5.3 Hydrogeological Provinces and Groundwater Quality

5.3.1 Geology by Drill Holes

The rocks on ground surface in the project area are considered to be well-consolidated enough as far as the current investigations on ground surface concerned, however, discharged cuttings by drill operations up to ground surface are generally argillaceous and clayey. Therefore, the direct estimations of rocks deep underground by cuttings are to be hardly made in general.

Estimations of general geology along drill hole walls and rock consolidation degrees were established by recording the bare facts and characters of cuttings in connection with references to the results of surface geological mapping, surface geophysics and geophysical hole loggings by the current works.

Drill site elevations above sea were determined by readings of contours on topographical maps of one to 50,000 scale.

(1) No.1: El Manantial

Drill hole depth	:	152.32 m
Drill site elevation	:	160.00 m high above sea level
Drill hole bottom elevation	:	7.65 m high above sea level
General characters of cuttings	:	Argillaceous and slimy, locally associated with breccia-formed crushed rock fragments.
General conditions of cuttings	:	
0.00 - 3.00 m	:	Brown soil
3.00 - 27.00 m	:	Brownish gray earthy slime
27.00 - 152.35 m	:	Gray and very adhesive clay slime
27.00 - 42.00 m	:	Granule-sized fragments of quartz and sandstone are associated. Specific resistivity values by geophysical hole loggings are slightly high and are disorderly represented.
99.00 - 114.00 m	:	Quantity of granule-sized fragments increases in. Those are not shown by geophysical loggings.

132.00 - 135.00 m	:	Associated with medium-grained (1/4 mm) fragments. Specific resistivity values are slightly high and are disorderly represented.

Geology in drill hole :

Chiefly consists of weakly-consolidated mudstone beds, intercalated by relatively well-consolidated mudstone beds.

(2) No.2 : El Guayo

Drill hole depth	:	150.00 m
Drill site elevation	:	148.00 m high above sea level
Drill hole bottom elevation	:	−2.00 m below sea level

General characters of cuttings:

Argillaceous and slimy, locally associated with breccia-formed crushed rock fragments.

General conditions of cuttings :

0.00 - 12.00 m	:	Brown soil
12.00 - 24.00 m	:	Brownish gray earthy slime
24.00 - 150.00 m	:	Gray and very adhesive clay slimeassociated with crushed angular slaty fragments
38.00 - 39.00 m	:	Quantity of granule-sized fragments of quartz and sandstone increases in. Specific resistivity values by geophysical hole logging are slightly high and are disorderly represented.

Geology in drill hole :

Chiefly consists of weakly-consolidated mudstone beds, intercalated by relatively well-consolidated mudstone beds.

(3) No.3 : Las Aguas

Drill hole depth	:	71.40 m
Drill site elevation	:	10.00 m high above sea level
Drill hole bottom elevation	:	−61.40 m below sea level

General characters of cuttings :

Silt and/or clay in upper and sandy cuttings in lower parts.

General conditions of cuttings :

0.00 - 3.00 m	:	Brown soil
3.00 - 27.4.00 m	:	Brown silt to clay, very adhesive, sparsely associated with fine-grained fragments.
27.40 - 71.40 m	:	Grayish to greenish brown silt, very adhesive, minorly associated with fine-grained fragments.
57.80 - 89.90 m	:	medium- to coarse-grained sand beds. High specific resistivity and negative spontaneous potential values by hole logging.

Geology in drill hole

Chiefly consists of silt and clay beds, intercalated by sands tone beds at 57.8 m.

(4) No.4 : Jobo Corcobado

Drill hole depth	:	61.00 m
Drill site elevation	:	30.00 m high above sea level
Drill hole bottom elevation	:	−31.00 m below sea level

General characters of cuttings:

Brownish slimy and sandy cuttings, with basal gravel bed at the depth of 30.5 m, underlain by grayish slimy and sandy cuttings.

General conditions of cuttings :

0.00 - 30.50 m	:	Alternations of brown fine sand and silt-sandy silt beds.
27.50 - 30.50 m	:	Quartz, sandstone, slate and shale fragments of granule to pebble size. Hole loggings were not made because of casing pipes infixing.
30.50 - 61.00 m	:	Chiefly consists of grayish alternation of mud and silt beds.

Geology in drill hole :

Floodplain sediments to the depth of 30.5 m from ground surface, underlain by basal gravel bed. Alternations of siltstone and sandstone beds of Tertiary age beyond the above.

(5) No.5 : La Pinta

Drill hole depth	:	151.00 m
Drill site elevation	:	48.00 m high above sea level
Drill hole bottom elevation	:	−103.00 m below sea level

General characters of cuttings :

Brown fragments and slimes of calcareous sandstone by weathering to the depth of 33.00 m, underlain by alternations of calcareous sandstone and greenish gray mudstone beds.

General conditions of cuttings :

0.00 - 6.00 m	:	Brown soil
6.00 - 33.00 m	:	Alternations of mudstone and calcareous sandstone beds, brown.
33.00 - 151.00 m	:	Alternations of mudstone and calcareous sandstone beds, greenish gray. Specific resistivity values by hole logging are higher in this segment than that in the upper.
42.00 - 48.00 m	:	Quartz fragments are observed.
48.00 - 68.00 m	:	Calcareous sandstone beds, well-consolidated. Specific resistivity values by hole logging are locally high.
96.00 - 114.00 m	:	Calcareous sandstone beds, well-consolidated. Specific resistivity by hole logging represents the highest specific resistivity values by geophysical hole logging in the current hole.
135.00 - 140.00 m	:	Fragments of arkose and metamorphic sandstone are observed. Specific resistivity values by geophysical hole logging are relatively high.

Geology in drill hole :

Chiefly consists of alternations of calcareous sandstone and mudstone beds. Mudstone beds are weakly-consolidated. Fragmental breccias of metamorphic rocks of Cretaceous age are observed in the beds at the depth of 135.00 m - 140.00 m segment.

(6) No.6 : Ranchadero

Drill hole depth	:	80.00 m
Drill site elevation	:	37.00 m high above sea level
Drill hole bottom elevation	:	−43.00 m below sea level

General characters of cuttings :
Almost homogeneous with slight change in lithology.

General conditions of cuttings :

0.00 - 9.10 m	:	Brown very fine grained sand
9.10 - 18.20 m	:	Gray very fine grained sand
18.20 - 54.76 m	:	Gray very fine grained sand to silt
54.76 - 63.80 m	:	Gray very fine grained sand
63.80 - 80.00 m	:	Gray very fine grained sand to silt
48.00 - 51.00 m	:	Granule sized fragment, partly silicified

Geology in drill hole :

ground surface - 18.20 m	:	fine grained sandstone
18.20 - 54.70 m	:	sandy siltstone
54.70 - 63.80 m	:	very fine grained sandstone
63.80 - 80.00 m	:	siltstone

(7) No.7 : Guayubincito

Drill hole depth	:	62.48 m
Drill site elevation	:	45.00 m high above sea level
Drill hole bottom elevation	:	−17.48 m below sea level

General characters of cuttings :

Characterized by being associated with carrying shell fragments. Chiefly consists of sandstone, fine-grained sand and silt beds in ascending order.

General conditions of cuttings :

0.00 - 18.20 m	:	Brown silt and fine-grained sand beds.
6.10 - 15.20 m	:	Shell fragments are observed.
18.20 - 48.60 m	:	Very fine-grained sandy silt beds, grayish.
24.30 - 27.40 m	:	Abundant quantity of fragmental shells.
39.50 - 42.60 m	:	Abundant quantity of fragmental shells. Specific resistivity values by geophysical logging are slightly disorderly.
48.60 - 60.80 m	:	Calcareous fine-grained sandstone cuttings and shell fragments. Specific resistivity values by geophysical logging sharply turn to higher ones than those in upper segments.
61.80 - 62.48 m	:	Grayish silt cuttings. Specific resistivity values by geophysical hole logging sharply turn to be low.

Geology in drill hole :

Alternations of fine-grained sandstone and silt beds, well-consolidated, and associated with shell fragments to the depth of 48.60 m. Silt beds are associated beyond 60.8 m depth.

(8) No.8 : Cabeza de Toro

Drill hole depth	:	134.30 m
Drill site elevation	:	115.00 m high above sea level
Drill hole bottom elevation	:	−19.30 m below sea level

General characters of cuttings :

Shown in the following section.

General conditions of cuttings :

0.00 - 18.20 m	:	Brown silt and fine-grained sand.
6.10 - 16.20 m	:	Shell fragments are associated.
18.20 - 48.60 m	:	Very fine-grained sandy silt, grayish.
4.30 - 27.40 m	:	Abundant quantity of shell fragments are associated.
39.50 - 42.60 m	:	Abundant quantity of shell fragments are associated. Specific resistivity values by geophysical hole logging are slightly disorderly.
48.60 - 60.80 m	:	Calcareous fine-grained sandstone, associated with shell fragments. Specific resistivity values by geophysical logging sharply turn to be higher than those in upper segments.
60.80 - 62.48 m	:	Grayish silt. Specific resistivity values by geophysical logging sharply turn to be low.

Geology in drill hole :

Alternations of fine-grained sandstone and silt beds to the depth of 48.6m. Associated with shell fragments. Sandstone beds, well-consolidated, associated with shell fragments, are observed beyond 48.6 m-depth, while, silt beds are associated beyond 60.8 m-depth.

(9) No.9: Palo Blanco

Drill hole depth	:	150.80 m
Drill site elevation	:	80.00 m high above sea level
Drill hole bottom elevation	:	−70.80 m below sea level

General conditions of cuttings :

Chiefly consists of sedimentary materials, finer in lower part of the hole, meanwhile, silty and fine-grained sandy cuttings from upper part, and silty and slimy cuttings from lower part. Generally associated with shell fragments, however, varies in quantity with the depth.

General conditions of cuttings :

0.00 - 27.00 m	:	Alternations of silt and fine- to medium-grained sands, brownish.
27.00 - 111.00 m	:	Gray sandstone cuttings, associated with shell fragments.
36.00 - 42.0 m	:	Increases in quantity of quartz grains.
42.0 - 45.0 m	:	Increases in quantity of shell fragments.
78.00 - 111.00 m	:	Extremely high association with shell fragments and quartz grains. High specific resistivity values by geophysical hole logging are shown in varied segments.
111.00 - 160.80 m	:	Gray silt and slime.

Geology in drill hole :

Alternations of siltstone and fine-grained sandstone beds are observed to the depth of 27.00 m from ground surface. Granularity of the above rocks slightly increases in size, while, quartz and shell fragments also increases in quantity beyond that to the 111.00m-depth. Fine-grained siltstone and sandstone beds, with finer quartz grains, and observed beyond 111.00 m-depth.

(10) No.10 : La Vigia

Drill hole depth	:	72.00 m
Drill site elevation	:	35.00 m high above sea level
Drill hole bottom elevation	:	−37.00 m below sea level

General conditions of cuttings :

Alternations of sandstone and shale beds, intercalated by gravel beds in upper part. Clay bed is observed in basal part of the alternations.

General conditions of cuttings

0.00 - 19.50 m	:	Gravel bed
17.50 - 19.50 m	:	Sand and gravel
19.50 - 47.50 m	:	Sandstone bed
19.50 - 35.00 m	:	Coarse-grained sandstone bed. High pecific resistivity values by geophysical logging are shown at the segment bottom.
35.00 - 39.00 m	:	Alternations of sandstone and shale beds.
39.00 - 47.00 m	:	Fine-grained sandstone beds. High specific resistivity values by geophysical logging are shown in upper part of the segment.
47.00 - 70.00 m	:	Shale bed
47.00 - 56.00 m	:	Brownish cuttings
56.00 - 70.00 m	:	Greenish gray cuttings
70.00 - 72.00 m	:	Very soft clay bed

Geology in drill hole :

Alternations of siltstone and fine-grained sand stone beds to 27.00 m-depth from ground surface. Granularity of the rocks increases in size beyond the above to 111 m-depth, while relatively increases in quantity of quartz grains and shell fragments. Rock faces beyond 111 m-depth turnedly show of siltstone and/or mudstone, while granularity of quart6z grains decreases in.

(11) No.11 : Esperon

Drill hole depth	:	151.00 m
Drill site elevation	:	85.00 m high above sea level
Drill hole bottom elevation	:	−66.00 m below sea level

General conditions of cuttings :

Cuttings of gravel beds, arkose sand cuttings in upper part and metamorphose rock cuttings in lower part. Largely recovered in quantity.

General conditions of cuttings :

0.00 - 6.00 m	:	Brown earthy materials
6.00 - 105.00 m	:	Arkose sandy fragments, associated with fragmental sandy materials - metamorphose sandstone - of small quantity.
21.00 - 27.00 m	:	Very coarse fragments
27.00 - 78.00 m	:	Fragments of granule size.
78.00 - 105.00 m	:	Slightly increases in quantity of fragmental sandy materials. High specific resistivity values by geophysical hole logging are shown in basal part of the segment.
105.00 - 151.00 m	:	Fragmental sandy materials, associated with arkose sandy fragments of small quantity.
105.00 - 114.00 m	:	Increases in quantity of brownish gray slimes.

Geology in drill hole :

Chiefly consists of arkose sand-gravel beds from ground surface to 105 m-depth, while, sand-gravel beds of metamorphose rocks beyond 105 m-depth to the hole bottom.

(12) No.12: Chacuey

Drill hole depth : 151.00 m

Drill site elevation : 90.00 m high above sea level

Drill hole bottom elevation : −61.00 m below sea level

General characters of cuttings :

Ground surface to 24.00 m-depth :

Sand and gravel cuttings rich in quartz grain contents.

24.00 m- to 30.00 m-depth : Slimy cuttings.

Further deep :

Chiefly of fragmental cuttings-metamorphosed sandstone cuttings -, associated with quartz grains.

General conditions of cuttings :

0.00 - 9.00 m	: Brown earthy cuttings.
9.00 - 24.00 m	: Arkose rock fragments, minorly associated with fragmental sandy cuttings - metamorphose sandstone -.
24.00 - 30.00m	: Adhesive slime and clay, associated with thin quartz grains and fragmental materials.
30.00 - 151.00 m	: Chiefly of fragmental cuttings - metamorphosed sandstone -, associated with quartz grains in some locations.
30.00 - 33.00 m	: Coarse-grained cuttings
51.00 - 57.00 m	: Coarse- to very-coarse-grained cuttings.
66.00 - 69.00 m	: Coarse-grained cuttings
84.00 - 99.00 m	: Granule-sized cuttings
111.00 - 114.00 m	: Coarse- to very-coarse-grained cuttings.
120.00 - 123.00 m	: Coarse- to very-coarse-grained cuttings, very hard.
132.00 - 135.00 m	: Coarse-grained cuttings, very hard. High specific resistivity values by geophysical hole logging are shown in the segments with coarse-grained cuttings. Those are parti-cularly sharply high beyond 120.00 m-depth.

Geology in drill hole :

Ground surface to 24.00 m-depth:

Sand-gravel beds, associated with coarse-grained quartz grain.

24.00 m - 30.00 m-depth : Mudstone beds and clay

30.00 m-depth to bottom :

Sandy metamorphic rock. The rock bed is intensely weathered to the depth of 114.00 m, while, unweathered beyond that.

(13) No.13 : Los Arroyos

Drill hole depth	:	135.20 m
Drill site elevation	:	59.00 m high above sea level
Drill hole bottom elevation	:	−76.20 m below sea level

General characters of cuttings:

Ground surface to about 30.00 m-depth :

Chiefly of arkose material cuttings, rich in quartz grain contents.

30.00 m to 120.00 m-depth :

Fragmental cuttings of arkose material and metamorphosed sandstone in equal quantity ratio. Very hard beyond 120.00 m-depth.

General conditions of cuttings :

0.00 - 3.00 m	:	Brown earthy
3.00 - 30.00 m	:	Arkose fragments, minorly associated with metamorphosed sandstone fragments. Partly rich in sandstone fragments contents.
30.00 - 39.00 m	:	Brown slime, associated with sandstone fragments.
30.00 - 102.00 m	:	Arkose and metamorphosed sandstone fragments in equal quantity ratio.
102.00 - 135.20 m	:	Increases in size of fragments, hard.

Geology in drill hole :

Ground surface to about 30.00 m-depth :

Arkose sand-gravel beds rich in quartz grain contents.

30.00 m to 39.00 m-depth :

Mudstone beds, underlain by metamorphosed sandstone beds.

Weathered to the depth of 102.00 m, while hard beyond that.

(14) No.14: La Gorra

Drill hole depth : 76.20 m

Drill site elevation : 118.00 m high above sea level

Drill hole bottom elevation : 41.80 m high above sea level

General characters of cuttings :

Chiefly of grayish silty cutting to the depth of 36.40 m, while, of metamorphosed sandstone cutting beyond that.

General conditions of cuttings :

0.00 - 9.10 m	: Cuttings of sand and gravel of metamorphosed sandstone.
9.10 - 36.40 m	: Silty fragmental cuttings, grayish brown, associated with metamorphosed sandstone cuttings.
36.40 - 76.20 m	: Cuttings of metamorphosed sandstone/ shaleand siltstone.
60.80 - 76.20 m	: Sparsely associated with siltstone cuttings. Specific resistivity values by geophysical hole logging gare shown to be very high.

Geology in drill hole :

Ground surface - 9.00 m	: Sand-gravel beds
9.00 m - 34.60 m	: Silt beds
Beyond 34.60 m	: Underlain by metamorphosed sandstone beds. Unweathered beyond 60.80 m-depth.

(15) No.15: Buen Gust

Drill hole depth : 44.40 m

Drill site elevation : 180.00 m high above sea level

Drill hole bottom elevation : 135.60 m high above sea level

General characters of cuttings :

Ground surface - 15.00 m	: Surface soil, and fragments of granodiorite cuttings.
15.00 m-35.00 m	: Weathered chips and fragments of granodiorite cuttings.
Beyond 35.00 m	: Unweathred granodiorite fragments.

General conditions of cuttings :

0.00 - 15.00 m	:	Earthy and weathered granodiorite fragments,
15.00 - 35.00 m	:	Weathered granodiorite fragments
35.00 - 44.40 m	:	Unweathered granodiorite gragments.

Geology in drill hole :

Ground surface - 15.00 m	:	Surface soil and gravels of granodiorite.
15.00 m - 35.00 m	:	Weathered granodiorite with cracks and joints.
Beyond 35.00 m	:	Unweathered granodiorite body.

(16) No.16 : La Penita Abajo

Drill hole depth	:	68.40 m
Drill site elevation	:	130.00 m high above sea level
Drill hole bottom elevation	:	61.60 m high above sea level

General characters of cuttings :

Ground surface - 15.00 m	:	Earthy and tonalite cuttings and fragments.
15.00 m-35.00 m	:	Weathered fragments of tonalite.
Beyond 35.00 m	:	Unweathred tonalite fragments.

General conditions of cuttings :

0.00 - 15.00 m	:	Earthy, fragments of weathered tonalite.
15.00 - 35.00 m	:	Fragmental cuttings of weathered tonalite.
35.00 - 68.40 m	:	Fragmental cuttings of unweathered tonalite.

Geology in drill hole :

Ground surface - 15.00 m	:	Surface soil and gravels of tonalite
15.00 m - 35.00 m	:	Weathered tonalite with cracks and joints
Beyond 35.00 m	:	Unweathered tonalite.

(17) No.17: La Penita Arriba

Drill hole depth : 89.00 m

Drill site elevation : 362.00 m high above sea level

Drill hole bottom elevation : 273.00 m high above sea level

General characters of cuttings :

Ground surface - 15.00 m : Earthy, cuttings and fragments of tonalite.

Beyond 15.00 m : Weathered and unweathered cuttings and fragments of tonalite alternatively.

General conditions of cuttings :

0.00 - 15.00 m : Slimy, fragments of weathered tonalite

15.00 - 35.00 m : Fragments of weathered tonalite.

35.00 - 55.00 m : Fragments of unweathered tonalite.

55.00 - 85.00 m : Fragments of weathered tonalite.

85.00 - 89.00 m : Fragments of unweathered tonalite.

Geology in drill hole :

Ground surface - 15.00 m : Surface soil and fragments of tonalite.

Beyond 15.00 m : Weathered and unweathered tonalite with cracks and joints.

(18) No.18 : Cruce de Mariano Cestero

Drill hole depth : 53.38 m

Drill site elevation : 680.00 m high above sea level

Drill hole bottom elevation : 626.62 m high above sea level

General characters of cuttings :

Ground surface - 15.25 m : Reddish slimy materials.

15.25 m - 21.35 m : Fragments and cuttings of arkose sand.

21.35 m - 39.65 m : Fragments of metamorphosed tuff.

39.65 m - 53.38 m : Fragments of metamorphosed sandstond.

Beyond 39.65 m : Fragments and cuttings of metamorphosed sandstond.

Geology in drill hole :

Ground surface - 15.25 m	:	Reddish surface soil.
15.25 m - 21.35:		Granitic rock.
21.35 m - 39.65		Altered andesitic tuff bed.
Beyond 39.65 m	:	Metamorphosed sandstone bed.

(19) No.19 : El Mamoncito

Drill hole depth	:	94.50 m
Drill site elevation	:	300.00 m high above sea level
Drill hole bottom elevation	:	205.50 m high above sea level

General characters of cuttings :

Argillaceous and slimy, associated with gravel formed crushed rock fragments.

General conditions of cuttings :

0.00 - 18.00 m	:	Yellowish brown silt with gravel (calcareous Sandstone)
18.00 - 21.50 m	:	Dark grayish fine grained sandy silt
21.50 - 33.00 m	:	Bluish gray to dark bluish gray fine sand to silt
33.00 - 46.00 m	:	Yellowish gray silty mud (mudstone/Shale)
46.00 - 52.00 m	:	Gravelly silt to mud
52.00 - 64.00 m	:	Bluish gray gravelly mudstone/shale
64.00 - 94.00 m	:	Gray gravelly fine sandy silt (mudstone/claystone with Conglomerate)

Geology in drill hole :

ground surface - 33.00 m	:	Surface soil and sandy silt
33.00 - 52.00 m	:	Silty mudstone
52.00 - 64.00 m	:	Gravelly shale
64.00 - 94.00 m	:	Sandy siltstone

(20) No.20 : Las Rosas

Drill hole depth	:	150.80 m
Drill site elevation	:	350.00 m high above sea level
Drill hole bottom elevation	:	199.20 m high above sea level

General characters of cuttings :

Argillaceous and slimy, associated with medium to coarse grain (partly granule sized) formed crashed rock fragments.

General conditions of cuttings :

0.00 - 9.00 m	:	Brownish soil with medium graind fragment of Sandstone white, greenish gray, brownish
9.00 - 21.00 m	:	Medium graind fragment of sandstone with brownish gray soil and Shell
21.00 - 27.00 m	:	Coarse graind of fragment of sandstone with weakly brownish colourd Shell fragment
27.00 - 33.00 m	:	Very coarse to granule sized black, blackish gray or sandstone with a lot of shell fragment.
33.00 - 63.00 m	:	Medium to Coarse graind sandstone
63.00 - 66.00 m	:	Gray silt with sandstone
66.00 - 69.00 m	:	Very coarse graind granule sized sandstone
69.00 - 78.00 m	:	Gray silt with medium graind sandstone
78.00 - 90.00 m	:	Coarse to very coarse graind sandstone with shell fragment
90.00 - 150.8 m	:	Gray Silt with coarse to very corse graind sandstone

Geology in drill hole :

ground surface - 69.00 m	:	Surface soil and medium-coarse sandstone with thin layer of siltstone
69.00 - 78.00 m	:	Gray sandy siltstone
78.00 - 90.00 m	:	Coarse graind sandstone with shell fragment
90.00 - 150.8 m	:	Sandy siltstone

(21) No.21 : Lamesdero

Drill hole depth	:	110.00 m
Drill site elevation	:	270.00 m high above sea level
Drill hole bottom elevation	:	160.00 m high above sea level

General characters of cuttings :

Argillaceous and slimy, associated with coarse grain (partly gravelly) formed crushed rock fragments.

General conditions of cuttings :

0.00 - 6.00 m	:	Weatherd gravel with coarse sand
6.00 - 12.00 m	:	Grayish clay with gravel
12.00 - 18.50 m	:	Bluish gray clay
18.50 - 30.00 m	:	Bluish gray clayey coarse grained sand/grarel
30.00 - 41.00 m	:	Bluish gray fine grained sandy mudstone with few of shale
41.00 - 47.00 m	:	Bluish gray fine grained sandstone/ gravelly mudstone
47.00 - 49.00 m	:	Fine sandy claystone
49.00 - 52.00 m	:	Gravelly mudstone
52.00 - 60.00 m	:	Bluish gray fine sandy/silty mudstone (mudstone/claystone with conglomerate)
60.00 - 68.00 m	:	Brown colourd Claystone
68.00 - 110.0 m	:	Bluish gray fine sandy/silty mudstone (mudstone/claystone with conglomerate) is accompanied by gray gravelly fine sand to silt at lower part

Geology in drill hole :

ground surface - 6.00 m	:	Weatherd gravel layer
6.00 - 18.50 m	:	Blue clay with gravel
18.50 - 30.00 m	:	Clayey coarse grained sand and gravel
30.00 - 68.00 m	:	Alternation of siltstone and mudstone
68.00 - 110.0 m	:	Sandy mudstone

(22) No.22 : Los Corvanos

Drill hole depth	:	120.00 m
Drill site elevation	:	390.00 m high above sea level
Drill hole bottom elevation	:	270.00 m high above sea level

General characters of cuttings :

Argillaceous and slimy, partly associated with gravelly formed crushed rock fragments at upper · most.

General conditions of cuttings :

0.00 - 11.00 m	:	Yellowish brown calcareous conglomerate
11.00 - 22.00 m	:	Dark gray mudstone to siltstone
22.00 - 120.0 m	:	Gray marine deposit fine sandy to silty mudstone/shale

Geology in drill hole :

ground surface - 11.00 m	:	Calcareous conglomerate
11.00 - 22.00 m	:	Mudstone
22.00 - 120.00 m	:	Shale

(23) No.23 : Palo Seco

Drill hole depth	:	100.00 m
Drill site elevation	:	450.00 m high above sea level
Drill hole bottom elevation	:	350.00 m high above sea level

General characters of cuttings :

Argillaceous and slimy, partly associated with gravelly formed crushed rock fragments at lower · most.

General conditions of cuttings :

0.00 - 4.50 m	:	Brown mudstone
4.50 - 100.0 m	:	Gray marine deposit fine sandy to silty mudstone/shale are accompanied by gray gravelly fine sand to silt at lowest part

Geology in drill hole :

ground surface - 100.0 m	:	Mudstone/shale

(24) No.24 : Asiento Miguel

Drill hole depth	:	65.00 m
Drill site elevation	:	630.00 m high above sea level
Drill hole bottom elevation	:	565.00 m high above sea level

General characters of cuttings :

Argillaceous and slimy, partly associated with gravelly formed crushed rock fragments at middle to upper part.

General conditions of cuttings :

0.00 - 13.00 m	:	Brown clay with gravel (marly shale)
13.00 - 24.00 m	:	Light brown calcareous conglomerate/ gravel
24.00 - 30.50 m	:	Grayish clay
30.50 - 45.00 m	:	Grayish gravelly marly shale/ mudstone
45.00 - 65.00 m	:	Bluish gray shale/mudstone

Geology in drill hole :

ground surface - 13.00 m	:	Marly shale with gravel
13.00 - 24.00 m	:	Calcareous conglomerate
24.00 - 30.50 m	:	Clay
30.50 - 65.00 m	:	Marly shale

(25) No.25 : Angostura

Drill hole depth	:	50.00 m
Drill site elevation	:	30.00 m high above sea level
Drill hole bottom elevation	:	−20.00 m below sea level

General characters of cuttings :

Argillaceous and slimy form

General conditions of cuttings :

0.00 - 2.50 m	:	Brown silty soil
2.50 - 10.00 m	:	Yellow clayey silt
10.00 - 21.00 m	:	Dark gray siltstone
21.00 - 50.00 m	:	Dark brown siltstone to claystone

Geology in drill hole :

ground surface - 10.00 m : Soil and clayey silt

10.00 - 21.00 m : Siltstone

21.00 - 50.00 m : Siltstone to mudstone

(26) No.26 : Baitoa

Drill hole depth : 50.00 m

Drill site elevation : 0.00 m high above sea level

Drill hole bottom elevation : --50.00 m below sea level

General characters of cuttings :

Argillaceous and slimy, associated with coarse grain to gravelly (at lower · most part) formed crushed rock fragments.

General conditions of cuttings :

0.00 - 3.00 m : Soil and calcareous mud

3.00 - 6.00 m : Calcareous coarse sand

6.00 - 27.00 m : Milky white siltstone and milky yellow white limestone

27.00 - 30.00 m : Very coarse grained calcareous sandstone

30.00 - 39.00 m : Medium sand with limestone gravel (coaral reaf)

39.00 - 50.00 m : Limestone gravel and milky white siltstone

Geology in drill hole :

ground surface - 3.00 m : Soil and calcareous mudstone

6.00 - 27.00 m : Alternation of calcareous siltstone and limestone

27.00 - 50.00 m : Calcarerous sandstone and limestone gravel (coral reef)

(27) No.27 : Mariano Cestero

Drill hole depth	:	61.00 m
Drill site elevation	:	680.00 m high above sea level
Drill hole bottom elevation	:	619.00 m high above sea level

General characters of cuttings :

Argillaceous and slimy, associated with coarse grain to granule size formed crushed rock fragments at lower · most part.

General conditions of cuttings :

0.00 - 30.00 m	:	Reddish brown soily clay
30.00 - 36.00 m	:	Reddish brown soily clay with brownish black metamorphosed tuffaceous sandstone
36.00 - 42.00 m	:	Angular and granule sized brownish black fragment of altered tuffaceous sandstone and brownish silt
42.00 - 45.00 m	:	Coarse graind fragment
45.00 - 48.00 m	:	Angular and granule sized fragment
48.00 - 51.00 m	:	Granule sized fragment, partly silicified quartz film
51.00 - 54.00 m	:	Very coarse graind to granule sized fragment, angular quartz film
54.00 - 61.00 m	:	Coarse medium grained
Geology in drill hole	:	
ground surface - 36.00 m	:	Soil clay and metamorphosed tuffaceous sandstone
36.00 - 61.00 m	:	Altered tuffaceous sandstone

5.3.2 Classification of the Project Area

1) Classification based on the lithofacies

The geology of the Project Area consists of the formations from Cretaceous to Quanternary on the geological time as mentioned in the item of the geology. Now, these formations could be regarded as follows on the major lithofacies.

(L1) alternation of mudstone, sandstone, and marl with limestone and few of sand and gravel ..... (OMce, Mice)

(L2) fine sand, silt, clay, intercalated by sand and gravel .. (Qal)

(L3) siltstone ..... (Mscm)

(L4) calcareous sandstone and marl ..... (Mmca)

(L5) alternation of sandstone and siltstone, or sandstone and/or silty sandstone ..... (Mice)

(L6) sandy siltstone or siltstone ..... (Mice)

(L7) weathered granite, tonalite or granodyorite .... (Intrusive)

(L8) slate, andesite, tuff and tuff breccia ..... (Ksvts)

(L9) limestone ..... (Ec)

(L10) calcareous conglomerate, calcareous sand and gravel . (Mg)

(L11) mudstone ..... (Pcmg)

(L12) limestone, calcareous mudstone ..... (Oce, Ec)

(L13) sand and gravel ..... (Qlac, Qtg)

(L14) conglomerate or alternation of conglomerate and sandstone ..... (Mpg, Mpc)

(L15) limestone ..... (Oc, Ec)

2) Classification based on the Result of the Test Drilling

On the other hand, it was attempted according to the result of the test drilling to divide the study area into the under-mentioned 13 hydrogeological provinces including the none of the data area and the saltmarsh and/or mangrove area.

(D1) Super-high productive aquifer (Q=300, partly Q >=500, unit: l/min/m)
existing between 60 - 120 m in depth

(D2) High to Super-high productive aquifer (200 > Q >=100, partly Q >=3000) existing between 30 - 60 m in depth

(D3) High productive aquifer (Q >=100, partly Q >=1000) existing between 60 - 90 m in depth

(D4) Intermediate to High productive aquifer (Q = 100, partly Q >=500) existing at shallow part of less than 60 m in depth

(D5) Intermediately high productive aquifer (Q = 100) existing between 60 - 90 m in depth

(D6) Low to Intermediately productive aquifer (60 > Q >= 10) existing between 30 - 60 m in depth

(D7) Low productive aquifer (20 > Q >=5, partly Q >= 300 - 500) existing between 30 - 60 m in depth

(D8) Lack of available aquifer up to the basement situated at 60 m in depth (5 > Q)

(D9) Lack of available aquifer up to the basement situated at 90 m in depth (5 > Q)

(D10) Lack of available auqifer within 120 m in depth (5 > Q)

(D11) Lack of available aquifer within 150 m in depth (5 > Q)

(D12) no data area

(D13) saltmarsh or mangrove area

3) Classification of the Hydrogeological Provinces

The Study Area was classified into the 8 major provinces as I - VIII referring to the aforementioned two kind of classifications and the hydrological data. And the province of III is divided into the 4 sub-provinces as III-1, III-2, III-3 and III-4, the province of IV is divided into the 3 sub-provinces as IV-1, IV-2 and IV-3, the province of V is divided into the 2 sub-provinces as V-1 and V-2 and the province of VII is divided into the 2 sub-provinces as VII-1 and VII-2 (Fig.5.3.1, Table5.3.1).

(1) Hydrogeological province I: Cordillera Septentrional
The geology of this province consists of Oligocene or Miocene and the topographical features is very mountainous at the northern part and is hilly at the southern part. The large and small flat intra-mountain basins are scattered in the mountainous side and

the residential areas are restricted to the places. On the other hand, the hilly area are mainly used for pasture.Almost of the river or stream has no water except just after rain. Therefore, many of ponds for agricultural use are constructed on the eroded depression by stream. And the water of those ponds is used also for livestock and laundry.

a: altitude: 0 - 200 - 500 m
b: annual rainfall potential: 600 - 700 mm, very seasonal
c: surfacewater resources potential:
very low and very seasonal
d: groundwater resources potential:
very low and very salty
e: correlation to the classification:
L1 / D11

(2) Hydrogeological province II: Rio Yaque del Norte
This province is mainly represented by the alluvial plain, formed by the sediments transported by Rio Yaque del Norte. Here is largely cultivated to be of paddy field and farms.The recharging place is estimated to be located outside of the study area in upstreams of Rio Yaque del Norte.The major tributaries flow down with rich rainfall figures from Central Mountains located at the southward of this province to the north, namely to Rio Yaque del Norte.

a: altitude: less than 50 m
b: annual rainfall potential: 700 mm
c: surfacewater resources potential:
very high, from the rio Yaque del Norte
d:groundwater resources potential:
very high, with floating material
e: correlation to the classification:
L2 / D 4

(3) Hydrogeological province III: Southern Rio Yaque del Norte
The general geology consists mainly of the Tertiary beds of sandstone-mudstone, calcareous mudstone-limestone, and mudstone-conglomerate.Flat land and hilly region are extend in this province located at the southward from the Hydrogeological

province II and have cultivated farms and ranches.The major streams flow down from Central Mountains located at the south part of this province to the north, but the downstream of the streams have seasonally few or no water because the water is storaged on the way in dam for agriculture.On the lithofacies, this province is divided into the 4 sub-provinces as the under-mention, and then all of the sub-provinces have comparatively high potential of discharge capacity, therefore, this province would be regarded as major target area for groundwater development, especially on the III-3 sub-province. However, it has been detected high concentration of SO_4^{2-} at limited area.

a: altitude: 50 - 300 m
b: annual rainfall potential: 700 - 1000 mm
c: surfacewater resources potential:
low and very seasonal from the rio Chacuey, Maguaca, Gayubin
d: groundwater resources potential:
very high, partly with floating material and SO_4^{2-}
e: correlation to the classification:
III-1 L3 / D5
III-2 L4 / D3
III-3 L5 / D1
III-4 L6 / D7

(4) Hydrogeological province IV: Cordillera Central

The geology consists of the Cretacious beds and volcanic products and the granitic rock (tonalite) that intrudes probably slightly later into the Cretaceous formation. Therefore, the Cretacious is metamolphosed into hornfels, slate and phyllite. This province is classified into 3 sub-province (IV-1, IV-2, IV-3).

The IV-1 sub-province consists of granitic rock and the rock bodies are heavily weathered to form uneven rugged appearance of ground surface occurrence to frequently show a spheroidal-weathered features.

The IV-2 sub-provinces are symmetrically situated at the both sides of the north and the south of the granitic rock body. The general geology of the both sides are the Cretaceous beds, but the

elevation is 100 - 300 m at the north side and is 500 - 1000 m at the south side.

The IV-3 sub-province is neighboringly situated at the southward of the IV-3 sub-province and the geology consists of massive limestone.
In the IV-1 sub-province, a number of inhabitant's abodes are located, and topographically, the typical dendritic drainage is formed, where is the upstream of the tributaries of Rio Yaque del Norte. Cultivated fields and farms are scattered here except steep land situated at the southern part.
In the north IV-2 sub-province, the primary and roof-pendant Cretaceous beds are situated. The inhabitant's abodes are located on the gently inclined part and the intra-mountainous flat land where are partly cultivated or farm. In the South IV-2 sub-province, high land, the inhabitant's abodes are located on only the small scale intra-mountainous flat land. The drainage is showing deep valley with a comparatively lot of water. Water supply to the inhabitants relies on the surface water sources.
In the IV-3 sub-province, the inhabitant's abodes are located on only west of this sub-province.

a: altitude:
- IV-1 300~500 m
- IV-2 North: 100~700 m
  South: 500~1000 m
- IV-3 200~1700 m

b: annual rainfall potential: 1000~2200 mm

c: surfacewater resources potential:
- IV-1 intermediate to high
- IV-2 North: very low to intermediate
  South: low cause of steep and deep valley
- IV-3 high

d: groundwater resources potential: Z
- IV-1 intermediate
- IV-2 North: low
  South: intermediate
- IV-3 low

e: correlation to the classification:

IV-1 L7 / D6
IV-2 North : L8 / D9
South : L8 / D8
IV-3 L9 / D12

(5) Hydrogeological Province V: Western San Juan Basin

Western San Juan Basin, extended on an approximate altitude of 300 to 400 meters high above sea level, shows a general land lay of gently undulated hills and tablelands. The Province, which is geologically featured by a running of the NNW-SSE-directional anticlinal axis, plunging toward NNW, is, consequently, divided into two sub-provinces, i.e., V-1 sub-province, chiefly geologically covered by upper formation units, and V-2 sub-province, chiefly by lower formation units.V-1 sub-province chiefly consists of mudstone beds, associated with overlying unconsolidated calcareous conglomerate bed, while, V-2 sub-province is with a lack of geological association of the overlying bed, the above.Macasia River, which flows down easterly in central part of the basin, has its riverheads in Central Mountains toward north and in Neiba Mountains toward south, and is remarkably ramified by a large number of tributaries of large-scale with substantial water quantities due to a relatively large annual rain fall.Living-use water for most of inhabitants in V-1 sub-province is available from the water sources in superficial weathered parts of calcareous conglomerate or mudstone beds, however, is of small quantities and relatively highly saline.

a: altitude: V-1 300 - 500 m high
V-2 300 - 500 m high

b: annual rainfall potential: 1500 - 1750 mm

c: surfacewater resources potential:

V-1 intermediate to high
V-2 very low to intermediate

d: groundwater resources potential:

V-1 intermediate
V-2 low

e: correlation to the classification:

V-1 L10 / D 7
V-2 L11 / D10

(6) Hydrological Province VI: Sierra de Neiba

Sierra de Neiba is located between V-2 sub-province and Lago Enriquillo. The Province is situated along the northern lake coast of Lago Enriquillo and is featured by a showing of mountainous land lay, extended east-westerly with relatively gentle slopes toward north, while, relatively steep ones toward south to form a relative height difference of 1500 meters from the Lago Enriquillo water level. The East-westerly ridges, the above, are generally 2300 meters high above sea level, 4 kilometers wide, and are dissected by east-westerly water systems in central part to form a land lay with paralleled mountainous ridges. Ephemeral streams of small-scale, downstreams of those are generally attenuated, and sinkholes are largely developed on ridge slopes and bottom flat lands.The Province geologically chiefly consists of limestone beds of Tertiary age, associated with occurrences of folding axes of N70o to 80oW directions. Inferred faults of small and large scales and lineaments on air-photographs of N70o to 80oW and NW directions are largely developed in the province to cause a localized geological blocking of the Sierra de Neiba body.The annual rain fall figure in the province reaches to the value of 750 to 2000 mm, which is to be of the largest in Republic of Dominica to provide for a sufficient water supply of living-use for the inhabitants in northern part of the mountainous ridges in the province, inversely, surface water flows are little observed in southern part of those to be caused by a swallowing of surface water into sinkholes of karst topography. However, an abundant number of water springs, which are utilized for living and water baths use of inhabitants in the following Province VII, is scatteredly observed in marginal alluvial fans, abundantly developed at hill feet.

a : altitude: —40 - 1700 m

b : annual rainfall potential: 750 - 2000 mm

c : surfacewater resources potential:

north high

south high at marginal fans

d : groundwater resources potential:

no used

e : correlation to the classification: L12 / D 7

(7) Hydrogeological Province VII: Lago Enriquillo

Lago Enriquillo forms a graben-like lay, Lake Enriquillo is at the center, which is situated between Sierra de Neiba toward north and Sierra de Baoruco toward south. The confluent fans in Sierra de Neiba feet, about minus 40 to 100 meters high above sea level, are located in northern lake coast of Lago Enriquillo (sub-province VII-1), while, fault valleys of NE-SW direction are well-developed in southern like coast of that to generally form an altitude of about minus 20 to 20 meters high above sea level, however, of about 100 to 400 meters high in some location scatteredly due to that had been out of intense erosions (sub-province VII-2).

The Province chiefly geologically consists of limestone, calcareous conglomerate and marl beds.

Surface water flow in northern lake coast of Lago Enriquillo is solely originated from karst springs of large scale in marginals alluvial fans of Sierra de Neiba hill feet. Surface water flow in southern lake coast of that, behind of which Sierra de Baoruco with a large figure of annual rainfall is situated, is not perennial to be caused by significant permeation of rain water into underground of Sierra de Baoruco body.

A large quantity of ground water, which underlies limestone beds, is estimated to be possible in some occasions, however, the selection of water yielding sites of those types are to be uneasily accomplished with required cautious studies. A relatively high content of sulphate ion in a part of karst spring water in the Province, meanwhile, a tendency to turn to a higher salinity of ground water in clastic-rocks-covered area of lower elevation is also known. Drill site locations of water well development are considered to be confinedly selected southern-sided apart from the area, where rock salt beds are being mined in large scale in eastern La Salina.

a: altitude: VII-1 -40 - 100 m
VII-2 -40 - 400 m

b: annual rainfall potential: 500 - 750 mm

c: surfacewater resources potential:

VII-1 high at marginal fans

VII-2 low

d: groundwater resources potential:

VII-1 high at fan

VII-2 intermediate

e: correlation to the classification:

VII-1 L13 / D12

VII-2 L14 / D 2

(8) Hydrogeological Province VIII: Sierra de Baoruco

Sierra de Baoruco is southernly adjacent to sub-province VII-2, and confines the southern end of Sierra de Baoruco mountainous ridges. The province is located on an altitude of 100 to 2100 meters high above sea level and shows a similar character of geology and land lay to those in Province VI, i.e., well-development of geological blocking by N70o to 80oW-directional faults and of karst topography. Fault valleys in northern foot provide for the significant occurrences of sufficient aquifers in sub-province VII-2.A significant figure of annual rain fall has been recorded in the Province, however, surface water flows are not perennial being caused by a significant permeation of rain water into underground of Sierra de Baoruco body.A large quantity of ground water, which underlies limestone beds, is expected to be possible, however, the selection of water yielding sites of those type are to be uneasily accomplished with required cautious studies.

a: altitude: VIII 100 - 2100 m

b: annual rainfall potential:

750 - 2000 mm

c: surfacewater resources potential:

VIII low

d: groundwater resources potential:

VIII high at alluvial fans

e: correlation to the classification: Z

VIII L15 / D12

5.3.3 Groundwater Quality

Groundwater test samples in polyethylene containers, collected before a completion of continuous pumping tests, refrigerated by a filling with ice chips, were sent to INAPA's chemical laboratory for an establishment of chemical assays of the elements and etc., as shown below.

HCO_3^-, Cl^-, SO_4^{2-}, K^+, Na^+, Ca^{2+}, Mg^{2+},
NO_3^-, NO_2^-, NH_4^-, F^-, PO_2^{2-}, Cr^{6+}, Fe, Cu,
Zn, Mn, Pb and Total Hardness

Chemical assay results are summarizedly shown in Table 5.3.2, while, the assay values, which exceed the allowable limitation values of ground water quality, stipulated by the INAPA, are shown in the following table in references to the related drill hole numbers:

Drill hold No.	Hydro-geological province		Total Solid	Na^+	Ca^{2+}	Mg^{2+}	SO_4^{2+}	$C\ell^-$	Total hardness
		Allowable Limitation value in ppm	1500	–	500	600	400	800	500
1	I		3032	1331	–	–	850	1500	–
2	I		6731	3213	–	–	4750	2500	771
3	I		1859	–	–	–	883	–	510
4	IV		–	–	–	–	500	–	–
13	IV 2		–	1610	–	–	1400	–	–
25	VII 2		–	49151	3209	3668	18500	67250	6877

Piper's diagram in Figure 5.3.2 and hexadiagram in Figure 5.3.3 are resultantly shown in reference to Table 5.3.2, which specifies and estimates the contents of HCO_3^-, $C\ell^-$, SO_4^{2-}, K^+, Na^+, Ca^{2+} and Mg^{2+} based on the results in Table 5.3.1.

Key diagram provides propensities as shown below: the values, which exceed the allowable limitations stipulated by the INAPA, tend to be shown in a close position to $Ca^{2+} + Mg^{2+}$ line in the key diagram. The general value propensity of chemical quality of ground water in the project areas, other than ones in mountainous districts with rich rain fall figures, is estimated to be shown close to the range of sea water. Content

values of cations are estimated to be gatheredly shown in the field, slightly close to Mg^{2+}, being apart from the perpendicular line toward $Ca^{2+}-Mg^{2+}$ line from the apex, $Na^{+}+K^{+}$. Inversely, content values of anions are estimated to be scatteredly shown in a whole of the three-component system. The general propensities of ion content values in respective hydrogeological provinces are shown in Figure 5.3.4 to set up standards of the areal selections of ground water development purposes. The figure of Province VII is not shown because of a dispersed result of value distributions, while, that of Province VII is also not shown due to a lack of assay values. Figure 5.3.4 is to show an estimation of high possibility of water yields of good quality in provinces III, IV and VI.

5.4 Groundwater Potentials

5.4.1 General Potentials of Groundwater

The study area has been divided into eight hydrogeological provinces initially, and parts of the provinces have been further sub-divided into some sub-provinces on the bases, shown in the previous section 5.3.2 - 3). Yield Capacity in the Table 5.3.1 shows the estimated potential quantities of ground water development program in the Project Area.

Estimated potential quantities of ground water development are shown on the results by pumping tests of test well drill operations. Potential quantities were estimated on an assumption, in references to the specific capacity values, obtained by the pumping tests, that the drawdown values of water level after about 24-hour continuous pumping-up operation should allowably be in the range of about 15 to 20 meters in principal. Drill depths values, shown in Table 5.3.1, show the totals of the depths toward aquifers, specified by test water wells, and depths of 20 meters each in considerations of the variations of electrical conductivity values observed in association with pumping tests and of disposals of fine sand materials break into wells through water screens.

The figures of (D1) through (D13) in the previous section 5.3.2 - 2) substantially show that the smaller figure should designate a possible occurrence of more productive aquifer. Consequently, (D1) through (D7) would designate an operative potential of ground water by water pump operations in aquifers, while, (D8) and (D9) would be that by hand-pump operations, while, (D10) and (D11) would be with an unlike possibility of

aquifers of ground water development. (D12) provide a lack of informations, while, (D13) would designate a possibility of a mixing of sea water or of sea water itself. Those characters are shown below in Figure 5.4.1. The figure shows that the aquifers delineated in upper positions would be of more productive, while, in more left-sided positions would be of more shallow-seated.

5.4.2 Groundwater Potentials in Respective Hydrogeological Provinces

1) Groundwater Potentials

Table 5.4.1 is established the interpretations of ground water development potentials, in connections with the classifications of category shown in the previous section 5.4.1 concerning to respective hydrogeological provinces. The figures of the item "Quality" in the Table are specified in compliance with the below categories in accordance with the chemical contents in the Figure 5.3.4, previously shown.

a: a shows the field, chiefly covered by Hydrogeological Province IV. Ground water of good quality is potential.

b: b shows the field, chiefly covered by Hydrogeological Province III. Ground water of good quality is potential. Qualitative potentials with close values to the allowable limitation by INAPA are variedly included. Hydrogeological Provinces I and IV are included in this field.

c: c shows the field, chiefly covered by Hydrogeological Province VI. Characterized by carrying high contents of Na^+ and Cl^-, however, less than the allowable upper limitation values by INAPA.

(1) Hydrogeological Province I: Cordillera Septentrional

Available aquifers are estimated to be unlikely potential within the depth of 150 meters in the Province I. Underground geology chiefly consists of the alternations of mudstone, sandstone and marl beds of Tertiary age. Static water level is seated 10 to 20 m deep, a water recharge potential in underground is estimated to be of 10 liters per min. to lead to an estimated drawdown value of 50 to 80 m. Content values of Cl^- and SO_4^{2-} reach so high as

more than 1500 ppm and 850 to 5000 ppm, respectively. Ground water development potential is estimated to be likely very low.

(2) Hydrological Province II: Llano de Yaque del Norte
Aquifers in the Province II, chiefly located in fine-grained sand and clay beds of Quaternary age and in intercalated sand and gravel beds, are estimated to be seated within the depths of 60 m underground. Ground water occurrences in the Province are unconfined, water quality is some around the values of the upper limitation, stipulated by the INAPA, while, an abundant quantity of solid suspension is locally observed. Static water level is seated about 5 m deep, while, water yield potential is expected to be of 100 liters per min. A highly-available aquifer, with a potential water yield of 500 liters per min. and a drawdown value of about 10 m, is locally observed.

(3) Hydrogeological Province III1: Sur del Yaque del Norte
Aquifers in the Province III are estimated to be formed in the alternations of siltstone and fine-grained sandstone beds of Tertiary age and to be seated 60 to 90 m deep underground, while ground water is estimated to be weakly confined. General static water level elevations are still obscure by the current work, while, a water well drill test by the current work has elucidated an occurrence of confined ground water, about several meters thick. The Province III shows a similar character of water quality, water quantity and drawdown value range to those in Province I.

(4) Hydrogeological Province III2: Sur del Yaque del Norte
Aquifers in Providence III2 are estimated to be formed in calcareous sandstone and marl beds of Tertiary age and to be seated 60 to 90 m deep underground. Ground water in the Province is estimated to be of confined type, while, water quality itself generally resembles to that in Province I. However, an abundant quantity of water recharge under a possible geological control, with a high content value of SO_4^{2-}, has been observed. Static water level in the Province is generally estimated to be seated 20 m deep underground, while, a potential water yield is estimated to be of more than 100 liters per min. A water yield

under a particular geological structure, as shown in the above, is inferred to be of about 1000 liters per min., while, the drawdown value while pumping operation is estimated to be of about 5 m.

(5) Hydrogeological Province III3: Sur del Yaque del Norte
Aquifers in the Province III3 are estimated to be formed in the alternations of arkose and massive sandstone and siltstone beds of Tertiary age and to be seated 60 to 120 m deep underground. Ground water in the Province is estimated to be of confined type. The Province is evaluated to be with the highest possibility of ground water development in the study area and the highest potential of ground water yield of good quality of the type a, stated above, which is also observed nearby Chacuey and Canderon. General water quality in the Province shows a resemblance to that in Hydrogeological Province I. Static water level is generally estimated to be seated 16 m deep, while, 50 m deep in Palo Blanco. A potential water yield is generally inferred to be of 300 liters per min., while possibly 500 liters per min. locally.

(6) Hydrogeological Province III4: Sur del Yaque del Norte
Aquifers in the Province III4 are estimated to be formed in calcareous sandstone beds of Tertiary age and to be seated 30 to 60 m deep underground. Ground water in the Province is of confined type. Water quality generally shows a resemblance to that in Province I, however, is slightly high in Cl^- quantity. Static water level is generally estimated to be seated several to ten and several meters deep underground, while, a potential water yield is inferred to be of about 5 to 20 liters per min.

(7) Hydrogeological Province IV1: Cordillera Central
Aquifers in the Province IV1 are estimated to be formed in weathered granitoid body (tonalite) of Cretaceous age and to be seated 30 to 60 m deep underground. Ground water in the Province is of unconfined type, while, the water quality, of Ca $(HCO_3)_2$ type, is evaluated to be the best in the Project Area. Potential water yields are evaluated to be variable in connection with the variations of thickness of weathered parts of tonalite body, what lead to an estimation that the water yields from the

wells allocated nearby the ridges of mountainous hills should be small, inversely, should be large from the wells, allocated in less-undulated hilly areas. Static water level is estimated to be seated 5 to 15 m deep underground, a potential water yield is inferred to be of about 10 to 60 liters per min.

(8) Hydrological Province IV2: Cordillera Central
Province IV2 is dividedly situated northerly and southerly, between where the Province IV1 is located. Aquifers in the Province, both of in north and in south, are estimated to be formed in mudstone, calcareous sandstone and sandstone beds of Cretaceous age, while, a potential water yield of ground water is estimated to be of 10 liters per min.

Occurrences of available aquifers in the bed rocks within the depth of 80 m deep are estimated to be unlikely potential in nouthern Province IV2. Static water level in the north is estimated to be sharply variable in the range of 8 to 50 m deep underground. A water-qualitative possibility of local high contents of SO_4^{2-} and Cl^- is required to be cautiously examined.

Occurrences of available aquifers in the bed rocks within the depth of 60 m deep are estimated to be unlikely potential in southern Province IV2. Static water level in the south is estimated to be seated about 14 m deep underground, while, water quality is of Ca $(HCO_3)_2$ types.

(9) Hydrogeological Province IV3: Cordillera Central
General geology in the Province IV3 chiefly consists of limestone beds. Informations of ground water in the Province have not yet been available.

(10) Hydrogeological Province V1: Valle de San Juan
Aquifers in the Province VI are estimated to be formed in calcareous conglomerate and muddy-calcareous sandstone beds of Tertiary age and to be seated about 30 to 60 m deep underground. Ground water in the Province is specified to be of unconfined type formed in loosely consolidated calcareous conglomerate beds, which spatially extend up to ground surface, and to be of confined type formed in calcareous sand-gravel beds, which are overlain by

aquiclude siltstone beds. Ground water is relatively qualitatively rich in Cl^- content, which does not exceed the allowable upmost limitation value stipulated by the INAPA. Static water level is estimated to be seated within the range of 20 m deep underground, while potential water yield is inferred to be of 5 to 20 liters per min.

(11) Hydrogeological Province V2: Valle de San Juan
Occurrences of available aquifers, within the range of 120 m deep underground, are hardly observed in the Province V2. General geology underground in the Province chiefly consists of calcareous mudstone beds of Tertiary age.

(12) Hydrogeological Province VI: Sierra de Neiba
Aquifers in the Province VI are estimated to be formed in calcareous sandstone layers, intercalated in calcareous mudstone beds. Ground water quality in the Province shows a resemblance to that in Hydrogeological Provinces I and III. Static water level is estimated to be seated about 20 m deep underground, while, potential water yield is inferred to be of 5 to 20 liters per min.

(13) Hydrogeological Province VII-1: Cuenca de Enriquillo
General geology in the Province chiefly consists of sand-gravel beds. Informations of ground water in the Province have not yet been available.

(14) Hydrogeological Province VII-2: Cuenca de Enriquillo
Aquifers in the Province VII-2 are estimated to be formed in calcareous conglomerate bed or in alternations of conglomerate and sandstone beds of Tertiary age. Rock salt beds are distributed in the environs of the Province to cause a carrying of very high contents of Cl^- and SO_4^{2-} in ground water. The selections of water well drill sites are required to be cautiously examined to be allocated as far as the southern part of the Province, where ground water of $Ca(HCO_3)_2$ type should be possibly supplied under a reasonably certain circumstance. Static water level is estimated to be seated about 20 m deep underground, while, potential water yield is inferred to be of 100 to 200 liters, locally of up to 300 liters, per min.

(15) Hydrogeological Province VIII: Sierra de Baoruco

General geology in the Province VIII chiefly consists of limestone beds. The Province shows a resemblance of hydrogeological character to that in the Province VI, while, informations of ground water in the Province have not yet been available.

2) Examinations of Influences by Pump-up Operations

A sphere, where an influence by drawdown of water level by pumping should be taken place, is referred as the "influence sphere". Two wells are substantially required at least for an estimation of a value of the above, one is for pumping and the other is for a determination of water level. An outlined estimation of the above value is made at times out of a requirement of an accuracy by using a single well, where pumping and water level determination should be operated. The value of "r", which is normally designated to be of a distance between two wells, the above, is tentatively used to be of a radius value of the above single well.

The extensions of the "influencial radius", outlinedly estimated by the above approximation in the current study area, on an assumption that yield capacity, shown in Table 5-3-1, should be continuously operated for 24 hours, are inferred to be of less than 100 meters. This would lead to a conclusion that drawdown effects of water level should be impossible when intervals of water wells for ground water development in the current study area should be separately allocated more than 200 meters apart respectively.

Relations between time hours and drawdown effect, concerning to pumping operations, are shown in Figure 5.4.2.

Holes 9 through 12, which have been operated in the III3 sub-province, are specified to be of the category of "D1", while, Hole 13 is of "D9" in the IV2 sub-province and Hole 16 is of "D6" in the IV1 sub-province.

Water balance estimation from a regional standpoint of potential view has been made, however, the accuracy of the estimations is considered to be barely satisfactory enough because that the meteorological observatory stations are currently in operations with

an insufficient coverage of the current Project Area, which was demarcated as being crossing to the general topographical configuration to intersect it in oblong mode. Tentative water balance estimation by the Phase-I work has been revised in line with the divisions of water Province-subprovince by the current work. Annual possible recharge of ground water and possible water yield per day per square kilometer in respective hydrogeological provinces are summarized in Table 5-4-2.

5.4.3 Recommendations

Hydrogeological Provinces in the Project Area, to be deserved of the ground water development programming in future are shown below in accordance with the interpretation results of water yield potentials by the current works.

Hydrogeological Province II	:	Llano de Yaque del Norte
Hydrogeological Province III1	:	Sur del Yaque del Norte
Hydrogeological Province III2	:	Sur del Yaque del Norte
Hydrogeological Province III3	:	Sur del Yaque del Norte
Hydrogeological Province III4	:	Sur del Yaque del Norte
Hydrogeological Province IV1	:	Cordillera Central
Hydrogeological Province IV2	:	Cordillera Central
Hydrogeological Province IV3	:	Cordillera Central
Hydrogeological Province V1	:	Valle de San Juan
Hydrogeological Province VI	:	Sierra de Nelba
Hydrogeological Province VII-1	:	Cuenca de Enriquillo
Hydrogeological Province VII-2	:	Cuenca de Enriquillo
Hydrogeological Province VIII	:	Sierra de Baoruco

1) Hydrogeological Province II: Llano de Yaque del Norte

The Province II is evaluated to be that ground water in the Province should be potentially developed by using submersible pump operations. Water well sites are to be successively re-examined and decided in accordance with the development progress under a cautious remarking of water quality, particularly of SO_4^{2-} and Cl^- contents, since the general characters of ground water quality in the Province by the current work are remarked to be shown in a wide range on Piper's diagram.

2) Hydrogeological Province III1: Sur del Yaque del Norte

Hydrogeological characters in the Province III1 show a resemblance to those in Province II. Ground water in the Province is evaluated to be developed by using submersible pump operations. The SO_4^- contents are to be cautiously remarked since that the general characters of water quality on the Piper's diagram in the Province show a resemblance to those in Provinces III2 and III3.

3) Hydrogeological Province III2: Sur del Yaque del Norte

Confined ground water resources with local abundance, under a geological structural control in the Province III2, are evaluated to be potentially developed by using submersible pump operations. Relations between water quality and geological structure are considered to be further studied in more details since that ground water in Tertiary-aged beds in the Province shows a very high content of SO42- at times. Developments of deep-seated ground water are estimated at present to be out of the future programming.

4) Hydrological Province III3: Sur del Yaque del Norte

Ground water development in the Province III3 is evaluated to be with the potentials of water, of $Ca(HCO_3)_2$ type, of the highest quality among the current project provinces and of large quantity.

5) Hydrological Province III4: Sur del Yaque del Norte

Ground water development in the Province III4 is evaluated to be possibly implemented by using manual pump operations. Pumping tests show an insufficient figures of potential water yield, while, static water level in the Province is shown to be shallow-seated.

6) Hydrogeological Province IV-1: Cordillera Central

Ground water in the Province IV-1 is evaluated to provide a water quality of the highest among the current project provinces. Ground water development by using manual pump operation is estimated to be suitable in the Province, since that static water level is considered to be shallow-seated and potential water yield figure is barely sufficient enough.

7) Hydrogeological Province IV-2: Cordillera Central

The Province IV-2 is divided into two parts, north and south.Ground water development in northern Province IV-2 is evaluated to be possibly implemented by using manual pump operations. Static water level is estimated to be seated in the range of 8 to 50 m deep underground, widely fluctuated with test well locations.Ground water development in southern Province IV-2 is evaluated to be possibly implemented by using manual pump operations, since static water level is shallow-seated. Water quality in the south is estimated to be of $Ca(HCO_3)_2$ type.

8) Hydrological Province V-1: Valle de San Juan

Ground water quality in the Province VI is estimated to be rich in Cl^- content, which does not exceed the allowable upmost limitation value of Cl^-, stipulated by the INAPA. Ground water development is evaluated to be possibly implemented by using manual pump operations, since static water level is estimated to be shallow-seated.

9) Hydrogeological Province VI: Sierra de Neiba

Ground water development in the Province VI is evaluated to be possibly implemented by using manual pump operations since static water level is estimated be to located within the range of 20 m deep underground. Water quality in the Province is estimated to be of $Ca(HCO_3)_2$ type.

10) Hydrogeological Province VII-2: Cuenca de Enriquillo

Water well sites for future ground water development in the Province VII-2 are considered to be selectedly possibly allocated as far as the hillfoot district of Sierra de Baoruco, where ground water of $Ca(HCO_3)_2$ type is available, because that rock salt layers are distributed in the Province to cause ground water occurrences of high salinity and high SO_4^{2-} contents.

5.5 Conclusions

The current Project Area has initially been divided by hydrogeological and geological structural studies into eight hydrogeological provinces, from I through VIII. Those studies have further been proceeded on the bases of modes of ground water occurrences to subdivide such certain provinces as Province III into sub-provinces from III-1 through III-4, as Province IV into those from IV-1 through IV-3, as Province V into those of V-1 and V-2, and as Province VIII into those of VIII-1 and VIII-2.

Section 5.3.2, 3) shows general lay, land utilization, meteorological characters, water supply source utilization, general geology particularly on lithofacies and ground water potentials in respective Hydrogeological Provinces and sub-provinces. Section 5.4.2 provides ground water potential in details in those provinces, while, section 5.4.3 shows the provinces, for which future ground water development programmings are evaluated to be deserved of.

Sub-province IV-2, which is chiefly occupied by granitoid body, partly subjected by weathering, is evaluated to be stably productive of ground water of high quality, however, is unlikely estimated to be highly potential from the viewpoint of potential yield quantity of water.

Sub-province III-3, in where sand and gravel beds of arkose and metamorphosed rock occur at the Tertiary-base, is evaluated to be highly potential from the viewpoints of quality and quantity of ground water. Sub-province III-3 includes Dajabon area. Stock farms are widely running in flat or hilly lands, which extend within the range of some 15 km from Dajabon. Inhabitant abodes are interspersed at every some several kilometers interval.

Sub-province IV-2 is situated on both of northern and southern sides of granitoid body. Ground water of good quality is estimated to be available in southern part of the Sub-province, however, potential water yield from a single well is estimated to be about 10 liters per min.

Hydrogeological Province VI is evaluated to carry ground water of $Ca(HCO_3)_2$ type, however, surface water of quantitative abundance is currently utilized for daily living purposes in northern part of the Province, while, ground water development in southern part of the Province is estimated to be hardly implemented under topographical difficulties.

Hydrogeological Province VI is evaluated to be that flow-out or spring water, observed in alluvial fans nearby footlands of Sierra de Neiba and Sierra de Baoruco and ground water of $Ca(HCO_3)_2$ type are evaluated to be possibly utilized.

General geology in the current Project Area chiefly consists of fine-grained clastic sediments to generally cause an insufficient development of available aquifers underground. The general permeability coefficient value in the study area, based on an assumption of the transmissibility value, obtained in accordance with test water well drill work and an assumed average thickness of aquifer of 20 meters, is estimated to be in the range of 10^{-4} to 10^{-5} cm^2/sec. This value is evaluated to be fairly low to be represented for any aquifer of the normal averaged character. Water well development works are currently in progress by INAPA in western parts of the Republic of Dominica for such aquifers with the characters as shown above.

The averaged chemical qualitative character of water for potations must be in the range of $Ca(HCO_3)_2$ - $NaHCO_3$ type on Piper's diagram. The allowable upmost limitation range for water of drinking use by INAPA is extended to that of ground water of $Ca(HCO_3)_2$ - $CaSO_4$ or $CaSO_4$ - NaCl types. This is considered to possibly be caused by being that ground water, available in the Republic of Dominica, generally carries a relatively high content of NaCl or CaSO4.

It has been reaffirmed that the evaluation works of ground water development potentials in the Republic of Dominica should have to be examined with emphases not only on water quantity but equally on water quality. It is likely considered that an extension of certain Cl^- content value in ground water shows a distributive feature of areal localization in the Project Area, meanwhile, that of high SO_4^{2-} content value unlikely provides a distributive localization, but shows scattered distributions of extremely high SO_4^{2-} content value. Those are widely observed from north toward south in western Republic of Dominica. Hydrological behaviors of chlorine and highly occurring sulphate ions of localized predomination are to be consecutively studied in more details in relations to geology, geological structure and historical geology in the Project Area.

TABLES

Table 2.4.1 Details of Major Satellites used for Earth Observation

Satellite for earth observation		Year of launching	Country of launching	Wavelength range	Wavelength range	Resolution (m)	Observation width (km)	Orbital height (km)	Observation period (day)	Covered field
LANDSAT	No.1	1972.7 (Functional stoppage)	USA	MSS	μm 0.5 - 0.6 0.6 - 0.7 0.7 - 0.8 0.8 - 1.1	80	185	920	18	Cover the earth and widely used for both land and water areas.
	No.2	1975.1 (Functional stoppage)								
	No.3	1978.3 (Functional stoppage)								
LANDSAT	No.4	1982.7 (Functional stoppage)	USA	MSS	The same with the above	The same with the above	180	700	16	The same with the above
	No.5	1984.3		TM	0.45 - 0.52 0.52 - 0.60 0.63 - 0.69 1.55 - 1.75 10.40 - 12.50 2.08 - 2.35	30 120 30	180	700	16	The same with the above
SPOT	No.1	1986.2	France	HVR	0.51 - 0.73 0.50 - 0.59 0.61 - 0.68 0.79 - 0.86	10 20	60	830	26	The same with the above Preparation of geographical maps is possible because of stereo visibility

Table 2.5.1 Employed Aerial Photographs
Scale 1:50,000 Data: 1983 - 1984 Photographs: US Army

Course No.	Photographs No.s	Number of Photos	Roll No.	Data Photo-graphed
1	594 - 604	11	R7	Feb/16/83
2	1870 - 1884	15	R15	Jan/12/83
3	2207 - 2191	17	R18	Jan/21/84
4	1813 - 1831	19	R14	Jan/11/84
5	1625 - 1642	18	R12	Mar/02/83
6	1754 - 1768	15	R14	Jan/11/84
7	2211 - 2220	10	R18	Jan/21/84
8	2890 - 2898	9	R26	Mar/07/84
9	2443 - 2435	9	R20	Jan/24/84
10	2410 - 2414	5	R20	Jan/24/84
11	2446 - 2452	7	R20	Jan/24/84
12	2366 - 2354	13	R20	Jan/24/84
13	2377 - 2389	13	R20	Jan/24/84
14	3422 - 3416	7	R31	Jan/21/84
15	1304 - 1311	8	R11	Mar/05/83
16	1300 - 1293	8	R11	Mar/05/83
17	154 - 145	10	R4	Feb/04/83
18	2029 - 2039	11	R17	Jan/19/84
19	235 - 227	9	R4	Feb/08/83
20	251 - 258	8	R4	Feb/08/83
21	302 - 294	9	R5	Feb/08/83
22	39 - 46	8	R1	Jan/26/83
23	26 - 14	13	R1	Jan/26/83
24	677 - 653	25	R8	Feb/16/83
25	685 - 700	16	R8	Feb/16/83
26	2322 - 2305	18	R20	Jan/24/84
27	3007 - 3012	6	R28	Mar/12/84
28	3003 - 3001	3	R28	Mar/12/84
	2999 - 2995	5	R28	Mar/12/84
		(total 325)		

Table 2.5.2 Topographic Maps of the Study Area

No.	Map ID	Name of Map
1	594 - IV	GUAROA
2	5871 - IV	BOCA CACHON
3	5871 - III	JIMANI
4	5875 - I	MONTE CRISTI
5	5875 - II	PEPILLO SALCEDO
6	5874 - I	DAJABON
7	5874 - II	LOMA DE CABRERA
8	5873 - I	RESTAURACION
9	5873 - II	BANICA
10	5872 - I	LAS MATAS DE FARFAN
11	5872 - II	EL CERCADO
12	5871 - I	LA DESCUBIERTA
13	5871 - II	DUVERGE
14	5870 - I	PUERTO ESCONDIDO
15	5870 - II	PEDERNALES
16	5975 - IV	CACAO
17	5975 - III	VILIA ISABEL
18	5974 - IV	MARTIN GARCIA
19	5974 - III	SANTIAGO RODRIGUEZ
20	5973 - IV	JICOME
21	5973 - III	ARROYO LIMON
22	5972 - IV	PEDRO CORTO
23	5972 - III	DERRUMBADERO
24	5971 - IV	GALVAN
25	5971 - III	NEIBA
26	5970 - IV	LA SALINA
27	5970 - III	POLO
28	5975 - I	BARRANCON
29	5975 - II	EL MAMEY
30	5974 - I	MAO
31	5970 - I	BARAHONA

Annex **Table 5.1.1 (1)** . List of Prospecting Sites (Monte Cristi)

MONTE CRISTI

Phase	Village No.	Village Name	Prospecting Method	Line	Number of Site	Remarks
I	M31	Las Canas	VES	B	5	near a pond
			EM	EM6	55	
I	M 8	Batey Higuero	VES	H	4	near a Canal and a river
I	M -	Las Aguas	VES	I	3	near a Canal
I	M27	Sanita	VES	J	3	near a Hand-pump and Canal
I	M -	Santa Maria	VES	K	4	
I	(EW,	NS) = (48.6, 92.5)	VES	N	3	
I	(EW,	NS) = (48.5, 90.2)	VES	O	3	
I	M -	Botoncillo	VES	P	3	
I	(EW,	NS) = (48.2, 87.8)	VES	S	3	
I	M -	Villa Garcia	VES	T	3	
I	(EW,	NS) = (33.8, 86.5)	VES	U	3	
I	M -	El Copey 1	VES	CC	4	near a Windmill
I	M -	El Copey 2	VES	DD	3	near a Windmill
I	M10	Batey Juliana	VES	HH	5	near a Canal
I	M 3	Hato Viejo	VES	II	2	near a River
I	M -	Hatillo Palma	VES	JJ	5	near a River and Canal
I	M24	Jobo Corcobado	VES	KK	4	near a Hand-pump
I	(EW,	NS) = (37.2, 73.2)	VES	LL	2	
I	M -	La Gata	VES	MM	2	near a River
I	(EW,	NS) = (50.5, 87.0)	EM	EM5	65	
	Sub Total		VES	19	64	
			EM	2	120	

Annex **Table 5.1.1 (2)** , List of Prospecting Sites (Dajabon)

DAJABON

Phase	Village No.	Village Name	Prospecting Method	Line	Number of Site	Remarks
I	D 2	Cayuco 1	VES	A	8	near a Windmill and H-pump
I	(EW, NS) = (19.0, 60.0)		VES	C	8	near a River and Spring
			EM	EM1	39	
I	D 2	Cayuco 2	VES	D	3	near a Hand-pump
I	D 1	Palo Blanco	VES	E	4	near a Windmill
I	(EW, NS) = (26.5, 73.8)		VES	F	3	near a River
I	(EW, NS) = (48.6, 72.6)		VES	G	4	
I	Los Arroyos		VES	L	4	near a Hand-pump
I	D 2	Cayuco 3	VES	M	2	near a Well
I	D 2	Cayuco 4	VES	M	2	near a Hand-pump
I	D 5	Clavellina	VES	Q	3	near a Hand-pump
I	D -	Esperon	VES	R	3	near a Hand-pump
I	D -	Jacuba 1	VES	V	3	near a River and Canal
I	D -	Jacuba 2	VES	W	3	near a River and Canal
I	D -	Donamaria	VES	X	3	near a Canal
I	D -	Campeche 1	VES	Y	3	near a River
I	D -	Campeche 2	VES	Z	3	near a Windmill
I	D35	Los Indios	VES	AA	4	near a Windmill and H.pump
	D -	La Vigia	VES	BB	8	near a Motor-pump and H.pump
	D18	El Cajuil	VES	EE	3	
	D55	Las Lagunas	VES	EE	3	
	(EW, NS) = (30.0, 48.2)		VES	EE	3	
	(EW, NS) = (31.0, 48.0)		VES	EE	2	
	D21	La Penita Arriba	VES	EE	2	near a Hand-pump
	D20	El Aguacate	VES	FF	2	near a Hand-pump
			EM	EM4	50	
	D -	Sabana Larga	VES	GG	7	near a Hand-pump
	D 4	La Cienaga	EM	EM2	79	near a Hand-pump and Pond
	D37	Partido	EM	EM3	51	near a Water Service
			VES	25	93	
	Sub Total		EM	4	219	

Annex **Table 5.1.1 (3)** List of Prospecting Sites (Elias Pina)

ELIAS PINA

Phase	Village No.	Village Name	Prospecting Method	Line	Number of Site	Remarks
I	(EW, NS) = (20.9, 86.9)		VES	EP1	3L	near a Canal
I	E31	Palo Seco	VES	EP2	2	near a Canal and Hand-pump
I	E -	Guanito	VES	EP3	3	near a Hand-pump and River
I	E -	Higuerito	VES	EP4	3	near a Windmill
I	E -	La Rosa	VES	EP5	3	
I	E -	Sabana larga	VES	EP6	3	near a Hand-pump
I	E -	Los Corvanos	VES	EP7	3	near a Hand-pump
I	E -	La Guna	VES	EP8	2	near a Hand-pump
I	E -	El Pino	VES	EP9	3	near a Spring
I	E -	La Meseta	VES	EP10	2	near a River
I	(EW, NS) = (21.0, 88.5)		VES	EP11	3	near a Water Service
I	E -	La Tinajita	EM	EM7	54	near a River
I	E 2	El Sobacon	EM	EM8	43	near a River
	Sub Total		VES	11	30	
			EM	2	97	

Annex **Table 5.1.1 (4)** List of Prospecting Sites (Independencia)

INDEPENDENCIA

Phase	Village No.	Name	Prospecting Method	Line	Number of Site	Remarks
I	I -	Jimani 1	VES	ID1	6	near a Canal
I	I -	Jimani 2	VES	ID2	2	
I	I -	Boca Cachon	VES	ID3	3	near a Spring
I	I -	Guayabal	VES	ID4	5	near a Spring and River
I	I -	Bayahondal	VES	ID5	2	near a Spring
I	I -	Descubierta	VES	ID6	6	near a Spring
I	I -	Los Cacheuales	VES	ID7	1	near a Canal and Well
	Sub Total		VES	7	25	
			EM	Ø	Ø	

Annex **Table 5.1.1 (5)** List of Prospecting Sites (Monte Cristi)

MONTE CRISTI

Phase	Village No.	Village Name	Prospecting Method	Line	Number of Site	Remarks
II	M -	El Duro	VES	M 1	3	near a Pond
II	M -	Isabel de Torres	VES	M 2	3	
II	M -	Hato Viejo	VES	M 3	5	near a River
II	M -	Las Aguitas	VES	M 4	3	near a Pond
II	M -	Las Clavellinas	VES	M 6	3	near a Hand-pump
II	M -	La Pinta	VES	M 7	5	near a Hand-pump
II	M -	Batey Higuero	VES	M 8	5	near a Canal, River
II	M -	Batey Juliana	VES	M10	2	near a Canal
II	M -	Los Conucos	VES	M11	3	near a Hand-pump
II	M -	Pena Ranchadero	VES	M14	5	near a River
II	M -	Cabeza de Toro	VES	M18	5	
II	M -	Guayubincito	VES	M19	5	near a River
II	M -	El Cayal	VES	M21	3	near a Windmill
II	M -	Los Amaceyes	VES	M23	3	near a Pond
II	M -	Jobo Corcobado	VES	M24	4	near a Hand-pump, River
II	M -	Buen Hombre	VES	M30	3	
II	M -	Los Canas	VES	M31	2	near a Pond
II	M -	Loma Atravezada	VES	M33	3	
II	M -	Sabana Cruz	VES	M34	3	near a Windmill, Pond
II	M -	La Horca	VES	M36	3	near a Windmill
II	M -	El Manantial	VES	M37	6	near a Pond
II	M -	Las Aguas	VES		5	near a Canal
II	M -	El Guayo	VES		5	
	Sub Total		VES EM	23	87	

Annex **Table 5.1.1 (6)** List of Prospecting Sites (Dajabon)

DAJABON (1/2)

Phase	Village No.	Name	Prospecting Method	Line	Number of Site	Remarks
II	D -	Palo Blanco	VES	D 1	5	near a Windmill, Hand Pump
II	D -	Cayuco abajo	VES	D 2	3	near a Hand Pump
II	D -	Laja	VES	D 3	2	near a Hand Pump
II	D -	La Cienaga	VES	D 4	3	near a Hand Pump
II	D -	Clavellina	VES	D 5	3	near a Hand Pump
II	D -	El Rodeo	EM	D 7	40	near a River Well
II	D -	La Gorra	VES	D 8	5	near a Hand Pump
II	D -	El Llano	VES	D11	3	near a River
II	D -	Tamarindo	EM	D12	40	
II	D -	La Penita Abajo 1	VES	D13	5	near a Hand Pump
II	D -	La Penita Abajo 2	VES	D13	6	near a Spring
II	D -	La Penita Abajo 3	VES	D13	3	near a Spring
II	D -	Pueblo Nuevo	EM	D14	40	near a River
II	D -	El Cajuil	EM	D18	40	near a Hand Pump
II	D -	El Aguacate	VES	D20	2	near a Hand Pump
II	D -	La Penita Arriba	VES	D21	4	near a Hand Pump
II	D		EM	D21	50	near a River
II	D -	La Aabanzada	EM	D23	40	near a River
II	D -	Piedra Blanca	EM	D33	80	near a Hand Pump
II	D -	Buen Gusto	VES	D39	5	near a Hand Pump
II	D -	Aminilla	VES	D43	3	near a Hand Pump
II	D -	Mariano Cestero	VES	D45	5	near a Hand Pump
II	D -	Jimenez Abajo	EM	D46	50	near a River (W.S?)
II	D -	Agua Blanca	EM	D48	50	near a River
II	D -	Valle Nuevo	EM	D49	80	near a River
II	D -	Valle Nuevo	EM	D49	80	near a River
II	D -	La Vigia	VES	D	4	near a M.H Pump
II	D -	Los Arroyos	VES	D	5	near a Hand Pump
II	D -	Chacuey 1	VES	D	5	
II	D -	Chacuey 2	VES	D	5	near a Hand Pump

DAJABON (2/2)

Phase	Village No.	Village Name	Prospecting Method	Line	Number of Site	Remarks
II	D -	Esperon 1	VES	D	2	near a Hand Pump
II	D -	Esperon 2	VES	D	5	near a Hand Pump
	Sub Total		VES	21	83	
			EM	10	510	

Annex Table 5.1.1 (7) List of Prospecting Sites (Elias Pina)

ELIAS PINA

Phase	Village No.	Village Name	Prospecting Method	Line	Number of Site	Remarks
II	E -	Potroso	VES	E 7	5	near a River
II	E -	Macasia	VES	E 8	3	near a Hand Pump
II	E -	Lamesdero 1	VES	E10	7	near a River
II	E -	Lamesdero 2	VES	E10	3	near a Hand Pump
II	E -	La Margarita	VES	E11	3	near a Hand Pump
II	E -	La Canita	VES	E16	3	near a River
II	E -	Los Memisos	VES	E17	3	near a River
II	E -	Mata Bonita 1	VES	E18	5	
II	E -	Mata Bonita 2	VES	E18	5	Windmill
II	E -	Higuerito	VES		5	
II	E -	El Mamoncito	VES	E19	7	near a Hand Pump
II	E -	Sabana Cruz 1	VES		5	near a Hand Pump, (W.S)
II	E -	Sabana Cruz 2	VES		5	near a Hand Pump, (W.S)
II	E -	Guayabal	VES	E22	3	near a Hand Pump, Windmill
II	E -	Hato Viejo	VES	E23	3	near a Hand Pump
II	E -	Pilon	VES	E24	3	near a Hand Pump
II	E -	Guaroa	VES	E25	3	near a Hand Pump, Windmill
II	E -	Los Yareyes	VES	E26	3	near a River
II	E -	Benancio	VES	E28	3	near a Canal
II	E -	Bruno	VES	E29	3	near a Canal, River
II	E -	Palo Seco	VES	E31	6	near a Canal, H. Pump, Spring
II	E -	Juan Cano	VES	E32	3	near a River
II	E -	Canada del Barrero	EM	E35	50	near a River
II	E -	Los Corvanos	VES		7	near a Hand Pump
II	E -	Rinconito	VES		4	near a Hand Pump
	Sub Total		VES	24	100	
			EM	1	50	

Annex **Table 5.1.1 (8)** . List of Sites (Independencia)

INDEPENDENCIA

Phase	Village No.	Village Name	Prospecting Method	Line	Number of Site	Remarks
II	I	- Florida	VES		5	
			VES	69	275	
	Sub Total		EM	11	560	

Table 5.1.2 Relation between Electrical Resistivity and Lithofacies

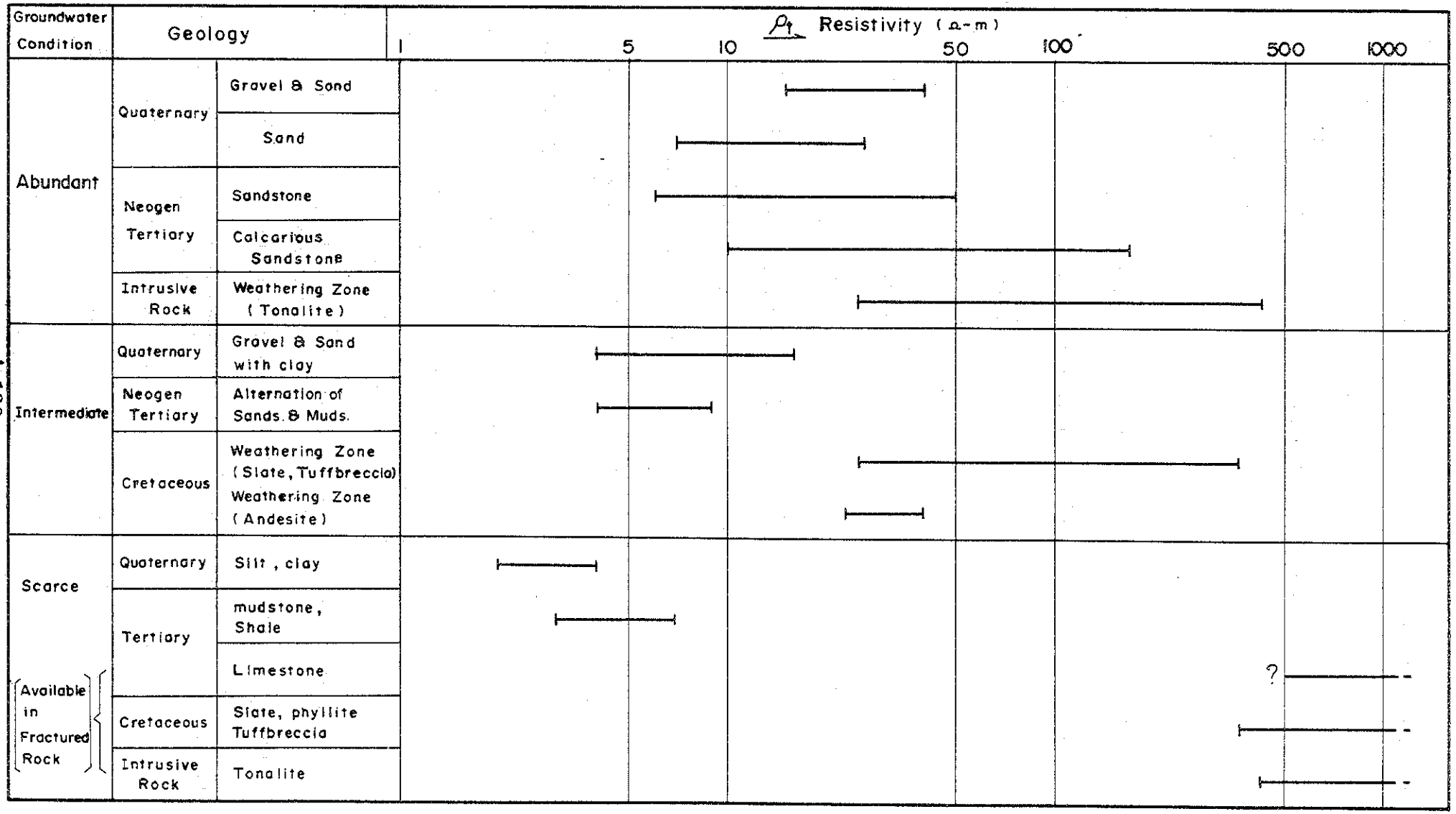

Table 5.2.1 List of Drilling Sites

Well No.	Location	Village
No. 1	No. M37	El Manantial
No. 2	No. –	El Guayo
No. 3	No. –	Las Aguas
No. 4	No. M24	Jobo Corcobado
No. 5	No. M 7	La Pinta
No. 6	No. M14	Ranchadero
No. 7	No. M19	Guayubincito
No. 8	No. M18	Cabeza de Toro
No. 9	No. D 1	Palo Blanco
No. 10	No. –	La Vigia
No. 11	No. –	Esperon
No. 12	No. –	Chacuey (Canderon)
No. 13	No. –	Los Arroyos
No. 14	No. D 8	La Gorra
No. 15	No. D39	Buen Gusto
No. 16	No. D13	La Penita Abajo
No. 17	No. D21	La Penita Arriba
No. 18	No. D45	Cruce de Mariano Cestero
No. 19	No. E19	El Mamoncito
No. 20	No. –	Las Rosas
No. 21	No. E10	Lamedero
No. 22	No. E49	El Corbano
No. 23	No. E31	Palo Seco
No. 24	No. –	Asiento Mguel
No. 25	No. I 6	Angostura
No. 26	No. –	Baitoa
No. 27	No. –	Mariano Cestero

Table 5.2.2 (1) Results of Test Drilling and Pumping Test

Well No.	Location	Results of Drilling Test						Result of Pumping Test			Transmissibility (m^2/min)			Water Quality		
		Drilling Rig	Started / Completed	Drilled Depth(m)	S.W.L (GLm)	Screen Position (GLm)	Lithofacies of Aquifer	P/Discharge (Q) ℓ/min	Drawdown (S)m	Specific Capacity (ℓ/min/m)	Theis	Jacob	Recovery	Electric Conductivity (μs/cm)	Cl mg/ℓ	pH
1	El Manantial	KANO KT-300WT	9/10/91 14/10/91	152.35	21.00	99.0-115.0 131.0-135.0	fine grained Sand in Mudstone	3.85	77.90	0.05	9.28×10^{-6}	1.00×10^{-5}	4.85×10^{-6}	3550-11940	>1500	7.3
2	El Guayo	KANO KT-300WT	28/ 9/91 7/10/91	150.00	13.38	100.0-116.0	fine grained Sand in Mudstone	11.02	55.82	0.20	5.77×10^{-5}	2.33×10^{-5}	8.79×10^{-5}	7890-12080	>2500	7.9
3	Las Aguas	Speed Star	8/10/91 17/10/91	71.40	2.20	48.0- 64.0	medium~coarse grained Sand	285.83	5.28	50.50	1.14×10^{-1}	1.11×10^{-1}	4.70×10^{-2}	2240- 2450	110	8.1~8.8
4	Jobo Corcobado	Speed Star	18/ 9/91 4/10/91	81.00	4.10	14.0- 18.0 28.0- 30.0	fine Sand to pebble	178.94	19.19	8.22	5.94×10^{-3}	6.35×10^{-3}	2.70×10^{-2}	1450- 1650	70	7.7~8.6
5	La Plata	KANO KT-300WT	11/11/91 17/11/91	151.00	17.33	81.0- 77.0 128.0-141.0	calcareous Sandstone	337.1	1.60	210.68	—	3.08×10^{-9}	2.50×10^{-9}	1700- 1920	70~80	8.5~9.0
6	Ranchadero	Speed Star	18/ 9/91 23/10/91	80.00	2.05	50.0- 54.0 58.0- 66.0	fine grained Sand	108.89	7.22	15.08	2.90×10^{-2}	2.75×10^{-2}	4.48×10^{-3}	=>2000	101	8.3
7	Guayubinclto	Speed Star	25/ 9/91 4/10/91	82.46	1.54	30.0- 34.0 42.0- 54.0	fine grained sandy Silt/ calcareous sandstone	34.11	47.03	0.73	6.78×10^{-4}	1.12×10^{-3}	7.98×10^{-4}	838- 901	30	8.7~9.1
8	Cabeza de Toro	KANO KT-300WT	18/12/91 29/12/91	134.30	58.75	59.0- 67.0 71.0- 87.0 107.0-111.0	calcareous Sandstone	23.64	30.62	0.77	1.95×10^{-4}	1.62×10^{-4}	2.75×10^{-4}	1900-1970	30	7.4~8.7
9	Palo Blanco	KANO KT-300WT	31/ 8/91 11/ 9/91	150.60	50.60	79.6- 83.6 91.6- 95.6 103.6-107.6 123.6-127.6 135.6-139.6	granule mized Sand in Mudstone/Siltstone	192.97	10.64	18.14	1.43×10^{-2}	1.33×10^{-2}	1.90×10^{-2}	=>2200	126	8.2
10	La Vigia	KANO KT-300WT	15/ 8/91 28/ 8/91	72.00	13.24	34- 46	alternation of fine grained Sandstone/Shale	204.12	3.58	57.34	—	1.25×10^{-1}	1.15×10^{-1}	=>1600	58	7.9
11	Esperon	KANO KT-300WT	15/ 9/91 23/ 9/91	151.00	9.53	40.0- 48.0 64.0- 68.0 80.0-100.0 116.0-126.0	granule to pebble sized arkosic/lithic Sand	204.20	8.62	23.69	3.27×10^{-2}	2.20×10^{-2}	2.69×10^{-2}	=>2200	107	7.7
12	Chacuey	KANO KT-300WT	5/12/91 16/12/91	151.00	14.95	32.0- 44.0 52.0- 60.0 68.0- 72.0 136.0-140.0	Weathered metamolphosed Sandstone	321.88	8.60	37.44	3.59×10^{-2}	3.27×10^{-2}	4.49×10^{-2}	424-450	10	8.8~9.6
13	Los Arroyos	KANO KT-300WT	19/10/91 10/11/91	135.20	8.77	29.3- 41.3 53.3- 61.3 85.3- 93.3	Weathered metamolphosed Sandstone arkosic /lithicsand	17.90	71.43	0.25	8.71×10^{-5}	8.83×10^{-5}	8.08×10^{-5}	810-2910	30~140	7.8~8.4
14	La Cerra	Speed Star	4/10/91 15/10/91	78.20	8.03	33.4- 81.4	Weathered metamolphosed Sandstone	18.25	33.68	0.57	2.06×10^{-4}	2.23×10^{-4}	2.18×10^{-4}	1241	143	7.7

Table 5.2.2 (2) Results of Test Drilling and Pumping Test

Well No. & Location		Results of Drilling						Result of Pumping Test			Transmissibility (m^2/min)			Water Quality		
		Drilling Rig	Started / Completed	Drilled Depth(m)	S.W.L (GL.m)	Screen Position (GL.m)	Lithofacies of Aquifer	P/Discharge (Q) ℓ/min	Drawdown (S)m	Specific Capacity (ℓ/min/m)	Theis	Jacob	Recovery	Electric Conductivity (μs/cm)	Cl mg/ℓ	pH
15	Buen Gusto	KANO KT-300HT	25/11/91 29/11/91	44.40	5.83	9.3- 29.3	Weathered Granodyorite	19.25	12.93	1.49	8.75×10^{-4}	8.81×10^{-4}	1.38×10^{-3}	278-308	10	8.6~9.0
16	La Penita Abajo	KANO KT-300HT	1/12/91 4/12/91	86.40	7.75	7.8- 19.8 23.8- 31.8	Weathered Granite	28.88	3.97	6.77	2.78×10^{-3}	3.38×10^{-3}	4.08×10^{-3}	478-586	20	8.2~8.6
17	La Penita Arriba	KANO KT-300HT	20/11/91 23/11/91	89.00	14.71	27.7- 35.7 39.7- 43.7 71.7- 75.7 79.7- 83.7	Weathered Granite	10.06	55.48	0.18	2.49×10^{-3}	3.64×10^{-3}	6.04×10^{-3}	310-330	10	8.4~8.9
18	Curca de Mariano Centero	Speed Star	19/10/91 2/11/91	53.38	14.04	14.7- 46.7	Weathered/altered tuffaceous Sandstone	10.06	9.10	1.11	7.68×10^{-4}	7.14×10^{-4}	9.17×10^{-4}	150-200	Tr	7.5~8.9
19	El Manzanillo	Speed Star	16/11/91 6/12/91	84.50	14.11	16.97- 23.77 68.67- 82.27	Calcareous Conglomerate gravelly fine sand-silt	27.00	14.03	1.92	7.19×10^{-3}	8.12×10^{-3}	1.02×10^{-4}	1200	1.25	7.6
20	Las Rosas	KANO KT-300HT	11/ 1/92 19/ 1/92	150.50	18.07	27.5- 35.5 43.5- 51.5 71.5- 75.5 87.5- 91.5 127.5-131.5	alternation of Gravel and Silt	337.10	8.41	35.82	4.38×10^{-2}	4.78×10^{-2}	4.45×10^{-2}	770-800	80	7.5~8.0
21	Lamadero	Speed Star	18/11/91 1/12/91	110.00	12.35	24.0- 32.0 40.0- 48.0	Clayly Coarse sand/ gravel fine sand or gravelly Mud	8.28	28.38	0.29	9.92×10^{-4}	1.12×10^{-3}	8.17×10^{-4}	2800	310	8.4
22	El Corbeao	Speed Star	16/11/91 14/12/91	120.00	—	—	Dry hole	—	—	—	—	—	—	—	—	—
23	Palo Seco	Speed Star	10/12/91 17/12/91	100.00	—	—	Dry hole	—	—	—	—	—	—	—	—	—
24	Asiento Nigel	Speed Star	18/12/91 22/12/91	85.00	19.22	12.28- 23.98 31.78- 43.48	Calcareous Conglomerate or gravel-marly gravel	27.00	12.82	2.11	8.69×10^{-3}	7.05×10^{-3}	5.61×10^{-4}	800	160	7.8
25	Angosturia	Speed Star	26/12/91 7/ 1/92	50.00	16.00	—	Silt/Claystone	—	—	—	—	—	—	70040	>3500	7.8
26	La Salina	Speed Star	8/ 1/92 18/ 1/92	50.00	19.53	19.8- 47.1	Siltstone/Coral Reef	178.94	0.81	230.07	$>1.77\times10^{-1}$	$>1.24\times10^{-1}$	$>8.74\times10^{-1}$	1300	650	8.6
27	Mariano Centero	KANO KT-300HT	3/ 1/92 6/ 1/92	61.00	14.41	34.5- 54.0	Weathered/altered tuffaceous Sandstone	11.02	8.21	1.34	8.05×10^{-4}	8.20×10^{-4}	8.85×10^{-4}	169-204	Tr	7.5~8.9

Table 5.3.1(1) Classification of the Hydrogeological Provinces and Yield Capacity

Hydrogeological Province		Hydrogeological Condition										Yield Capacity	Recommendable Drilling Depth with part for Deposit
No.	Hydrogeological and Province Name	Test Drilling No. and Village Name	Aquifer Lithofacies	Thickness (m)	Type of Groundwater	Water Level S.W.L.(GL-m)	Water Level D.D. (m)	Yield (ℓ/min)	Specific Capacity (ℓ/min/m)	Water Quality EC; μs/cm, SO_4^{2-}; ppm	Characteristic	(ℓ/min)	(m)
I	Cordillera Septentrio	1.EL Manatial	Calcareous sand-gravel	<15	Unconfined	21.0	77.90	3.65	0.05	EC = 3,550～11,340 SO_4^{2-} = 850 pH = 7.3	Chiefly composed of sediments of Tertiary age. Generally consists of mudstone beds with low permeability, ranging in figures of 10^{-6} to 10^{-5}. Partly associated with sandy facies. Electric conductivity values of ground water are shown in left column, while, those correspond to the chlorine ion concentration values of 1500 to 2500 ppm.	0	—
		2.EL Guayo			Unconfined	-	55.82	11.02	0.20	EC = 7,890～12,080 SO_4^{2-} = 4,750 pH = 7.8		0	—
II	Llano de Rio Yaque del Norte	3.Las Aquas	Fine sand	20～30	Unconfined	2.20	5.26	265.83	50.60	EC = 2,240～ 2,450 SO_4^{2-} = 883 pH = 8.1～8.6	Ground water occur in significantly permeable beds of fine- to medium-grained sand, transmissibility coefficient values of which range in figures of 10^{-3} to 10^{-1}. Observed along Yaque del Norte River bank. In-flow of fine sand grains into screen meshes and organic solid suspensions in ground water in some places are to be carefully examined.	>500	80～90
		4.Jabo Corcobado	Fine sand	20～30	Unconfined	4.10	19.18	178.94	9.22	EC = 1,480～ 1,880 SO_4^{2-} = 500 pH = 7.7～8.6		100	60～70
III$_1$	Sur del Yaque del Norte	8.Ranchadero	Very fine-grained sand	20	Weakly confined	2.05	7.22	108.89	15.08	EC => 2,000 SO_4^{2-} = 340 pH = 8.3	Ground water is observed in alternations of fine sand and silt beds of Tertiary age. In-flow of silt grains into screen meshes is to be carefully examined.	100	70～80
III$_2$	Sur del Yaque del Norte	5.La Pinta	Calcareous sandstone	20～30	Confined	17.33	1.80	337.10	210.69	EC = 1,700～ 1,920 SO_4^{2-} = 2,171 pH = 8.6～9.0	Ground water is observed in calcareous sandstone beds of Tertiary age. Water yield is estimated to be very high, however, a very high content of sulphate ion concentration is carried. Water well drill depth is to be made some 80 meters deep. Highly permeable with transmissibility coefficient values in range of 10^{-3} to 10^{-2}.	>1000	70～80
III$_3$	Sur del Yaque del Norte	9.Palo Blanco	Silty sandstone	50～60	Confined	50.80	10.84	192.97	18.14	EC => 2,200 SO_4^{2-} = 115 pH = 8.2	Aquifers are comprised of several calcareous sandstone beds, intercalated in thick siltstone beds. Highly permeable with transmissibility coefficient values in range of 10^{-3} to 10^{-2}.	150～200	140～150
		10.La Vigia	Alternations of sandstone as Siltstone	10～15	Confined	13.24	3.58	204.12	57.34	EC => 1,500 SO_4^{2-} = 205 pH = 7.9	Aquifers show the similar character to the above, III$_3$-9. Highly permeable with transmissibility coefficient values in range of 10^{-1}.	>500	80
		11.Esperon	Sandstone	20～30	Confined	9.53	8.62	204.20	23.69	EC => 2,200 SO_4^{2-} = 88 pH = 7.7	Aquifers are comprised of conglomeratic sandstone beds of Tertiary age, which underlie arkose sandstone beds of Tertiary age. Occur about 80 to 100 meters deep underground. Highly permeable with transmissibility coefficient values in range of 10^{-1}.	200～300	120
		12.Chacuey	Sandstone	28	Confined	14.95	8.80	321.99	37.44	EC = 424～ 450 SO_4^{2-} = 8 pH = 8.8～9.8	Aquifers are comprised of conglomeratic sandstone and arkose sandstone beds, which overlie weathered metamorphic rocks of Cretaceous age. Transmissibility coefficient values show about 10^{-2}. Water quality is good.	300～500	120～140

S.W.L. : Static Water Level
D.D. : Draw Down

Table 5.3.1 (2) Classification of the Hydrogeological Provinces and Yield Capacity

Hydrogeological Province		Hydrogeological Condition										Yield Capacity	Recommendable Drilling Depth with part for Deposit
No.	Hydrogeological and Province Name	Test Drilling No. and Village Name	Aquifer Lithofacies	Thickness (m)	Type of Groundwater	Water Level S.W.L.(GL-m)	Water Level D.D. (m)	Yield (ℓ/min)	Specific Capacity (ℓ/min/m)	Water Quality EC; μs/cm, SO_4^{2-}; ppm	Characteristic	(ℓ/min)	(m)
III4	Sur del Yaque del Norte	7.Guayubincito	Sandysild	5～10	Weakly Confined	1.54	47.03	34.11	0.73	EC = 838～ 901 SO_4^{2-} = 255 pH = 8.7～9.1	Confining layers of Tertiary age.	5～10	70～80
			Calcareous Sandstone	10～20							Aquifers are comprised of sandy sediment parts, intercalated in alternations of calcareous shale and sandstone beds of Pliocene - Tertiary age. Transmissibility coefficient values show about 10^{-4}. Water quality is good.		
IV1	Cordillera Central	15.Buen Guato	Weathered Granodyorite	20	Unconfined	5.83	12.93	18.25	1.48	EC = 273～ 308 SO_4^{2-} = 5 pH = 8.6～9.0	Weathered zones of granitoid of Mesozoic age form aquifer beds. Aquifers are, consequently, located close to the ground surface to inevitably cause a seasonal fluctuation of water table level. Transmissibility coefficient values show in range of 10^{-4} to 10^{-3} while, apparently about as low as 10^{-5} in the occasion, when research drill had been made in the site location close to mountainous ridge, due to that lowering of water level has been large in comparison with water yield quantity in the above site, where ground water recharge had been hardly made. Superior quality of ground water.	10～15	60
		18.La Penita Abajo	Weathered Tonalite	30	Unconfined	7.75	3.97	28.88	8.77	EC = 478～ 585 SO_4^{2-} = 13 pH = 8.2～8.0		50～60	60
		17.La Penita Arriba	Weathered Tonalite	40	Unconfined	14.71	55.49	10.08	0.18	EC = 310～ 330 SO_4^{2-} = 10 pH = 8.4～8.9		2～3	60
IV2	Cordillera Central	8.Cabeza de Toro	Calcareous Sandstone		Confined	53.75	30.62	23.64	0.77	EC = 1,900～ 1,970 SO_4^{2-} = 2,400 pH = 7.4～8.7	Aquifers are comprised of weathered phillitic metamorphosed rocks of Cretaceous age with transmissibility coefficient values of about 10^{-4}. Less permeable. A possible high content value of sulphate ion contration should be cautiously examined.	5～10	140～150
IV3	Cordillera Central	13.Los Arroyos	Gravelly Sandstone	12～15	Unconfined	8.77	71.43	17.90	0.25	EC = 810～ 2,910 SO_4^{2-} = 1,400 pH = 7.8～8.4	Conglomeratic sandstone beds of Tertiary age, which overlie metamorphic rocks of Cretaceous age, are estimated to possibly form aquifers with possibly low water yield quantity.	5	70～80
			Coarse grained Sandstone	8～15	Weakly Confined						Aquifers are comprised of weathered zones of metamorphic rocks of Cretaceous age. Less water yield quantity with transmissibility coefficient values in range of 10^{-5} to 10^{-4}.	—	—
		14.La Gorra	Weathered Sandstone	30～40	Unconfined	8.03	33.88	19.25	0.57	EC = 1,241 SO_4^{2-} = 83 pH = 7.7	Aquifers in Curce de Mariano Castero and Mariano Castero are observed in argillaceously altered parts by granitic rock intrusion. Superior quality of ground water.	5～10	80～90
		18.Curce de Mariano Castero	Weathered Sandstone	32	Unconfined	14.04	8.10	10.08	1.11	EC = 150～ 200 SO_4^{2-} = 18 pH = 7.5～8.9		10～15	70～80
		27.Mariano Castero	Weathered Sandstone	20	Unconfined	14.41	8.21	11.02	1.34	EC = 158～ 204 SO_4^{2-} = Tr pH = 7.5～8.9		10～15	70～80
IV5	Cordillera Central		Limestone	<nx100	Confined	—	—	—	—		Ground water mobilises through sinkholes in limestone beds. Water is abundantly yielded when sinkholes are open to ground surface. Ground water quality is good.		

S.W.L. : Static Water Level
D.D. : Draw Down

Table 5.3.1 (3) Classification of the Hydrogeological Provinces and Yield Capacity

Hydrogeological Province		Hydrogeological Condition										Yield Capacity	Recommendable Drilling Depth with part for Deposit
No.	Hydro-geological and Province Name	Test Drilling No. and Village Name	Aquifer Lithofacies	Thick-ness (m)	Type of Groundwater	Water Level S.W.L.(GL-m)	Water Level D.D. (m)	Yield (ℓ/min)	Specific Capacity (ℓ/min/m)	Water Quality EC; μs/cm. SO_4^{2-}; ppm	Characteristic	(ℓ/min)	(m)
V_1	Valle de San Juan	19. El Manoncito	Calcareous Conglomerate	25	Unconfined	14.11	14.03	27.00	1.92	EC = 1,200 SO_4^{2-} = xx pH = 7.6	Lower part of the alternations of calcareous conglomerate, mudstone and conglomerate beds of Tertiary, which are observed on ground surface, forms aquifers. General depths toward aquifers are shallow in dissected valley areas, inversely are relatively deep in hilly areas. Ground water level in hilly areas shows a seasonal remarkable fluctuation. General transmissibility coefficient values show in range of 10^{-3} to 10^{-5}, while, about 10^{-2} in Las Rosas. Salinity values of ground water are also varied.	15~20	50~70
		20. Las Rosas	Calcareous Conglomerate	20~30	Confined	19.07	9.41	337.10	35.82	EC = 770~ 800 SO_4^{2-} = Tr? pH = 7.5~8.0		300~500	50~70
		21. Lamesdero	Calcareous muddy sandstone	20~30	Unconfined	12.35	28.38	8.28	0.29	EC = 2,800 SO_4^{2-} = xx pH = 7.7		3~5	50~70
V_2	Valle de San Juan	22. El Corbano	Calcareous sand-gravel	—	Dry	Dry	Dry	—	—	—	The areas are geologically located in anticlinal part of the beds. Chiefly consists of siltstone beds, which are correlated to the above layers shown in V1. Thick-bedded and aquiclude. Occurrences of ground water in shallow depth in the Province are evaluated to be unlikely potential. Utilization of spring water from weathered zones, close to ground surface, is to be examined.	—	—
		23. Palo Seco	Calcareous sand-gravel	—	Dry	Dry	Dry	—	—	—		—	—
VI	Sierra de Neiba	24. Asiento Miguil	Calcareous sandstone	20~30	Unconfined	19.22	12.82	27.00	2.11	EC = 600 SO_4^{2-} = 185 pH = 7.8	Unconfined ground water of quantitative insignificance is observed in calcareous sandstone beds, intercalated in shale beds of marine sedimentation in Tertiary age.	20	50~70
			Limestone	>50	Confined						Confined water of good quality is observed associated with limestone beds of Oligocene-Tertiary age. The ground water springingly flows into streams in low ground. Selections of drill site are to be cautiously studied.	—	—
VII_1	Cuenca de Enriquillo		Sand-gravel Coral sand		Unconfined	—	—	—	—		Occurrences of ground water are evaluated to be unlikely potential in the Province, geologically covered by such sediments as calcareous clay, sand, gravel and etc. on ex-sea-floor and with less vegetation.		
VII_2	Cuenca de Enriquillo	25. Angustora	Marly limestone	30	Unconfined	15.00	—	—	—	EC = 70,400 SO_4^{2-} = 18,500 pH = 7.6	Marly limestone beds are of aquiclude, therefore, are evaluated to unlikely form aquifers.	—	—
			Alternations of conglomerate-sandstone	750		—	—	—	—		Ground water is remarkably saline due to local extensions of rock salt beds of Tertiary age. Run-off and spring water from Baoruco Mountains are to be reasonably collectively utilized.	100~200	80
		26. La Baitoa	Coral reaf, alternations of conglomerate-sandstone	750	Confined in fissure system cavities	19.53	0.81	176.34	290.07	EC = 1,300 SO_4^{2-} = xx? pH = 7.8	Spring water from Baoruco Mountains are to be abundantly collected as shown by the current drill operation.	>3,000	80
VIII	Sierra de Baoruco		Limestone	>nx100	—	—	—	—	—		Sinkholes in limestone beds are well-developed to cause a downward mobilization of rain water. A part of ground water is observed in northern hillfoot.		

S.W.L. : Static Water Level
D.D. : Draw Down

Table 5.3.2 Groundwater Quality of Test Drill Hole

Analysis Elements \ Drill Site	No.1 El Manantial	No.2 El Guayo	No.3 Las Aguas	No.4 Jobo Corcobado	No.5 La Pinta	No.6 Ranchadero	No.7 Guayubincito	No.8 Cabeza de Toro	No.9 Palo Blanco	No.10 La Vigia	No.11 Esperon	No.12 Chacuey	No.13 Los Arroyos	No.14 La Gorra	No.15 Buen Gusto	No.16 La Penita Abajo	No.17 La Penita Arriba	No.18 Curce de Marjano Centero	No.19 El Mamoncito	No.20 Las Rosas	No.21 Lasesdero	No.22 Los Corbanos	No.23 Palo Seco	No.24 Asiento Nigel	No.25 Angustoria	No.26 La Baitoa	No.27 Mariano Centero
HCO_3^-	95	270	140	345	227	286	171	238	158	317	177	186	97	320	122	78	141	81	205	145	188	-	-	383	152	188	87
Cl^-	1500	2500	525	75	328	101	118	35	128	58	108	23	278	143	10	54	12	11	1250	107	3100	-	-	34	67250	237	7
SO_4^{2-}	850	4750	883	500	2171	340	255	1425	115	205	88	8	1400	83	5	13	10	13	384	350	355	-	-	185	18500	400	0
$Na^+ + K^+$	1331	3213	548	308	338	188	239	418	185	201	22	20	1810	148	8	11	16	12	183	124	176	-	-	148	49151	130	0.48
Ca^{2+}	44	178	90	95	88	166	37	432	83	85	93	97	285	97	78	144	74	25	11	18	9	-	-	155	3208	181	31
Mg^{2+}	148	595	420	208	110	225	51	439	34	88	74	84	126	170	55	88	80	38	8	6	12	-	-	107	3888	57	45
NO_3^-	5.0	5.0	0.02	15.0	18.0	12.0	8.0	8.0	18.0	13.0	10.0	8.0	25.0	22.0	15.0	13.0	5.0	10.0	5.0	12.0	2.0	-	-	10.0	1.0	1.0	11.0
NO_2^-	< 0.02	< 0.02	3.0	1.0	5.0	0.02	< 0.02	< 0.02	< 0.02	< 0.05	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	1.0	0.02	0.02	-	-	0.1	0.05	0.02	< 0.02
NH_4^-	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.05	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	-	-	< 0.5	< 0.5	< 0.5	< 0.5
F^-	0.1	0.7	0.1	0.4	1.5	0.7	Tr	0.8	0.4	0.4	Tr	0.2	Tr	Tr	0.15	0.10	0.20	0.40	0.20	0.80	0.90	-	-	1.20	1.20	Tr	Tr
PO_4^{2-}	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	-	-	Tr	Tr	Tr	Tr
Cr	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	-	-	< 0.02	< 0.02	< 0.02	< 0.02
Fe	2.0	Tr	3.0	Tr	0.2	Tr	Tr	0.7	Tr	< 0.2	1.8	0.3	3.0	Tr	Tr	Tr	Tr	7.0	Tr	Tr	Tr	-	-	Tr	0.7	Tr	0.7
Cu	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	-	-	< 0.5	< 0.5	< 0.5	< 0.5
Zn	1.0	1.0	0.5	0.5	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.5	0.5	1.0	0.5	0.5	0.5	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0
Mn	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	-	-	< 0.5	< 0.5	< 0.5	< 0.5
Pb	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	-	-	Tr	Tr	Tr	Tr
TH	193.0	771.0	510.0	303.0	178.0	393.0	88.0	871.0	97.0	173.0	187.0	181.0	411.0	267.0	134.0	213.0	134.0	63.0	208.0	24.0	184.0	-	-	262.0	8877.0	238.0	76.0

Table 5.4.1 Groundwater Development Potential and it's Magnitude

Hydrogeological Province No.	Hydrogeological and Province Name	Type of Aquifer	Hydrogeological Condition: Yield Capacity (l/min)	Drilling Depth (m)	Target of Aquifer
I	Cordillera Septentrio	Confined	D11 Lack of available aquifer within 150 m in depth	—	×
II	Llano de Rio Yaque del Norte	Unconfined	D 4 Q = 100 , partly Q ≧ 500	< 60	unconfined
III$_1$	Sur del Yaque del Norte	weakly Confined	D 5 Q = 100	60 ～ 90	confined
III$_2$	Sur del Yaque del Norte	Confined	D 3 Q ≧ 100 , partly Q ≧ 1000	60 ～ 90	confined
III$_3$	Sur del Yaque del Norte	Confined	D 1 Q = 300 , partly Q ≧ 500	60 ～ 120	confined
III$_4$	Sur del Yaque del Norte	weakly Confined	D 7 20 > Q ≧ 5 , partly Q ≧ 300 ～ 500	30 ～ 60	confined
IV$_1$	Cordillera Central	Unconfined	D 6 60 > Q ≧ 10	30 ～ 60	unconfined
IV$_2$	Cordillera Central (north)	Unconfined and weakly Confined	D 9 Lack of high available aquifer up to the basement situated at 90 m in depth	70	unconfined
IV$_2$	Cordillera Central (south)	Unconfined	D 8 Lack of high available aquifer up to the basement situated at 60 m in depth	70	unconfined
IV$_3$	Cordillera Central	Confined	D12 no datum	—	(surface water)
V$_1$	Valle de San Juan	Unconfined and Confined	D 7 20 > Q ≧ 5 , partly Q ≧ 300 ～ 500	50 ～ 70	confined
V$_2$	Valle de San Juan	dry	D10 Lack of available aquifer whithin 120 m in depth	—	×
VI	Sierra de Neiba	Unconfined and Confined	D 7 20 > Q ≧ 5 , partly Q ≧ 300 ～ 500	50 ～ 70	(surface water)
VII$_1$	Cuenca de Enriquillo	Unconfined	D12 no datum	—	(spring)
VII$_2$	Cuenca de Enriquillo	Unconfined and Confined	D 2 200 > Q ≧100 , partly Q ≧ 3000	80	unconfined
VII	Sierra de Baoruco	Unconfined	D12 no datum	—	unconfined

Table 5.4.2 Water Balance

Hydrogeologic Province		area	annual mean rainfall	annual Evapo-traspiration	annual Run-off	annual Recharge	Yield Capacity
current	former	(Km^2)	(x10^9 m^3)	(x10^9 m^3)	(x10^9 m^3)	(x10^9 m^3)	(m^3/d/Km^2)
Ⅰ	(1-1)+	305					
	(1-2)	462	64.42	32.75	17.488	14.182	50658
Ⅱ	(2)	422	36.93	21.6	8.118	7.212	46822
Ⅲ1	(3-1.1)+	120					
	(3-1.2)+	120					
	(3-1.3)	86	32.73	20.16	7.182	5.388	45281
Ⅲ2	(3-2.2)	124	16.92	11.22	2.901	2.799	61843
Ⅲ3	(3-3)	130	19.78	11.7	5.157	2.923	61602
Ⅲ4							
Ⅳ1	(4-1)	346	60.55	34.06	15.134	11.356	89920
Ⅳ2	(3-2.1)+	124					
	(4-2)+	44					
	(5)	782	186.28	101.03	54.213	31.037	89508
Ⅳ3	(6)	115	22.08	11.55	6.687	3.843	91554
Ⅴ1	(7-1)+	98					
Ⅴ2	(7-2)+	461					
Ⅵ	(8-1)+	327					
	(8-2)	419	220.77	138.54	47.206	35.024	73530
Ⅵ1	(9)	779	50.63	30.77	17.66	2.2	7737
Ⅵ2	(10-1)	429	47.19	24.64	20.586	1.964	12543
Ⅶ	(10-2)	523	101.99	52.98	35.675	13.335	69855
	Total	6216	860.27	491.00	238.007	131.263	700853

FIGURES

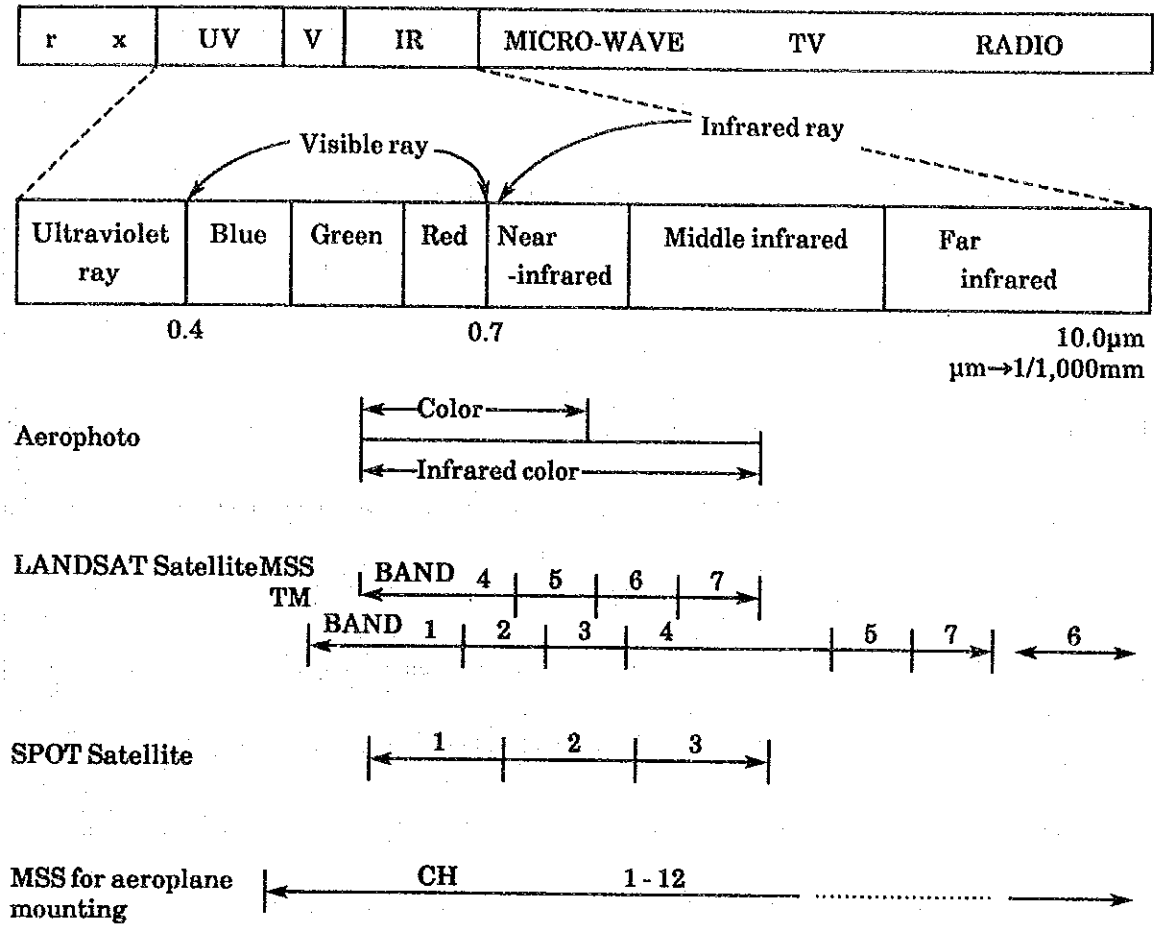

Fig. 2.4.1 Sensors and Ranges of Electromagnetic Waves

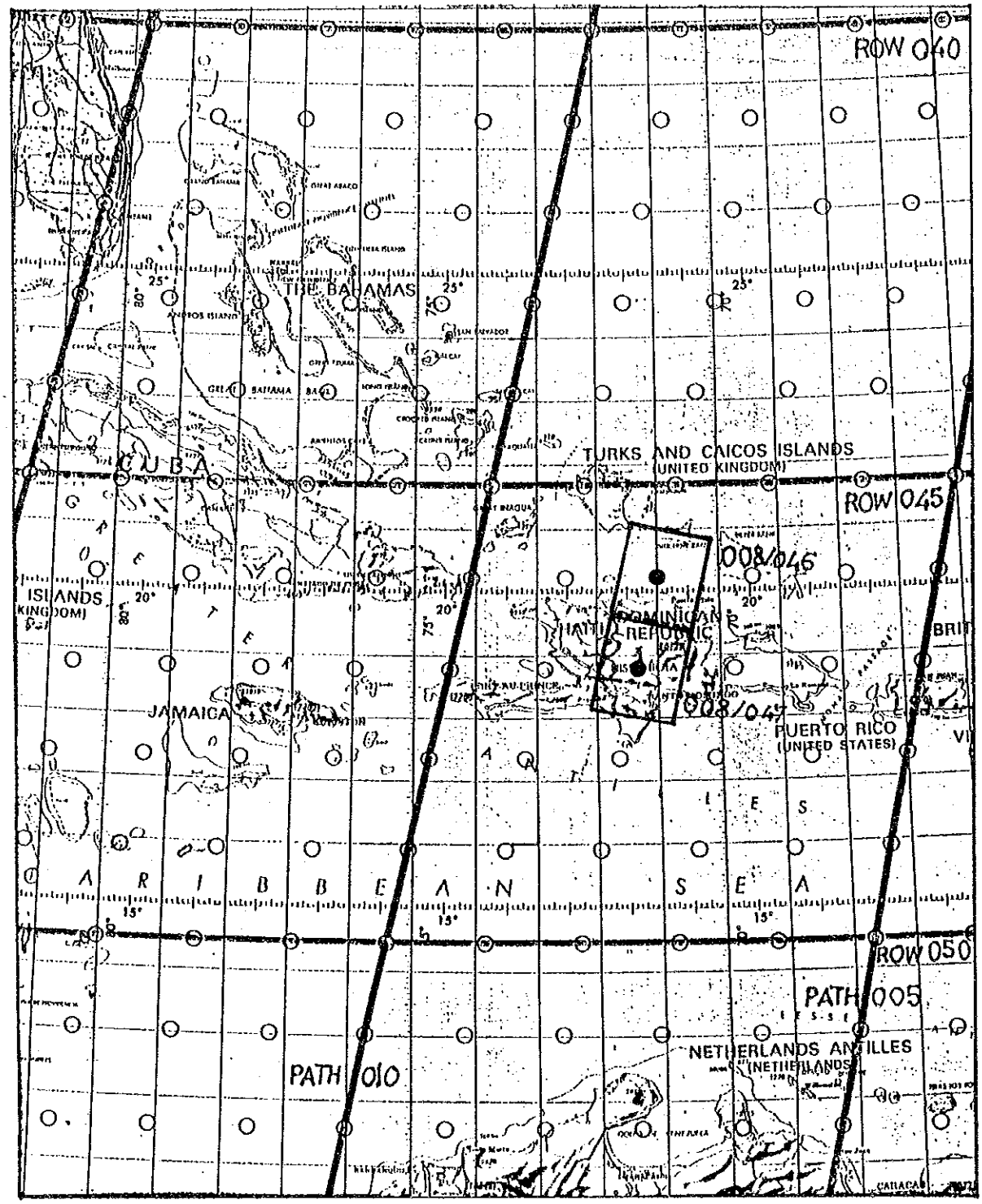

Figure 2.5.1 Index Map of LANDSAT Images

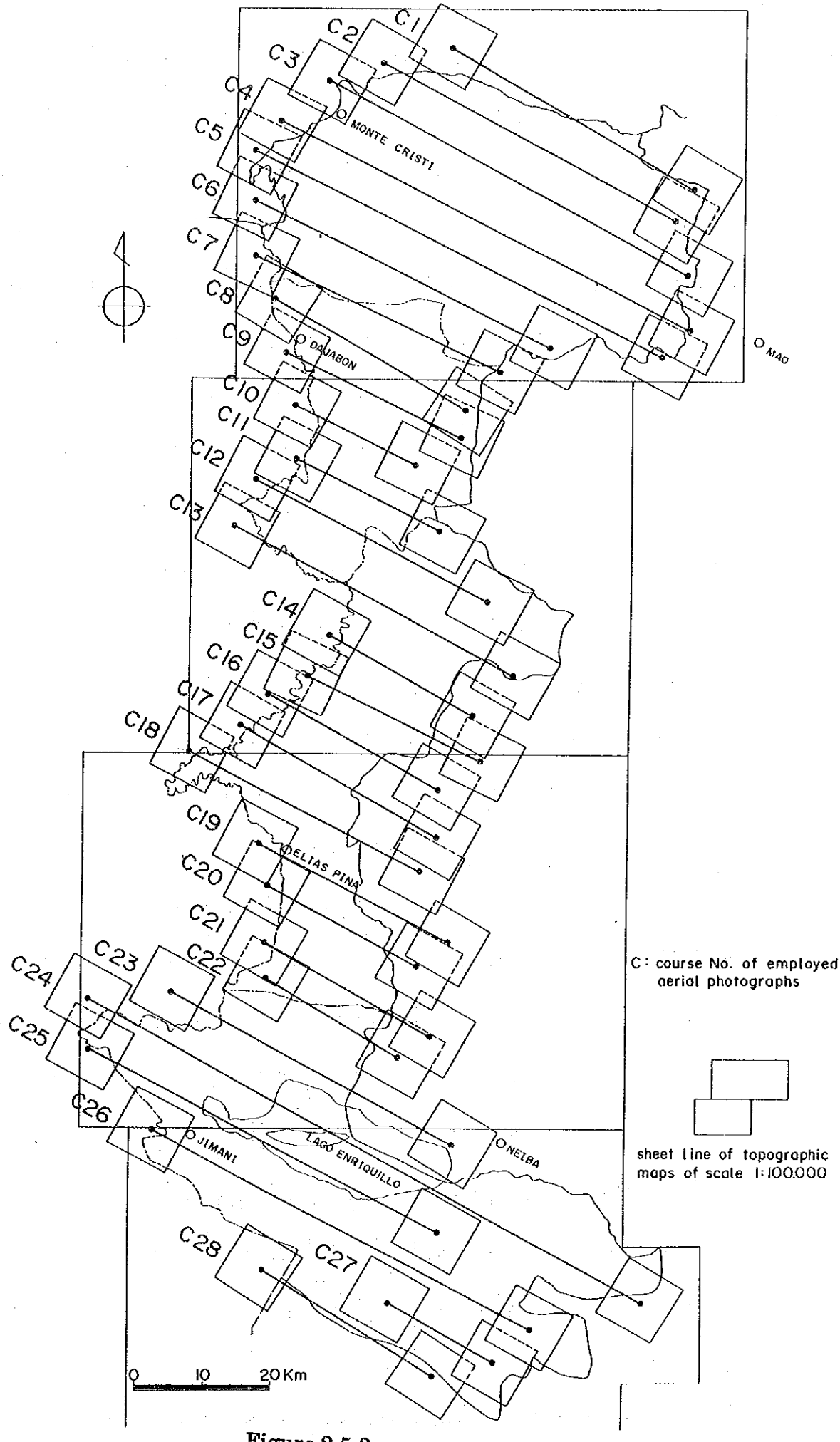

Figure 2.5.2 Index Map of Aerial Photographs

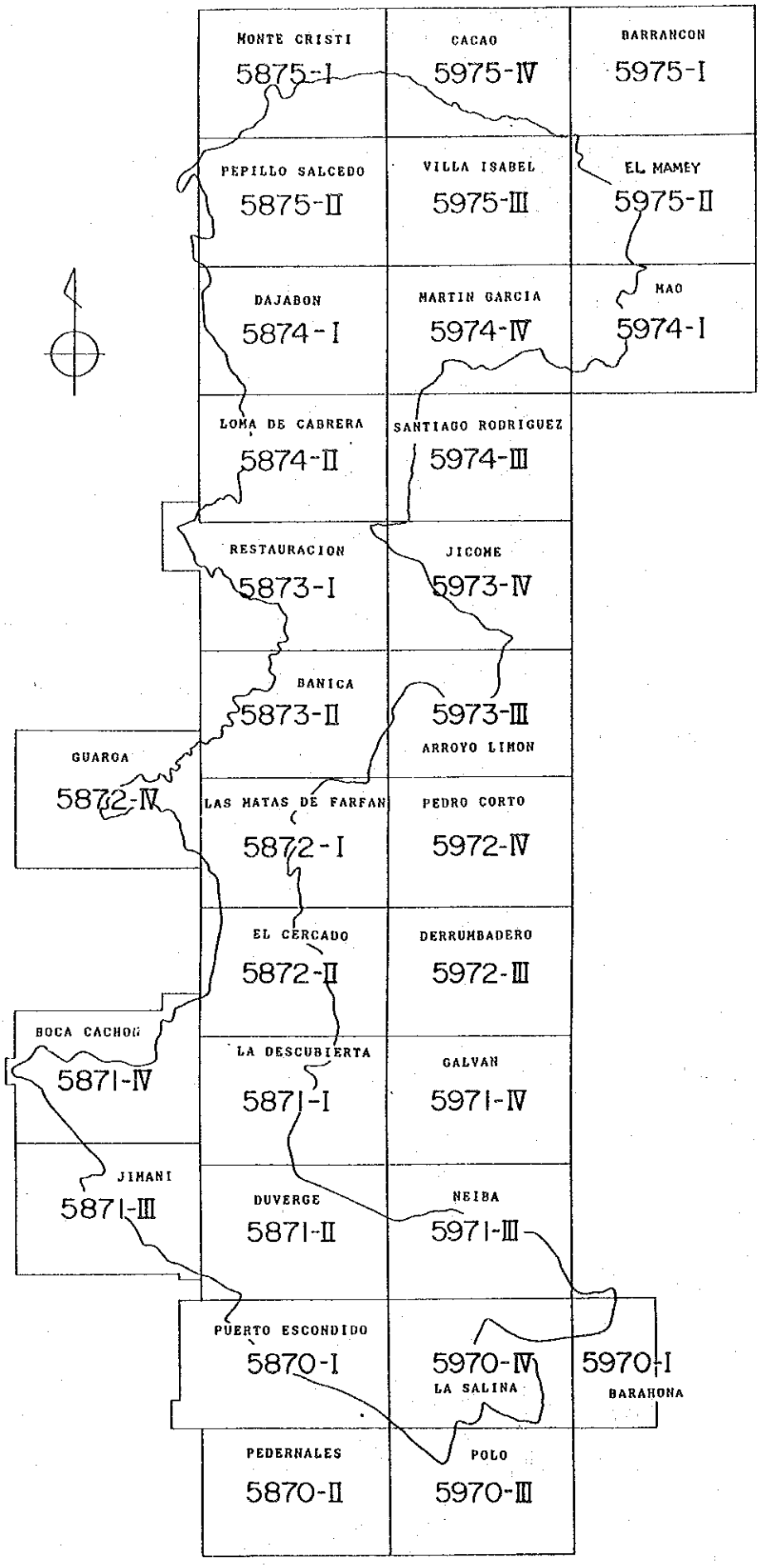

Figure 2.5.3 Index Map of Employed Topographic Maps of scale 1:50,000

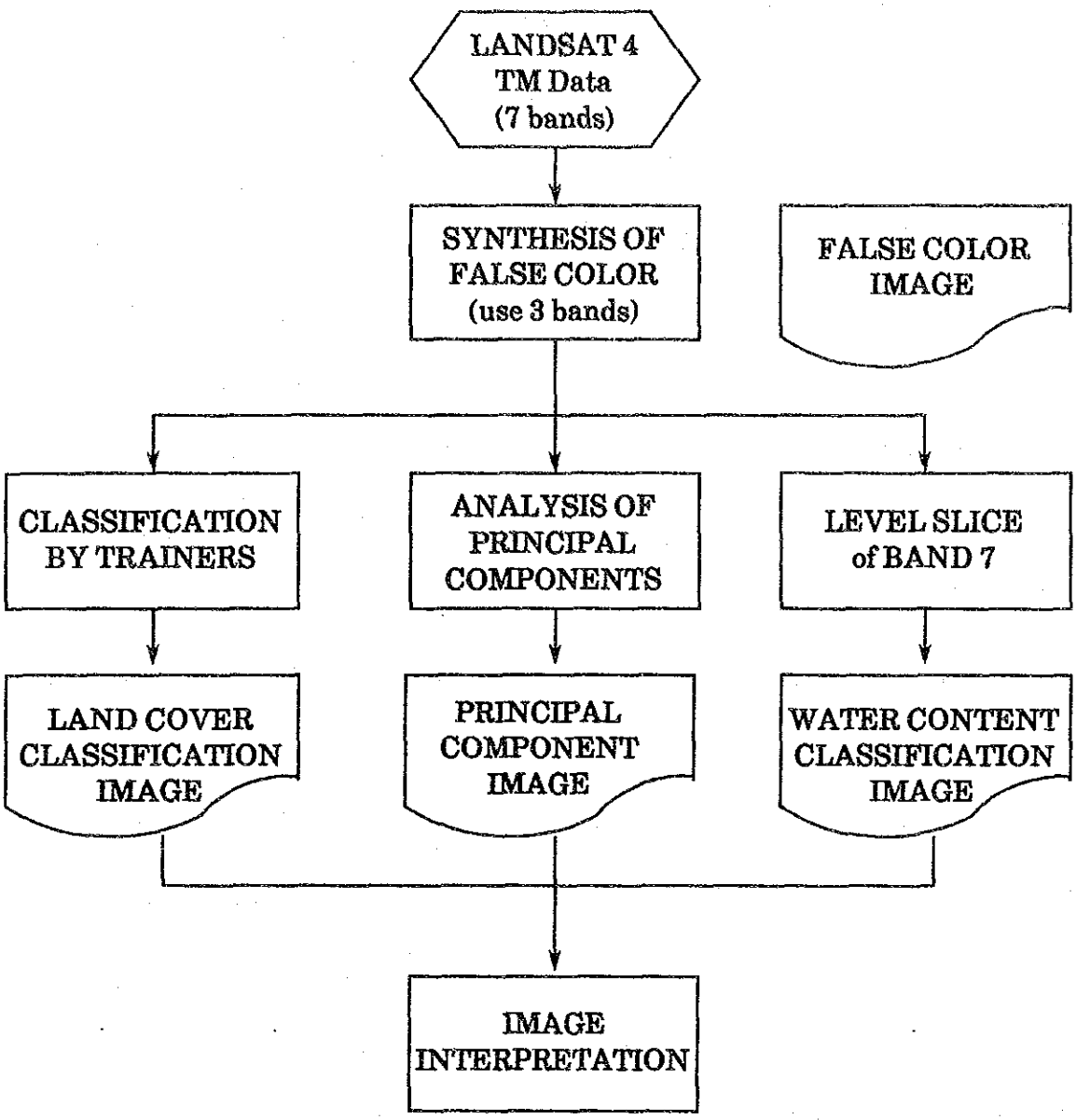

Fig. 2.6.1 Flow Chart of LANDSAT TM Data Processing

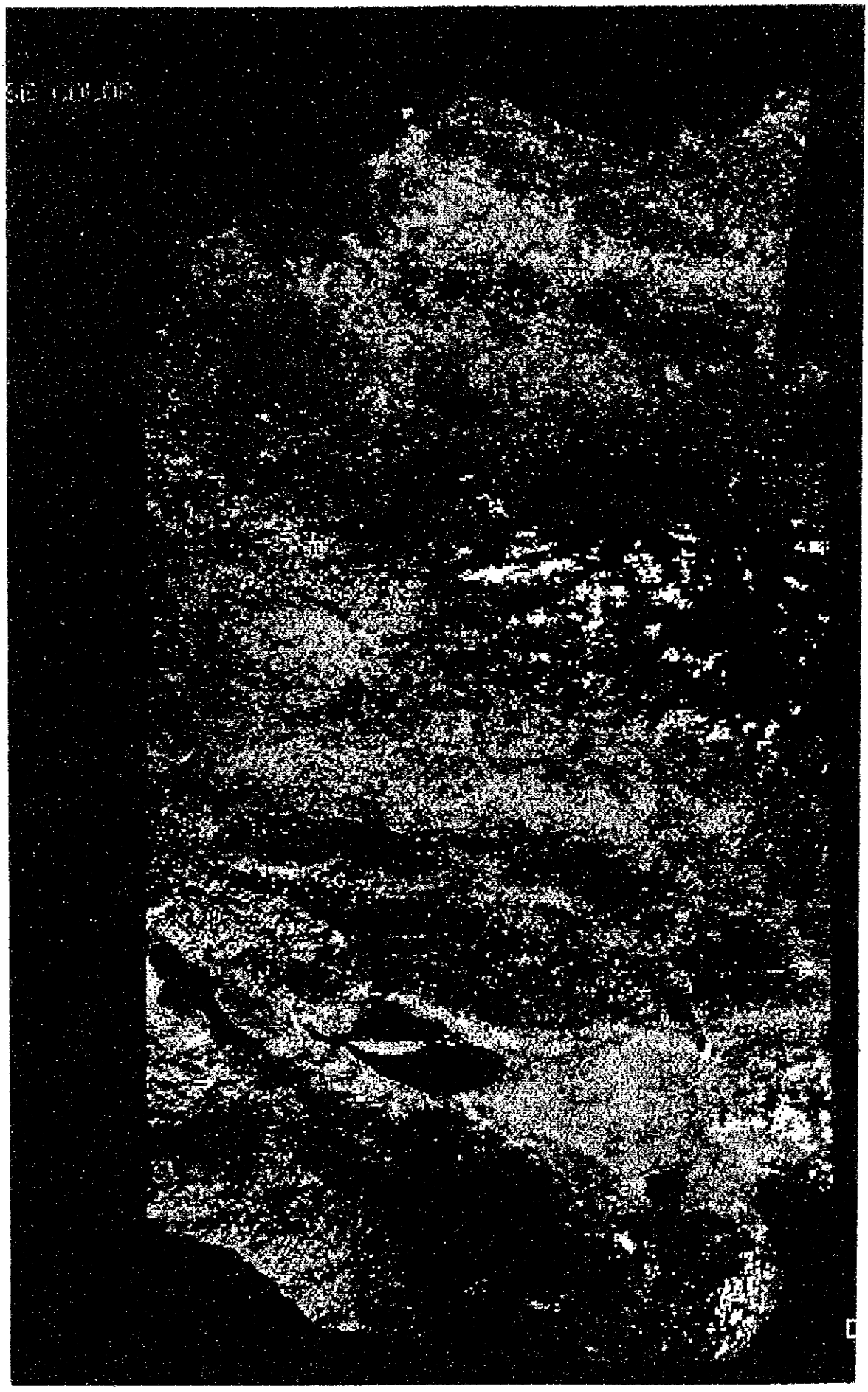

Fig. 2.6.2 Landsat False Color Image

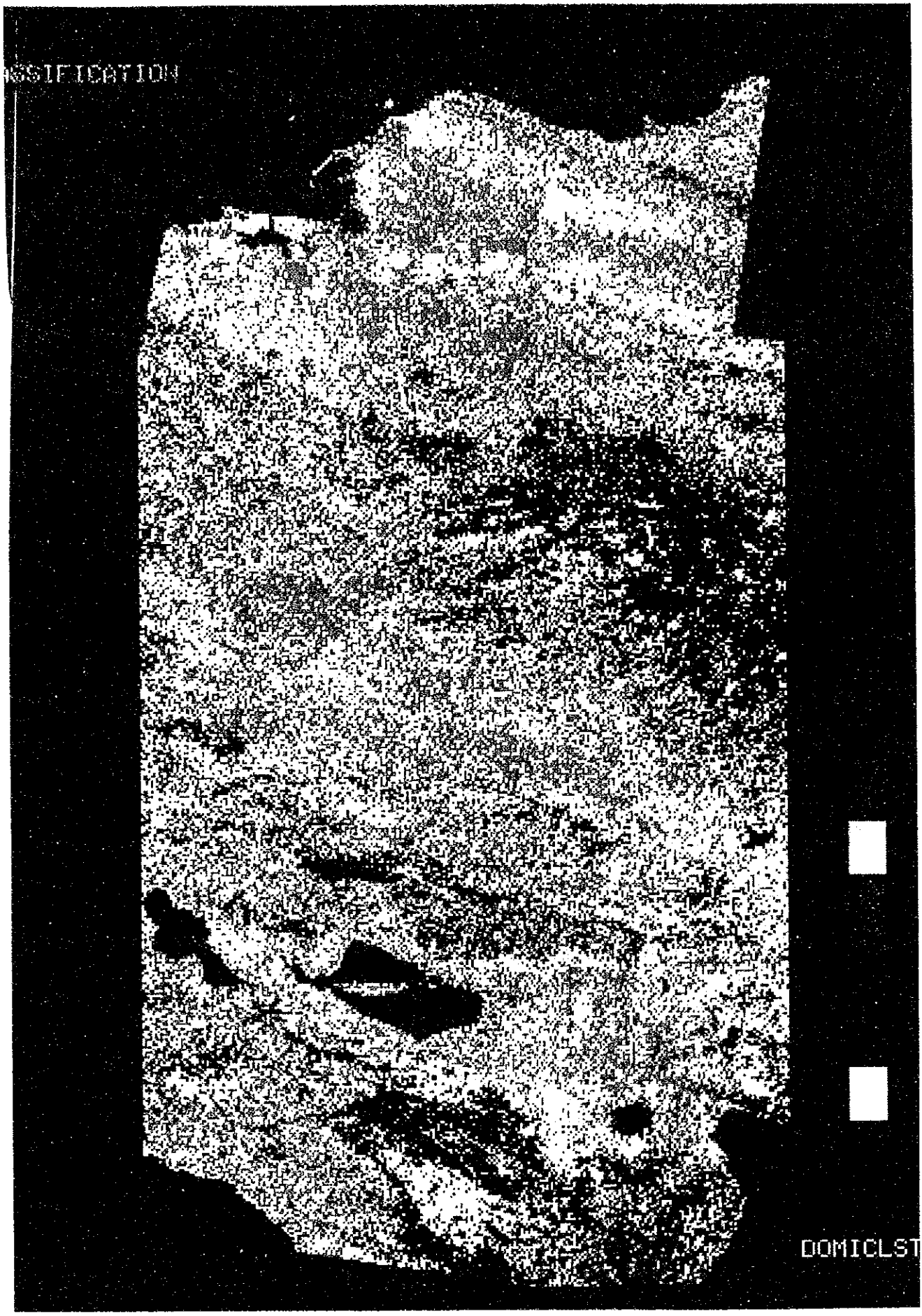

Fig. 2.6.3 Landcover Classification Image

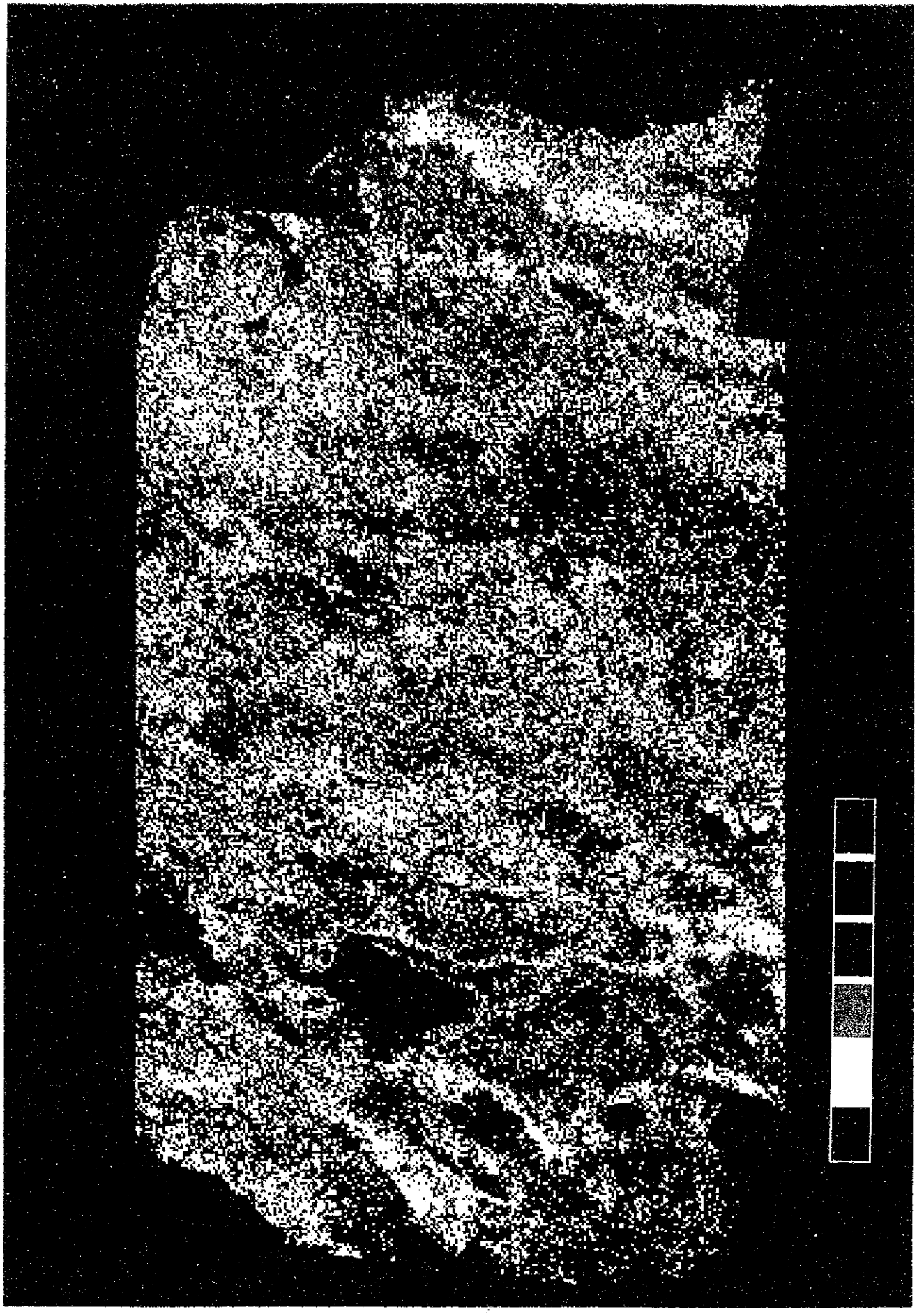

Fig. 2.6.4 Water Content Classification Image

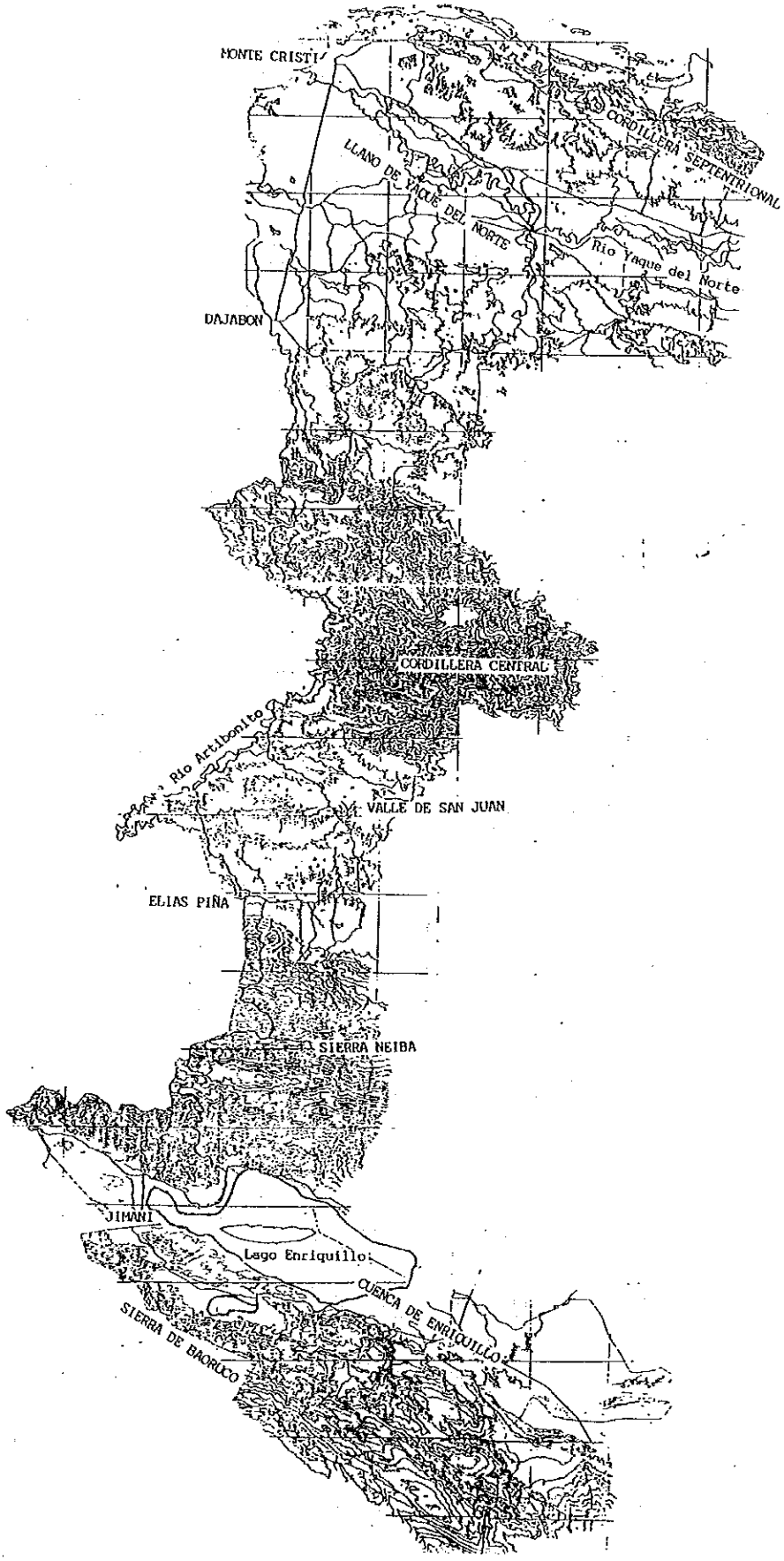

Figure 3.1.1 Contour Line Map of the Area

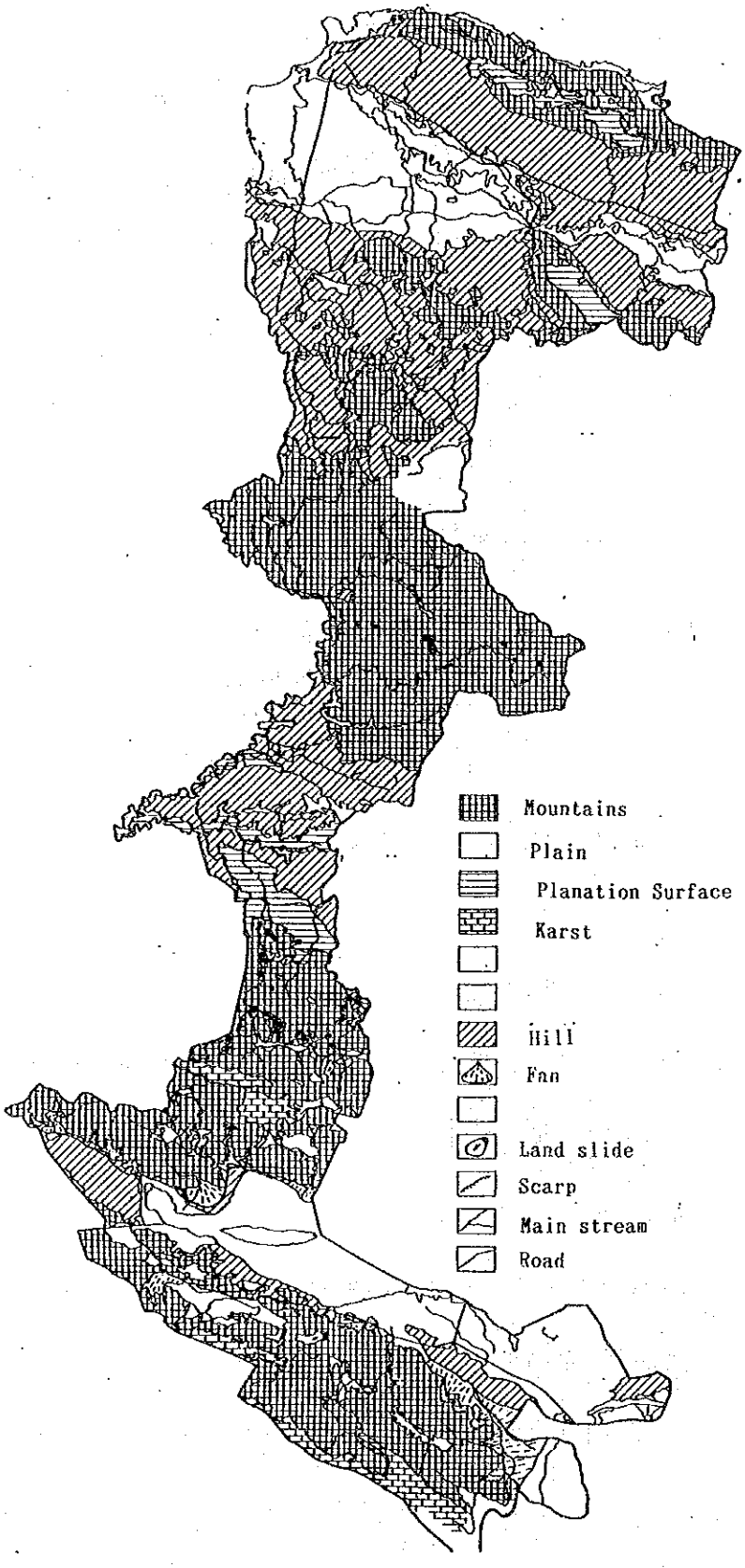

Figure 3.1.2 Landform Classification Map

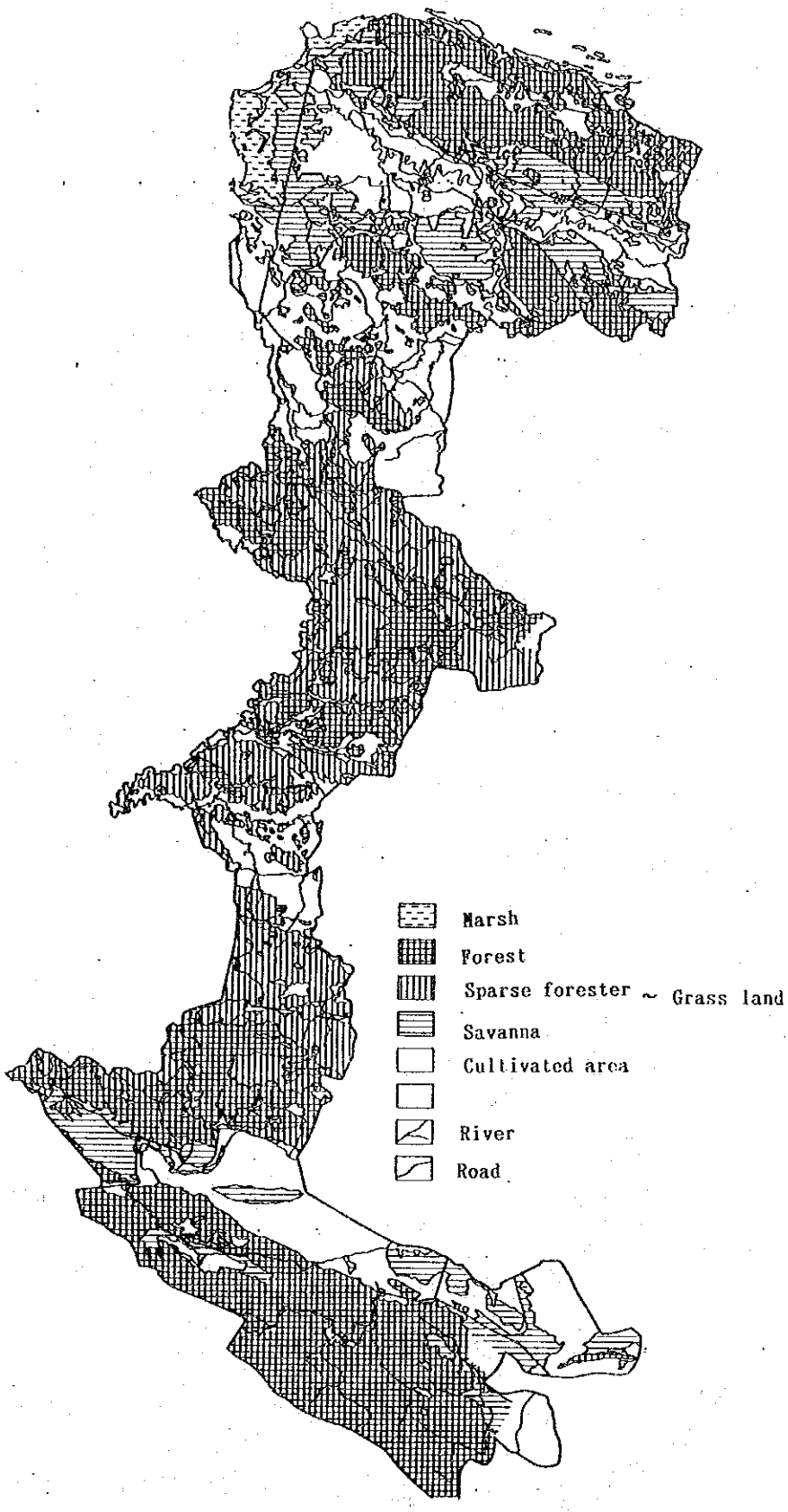

Figure 3.1.3 Land use and Vegetation Cover Condition Map

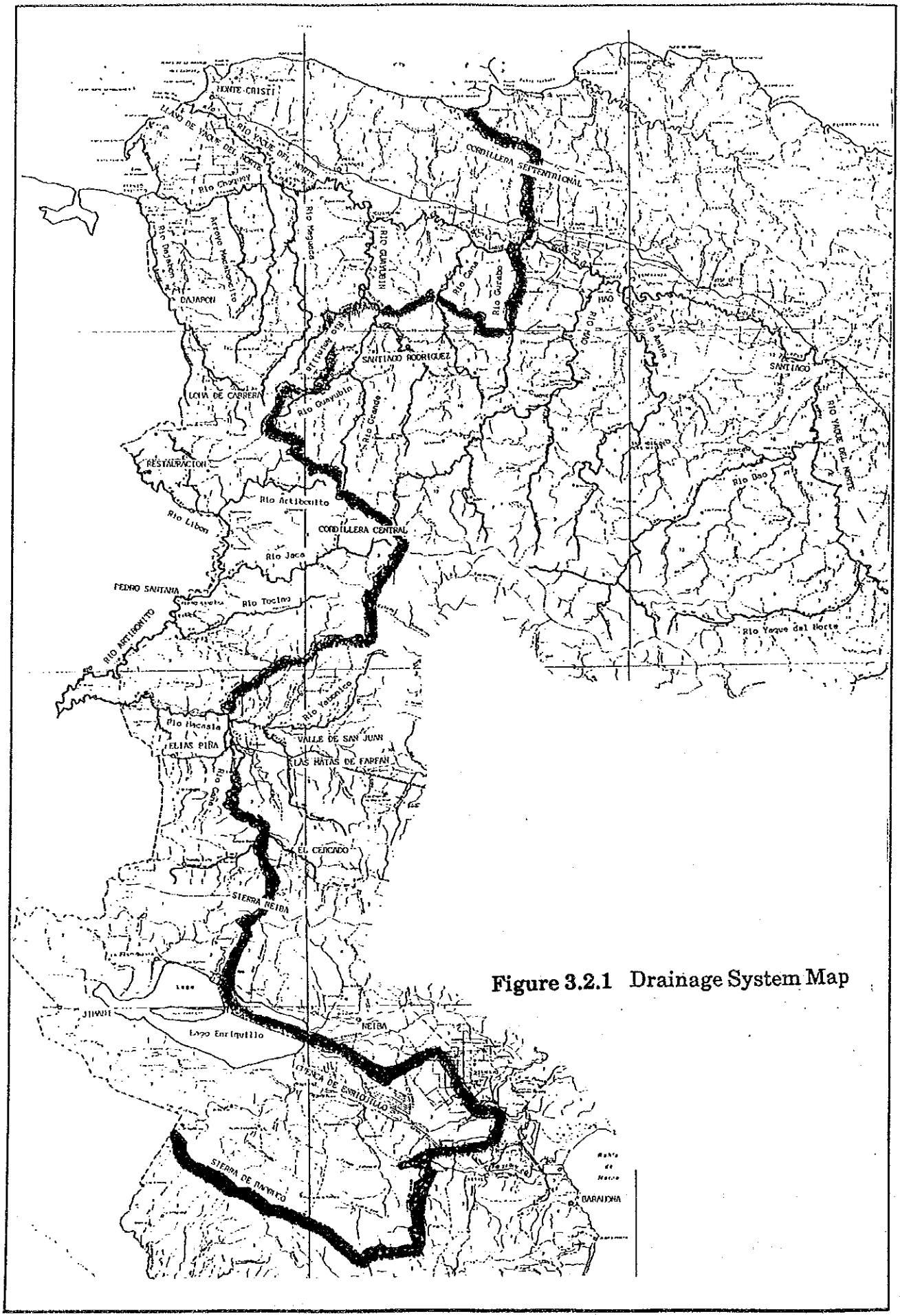

Figure 3.2.1 Drainage System Map