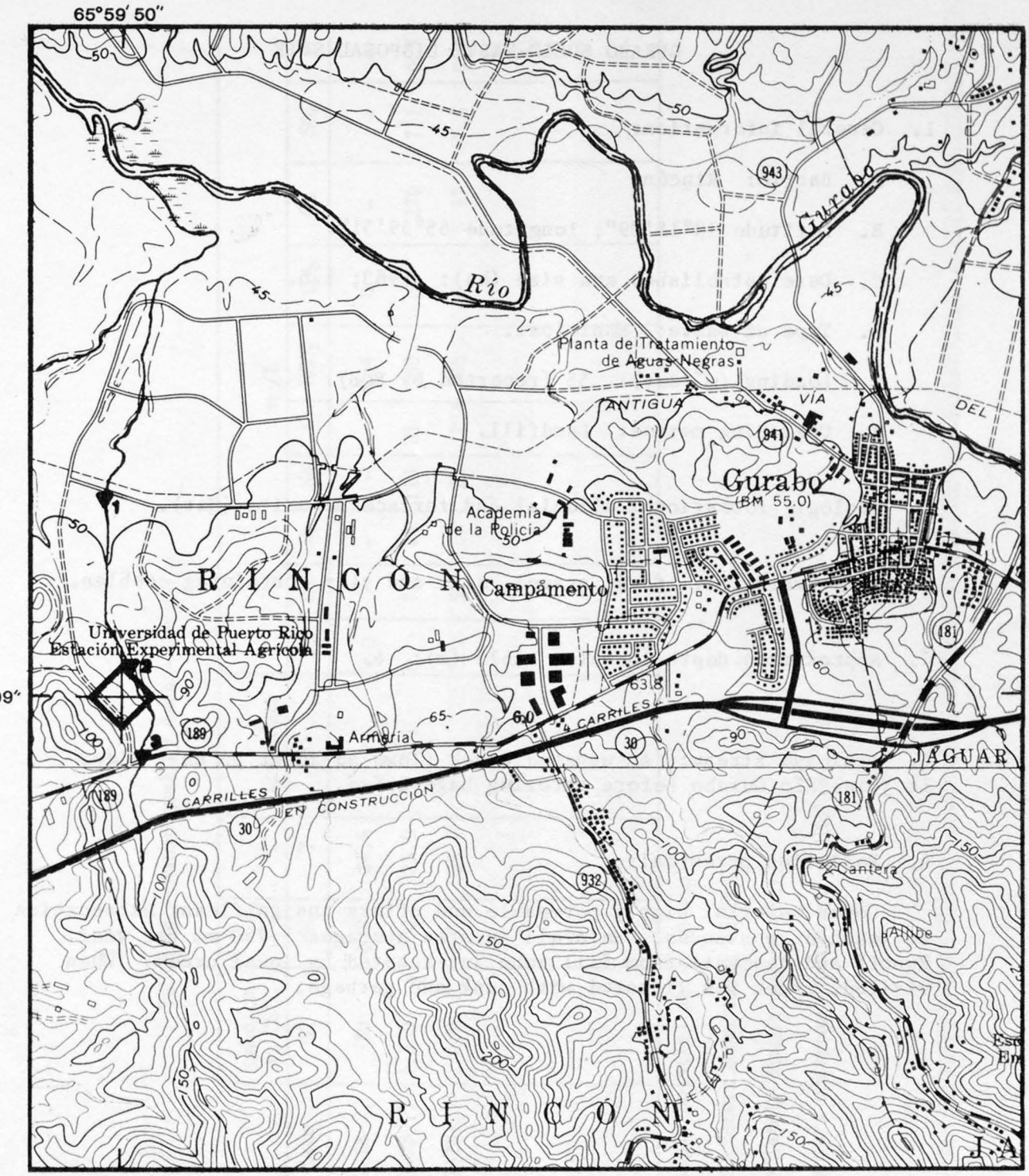


Figure 24.--Gurabo solid-waste disposal site at Rincón.

GURABO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Rincón.

   B. Latitude 18°15'09", longitude 65°59'51".

   C. Date established and size (ha): 1963; 1.6.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 55 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Alluvial and terrace deposits (Qat).

3. Cover material: Sand, gravel, silt and clay containing cobbles.

4. Approximate depth to water table (m): 6.

5. Drainage stream: An unnamed creek flows adjacent on east side. It joins Río Gurabo before entering Lago Loíza.

6. Pollution potential:

Cover material highly permeable and offers insignificant attenuation to leached substances. Rainfall in area averages 1,730 mm per year. Runoff and leachate from fill zone intercepted by local creek. When visited, creek was littered with junk and garbage.

Table 14.--Water-quality data - Gurabo

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	12-28-77	780	6.9	24.5	-	1.6	-	-	-	-	264	0	-	-	-
2	12-28-77	1,350	7.0	25.0	5.6	0	79	43	110	21	380	0	270	7.1	0.3
3	12-28-77	600	6.7	25.0	-	1.2	56	28	25	1.4	406	0	17	7.3	0.2

Description: (sample point(s) shown on map)

1. At culvert 300 meters downstream of fill.
2. At creek immediately downstream of fill.
3. At creek 15 meters upstream of culvert on Highway 189.

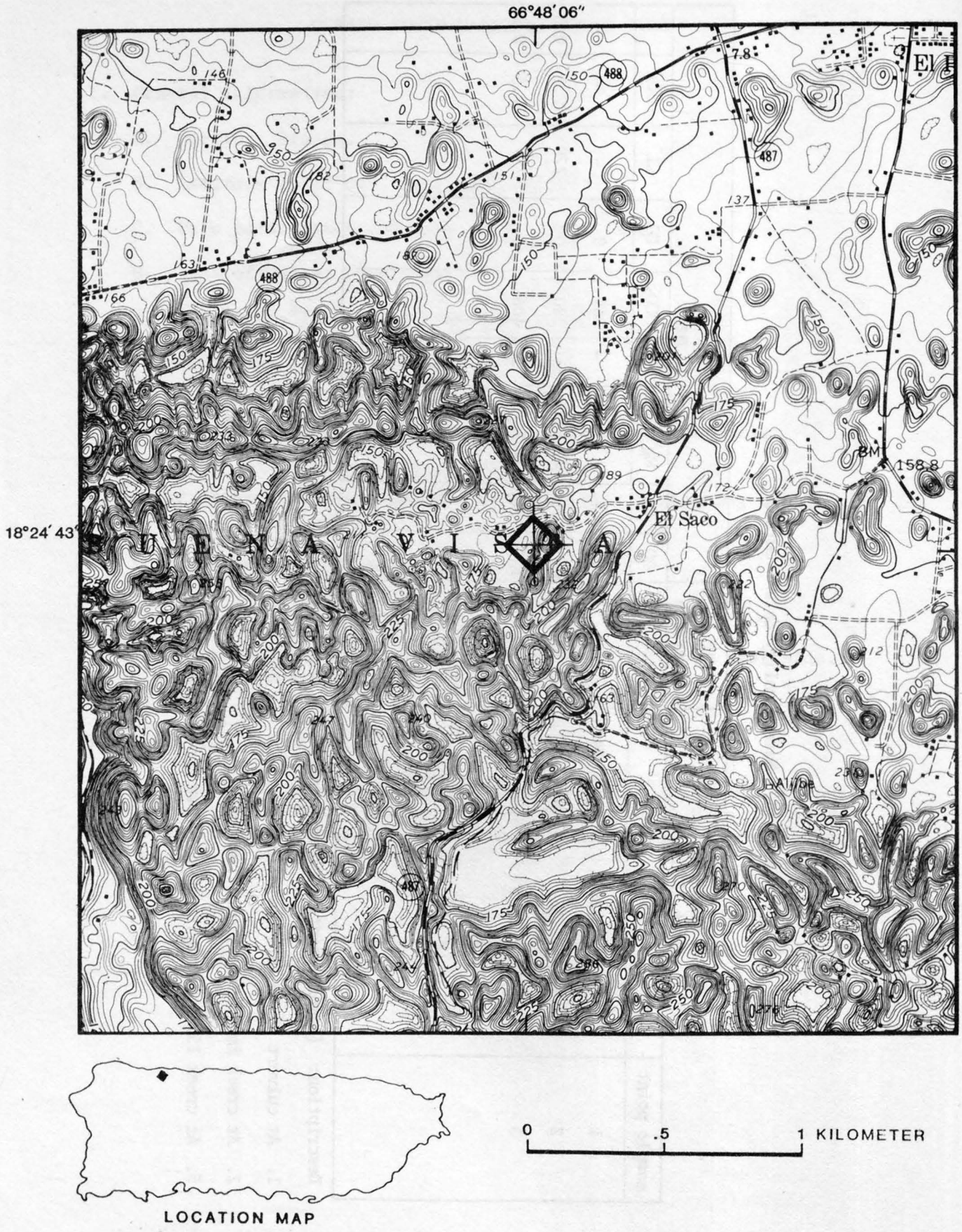


Figure 25.--Hatillo solid-waste disposal site at Buena Vista.

HATILLO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Buena Vista.

   B. Latitude 18°24'43", longitude 66°48'06".

   C. Date established and size (ha): 1957; 2.0.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 49 (reported by EQB).

   F. Operating method: Open dump and landfill.

2. Geologic formation: Aguada Limestone (Ta).

3. Cover material: Limestone fragments mixed with reddish clay and material brought from outside.

4. Approximate depth to water table (m): 60-70 to regional water table. Local perched conditions might exist.

5. Drainage stream: No surface stream nearby. Sinkhole used for waste disposal. Within Río Camuy drainage area boundary.

6. Pollution potential:

   For all purposes it is an open dump. Rainfall in area averages 1,520 mm per year. Limestone in area is relatively highly permeable.

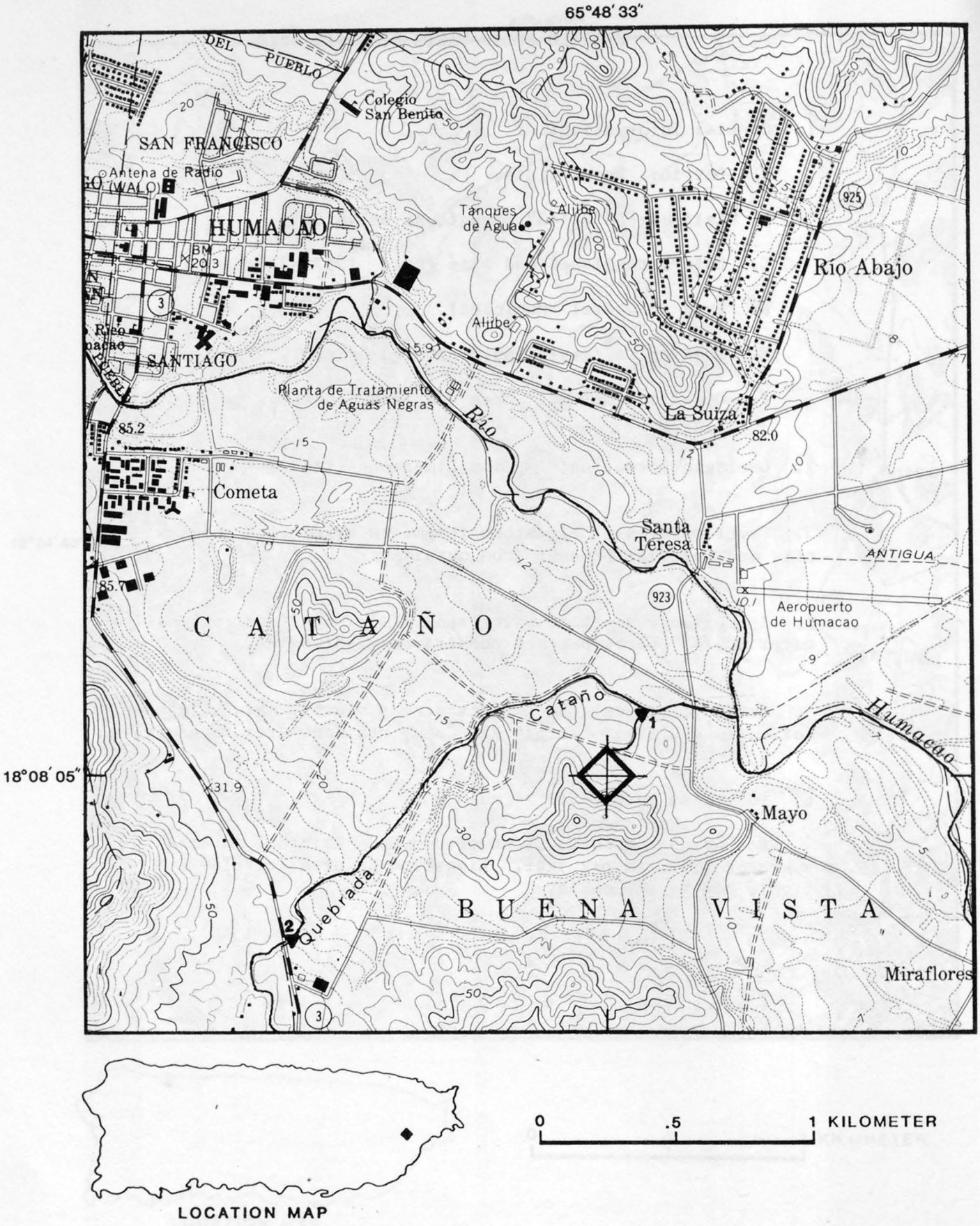


Figure 26.--Humacao solid-waste disposal site at Buena Vista.

HUMACAO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Buena Vista.

   B. Latitude 18°08'05", longitude 65°48'33".

   C. Date established and size (ha): 1973; 7.9.

   D. Type of waste: Municipal and industrial.

   E. Loading (m^3/day): 150 (estimated).

   F. Operating method: Landfill.

2. Geologic formation: Tuffaceous sandstone, siltstone and breccia (KL).

3. Cover material: Loose coarse material extracted from surrounding hills.

4. Approximate depth to water table (m): Water table mound has reached ground surface at toe of landfill creating a marsh.

5. Drainage stream: Quebrada Cataño which joins Río Humacao flows adjacent to landfill. Both Quebrada Cataño and Río Humacao were recently channelized not conforming to topographic map section shown.

6. Pollution potential:

   Cover material is relatively highly permeable and offers insignificant attenuation to leached substances. Rainfall in area averages 2,150 mm per year. Runoff from adjacent slopes affects fill zone. A poorly drained marshy area has developed at base of landfill. Leachate moves out of marsh into Quebrada Cataño.

Table 15.--Water-quality data - Humacao

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	12-29-77	2,080	6.8	29.0	±30	0	270	100	280	46	1,392	0	480	6	0.2
2	12-29-77	410	—	29.0	±100	—	—	—	—	—	—	—	—	—	—

Description: (sample point(s) shown on map)

1. Leachate flow entering Quebrada Cataño.
2. At Quebrada Cataño, upstream of fill, in culvert at Highway 3.

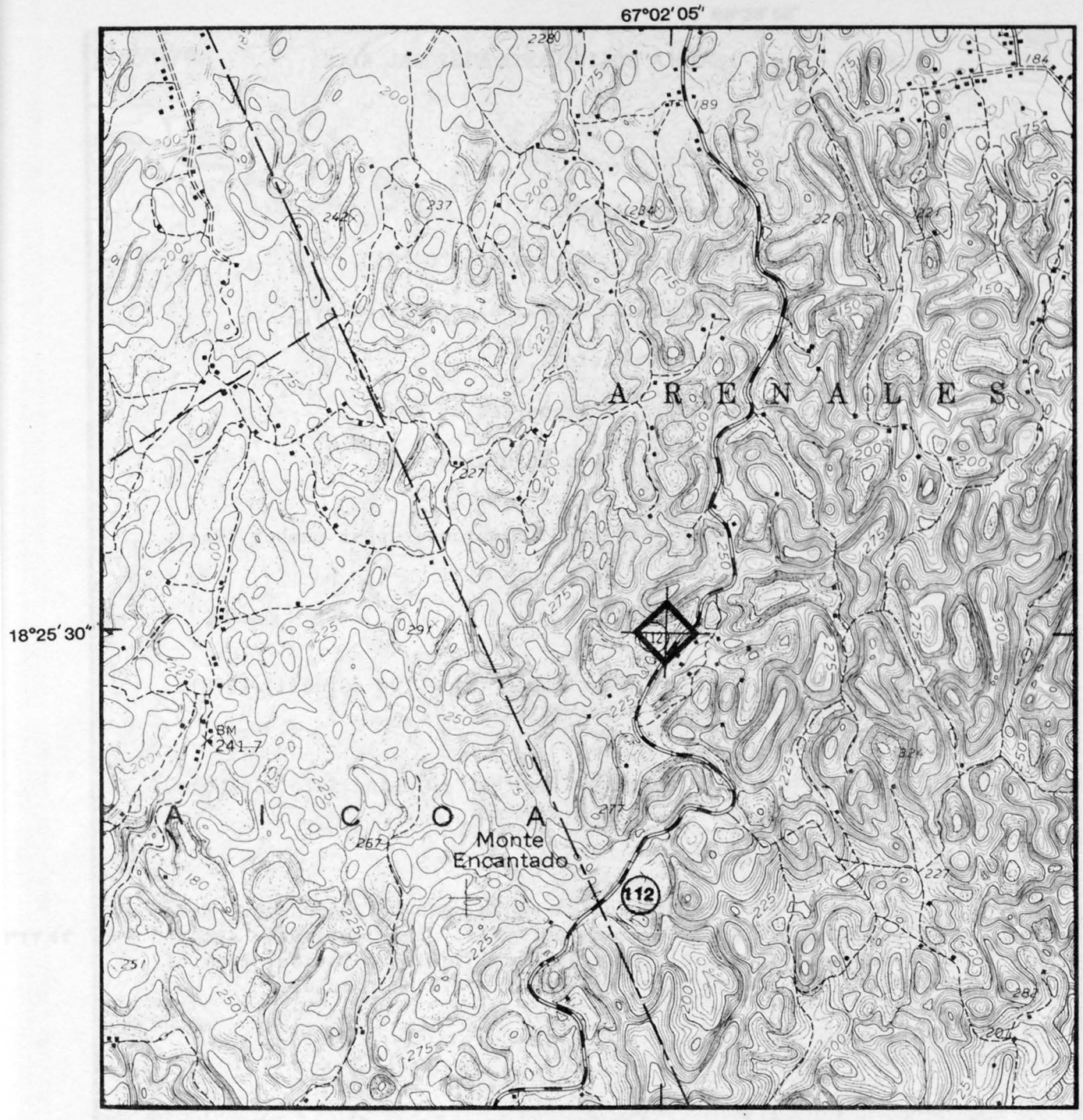


Figure 27.--Isabela solid-waste disposal site at Arenales Altos.

ISABELA SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Arenales Altos.

   B. Latitude 18°25'30", longitude 67°02'05".

   C. Date established and size (ha): 1969; 0.8.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 89 (reported by EQB).

   F. Operating method: Open burning dump.

2. Geologic formation: Aymamón Limestone, upper member (Tay).

3. Cover material: None.

4. Approximate depth to water table (m): 100 (Giusti, 1978). Local perched conditions might exist.

5. Drainage stream: No stream nearby. Dumping into sinkhole.

6. Pollution potential:

Operation has been conducted as an open burning dump. Rainfall in area averages 2,080 mm per year. Base material, Aymamón Limestone, is relatively permeable due to its solution, type of porosity, and ground-water pollution could be possible.

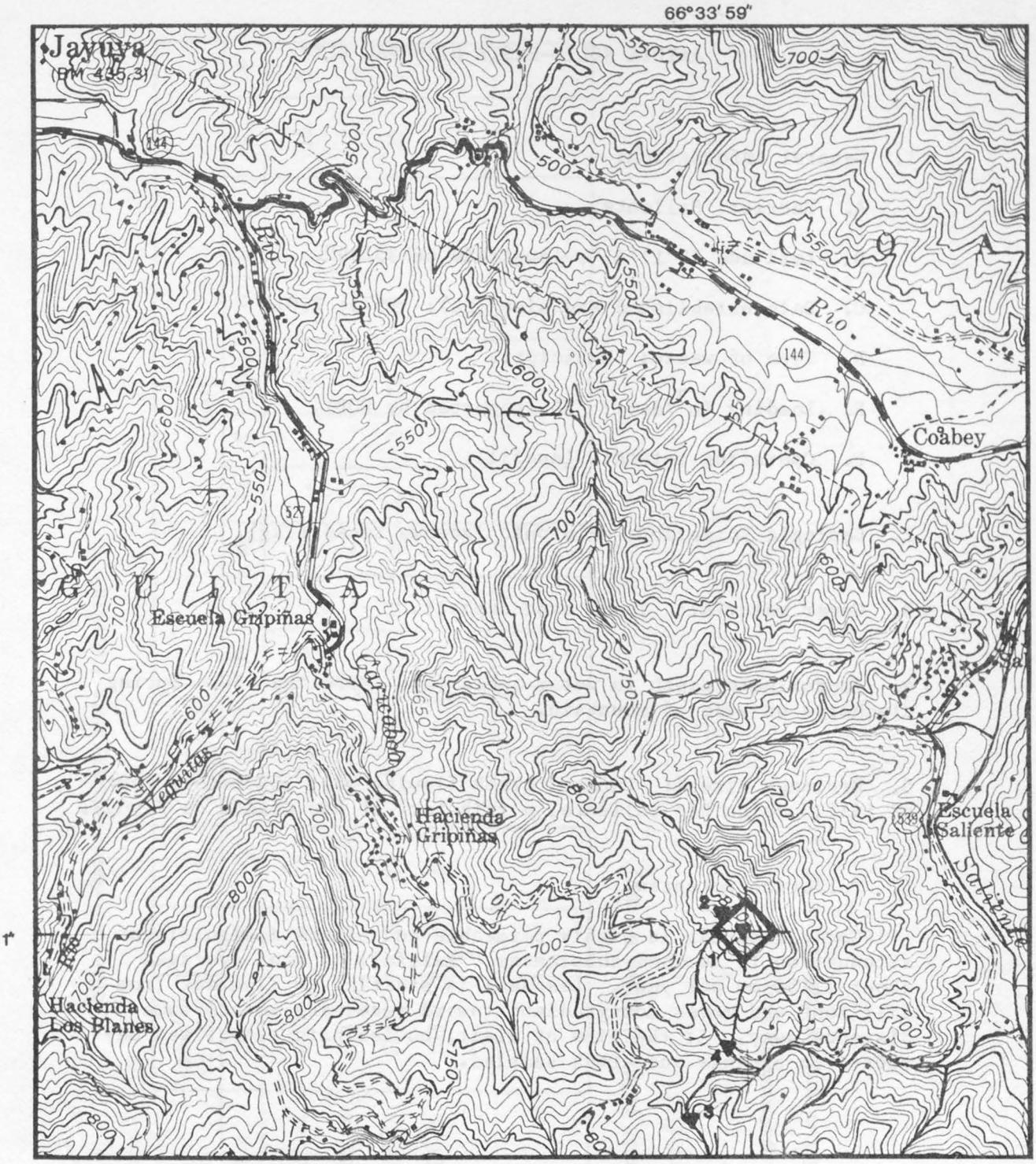


Figure 28.--Jayuya solid-waste disposal site at Saliente.

JAYUYA SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Saliente.

   B. Latitude 18°11'41", longitude 66°33'59".

   C. Date established and size (ha): 1975; 2.0.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 55 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Plutonic igneous rocks (Tkg).

3. Cover material: Thick sand deposit.

4. Approximate depth to water table (m): More than 50. Spring discharge on side of mountain.

5. Drainage stream: Unnamed creek flowing west 300 meters south of fill. Joins Río Saliente, a tributary of Rio Grande de Jayuya.

6. Pollution potential:

Cover material is highly permeable and offers insignificant attenuation to leached substances. Rainfall in area averages about 2,150 mm per year. Leachate is starting to flow out from fill zone and moves downgradient toward receiving waters some distance away. At the time of visit, no leachate effect was detected on springs and creek sampled.

Table 16.--Water-quality data - Jayuya

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	4-28-78	185	6.6	23.5	0.5	7.4	-	-	-	-	48	0	12	16	0
2	4-28-78	750	-	29.0	0.5	-	-	-	-	-	-	-	-	-	-
3	4-28-78	178	6.6	20.5	3	7.7	17	5	12	2	76	0	9.2	22	0.1
4	4-28-78	183	-	20.5	-	-	-	-	-	-	-	-	-	-	-

Description: (sample point(s) shown on map)

1. At spring above fill.
2. Leachate flow.
3. Unnamed creek upstream of fill.
4. At junction of two springs downstream of fill.

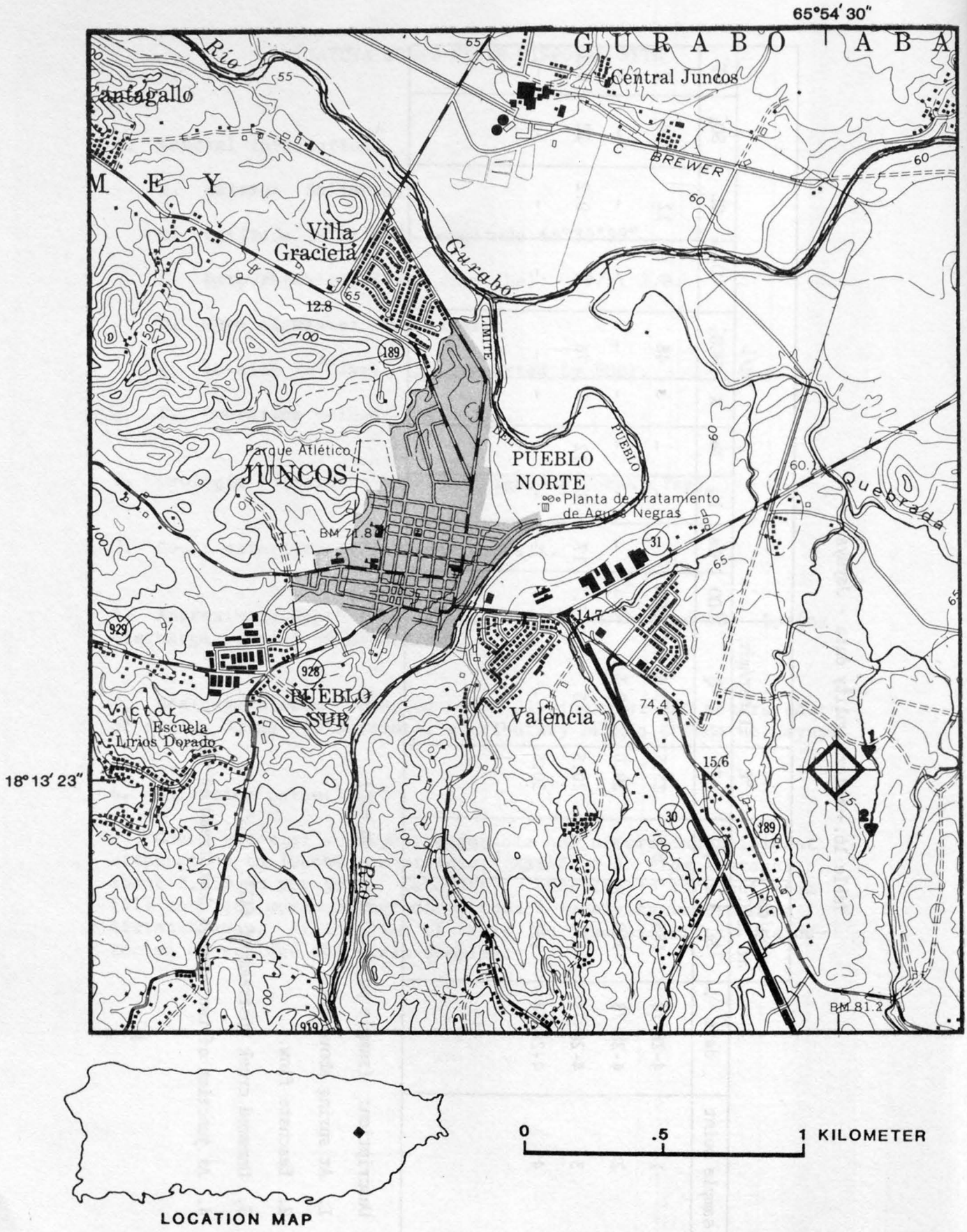


Figure 29.--Juncos solid-waste disposal site at Ceiba Norte.

JUNCOS SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Ceiba Norte.

   B. Latitude 18°13'23", longitude 65°54'30".

   C. Date established and size (ha): 1977; 0.8.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 151 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Plutonic rocks (Tkgd).

3. Cover material: Sand which is obtained at site.

4. Approximate depth to water table (m): 6.

5. Drainage stream: Artificial channel east of landfill. An unnamed creek, tributary to Quebrada Ceiba, drains this trench or channel. Further downstream Quebrada Ceiba joins Río Gurabo.

6. Pollution potential:

Cover material used is highly permeable and also offers negligible attenuation to leached substances. Rainfall in area averages about 1,790 mm per year. Leachate from fill zone enters a highly wet area and drains toward artificial channel. Livestock utilize channel for watering.

Table 17.--Water-quality data - Juncos

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	12-29-77	750	7.0	30.5	1	5.8	27	14	80	10	226	0	100	13	0.2
2	12-29-77	455	7.3	29.5	1	5.2	10	6.3	55	1.9	122	0	43	16	0.2

Description: (sample point(s) shown on map)

1. At trench on eastern side, downstream of fill.

2. At trench upstream of fill. Livestock wastes near here.

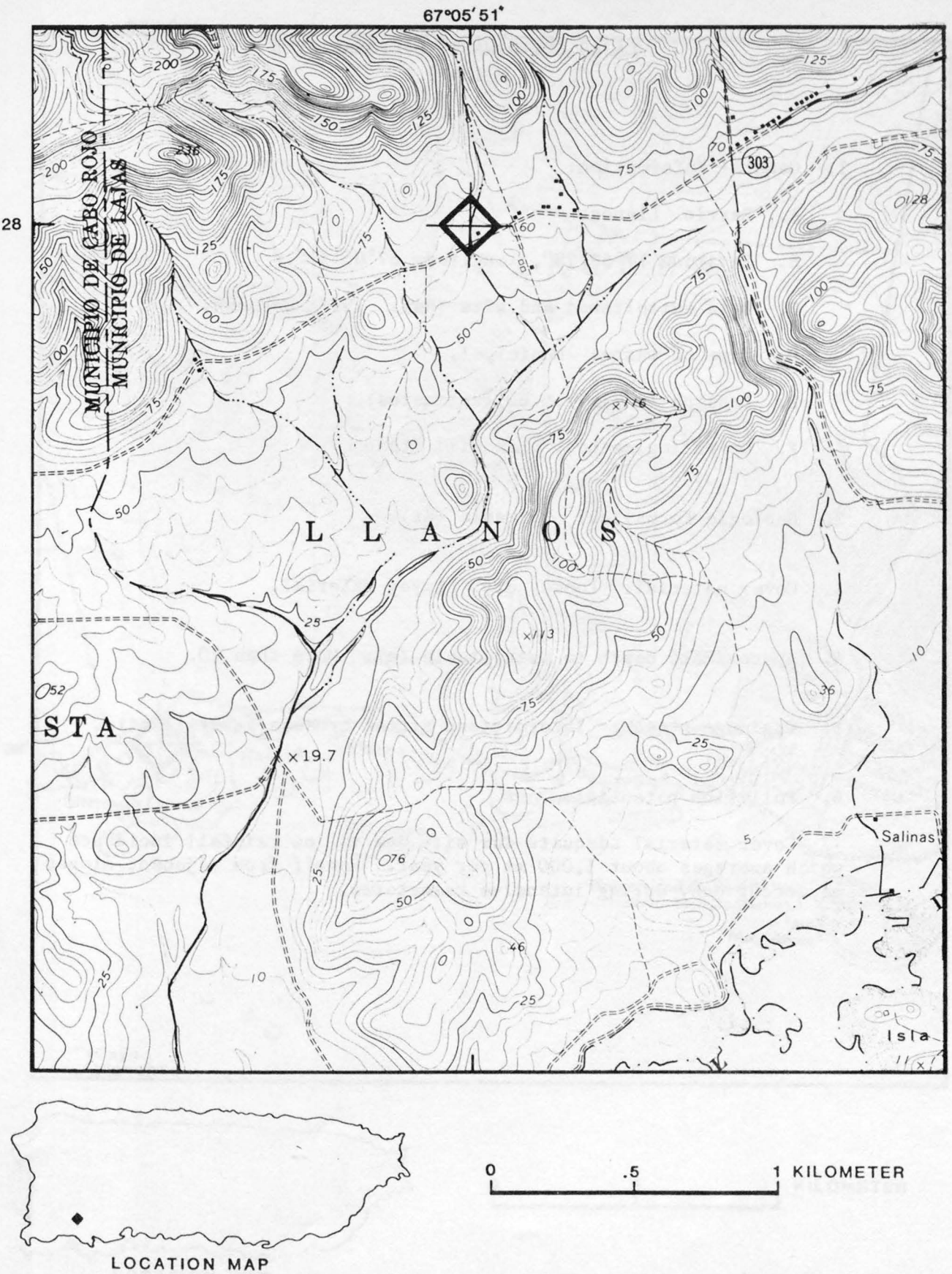


Figure 30.--Lajas solid-waste disposal site at Llanos, (new landfill).

LAJAS SOLID-WASTE DISPOSAL SITE
(New)

1. General information:

   A. Barrio Llanos.

   B. Latitude 17°59'28", longitude 67°05'51".

   C. Date established and size (ha): 1977; unknown.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 60 (estimated).

   F. Operating method: Landfill (trench).

2. Geologic formation: Volcanic (Kt).

3. Cover material: Loose, dry, clayey material.

4. Approximate depth to water table (m): More than 20.

5. Drainage stream: Intermittent stream crosses landfill site.

6. Pollution potential:

Cover material adequate for site due to low rainfall incidence which averages about 1,000 mm per year. Runoff from adjacent slopes may occur only during intensive rainstorms.

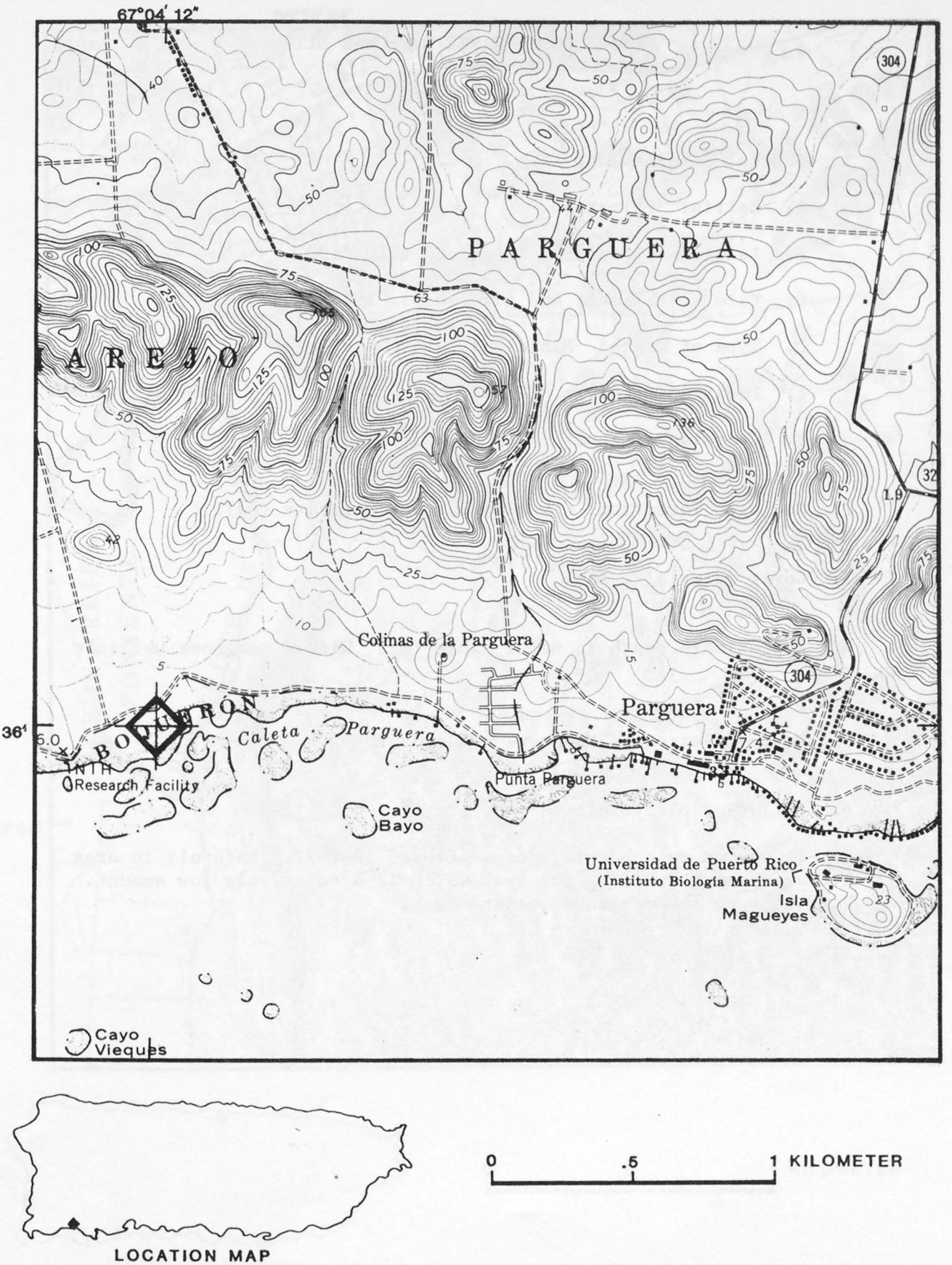


Figure 31.--Lajas solid-waste disposal site at Palmarejo, (old landfill).

LAJAS SOLID-WASTE DISPOSAL SITE
(Old)

1. General information:

   A. Barrio: Palmarejo.

   B. Latitude 17°58'36", longitude 67°04'12".

   C. Date established and size (ha): 1957; 0.4.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): (Closed).

   F. Operating method: Open dump (closed).

2. Geologic formation: Swamp and marsh deposits (Qs).

3. Cover material: None.

4. Approximate depth to water table (m): Within mangrove wetlands zone.

5. Drainage stream: Mangrove wetlands zone.

6. Pollution potential:

It was an open burning dump. Closed in 1977. Rainfall in area averages about 1,000 mm per year which is a relatively low amount. Very near to the mangrove wetland zone.

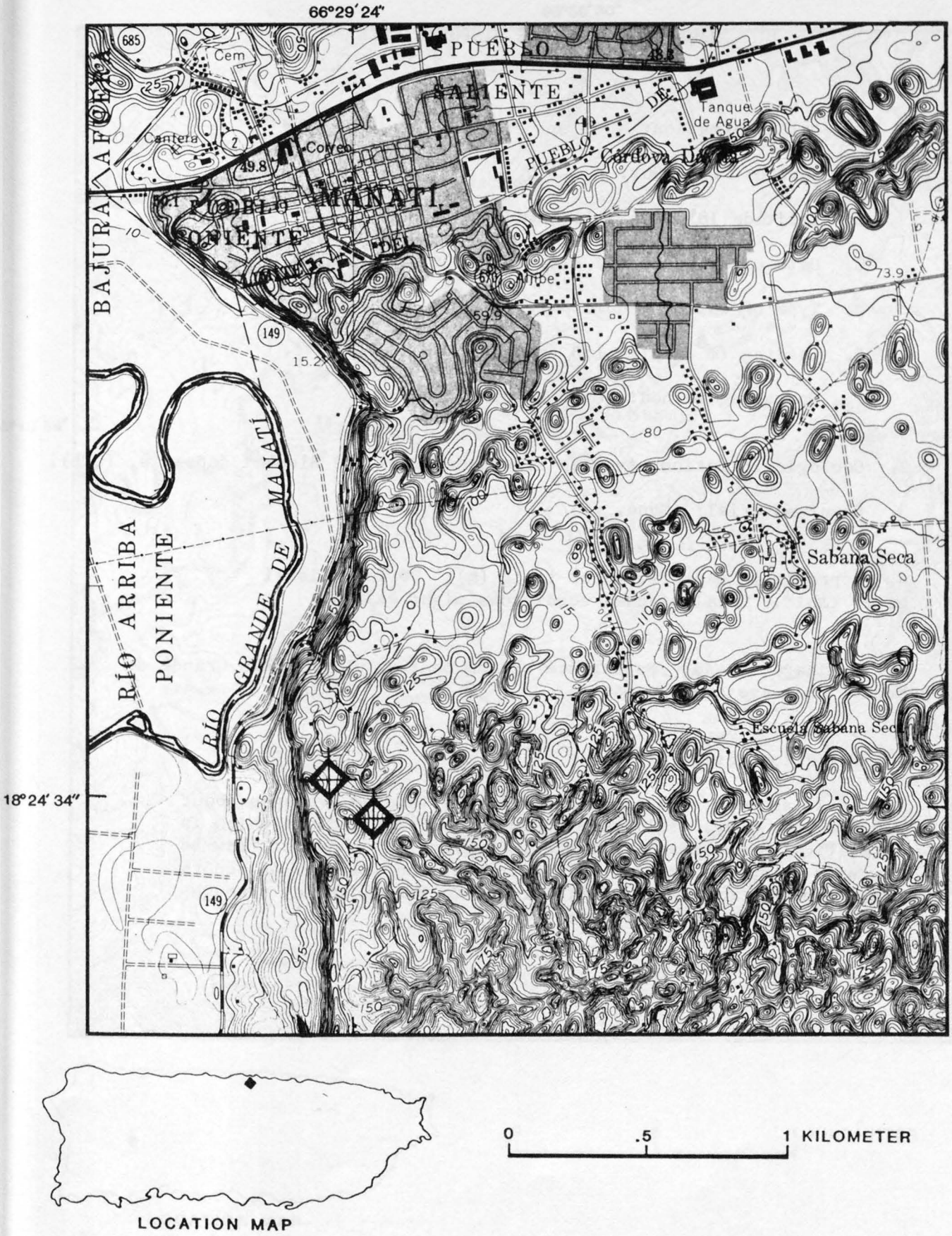


Figure 32.--Manatí solid-waste disposal site at Coto Sur.

MANATI SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Coto Sur.

   B. Latitude 18°24'34", longitude 66°29'24".

   C. Date established and size (ha): unknown; 2.4.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 153 (reported by EQB).

   F. Operating method: Open burning dump.

2. Geologic formation: Aymamón limestone (Tay) and Blanket deposits, (QTb).

3. Cover material: None.

4. Approximate depth to water table (m): 90 to regional water table. Local perched conditions might exist.

5. Drainage stream: No surface stream nearby. Within Río Grande de Manatí drainage area boundary.

6. Pollution potential:

It is an open burning dump. Rainfall in area averages about 2,030 mm per year. Fill zone on top of blanket deposit which is a relatively impermeable material. Regional groundwater flow below site is toward the north to northeast, but seepage of runoff could probably occur toward Río Grande de Manatí valley through solution cavities in limestone.

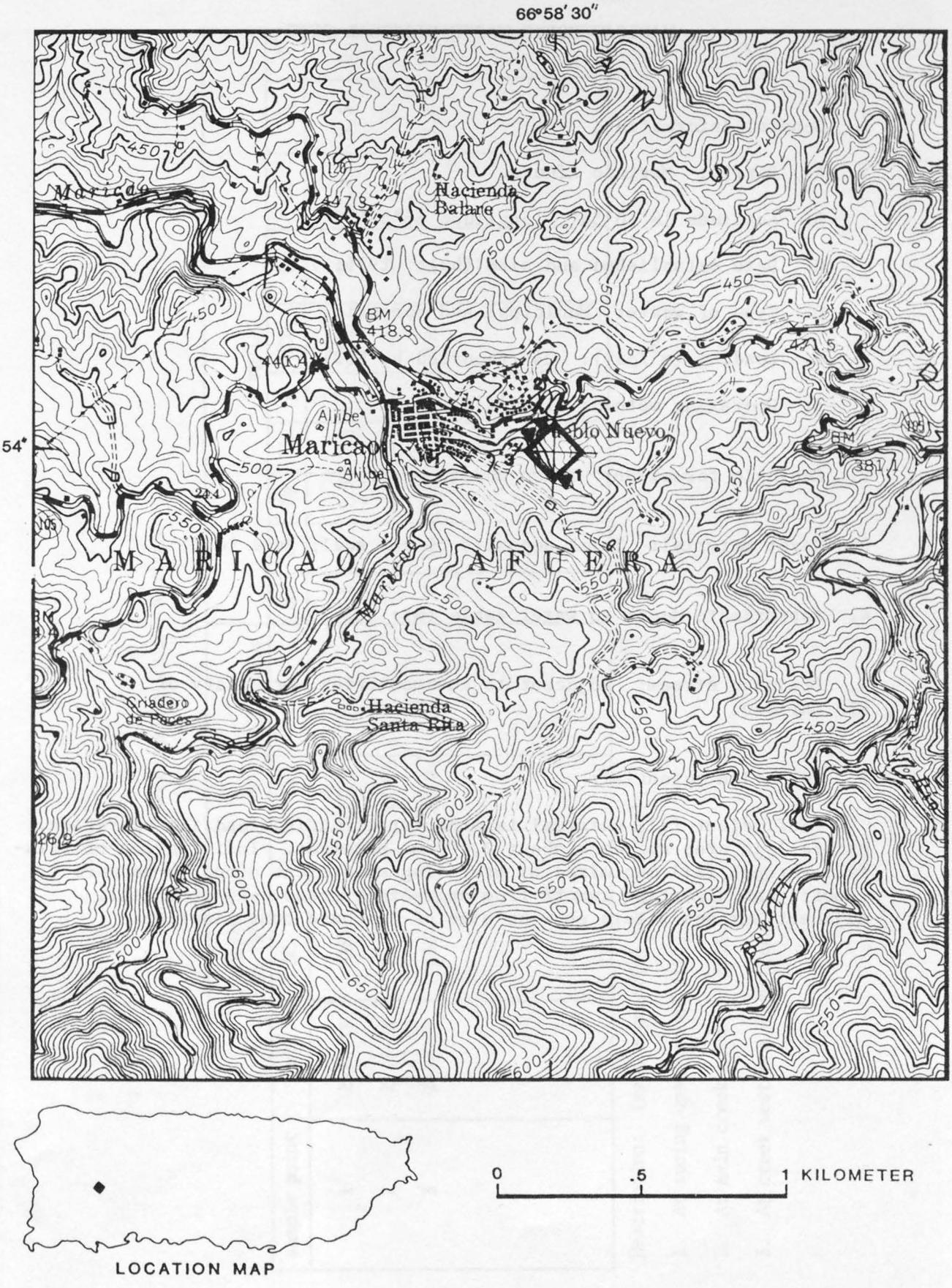


Figure 33.--Maricao solid-waste disposal site at Maricao Afuera.

MARICAO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Maricao Afuera.

   B. Latitude 18°10'54", longitude 66°58'30".

   C. Date established and size (ha): 1975; 7.9.

   D. Type of waste: Municipal and domestic.

   E. Loading (m^3/day): 24 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Yauco mudstone (Ky).

3. Cover material: Thick deposits of red soil; lava tuff.

4. Approximate depth to water table (m): 15-20.

5. Drainage stream: Adjacent to unnamed creek, tributary of Río Maricao.

6. Pollution potential:

Sufficient fill material in area for effective landfill operation. Rainfall in area averages about 2,400 mm per year. Infiltration of rainfall through fill minimized by providing sufficient slope to enhance runoff, and diverting runoff from upgradient areas away from fill. Adjacent surface waters show no sign of leachate contamination.

Table 18.--Water-quality data - Maricao

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	2-22-78	328	6.9	21.5	0.5	4.6	57	7.9	7.8	0.7	228	0	7.4	9.5	0
2	2-22-78	222	-	17.2	-	-	-	-	-	-	-	-	-	-	-
3	2-22-78	235	7.7	18.0	15	7.8	34	5.9	7.5	1.2	156	0	5.6	5.4	0

Description: (sample point(s) shown on map)

1. At spring upstream of fill.
2. At main creek north of fill.
3. At creek west and downstream of fill.

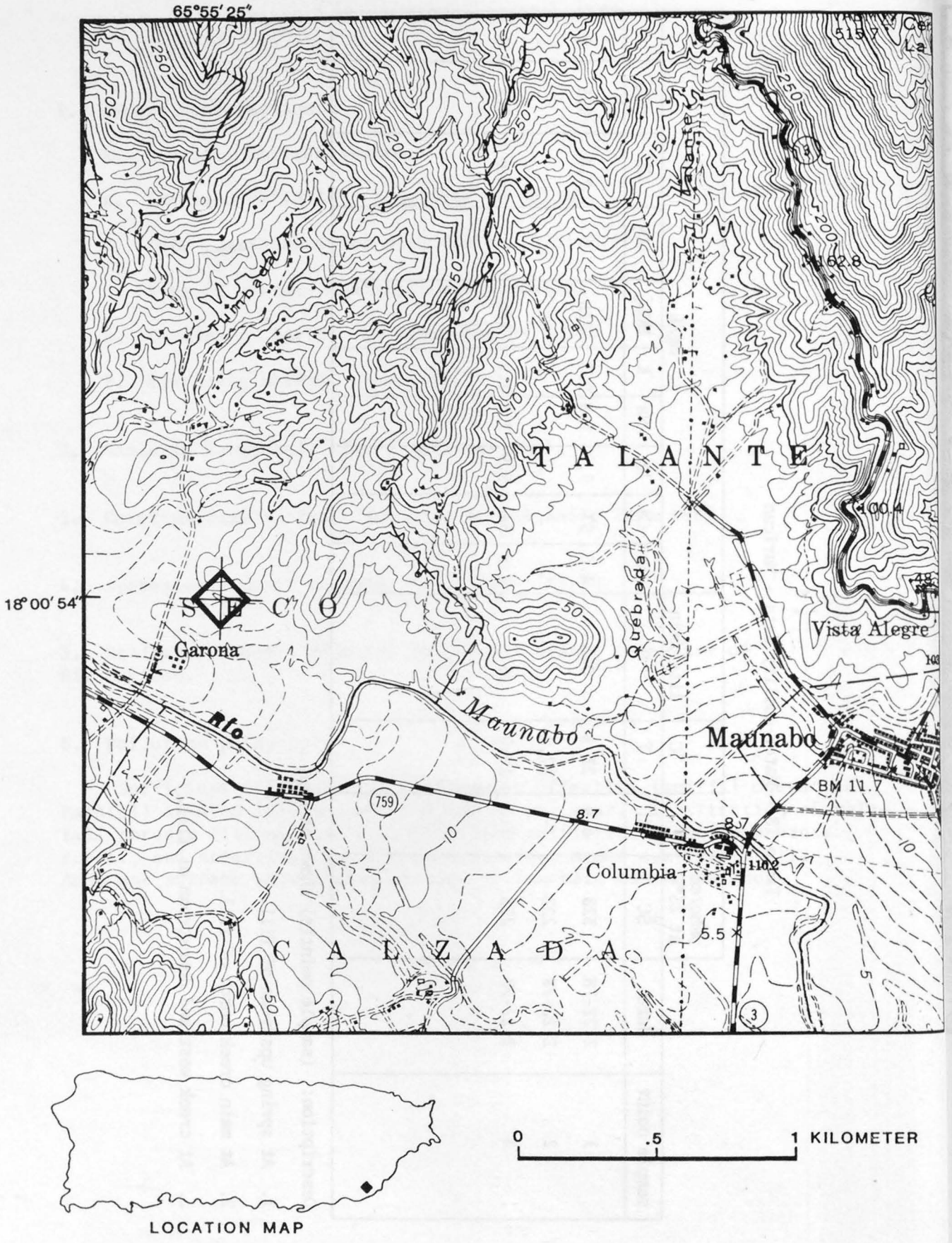


Figure 34.--Maunabo solid-waste disposal site at Palo Seco.

MAUNABO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Palo Seco.

   B. Latitude 18°00'54", longitude 65°55'25".

   C. Date established and size (ha): 1974; 3.1.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 75 (estimated).

   F. Operating method: Landfill.

2. Geologic formation: Plutonic rock (Tkp), and alluvial deposits (Qa).

3. Cover material: Loose sandy material.

4. Approximate depth to water table (m): 10.

5. Drainage stream: Adjacent to Río Maunabo flood plain.

6. Pollution potential:

Cover material is highly permeable and offers little attenuation to leached substances. Rainfall in area averages about 1,770 mm per year. When visited, no leachate was observed. Leached substances might move downward and reach local ground-water system.

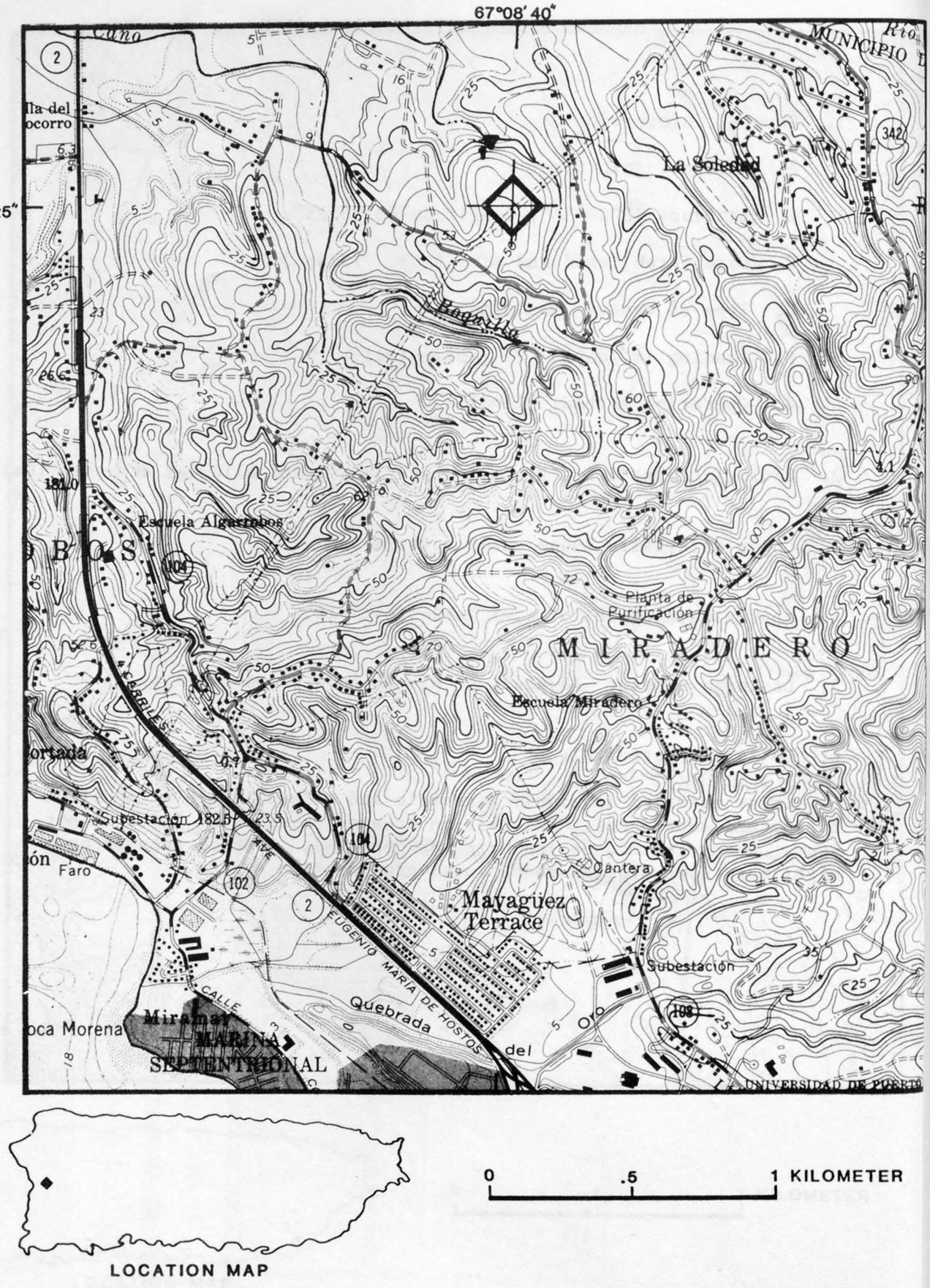


Figure 35.--Mayaguez solid-waste disposal site at Sabanetas.

MAYAGUEZ SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Sabanetas.

   B. Latitude 18°14'25", longitude 67°08'40".

   C. Date established and size (ha): 1974; 16.0.

   D. Type of waste: Municipal and industrial.

   E. Loading (m^3/day): 562 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Lava tuff and shale (Kt).

3. Cover material: Medium-brown to reddish clay. Lava tuff.

4. Approximate depth to water table (m): 5 at lower area and as much as 30 at upper area.

5. Drainage stream: Unnamed and intermittent creek crosses side of landfill.

6. Pollution potential:

Cover material consists of slightly permeable lava tuff. In area where domestic wastes are deposited, rainwater infiltration may be significant. Mean annual rainfall at the site is about 2,000 mm. At present, no observation wells exist downgradient of site for water-quality monitoring. There is no major surface- or ground-water user downgradient from the landfill.

Table 19.--Water-quality data - Mayaguez

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	5-25-76	230	6.9	25.0	-	1.8	16	16	11	2.5	116	0	23	6.1	-

Description: (sample point(s) shown on map)

1. Observation well drilled in 1975.

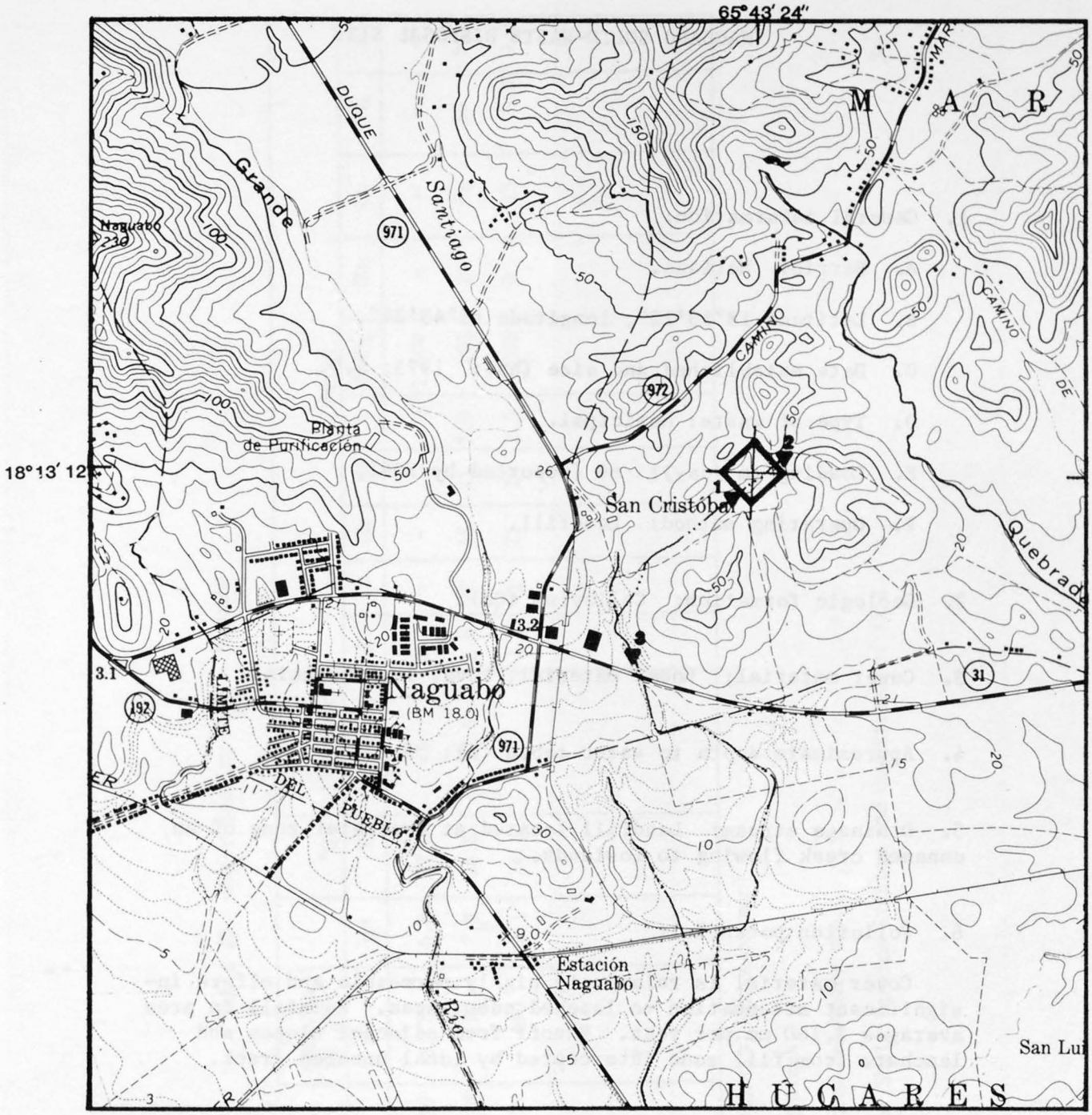


Figure 36.--Naguabo solid-waste disposal site Mariana.

NAGUABO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Mariana.

   B. Latitude 18°13'12", longitude 65°43'24".

   C. Date established and size (ha): 1975; 5.9.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 60 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Colluvium (Qa).

3. Cover material: Loose material, lava, lava breccia.

4. Approximate depth to water table (m): 5.

5. Drainage stream: Landfill located at headwater zone of an unnamed creek flowing to lowlands.

6. Pollution potential:

Cover material is relatively highly permeable and offers insignificant attenuation to leached substances. Rainfall in area averages 2,160 mm per year. Runoff from adjacent slopes and leachate from fill zone intercepted by local unnamed creek.

Table 20.--Water-quality data - Naguabo

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	12-29-77	2,570	6.8	27.0	<4	0	-	-	-	-	1,600	-	-	-	-
2	12-29-77	370	7.2	24.5	<0.5	1.6	22	15	25	3.9	102	0	51	36	0.1
3	12-29-77	490	7.1	24.5	-	2.2	41	21	28	2.5	358	0	23	3.8	0.2

Description: (sample point(s) shown on map)

1. Leachate flow along creek.
2. Stagnant pool on creek headwater zone.
3. At creek upstream of Shell Service Station and downstream of fill.

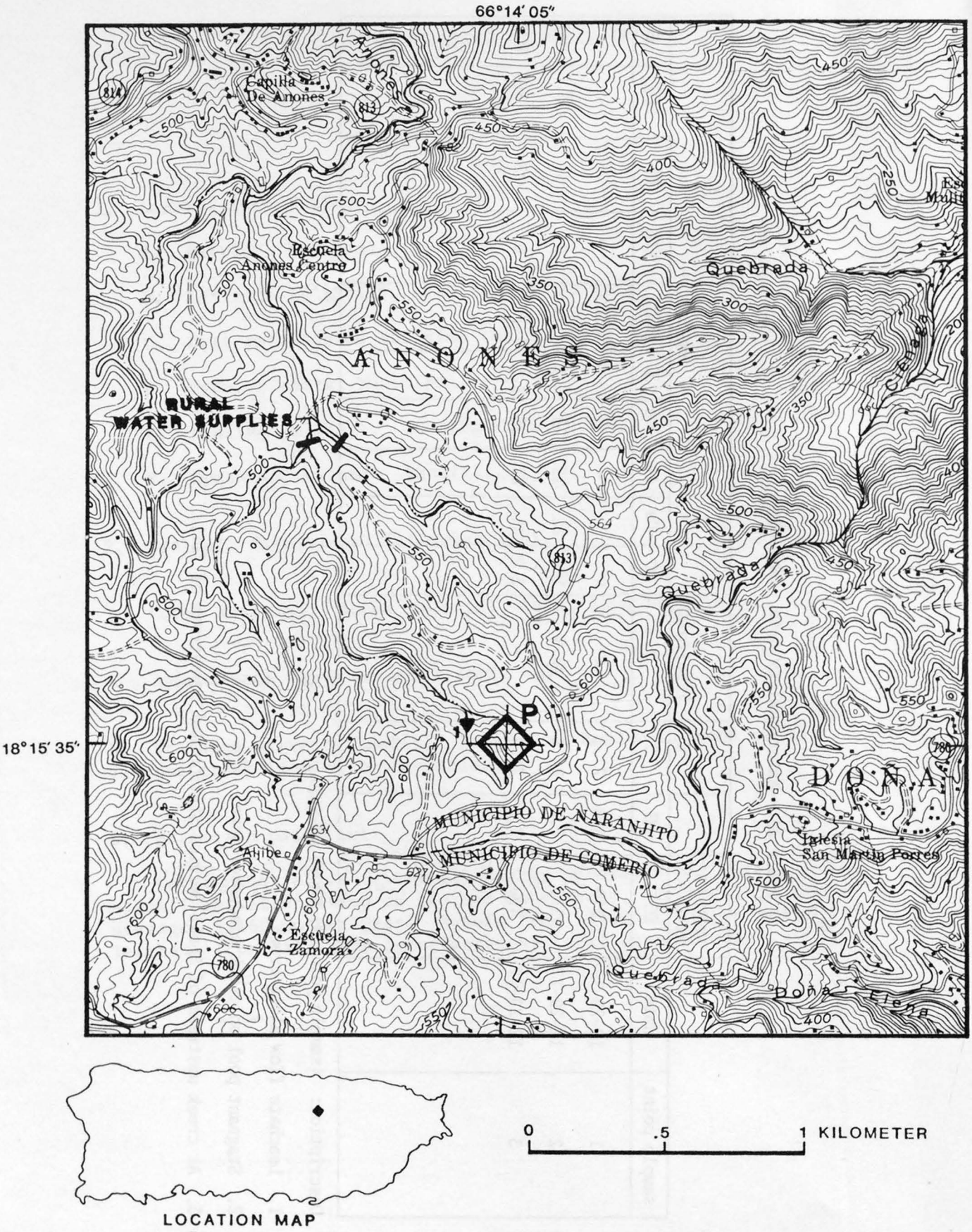


Figure 37.--Naranjito solid-waste disposal site at Anones.

NARANJITO SOLID-WASTE DISPOSAL SITE
(Proposed)

1. General information:

   A. Barrio: Anones.

   B. Latitude 18°15'35", longitude 66°14'05".

   C. Date established and size (ha): Proposed landfill site.

   D. Type of waste: Proposed landfill site.

   E. Loading (m^3/day): --

   F. Operating method: Proposed landfill.

2. Geologic formation: Perchas Formation (Kp).

3. Cover material: Proposed landfill.

4. Approximate depth to water table (m): 20.

5. Drainage stream: Unnamed creek drained by Quebrada Anones which joins Río Guadiana. Río Guadiana is a tributary of Río de la Plata.

6. Pollution potential:

Site is being proposed for a landfill. Cover material will be relatively highly permeable if not properly compacted. Rainfall in area averages about 2,030 mm per year. Unnamed creek, used for water supply farther downstream, will be draining any leached substances produced on site.

Table 21.--Water-quality data - Naranjito
(Proposed)

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	2-6-78	250	6.5	19.5	1	5.2	18	13	9.2	1.1	106	0	15	3	0.1

Description: (sample point(s) shown on map)

1. At spring below site proposed.

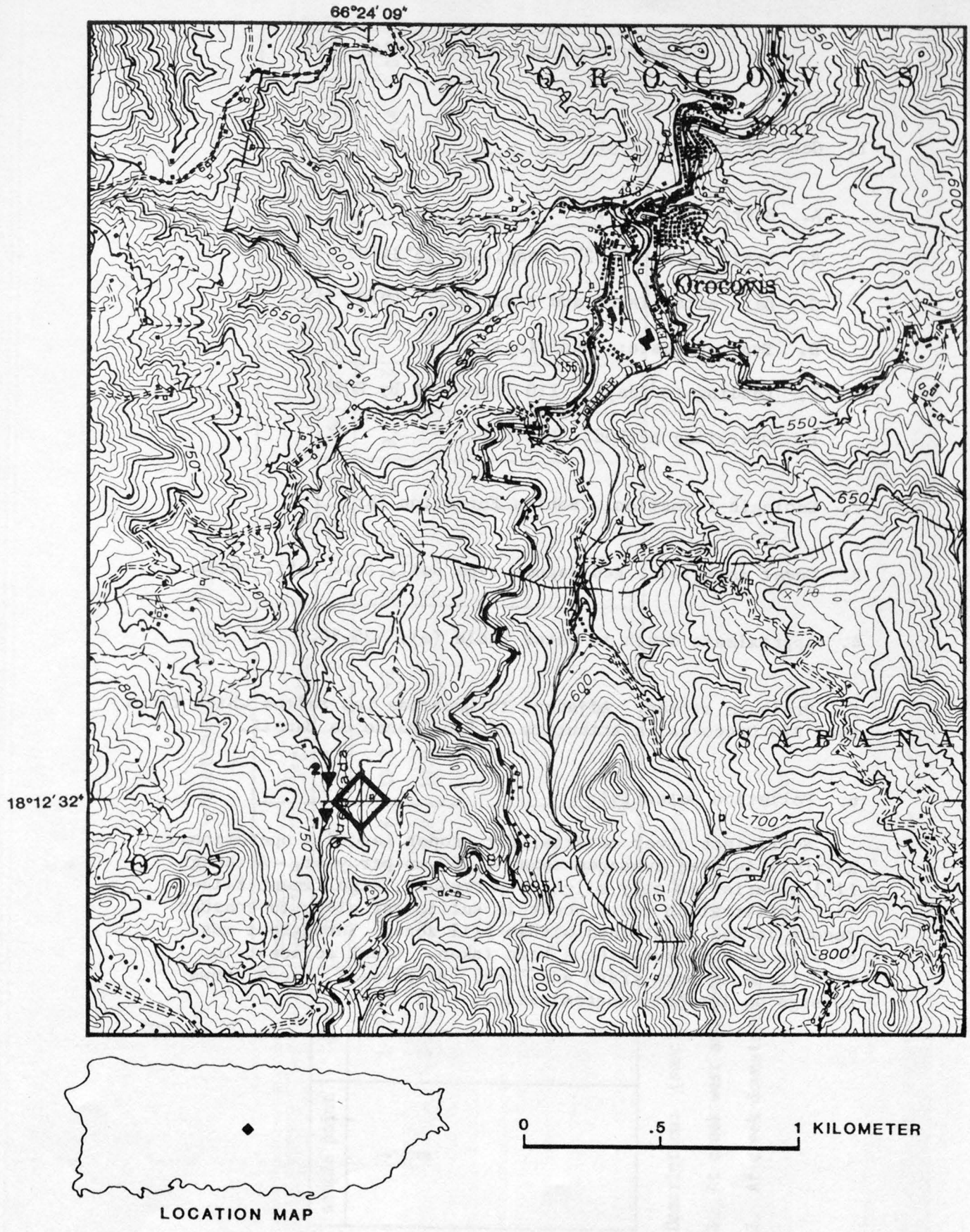


Figure 38.--Orocovis solid-waste disposal site at Saltos.

OROCOVIS SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Saltos.

   B. Latitude 18°12'32", longitude 66°24'09

   C. Date established and size (ha): 1974; 5.9.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 110 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Robles Formation (Kr).

3. Cover material: Red daguey type soil, lava tuff, thick.

4. Approximate depth to water table (m): 25-30.

5. Drainage stream: Adjacent to Quebrada Los Saltos which flows into Río Orocovis, a tributary of Río Grande de Manatí.

6. Pollution potential:

Sufficient cover material for proper landfill operations. Rainfall in area averages about 2,160 mm per year. Although fill material is only slightly permeable, significant rainfall infiltration could occur if sufficient slope to enhance runoff is not maintained within fill zone. Throughout most of site such measures have been taken. Creek adjacent to site littered with trash and junk. At present, creek shows no sign of leachate contamination.

Table 22.--Water-quality data - Orocovis

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	2-16-78	183	6.9	19.0	±2	8.2	17	11	9.5	1.4	118	0	10	3.4	0.1
2	2-16-78	189	6.9	19.0	±2	8.4	-	-	-	-	116	0	-	-	-

Description: (sample point(s) shown on map)

1. At creek west and upstream of fill.

2. At creek downstream of fill.

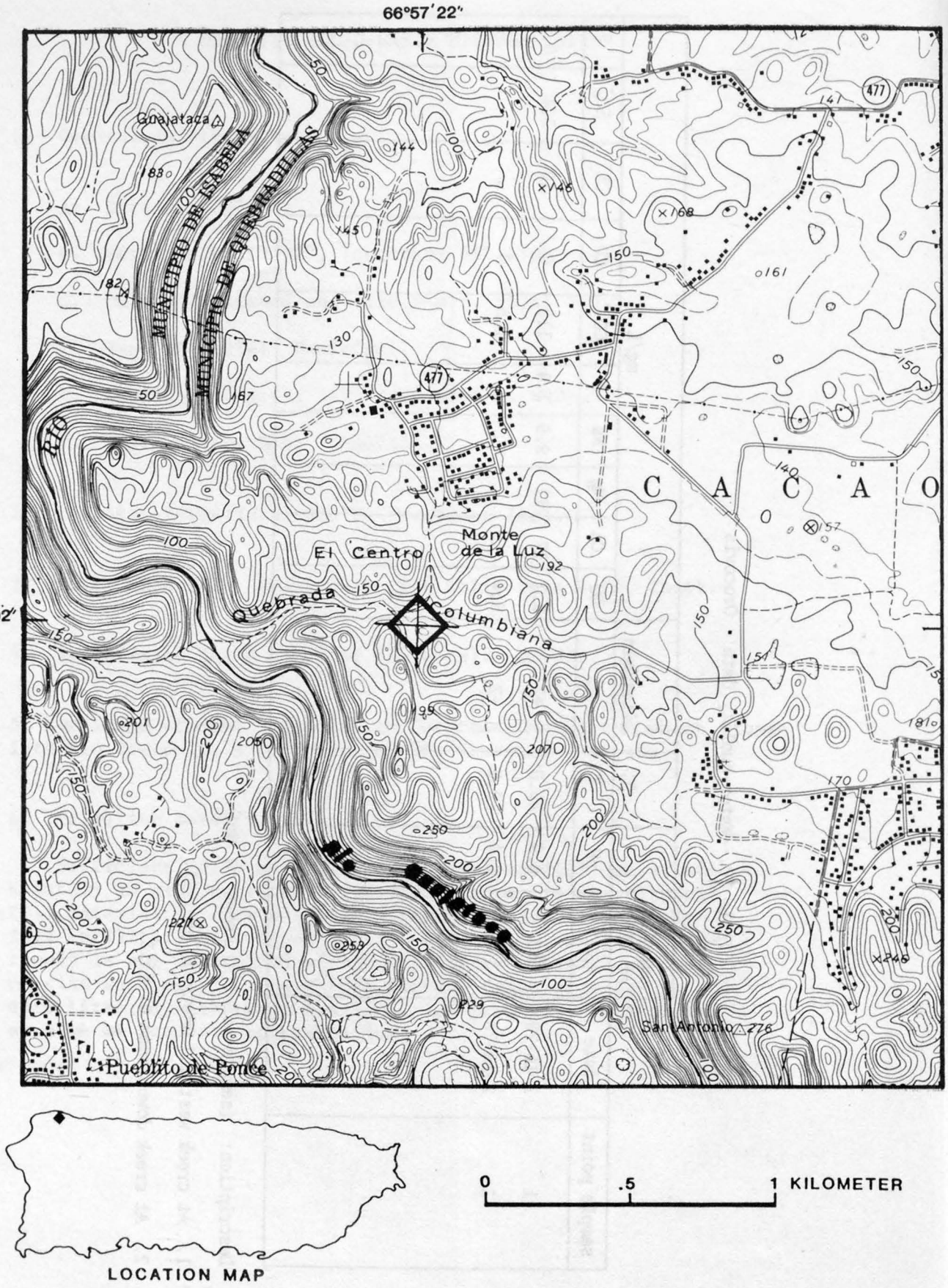


Figure 39.--Quebradillas solid-waste disposal site at Cacao.

QUEBRADILLAS SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Cacao.

   B. Latitude 18°27'02", longitude 66°57'22".

   C. Date established and size (ha): 1970; 2.0.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 40 (reported by EQB).

   F. Operating method: Open dump and landfill.

2. Geologic formation: Aymamón Limestone (Tay).

3. Cover material: Mixture of red soil and limestone fragments.

4. Approximate depth to water table (m): 100 to regional water table. Local perched conditions might exist.

5. Drainage stream: Landfill located at headwater zone of Quebrada Columbiana which flows into Río Guajataca.

6. Pollution potential:

It is partially operated as an open dump. Rainfall in area averages about 1,520 mm per year. Sinkhole which drains runoff from adjacent slopes is being used as the dump. No signs of leachate were observed. The geologic formation, Aymamón Limestone, is relatively permeable due to its solution-type porosity, and ground-water pollution could be possible.

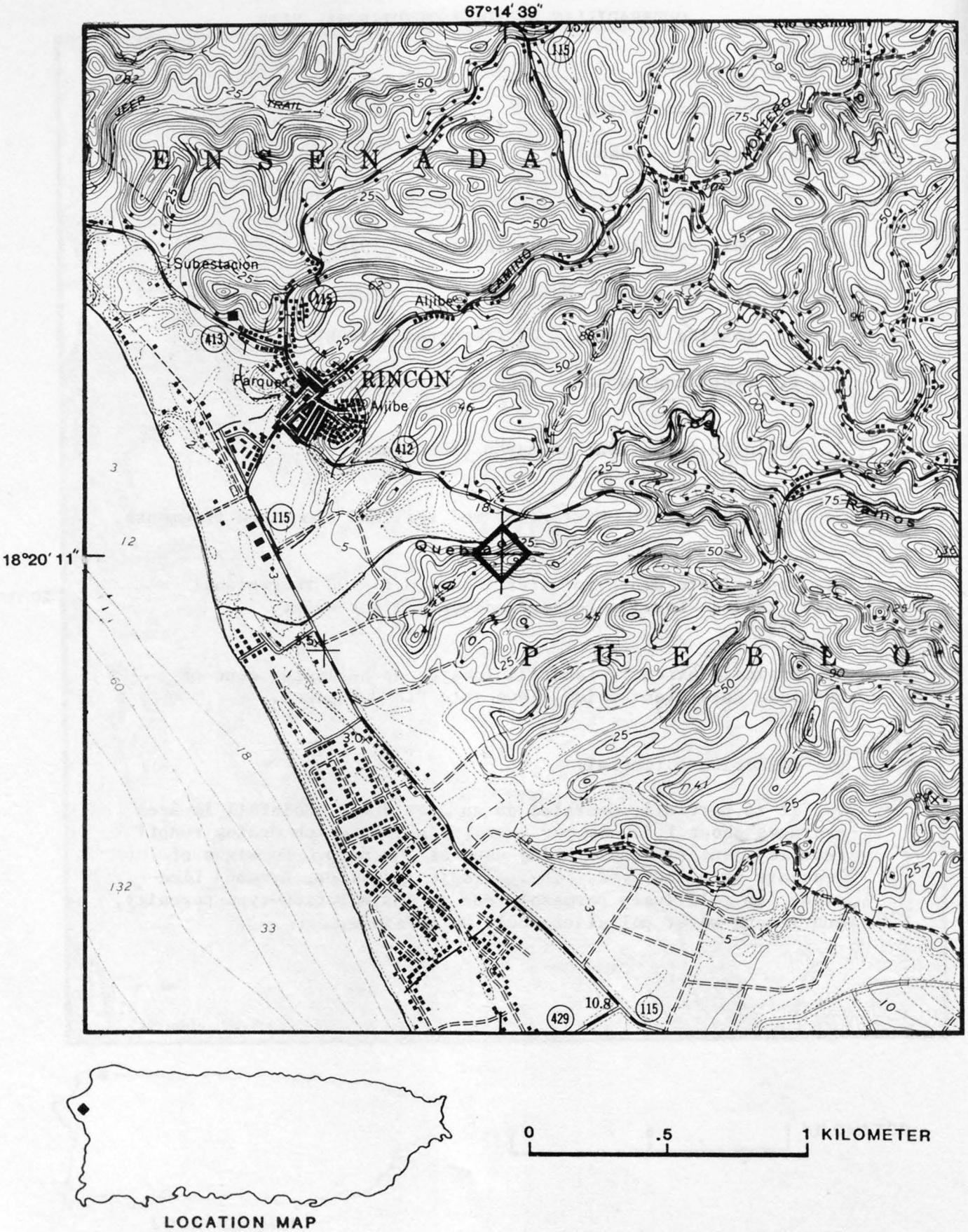


Figure 40.--Rincón solid-waste disposal site at Pueblo.

RINCON SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Pueblo.

   B. Latitude 18°20'11", longitude 67°14'39".

   C. Date established and size (ha): 1974; 2.0.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 37 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Volcanic rocks, undivided (Tks).

3. Cover material: Coarse loose materials extracted from hills surrounding landfill.

4. Approximate depth to water table (m): 20.

5. Drainage stream: Intermittent Quebrada Los Ramos runs on north side toward the west coast. It was completely dry the day landfill was visited.

6. Pollution potential:

Cover material is highly permeable but if properly compacted could be considered adequate for site due to a relatively low rainfall incidence which averages about 1,400 mm per year and potential evapotranspiration about 960 mm per year. When visited, adjacent creek, Quebrada Los Ramos, was dry but littered with junk and garbage. No signs of leachate were observed.

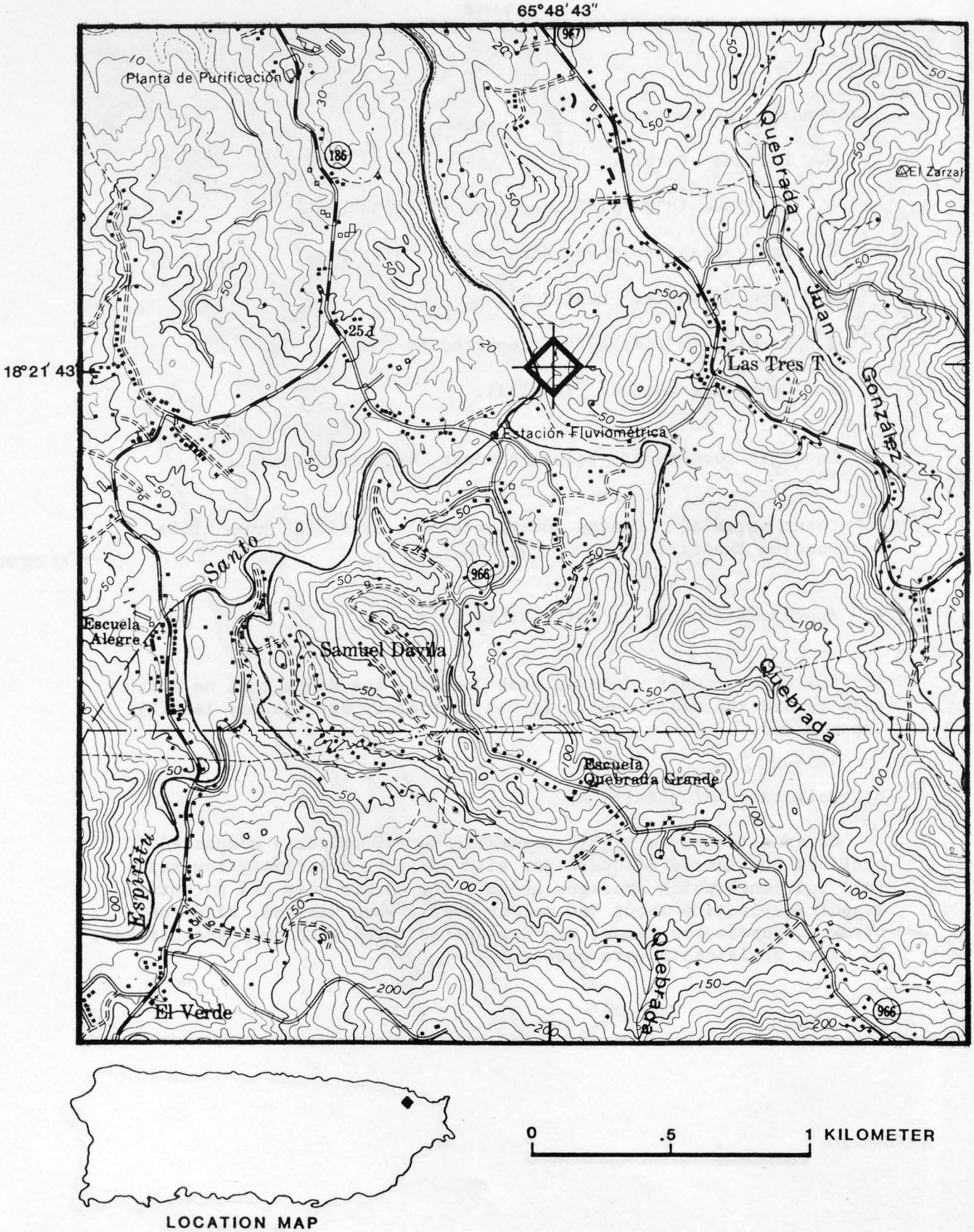


Figure 41.--Río Grande solid-waste disposal site at Jiménez.

RIO GRANDE SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Jiménez.

   B. Latitude 18°21'43", longitude 65°48' 43".

   C. Date established and size (ha): 1970; 0.8.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 85 (estimated).

   F. Operating method: Open dump.

2. Geologic formation: Mafic dikes and sheet (TKmi).

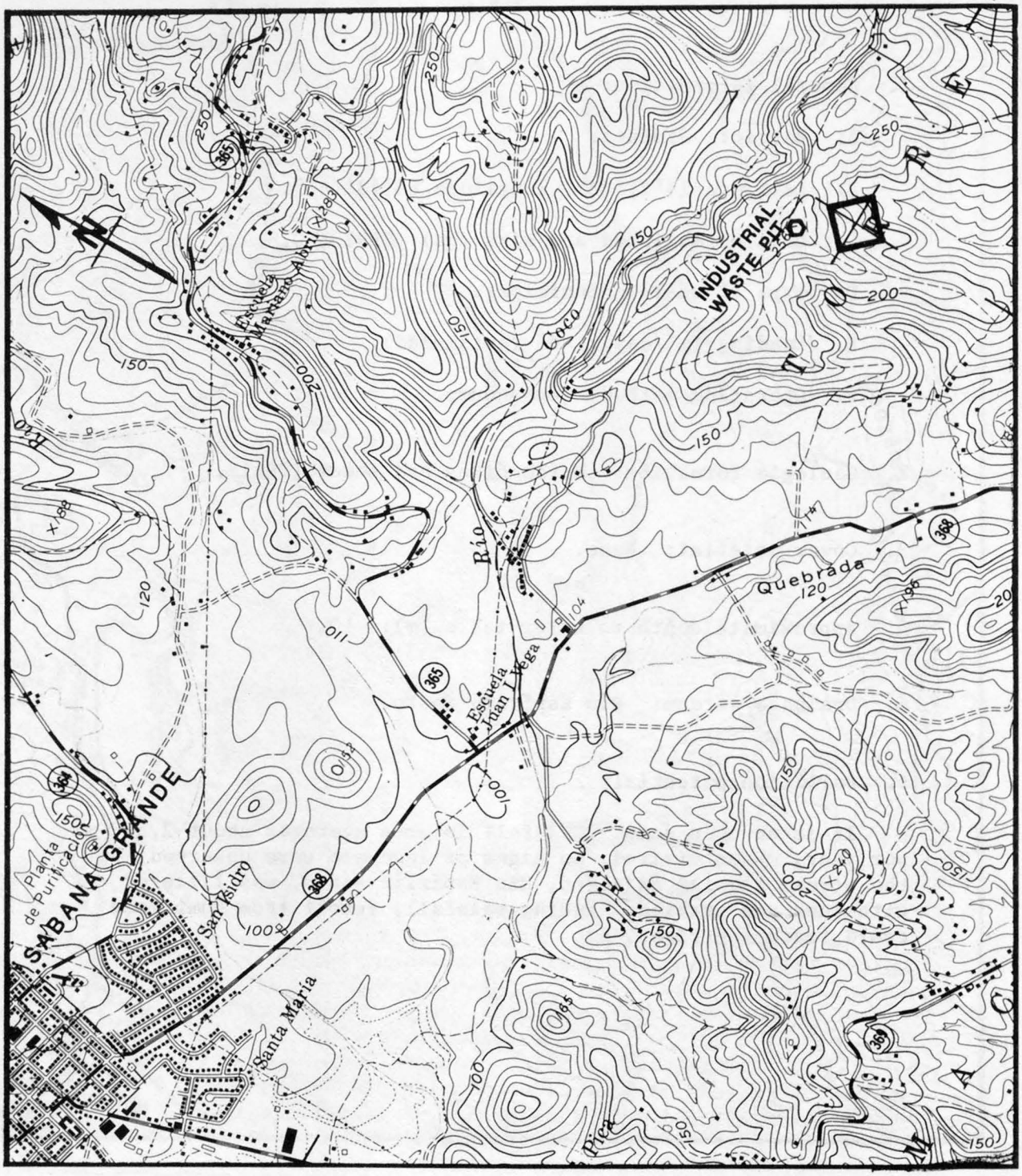
3. Cover material: None.

4. Approximate depth to water table (m): 10.

5. Drainage stream: Río Espíritu Santo.

6. Pollution potential:

It is an open dump. Rainfall in area averages about 2,300 mm per year. When visited, no signs of leachate were observed, but the stream flowing adjacent, Río Espíritu Santo, was littered with junk and garbage. During rainfall, runoff from dump zone could reach the river.



0 .5 1 KILOMETER

Figure 42.--Sabana Grande solid-waste disposal site at Torre.

SABANA GRANDE SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Torre.

   B. Latitude 18°14'23", longitude 66°55'28".

   C. Date established and size (ha): 1960; 3.9.

   D. Type of waste: Municipal and industrial.

   E. Loading (m^3/day): 70 (estimated).

   F. Operating method: Open dump and landfill.

2. Geologic formation: Serpentinite (Ks).

3. Cover material: Extracted from locality, dark-brown soils, high in rock fragments (sepentinite).

4. Approximate depth to water table (m): Local water table is nonexistent. Regional water table at about 40 meters.

5. Drainage stream: Unnamed creek and part of the headwaters of Río Cañas, a tributary of Río Loco.

6. Pollution potential:

Within site there is insufficient soil for an effective landfill operation. Refuse exposed along lower gradient. Although the site lies within a semiarid region (annual mean rainfall less than 1,525 mm and pan evaporation about 2,060 mm), showers equal to or in excess of 12.7 mm may occur on an average of about 30 days per year. No provisions exist to divert runoff from upper slopes away from refuse. As a consequence, refuse may be washed toward adjacent dry streambed. Pollution due to production of leachate may be negligible (lower edge of landfill could not be checked due to thick brush and steep slopes).

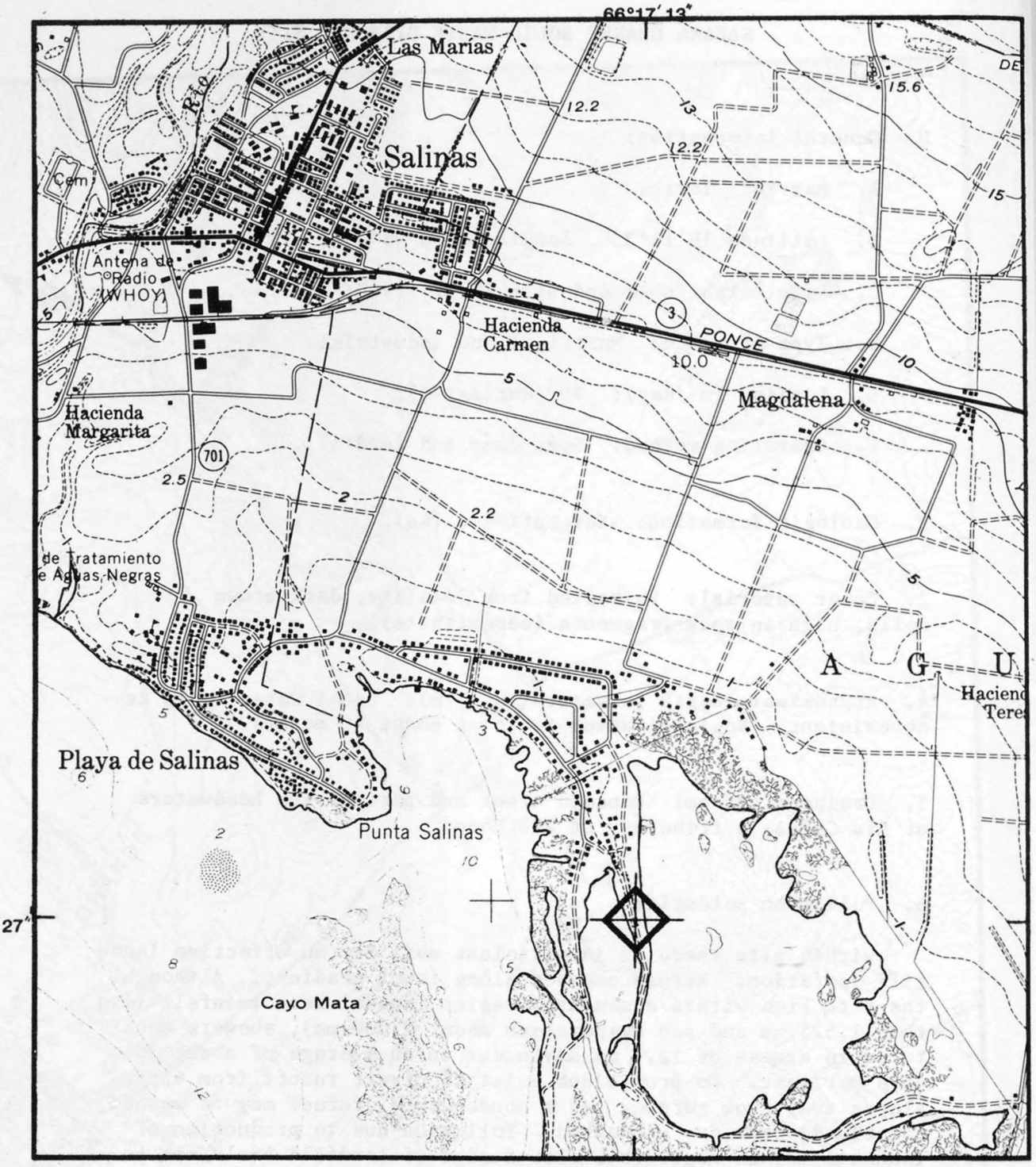


Figure 43.--Salinas solid-waste disposal site at Aguirre.

SALINAS SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Aguirre.

   B. Latitude 17°57'27", longitude 66°17'13".

   C. Date established and size (ha): unknown.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): (Closed).

   F. Operating method: Open dump (closed).

2. Geologic formation: Swamp and marsh deposits (Qs).

3. Cover material: Open dump.

4. Approximate depth to water table (m): Within mangrove wetlands zone.

5. Drainage stream: Mangrove wetlands zone.

6. Pollution potential:

It was an open dump. Closed in 1977. Rainfall in area averages about 1,150 mm per year. Located within mangrove wetland zone.

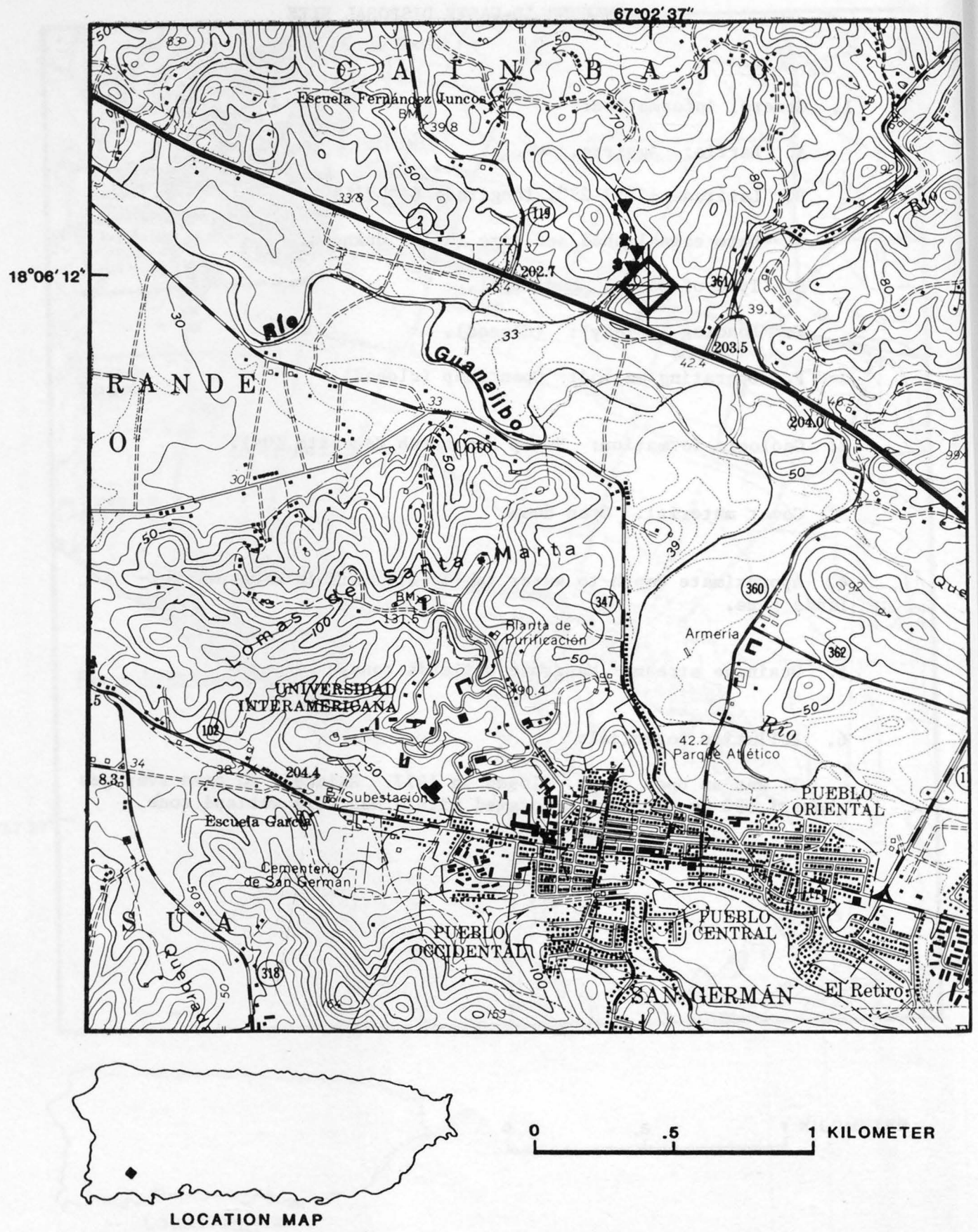


Figure 44.--San Germán solid-waste disposal site at Sabana Grande Abajo.

SAN GERMAN SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Sabana Grande Abajo.

   B. Latitude 18°06'12", longitude 67°02'37".

   C. Date established and size (ha): 1962; 1.6.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 195 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Tuffaceous breccia and conglomerate (Kt).

3. Cover material: Gravel and boulder-type material (breccia) mixed with fill brought from outside.

4. Approximate depth to water table (m): 10-15.

5. Drainage stream: Leachate spring drained by unnamed creek adjacent to landfill and flowing toward Río Guanajibo.

6. Pollution potential:

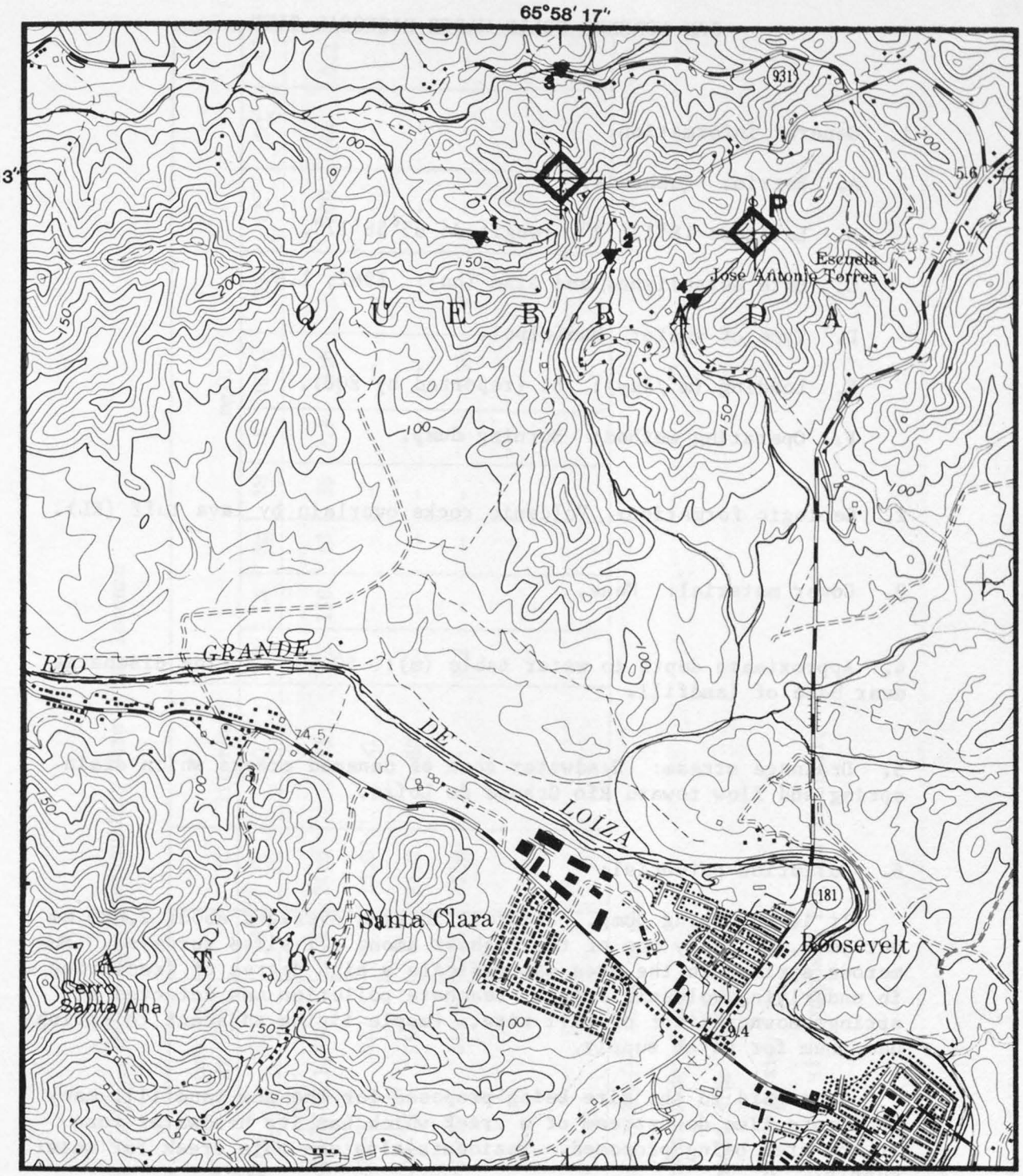
Cover material highly permeable and offers insignificant attenuation to leached substances. Rainfall in area averages about 1,900 mm per year. Leachate spring flowing out of base of landfill affects water quality of adjacent unnamed creek, which eventually joins Río Guanajibo. When visited, creek was littered with junk and garbage.

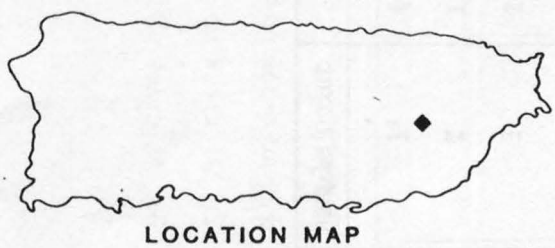
Table 23.--Water-quality data - San Germán

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	4-26-78	600	7.2	25.0	2	3.6	48	27	20	2.2	234	0	17	98	0.1
2	4-26-78	750	-	25.0	-	-	-	-	-	-	-	-	-	-	-
3	4-26-78	2,900	7.4	32.0	2	0	51	96	210	94	734	0	360	110	0.1

Description: (sample point(s) shown on map)

1. At creek upstream of fill.
2. At creek upstream of leachate spring.
3. At creek where leachate spring enters.





LOCATION MAP

0 .5 1 KILOMETER

Figure 45.--San Lorenzo solid-waste disposal site at Quebrada.

SAN LORENZO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Quebrada.

   B. Latitude 18°13'12", longitude 65°58'17".

   C. Date established and size (ha): 1962; 1.6.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 61 (reported by EQB).

   F. Operating method: Burning dump.

2. Geologic formation: Volcanic rocks overlain by lava tuff (KL).

3. Cover material: None.

4. Approximate depth to water table (m): 50-60. Spring discharge near base of landfill.

5. Drainage stream: Headwater zone of unnamed creeks which drain spring and flow toward Río Grande de Loíza.

6. Pollution potential:

It is a burning dump. Rainfall in area averages about 2,080 mm per year, probably one of the highest among all sites surveyed. Numerous springs in the area may indicate a high degree of fracturing in underlying volcanic rocks. Leachate pollution was detected at springs downgradient of fill site. People living adjacent to springs use them for water supply.

In regard to the site being proposed for the new landfill, many residents live downstream of a creek which has its headwater zone in the area being proposed. Residents also use this creek for water supply.

Table 24.--Water-quality data - San Lorenzo

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	12-28-77	1,350	6.6	24.0	<1	3.2	130	53	36	0.8	316	0	200	44	0.1
2	12-28-77	620	-	23.0	<1	-	-	-	-	-	-	-	-	-	-
3	12-28-77	550	-	23.0	±30	-	-	-	-	-	-	-	-	-	-
4	12-28-77	315	7.5	22.0	-	7.2	-	-	-	-	156	0	-	-	-

Description: (sample point(s) shown on map)

1. Spring on southwest side of dump.
2. Spring on southeast side of dump.
3. Creek flowing on north side.
4. At creek downstream of site proposed for new landfill.

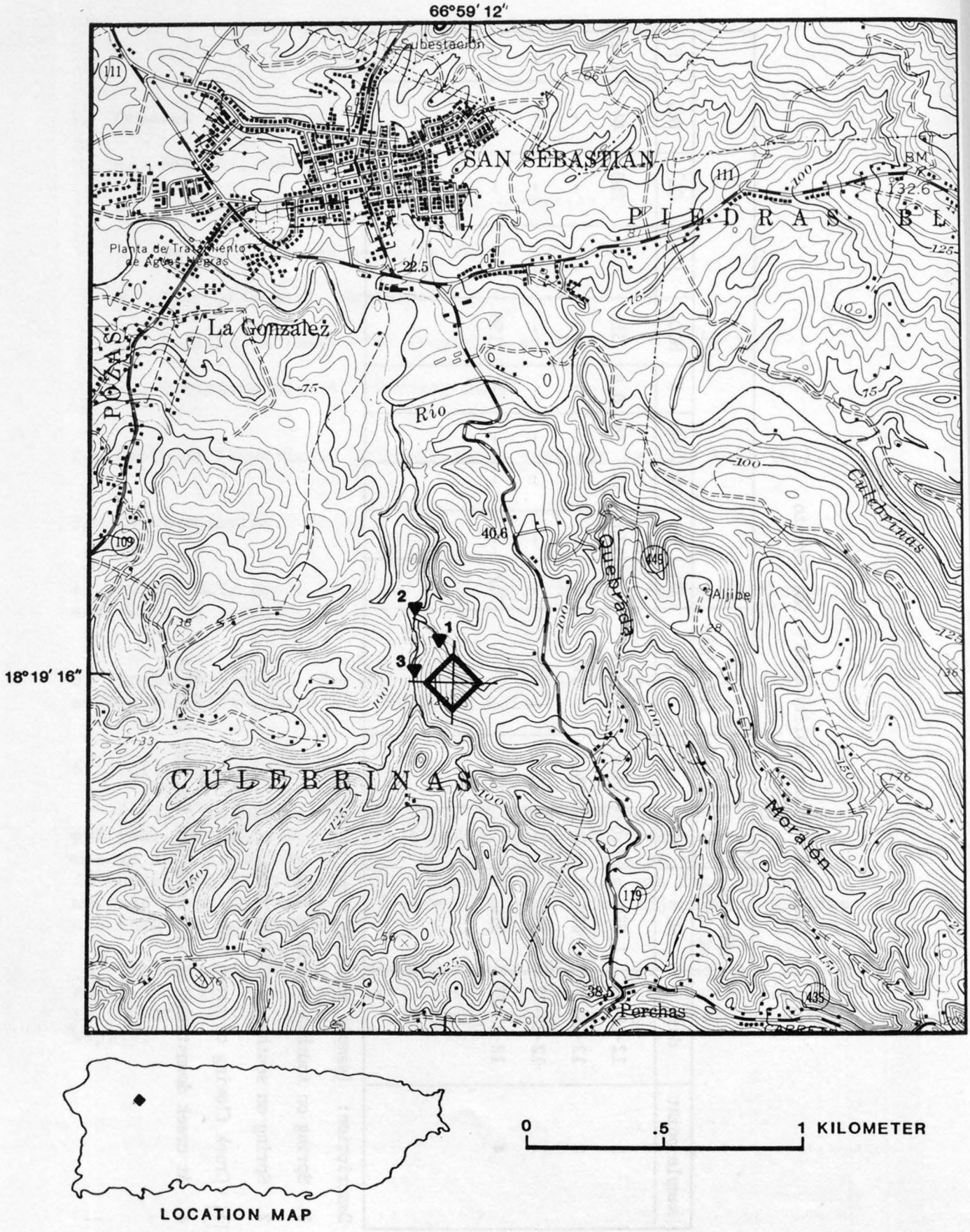


Figure 46.--San Sebastián solid-waste disposal site at Culebrinas.

SAN SEBASTIAN SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Culebrinas.

   B. Latitude 18°19'16", longitude 66°59'12".

   C. Date established and size (ha): 1960; 2.8.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 130 (estimated).

   F. Operating method: Landfill, open burning dump.

2. Geologic formation: San Sebastián Formation (Tscc).

3. Cover material: Yellowish-red clayey soil.

4. Approximate depth to water table (m): 15-20.

5. Drainage stream: Unnamed creek on west side which joins Río Culebrinas.

6. Pollution potential:

Cover material yellowish-red soil with relatively low permeability. The landfill lies within an area receiving an average of 2,400 mm per year of rainfall. No provisions have been made to give the fill zone sufficient slope to enhance runoff; therefore, rainwater infiltration through buried refuse may be significant. Leachate flow at toe of fill and refuse exposed along lower gradient. Higher flow at adjacent creek dilutes leachate flow considerably causing undetectable change in its specific conductance.

Table 25.--Water-quality data - San Sebastián

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	2-2-78	1,230	6.8	20.3	2	3.5	92	27	95	25	314	0	270	3.2	0
2	2-2-78	190	-	21.0	300	-	-	-	-	-	-	-	-	-	-
3	2-2-78	189	-	20.5	300	-	-	-	-	-	-	-	-	-	-

Description: (sample point(s) shown on map)

1. Leachate red colored.
2. At creek downstream of fill.
3. At creek upstream of fill.

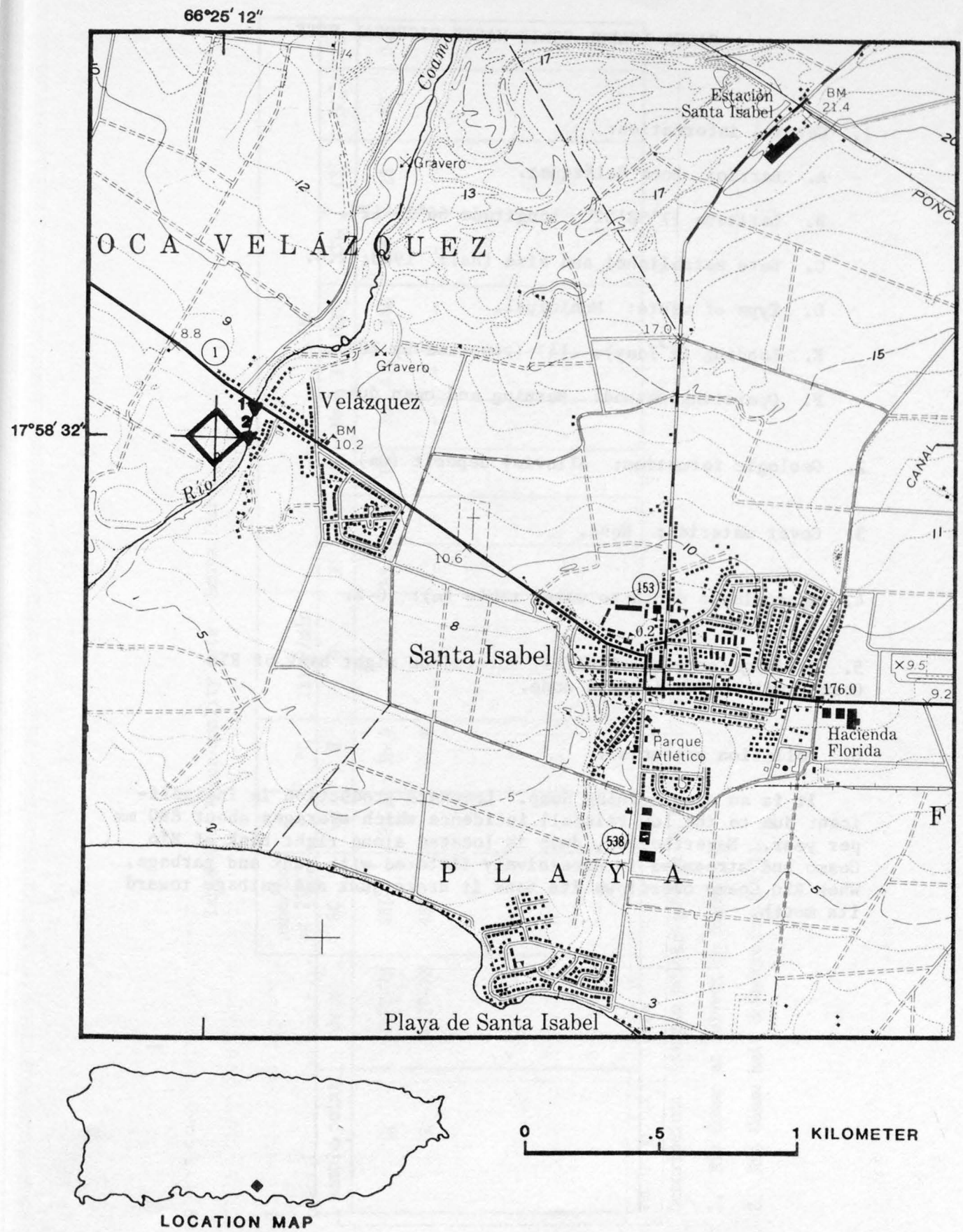


Figure 47.--Santa Isabel solid-waste disposal site at Boca Velázquez.

SANTA ISABEL SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Boca Velázquez.

   B. Latitude 17°58'32", longitude 66°25'12".

   C. Date established and size (ha): 1963; 2.4.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 147 (reported by EQB).

   F. Operating method: Burning and open dump.

2. Geologic formation: Alluvial deposit (Qa).

3. Cover material: None.

4. Approximate depth to water table (m): 0-2.

5. Drainage stream: Landfill located on right bank of Río Coamo, within flood-plain zone.

6. Pollution potential:

It is an open burning dump. Leachate production is insignificant due to the low rainfall incidence which averages about 890 mm per year. Nevertheless, dump is located along right bank of Río Coamo and streambed is excessively littered with junk and garbage. When Río Coamo overflows its bank it drags junk and garbage toward its mouth.

Table 26.--Water-quality data - Santa Isabel

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	4-27-78	485	9.2	36.0	<5	13.2	42	13	26	4.1	146	46	25	32	0.2
2	4-27-78	495		35.0	-	-	-	-	-	-	-	-	-	-	-

Description: (sample point(s) shown on map)

1. Río Coamo at culvert on Highway 1.

2. Río Coamo half downstream of fill.

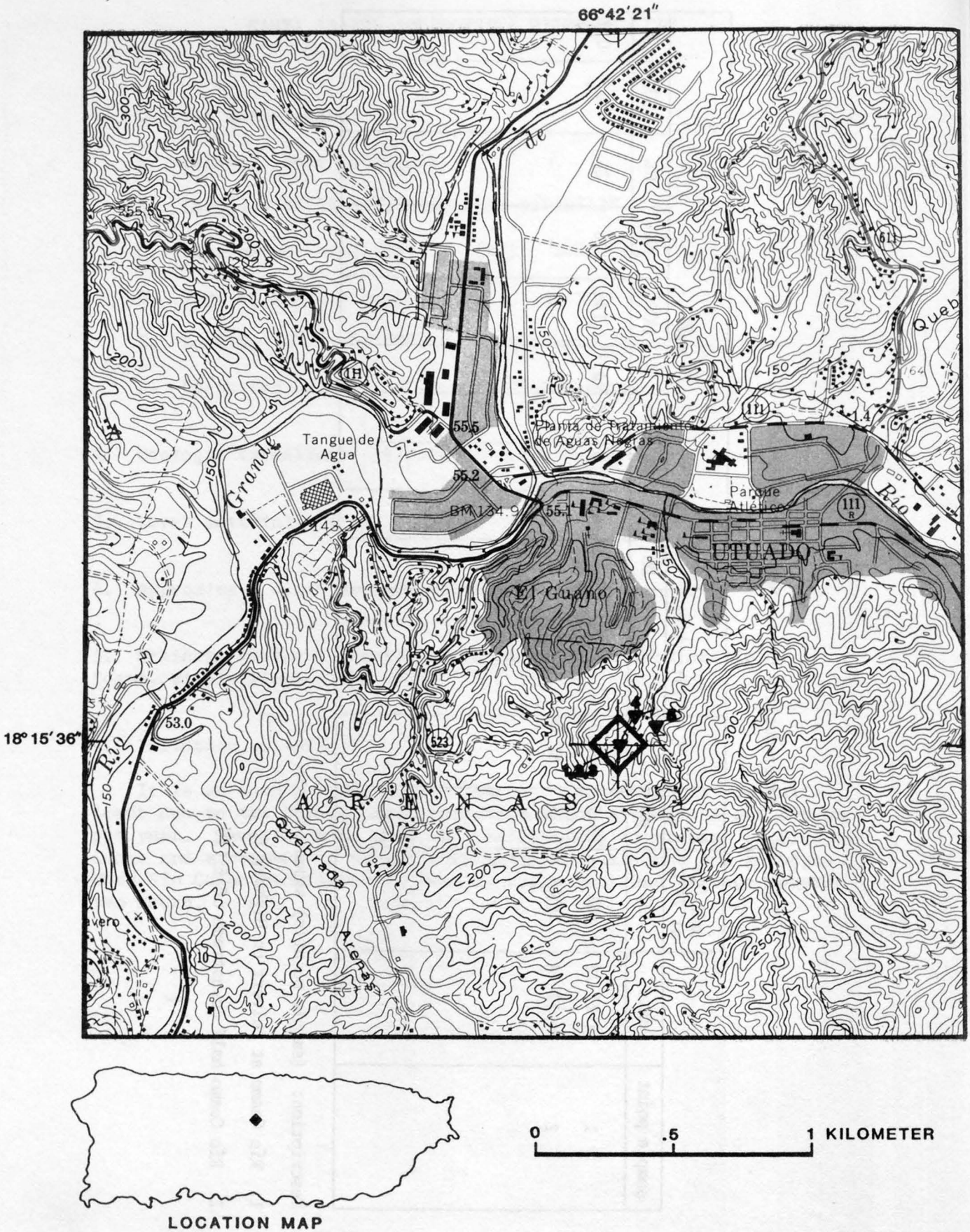


Figure 48.--Utuado solid-waste disposal site at Arenas.

UTUADO SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Arenas.

   B. Latitude 18°15'36", longitude 66°42'21".

   C. Date established and size (ha): 1974; 2.4.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 69 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Rocks of the Utuado pluton (TKu).

3. Cover material: Thick sand deposit.

4. Approximate depth to water table (m): 15-20.

5. Drainage stream: Headwater zone of an unnamed creek which flows toward the town of Utuado. Joins Río Viví, a tributary of Río Grande de Arecibo.

6. Pollution potential:

Cover material used is highly permeable and also offers negligible attenuation to leached substances. Rainfall in area averages about 2,000 mm per year. Runoff from adjacent slopes not directed away from fill site. Other residents upgradient from site must cross through it to reach their homes. When visited, leachate from landfill site was flowing into residential zone.

Table 27.--Water-quality data - Utuado

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	4-20-78	5,500	6.9	29.5	-	0	-	-	-	-	-	-	-	-	-
2	4-20-78	3,350	-	29.5	-	0	-	-	-	-	-	-	-	-	-
3	4-20-78	10,800	-	27.0	-	0	-	-	-	-	-	-	-	-	-
4	4-20-78	75	6.2	23.5	<1	7.5	5.7	2.4	6.8	1.7	30	0	3.4	8.2	0.1
5	4-20-78	115	6.5	23.5	<1	7.7	7.0	4.6	7.5	1.7	44	0	5.5	7.0	0.1

Description: (sample point(s) shown on map)

1. Leachate pond.
2. Leachate pond.
3. Leachate pond.
4. Spring below fill coming from west side.
5. Spring below fill coming from east side.

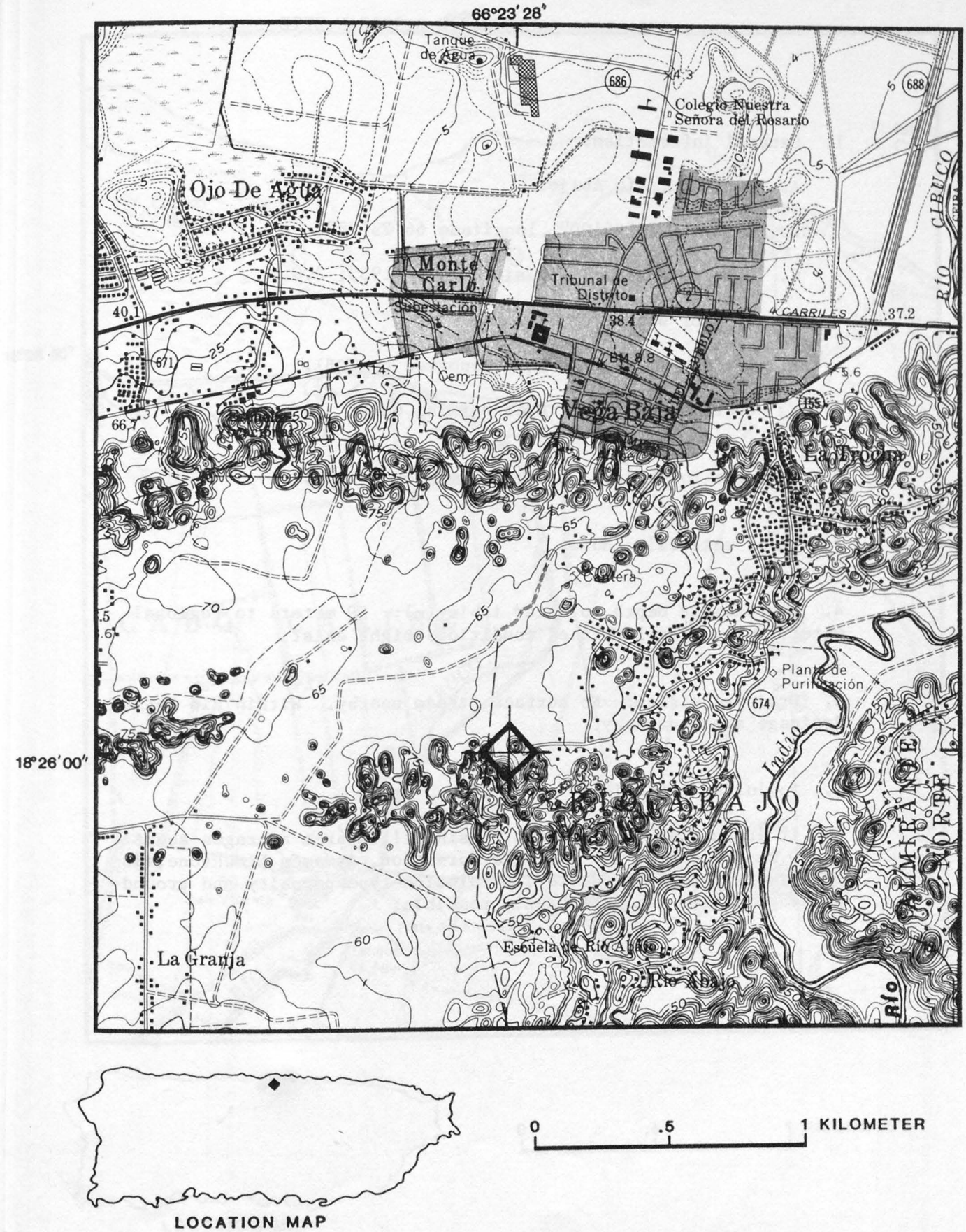


Figure 49.--Vega Baja solid-waste disposal site at Río Abajo, (old landfill).

VEGA BAJA SOLID-WASTE DISPOSAL SITE
(Old)

1. General information:

   A. Barrio: Río Abajo.

   B. Latitude 18°26'00", longitude 66°23'28".

   C. Date established and size (ha): 1953; 2.0.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 147 (reported by EQB).

   F. Operating method: Open burning dump.

2. Geologic formation: Aymamón Limestone (Tay).

3. Cover material: None.

4. Approximate depth to water table (m): 50 meters to regional water table. Local perched conditions might exist.

5. Drainage stream: No surface stream nearby. Within Rio Indio drainage area boundary.

6. Pollution potential:

It is an open burning dump. Rainfall in area averages about 1,900 mm per year. The geologic formation, Aymamón Limestone, is relatively permeable due to its solution-type porosity and groundwater pollution could be highly possible.

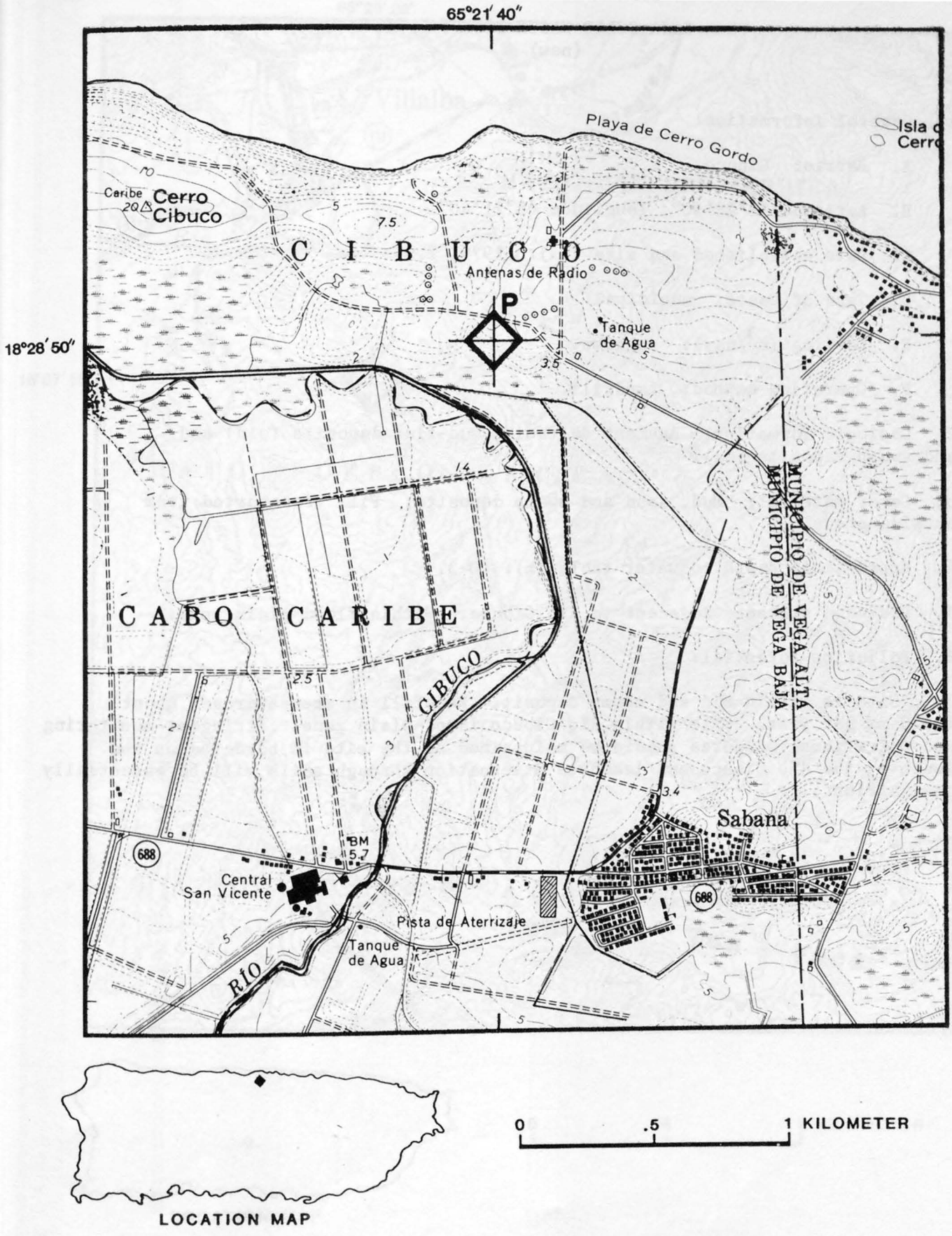


Figure 50.--Vega Baja solid-waste disposal site at Cibuco, (new landfill).

VEGA BAJA SOLID-WASTE DISPOSAL SITE
(new)

1. General information:

   A. Barrio: Cibuco.

   B. Latitude 18°28'50", longitude 65°21'40".

   C. Date established and size (ha): 1979; 7.9.

   D. Type of waste: municipal.

   E. Loading (m^3/day): unknown.

   F. Operating method: Landfill.

2. Geologic formation: Ancient deltaoic, mud-flat deposits (old) and and swamp deposits (Qs).

3. Cover material: Mud, sand and swamp deposits. Fill transported from outside areas.

4. Approximate depth to water table (m): 0-3.

5. Drainage stream: Adjacent to Río Cibuco. Within flood-plain zone.

6. Pollution Potential:

Site is within mud and swamp deposit. Rainfall in area averages about 1,520 mm per year. Site within Río Cibuco flood-plain zone. Stringent monitoring and operational measures should be maintained as the site is bordered on the south by the Río Cibuco and leachate attenuation through soils will be essentially insignifiant.

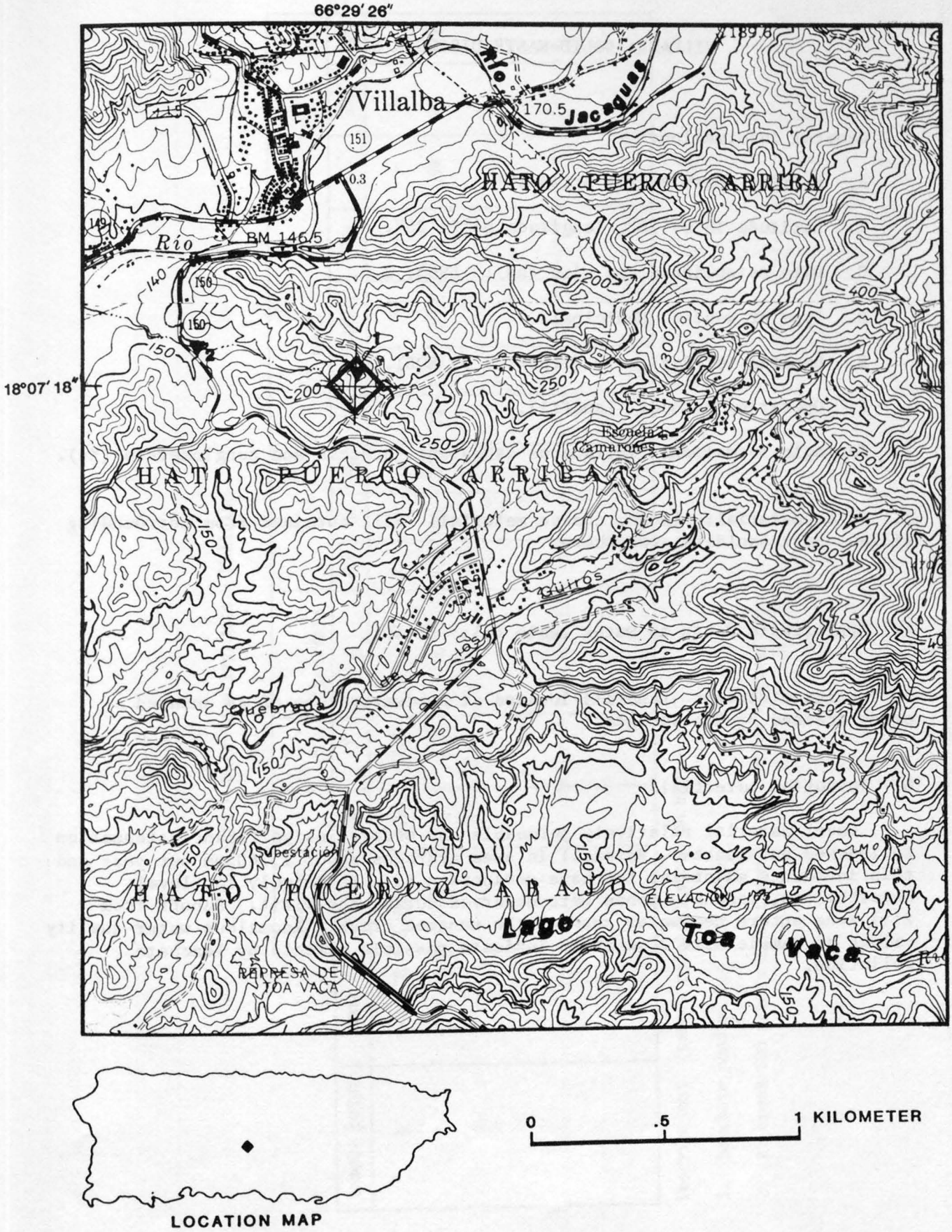


Figure 51.--Villalba solid-waste disposal site at Hato Puerco Arriba.

VILLALBA SOLID-WASTE DISPOSAL SITE

1. General information:

   A. Barrio: Hato Puerco Arriba.

   B. Latitude 18°07'18", longitude 66°29'26".

   C. Date established and size (ha): 1965; 2.0.

   D. Type of waste: Municipal.

   E. Loading (m^3/day): 79 (reported by EQB).

   F. Operating method: Landfill.

2. Geologic formation: Tuffaceous sandstone, breccia and conglomerate (Kt).

3. Cover material: Loose, coarse material. Fill obtained from surrounding hills. Rock boulders everywhere.

4. Approximate depth to water table (m): 35-40.

5. Drainage stream: Landfill located at headwater zone of an unnamed creek drained by Río Jacaguas.

6. Pollution potential:

Cover material relatively permeable and offers insignificant attenuation to leached substances. Rainfall in area averages about 1,240 mm per year and this incidence maintains leachate production at a relatively low level. Nevertheless, leachate ponds were observed during the visit. Runoff from fill zone enters headwater zone of the unnamed creek. Anomalous water-quality values at sample site 2 seems to indicate possible effects by leachate pollution.

Table 28.--Water-quality data - Villalba

		µmho/cm at 25°C		°C	liter/min	mg/L									
sample point	date	SC	pH	T	Q	DO	Ca	Mg	Na	K	HCO_3^-	CO_3	CL^-	SO_4^-	F^-
1	4-20-78	3,250	6.9	27.5	-	0	-	-	-	-	-	-	-	-	-
2	4-20-78	900	7.2	23.5	1	6.0	96	35	25	1.1	394	0	94	23	0.1

Description: (sample point(s) shown on map)

1. Leachate pond within fill site.

2. At creek 500 meters downstream of fill below Highway 150.

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APPENDIX

Description of Geologic Symbols

GEOLOGIC DESCRIPTION

Solid-waste disposal site		Geologic symbol	Description	Reference number
1	Aguada	Tt	Tuffaceous sandstone, siltstone, and shale.	6
2	Aguadilla	Tau	Aguada Limestone, upper member.-- Thick layers of very pale orange to pink hard calcarenite alternating with chalky and rubbly limestone; sparsely fossiliferous; at top and locally at lower positions 1 to 9 of orange to pink thin-bedded and cross-laminated calcarenite in which individual beds range in thickness from 1 to 7 cm; deep sinkholes common throughout belt of outcrop, 30-90 m thick.	18
3	Aguas Buenas	TKhv TKhd; KKa	Metamorphic hydrothermally altered rock. Light-gray clayey rock. TKhd.-- Intrusive rock, Hornblende diorite. KKa.--sedimentary rock, Aguas Buenas limestone member.	26
4	Aibonito	Kr	Robles Formation. Dominantly medium-gray to light-brown tuffaceous siltstone and medium-dark-gray to brownish-gray water-laid lapilli tuff common.	5
5	Añasco	TKs	Volcanic rocks, undivided. Sandstone, siltstone, conglomerate, lava, tuff, and tuffaceous breccia largely deposited in a marine environment.	6
6	Barceloneta	Ta;QTb	Ta.--Aguada Limestone. Limestone, medium- and fine-grained, locally very fine-grained, very pale- to grayish and pale-yellowish orange, yellowish orange, yellowish brown, grayish yellow, and dark gray, interbedded with subordinate grayish-orange and light-gray chalk and marl; commonly thick-bedded, but upper 2 to 5 meters is thin-bedded at most localities and commonly contains some quartz grains; 2 to 3 meters of translucent porcelaneous limestone occurs locally at the base.	17

GEOLOGIC DESCRIPTION--Continued

Solid-waste disposal site		Geologic symbol	Description	Reference number
			QTb.--Blanket deposits. Clayey quartz sand and sandy clay; moderate reddish brown, moderate yellowish brown, light brown and pinkish gray; locally cemented by iron oxides; cohesive even-textured mixtures of medium and fine quartz grains and kaolinitic clay; quartz sand to clay ratios commonly range from 90:10 to 30:70; deposits probably average more than 4 m thick and locally may exceed 30 m in thickness.	
7	Barranquitas	Kr	Robles Formation. Medium gray to light-brown tuffaceous siltstone.	5
8	Bayamón (old)	Kcn	Cancel Breccia Formation.	25
9	Cabo Rojo	Qs	Swamp and marsh deposits. Largely organic swamp muck, locally sandy or silty, and peat; water in these swamps is commonly moderately saline.	6
10	Caguas	Kl	Upper Cretaceous volcanic rocks.	6
11	Camuy	Tay;QTbs	Tay.--Aymamón Limestone. White to very pale orange, locally pale yellow and grayish-pink very pure limestone; lower part generally indurated into finely crystalline rather dense limestone, locally a rubble of recemented solution fragments generally of cobble size; upper part compact very finely crystalline chalk; on surface both parts weathered and recemented into irregular, solution sculptured dense limestone having abundant sharp spires a few centimeters high; thickness is 200± m.	19

GEOLOGIC DESCRIPTION--Continued

Solid-waste disposal site		Geologic symbol	Description	Reference number
			QTbs.--Blanket sand deposits. Mixtures of fine to medium quartz sand and light-brown to moderate-brown clay; all material mapped in this category has been lowered in altitude subsequent to deposition by solution of underlying limestone. Thickness is 0-30 (?) m.	
12	Carolina	Ta;Qa	Ta.--Aguada Limestone (Miocene)--Alternating beds of indurated, slightly quartziferous, very pale orange to pink, fine calcarenite and grayish-orange to very pale orange clayey and chalky limestone; some beds of soft sandy marlstone. Thickness about 50 m. Qa.--Alluvium and river-terrace deposits (Holocene and Pleistocene)--Sand, clay, and sandy clay. Thickness variable, possibly as great as 100 m.	16
13	Cayey	Kl	Upper Cretaceous volcanic rocks.	6
14	Ceiba	Kl	Lava, lava breccia, tuff, and tuffaceous breccia. Largely deposited in a marine environment; some thin-bedded sandstone and siltstone.	6
15	Ciales	Tl	Lares Limestone.	6
16	Cidra	Kl	Lava, tuffaceous breccia.	6
17	Corozal	Ka	Avispa Formation. Greenish-gray to dark gray andesite lava flows. Interbedded volcanic sandstone and siltstone.	22
18	Fajardo	Kl	Lava, lava breccia, tuff, and tuffaceous breccia. Largely deposited in a marine environment; some thin-bedded sandstone and siltstone.	6
19	Guánica	Tpl;Qa	Ponce Limestone and colluvium.	6

	Solid-waste disposal site	Geologic symbol	Description	Reference number
20	Guayama (new)	Kl	Lava tuff.	6
21	Guayama (old)	Qa	Alluvial deposits.	6
22	Guaynabo	TKd;Kc	TKd.--Quartz diorite, chiefly medium to light-greenish gray albitized quartz porphyry. Rock is medium-grained and equigranular in centers of large stocks and finer-grained in the smaller dikes. Weathers to yellowish-gray sand containing flecks of mica. Kc.--Camarones Sandstone, thin-bedded dark-gray calcareous siltstone (possibly carbonaceous), and thicker bedded dark-gray volcanic wacke; contains some volcanic pebble conglomerate. Thickness uncertain.	24
23	Gurabo	Qa	Colluvium.	6
24	Hatillo	Tag	Aguada Limestone. Hard, thick-bedded to massive calcarenite and dense limestone and marl; commonly contains some quartz grains.	6
25	Humacao	Kl	Tuffaceous sandstone, siltstone and breccia.	6
26	Isabela	Tay	Aymamón Limestone, lower member. White to very pale orange, locally pale-yellow and grayish-pink, massive to thick-bedded very pure fossiliferous limestone; generally indurated into finely crystalline rather dense limestone, locally a rubble of recemented solution cobbles. Local beds of thin-bedded granular limestone and chalk. Commonly solution riddled and weathered on surface into dense limestone having abundant sharp spires as much as 30 cm high. Rests with sharp contact on underlying Aguada Limestone. 110-140 m thick.	18

GEOLOGIC DESCRIPTION--Continued

	Solid-waste disposal site	Geologic symbol	Description	Reference number
27	Jayuya	Tkg	Plutonic igneous rocks.	11
28	Juncos	Tkgo	Plutonic rocks.	6
29	Lajas (new)	Kt	Tuffaceous breccia and tuff.	6
30	Lajas (old)	Qs	Swamp and marsh deposits. Largely organic swamp muck, locally sandy or silty, and peat; water in these swamps is commonly moderately saline.	6
31	Manatí	Tay; QTb	Tay.--Aymamón Limestone.	17
			QTb.--Blanket deposits, clay, sandy clay found between limestone ridges and believed to have been lowered by solution of the underlying limestone (Briggs, 1966). 0-30(?) m thick.	
32	Maricao	Ky	Yauco mudstone.	6
33	Maunabo	TKp; Qa	Plutonic rocks, diorite and granodiorite rock of the San Lorenzo batholith.	6
			Qa.--Alluvial deposits.	
34	Mayaguez	Kt	Lava tuff and shale.	6
35	Naguabo	Qa	Colluvium.	6
36	Naranjito (proposed)	Kp	Perchas Formation.	25
37	Orocovis	Kr	Robles Formation. Medium gray to light-brown tuffaceous siltstone.	4
38	Quebradillas	Tay;QTbs	Tay.--Aymamón Limestone. White to very pale orange, locally pale yellow and grayish-pink very pure limestone; lower part generally indurated into finely crystalline rather dense limestone, locally a rubble of recemented solution fragments generally of cobble size; upper part compact very finely crystalline chalk; on surface both parts weathered and recemented into irregular, solution sculptured dense limestone having abundant sharp spires a few centimeters high; thickness is 200± m.	19

GEOLOGIC DESCRIPTION--Continued

Solid-waste disposal site	Geologic symbol	Description	Reference number
		QTbs.--Blanket sand deposits. Mixtures of fine to medium quartz sand and light-brown to moderate-brown clay; all material mapped in this category has been lowered in altitude subsequent to deposition by solution of underlying limestone. Thickness is 0-30 (?) m.	
39 Rincón	TKs	Tuffaceous sandstone, siltstone, and shale.	6
40 Río Grande	TKmi	Mafic dikes and sheet, chiefly fine- to coarse-grained diabase and diabase porphyry. Most bodies are early Tertiary in age, younger than the major folds and faults. Includes some andesitic to basaltic dikes related to Cretaceous and lower Tertiary volcanic rocks.	27
41 Sabana Grande	Ks	Serpentinite. Serpentinized peridotite (?); probably emplaced during the Early or early Late Cretaceous. Extensive deep weathering.	6
42 Salinas	Qs	Swamp and marsh deposits. Largely organic swamp muck, locally sandy or silty, and peat; water in these swamps is commonly moderately saline.	6
43 San Germán	Kt	Tuffaceous breccia and conglomerate.	6
44 San Lorenzo	Kl	Lava, lava breccia, tuff, and tuffaceous breccia.	6
45 San Sebastián	Tscc	San Sebastián Formation. Clay with chert pebbles; clay usually white, but other colors at same localities; widespread lenses up to 2 m thick, pebbles up to 5 cm in diameter.	28
46 Santa Isabel	Qa	Alluvial deposit.	6

GEOLOGIC DESCRIPTION--Continued

Solid-waste disposal site	Geologic symbol	Description	Reference number
47 Utuado	TKu	Rocks of the Utuado pluton. Mostly massive granodiorite, but includes quartz diorite, quartz monzonite, diorite and gabbro.	23
48 Vega Baja	Qd;Qs	Qd.--Ancient deltaic and mud-flat deposits.--In the northern third of the quadrangle extensive deposits of carbonaceous sandy clay seemingly are parts of an ancient delta and related mud flats deposited by the Río de la Plata at the time the river flowed through the Higuillar gap.	20
		Qs.--Swamps and swamp deposits.--In the coastal area of the quadrangle extensive deposits of carbonaceous sandy clay and muck fill depressions between ancient and recent deltaic deposits and areas that until recently were lagoons. Some of the swamps are underlain by thin beds of peat, derived largely from mangrove and grasses.	
49 Vega Baja (old)	Tay	Aymamón Limestone, white to very pale orange, locally pale yellow and grayish pink, massive to thick-bedded very pure fossiliferous limestone generally indurated by secondary cementation into finely crystalline rather dense limestone (Monroe, 1966), locally a rubble of recemented solution breccia. Commonly solution riddled and indurated on surface into hard limestone having abundant sharp spires as much as 30 cm high. Rests with sharp contact on underlying Aguada Limestone. 190-200 m thick.	17
50 Villalba	Kt	Tuffaceous sandstone, breccia and conglomerate.	6

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