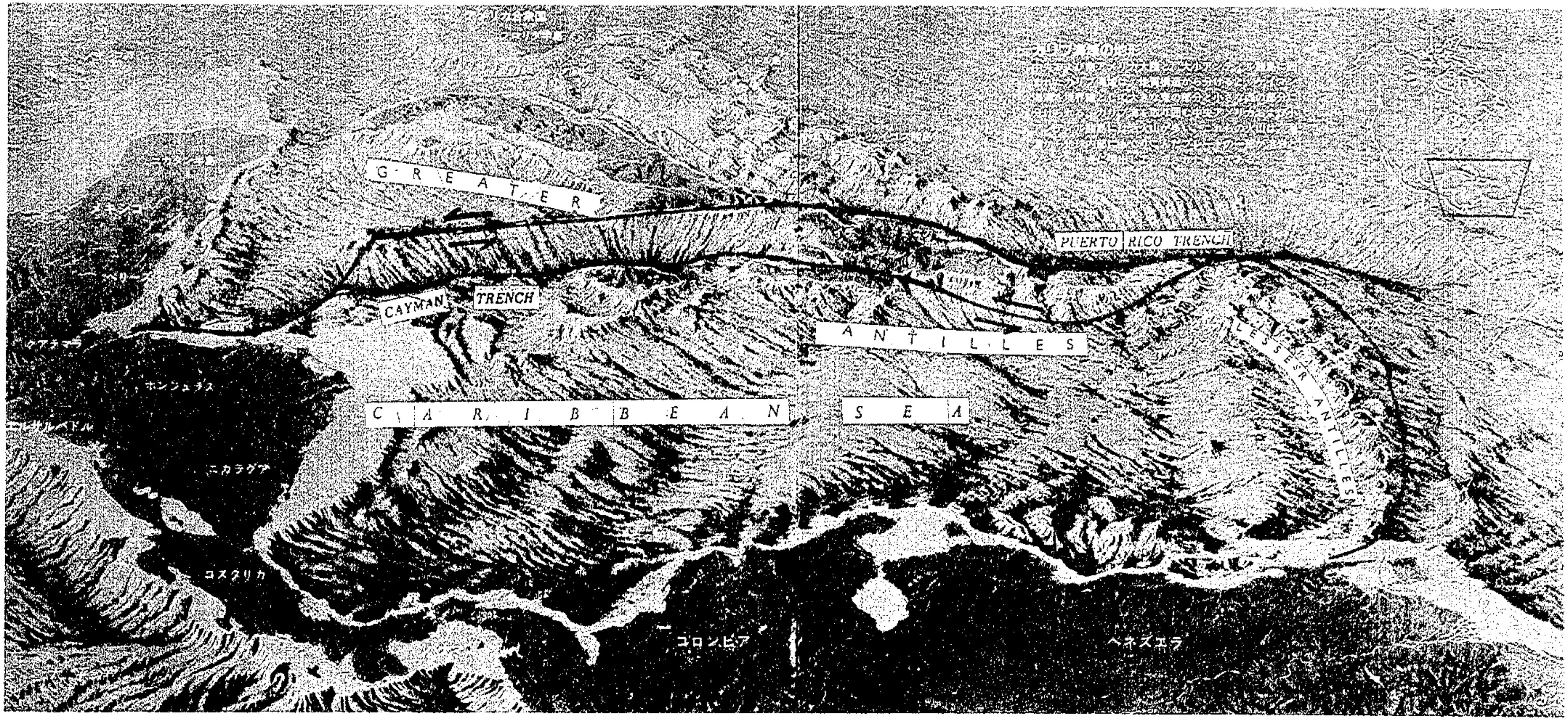


Figure 4.1.1 Tectonic Structure of Caribbean Sea

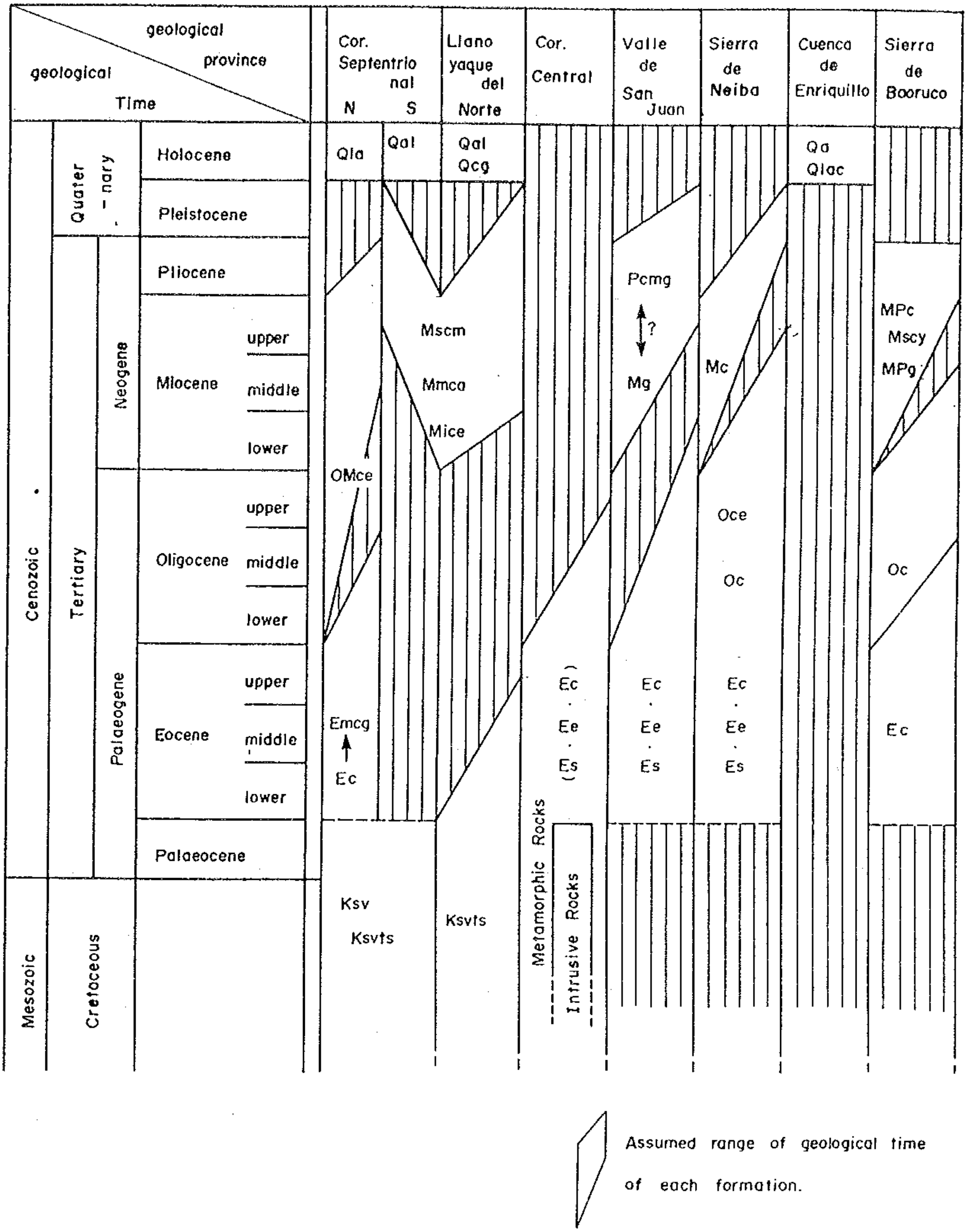


Figure 4.2.1 Stratigraphic Classification

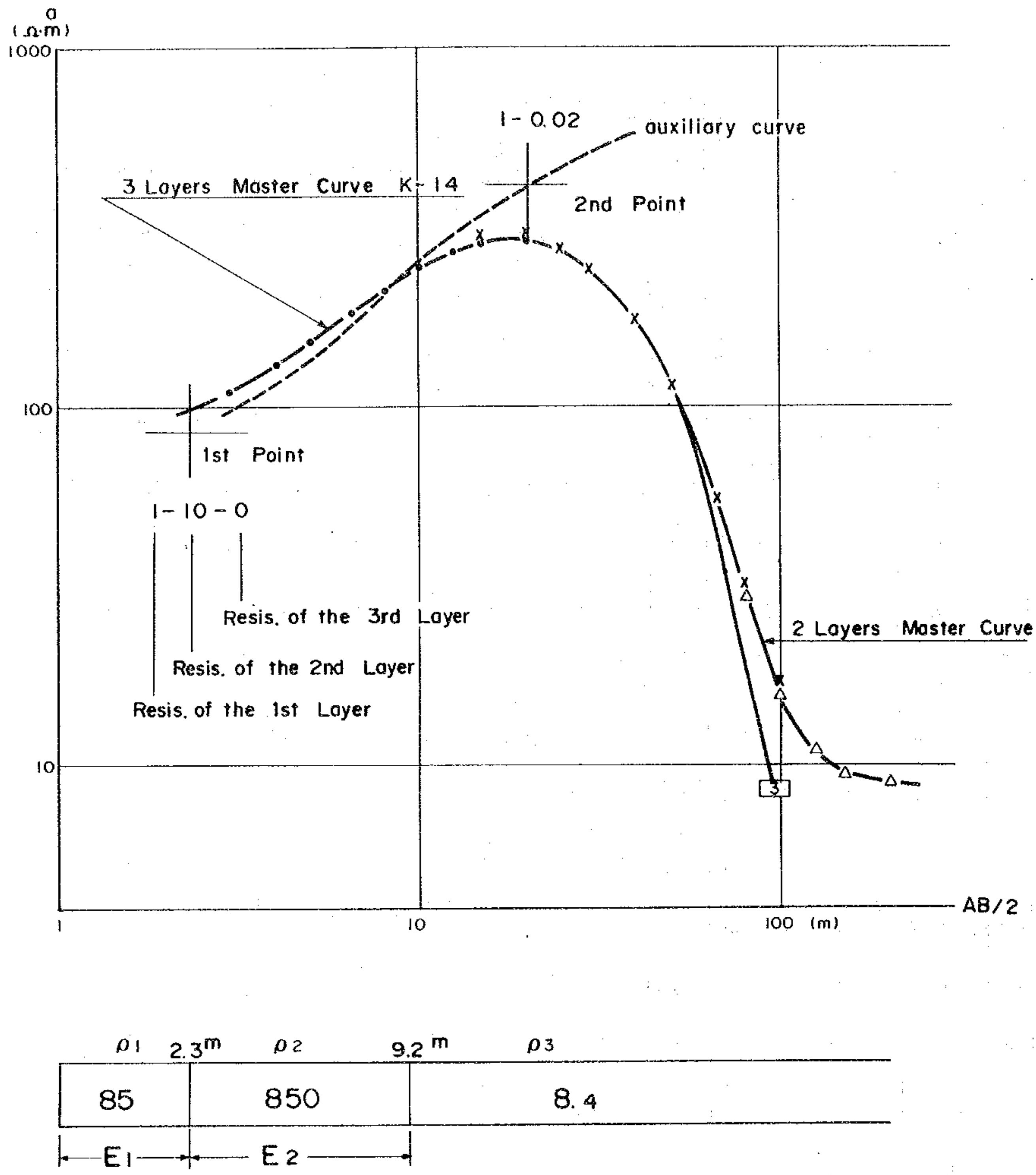
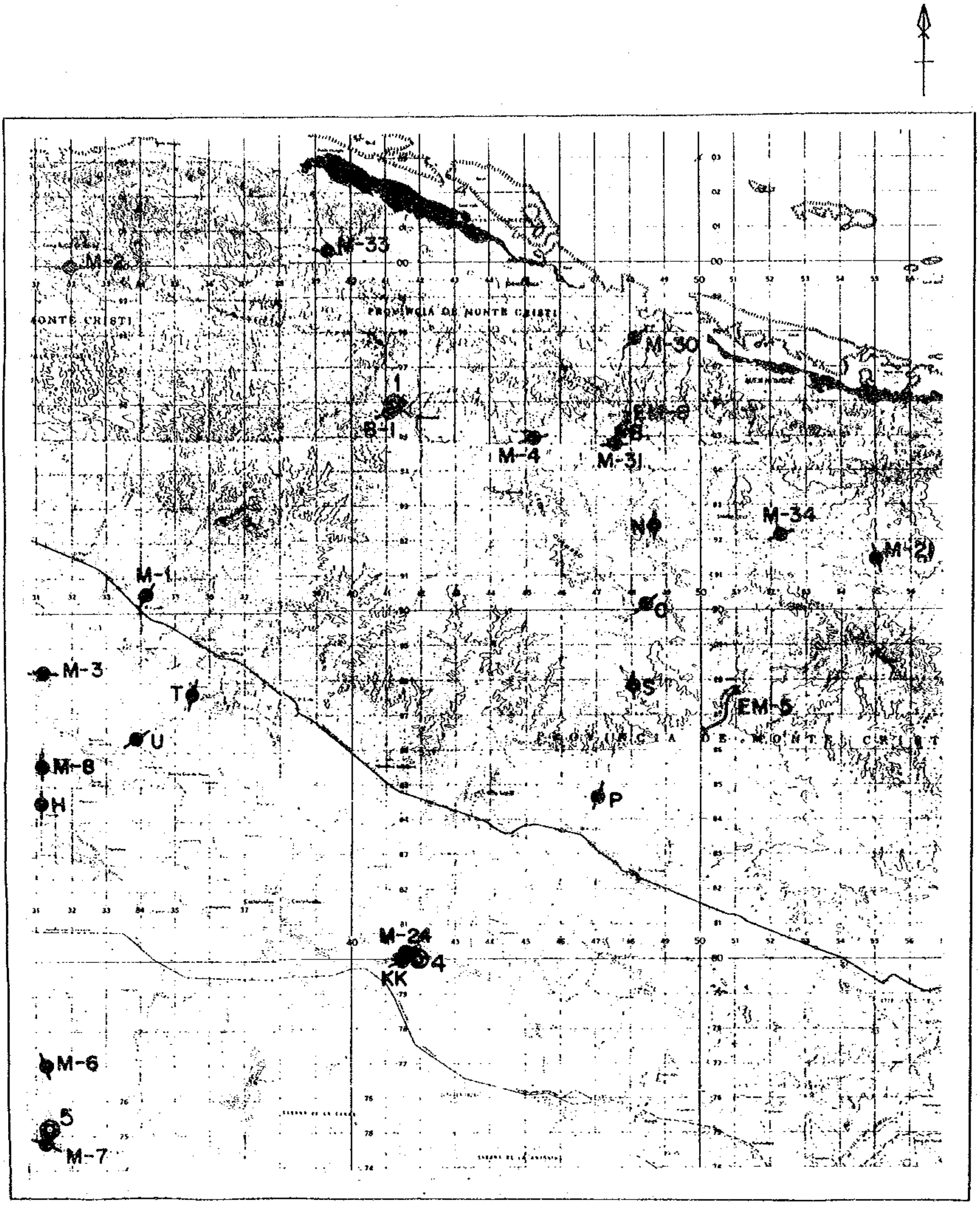


Figure 5.1.1 Example of the Interpretation by Master Curve



Vertical Electrical Sounding

D-13 surveyed point, direction and it's number

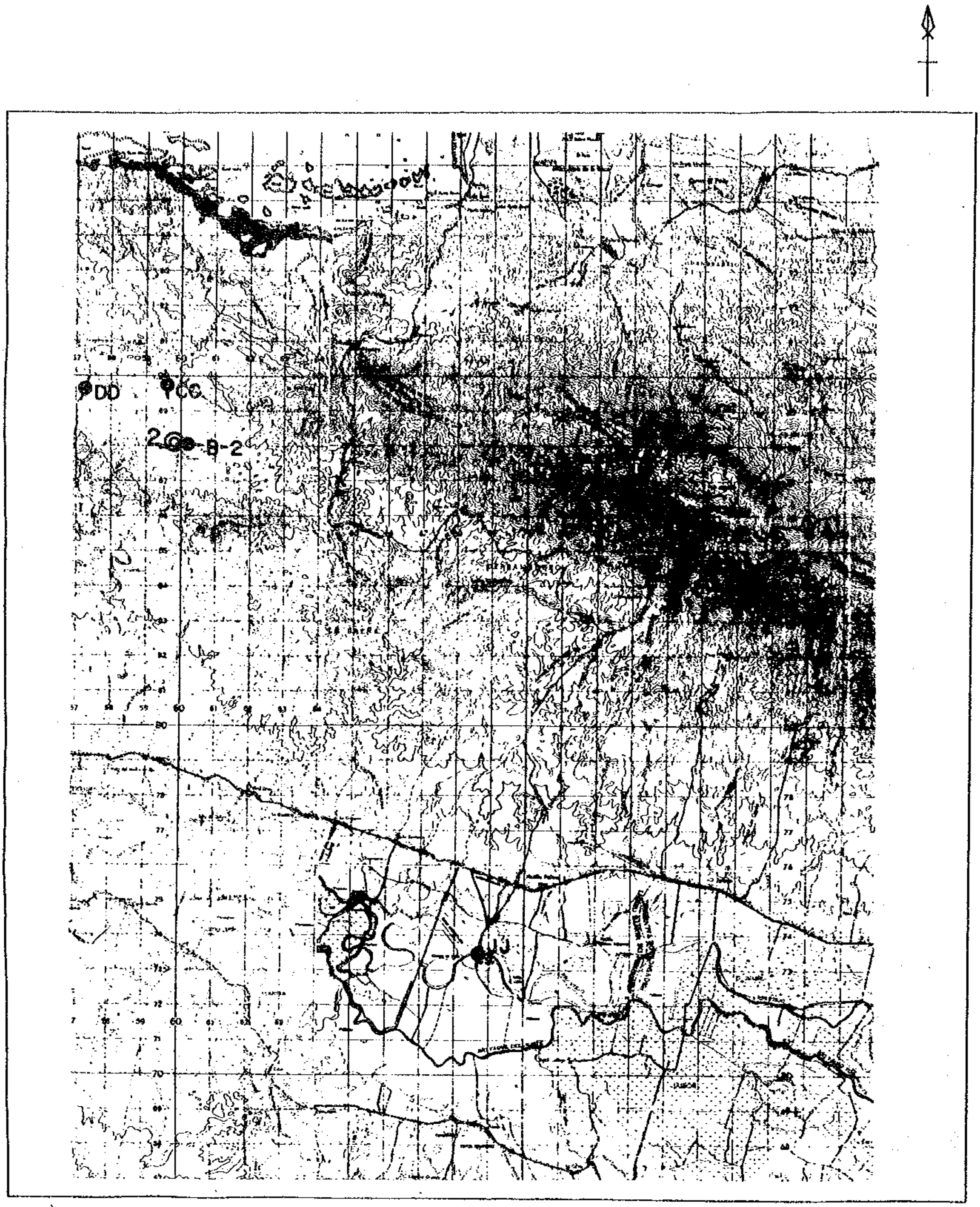
Electromagnetic Sounding

D-46 surveyed line and it's number

16 Test Drilling and it's number

2 1 0 1 2 3 4 5 Km

Figure 5.1.2 Location Map of Geophysical Prospecting Sites (1)



Vertical Electrical Sounding

D-13 surveyed point, direction and it's number

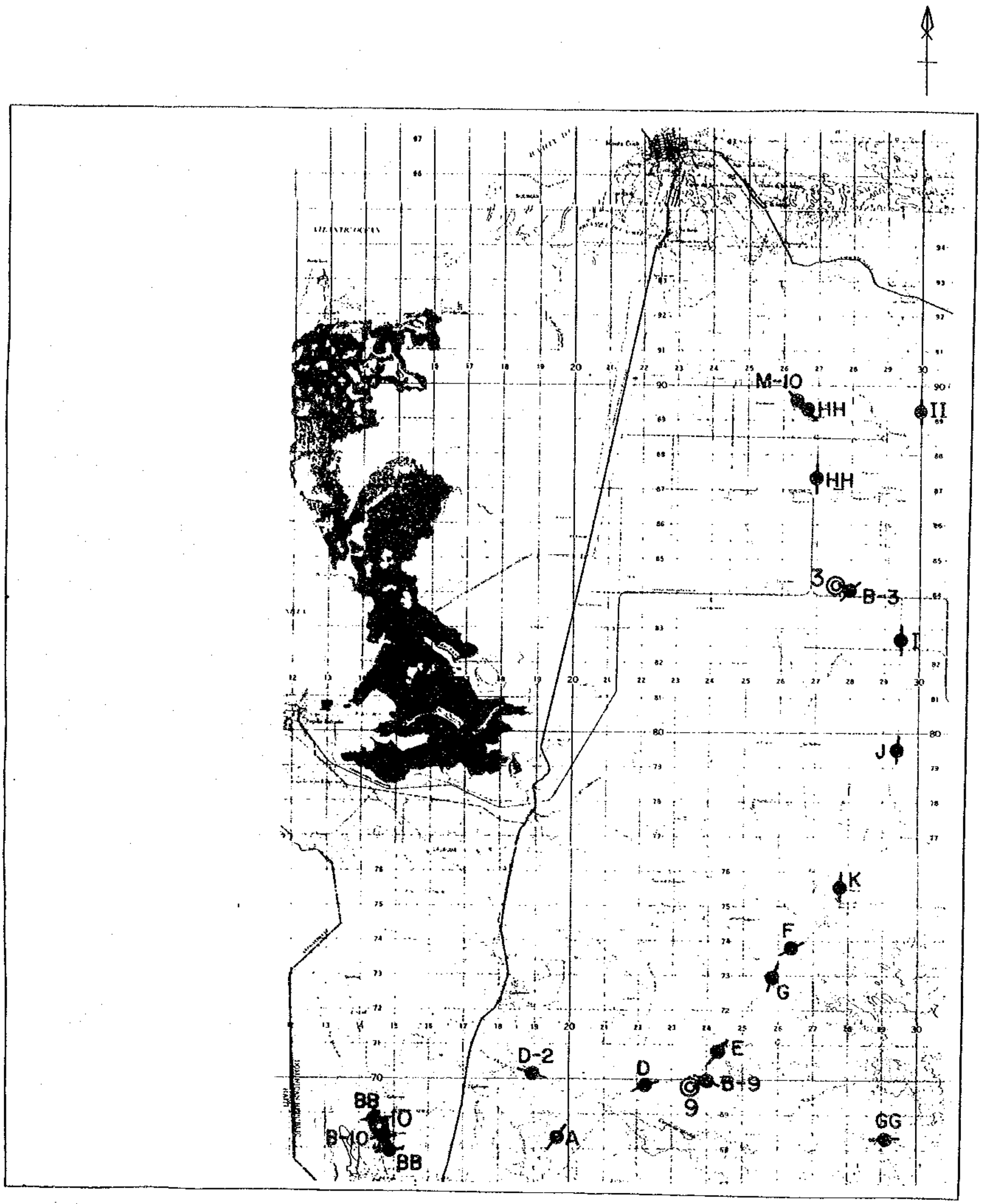
Electromagnetic Sounding

D-46 surveyed line and it's number

16 Test Drilling and it's number

2 1 0 1 2 3 4 5 Km

Figure 5.1.2 Location Map of Geophysical Prospecting Sites (2)



Vertical Electrical Sounding

D-13 surveyed point, direction and it's number

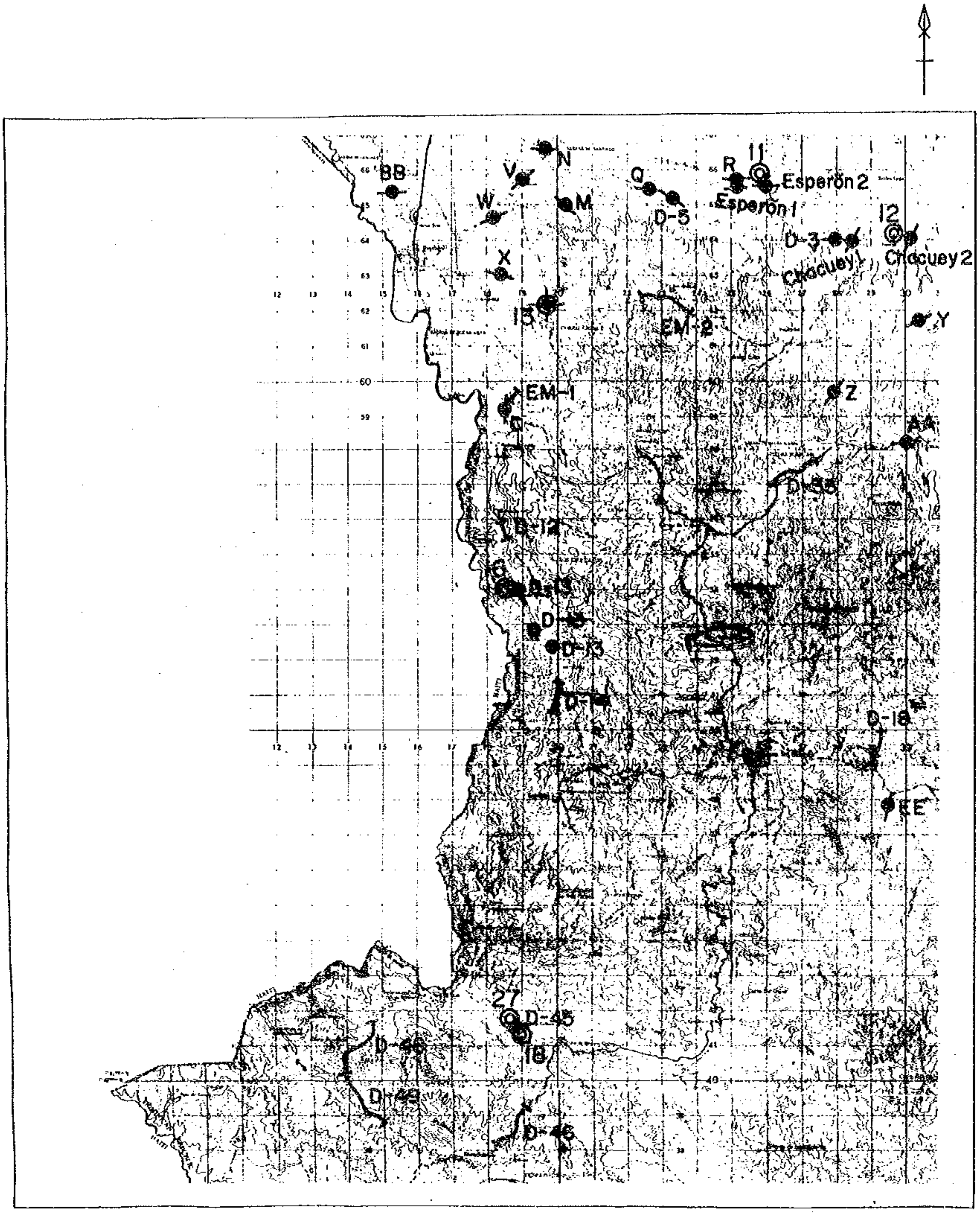
Electromagnetic Sounding

D-46 surveyed line and it's number

◎ 16 Test Drilling and it's number

2 1 0 1 2 3 4 5 Km

Figure 5.1.2 Location Map of Geophysical Prospecting Sites (3)



Vertical Electrical Sounding

D-13 surveyed point, direction and it's number

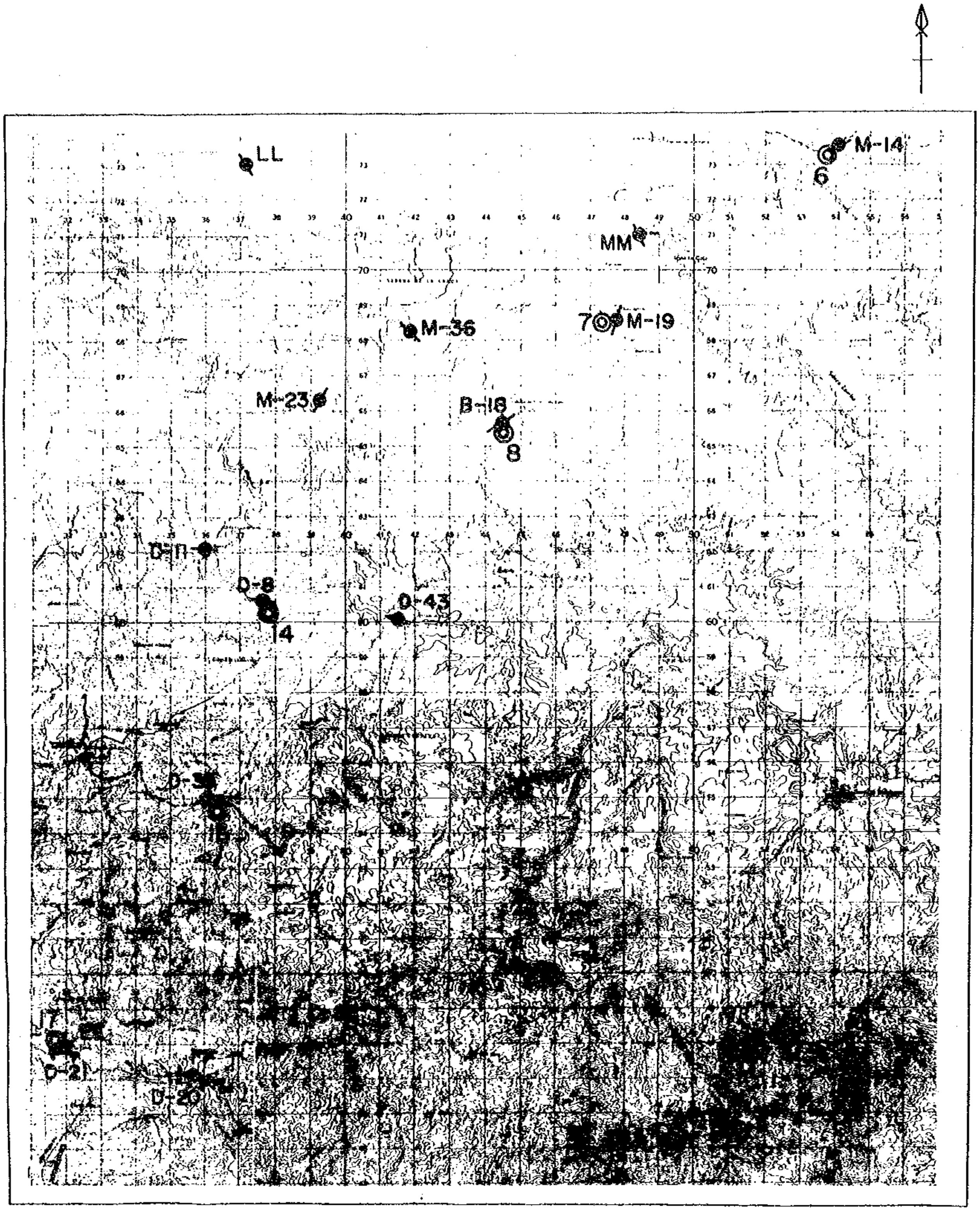
Electromagnetic Sounding

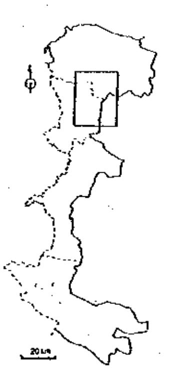
D-46 surveyed line and it's number

◎ 16 Test Drilling and it's number

2 1 0 1 2 3 4 5 Km

Figure 5.1.2 Location Map of Geophysical Prospecting Sites (4)





Vertical Electrical Sounding

D-13 surveyed point, direction and it's number

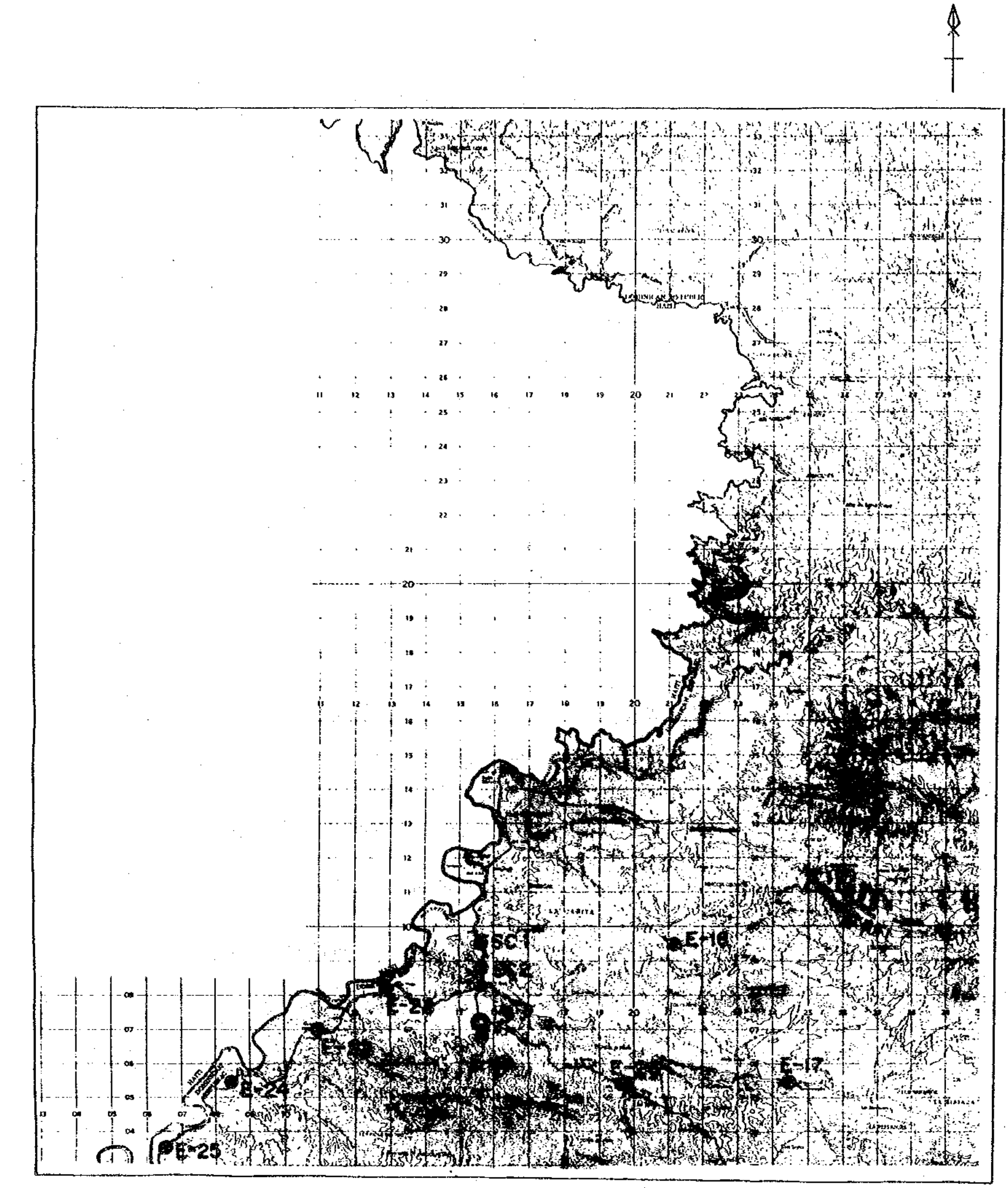
Electromagnetic Sounding

D-46 surveyed line and it's number

◎ Test Drilling and it's number
16

2 1 0 1 2 3 4 5 Km

Figure 5.1.2 Location Map of Geophysical Prospecting Sites (5)



Vertical Electrical Sounding

D-13 surveyed point, direction and it's number

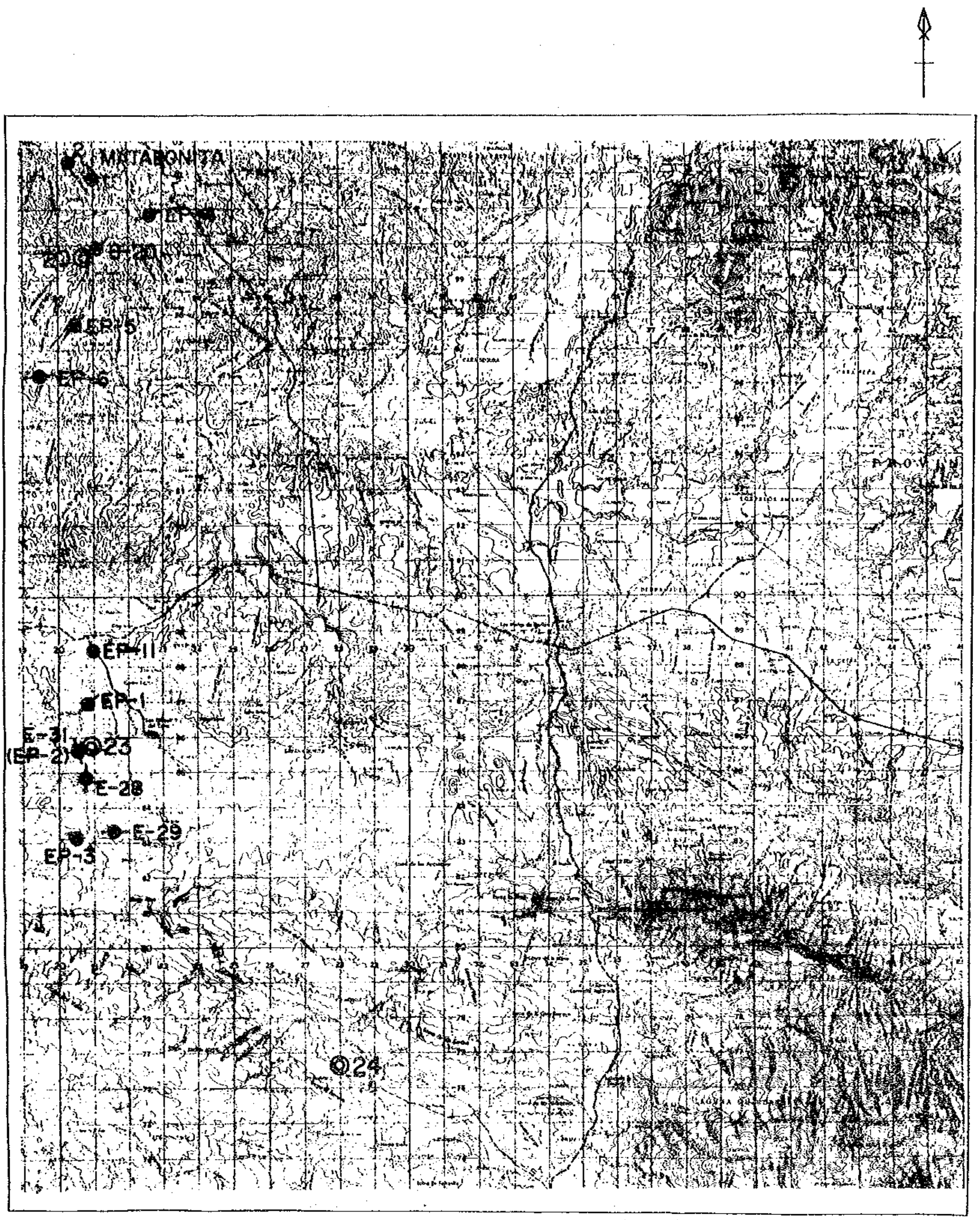
Electromagnetic Sounding

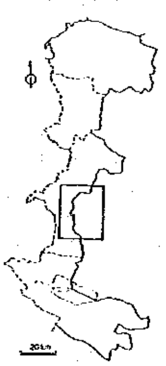
D-46 surveyed line and it's number

16 Test Drilling and it's number

2 1 0 1 2 3 4 5 Km

Figure 5.1.2 Location Map of Geophysical Prospecting Sites (6)





Vertical Electrical Sounding

D-13 surveyed point, direction and it's number

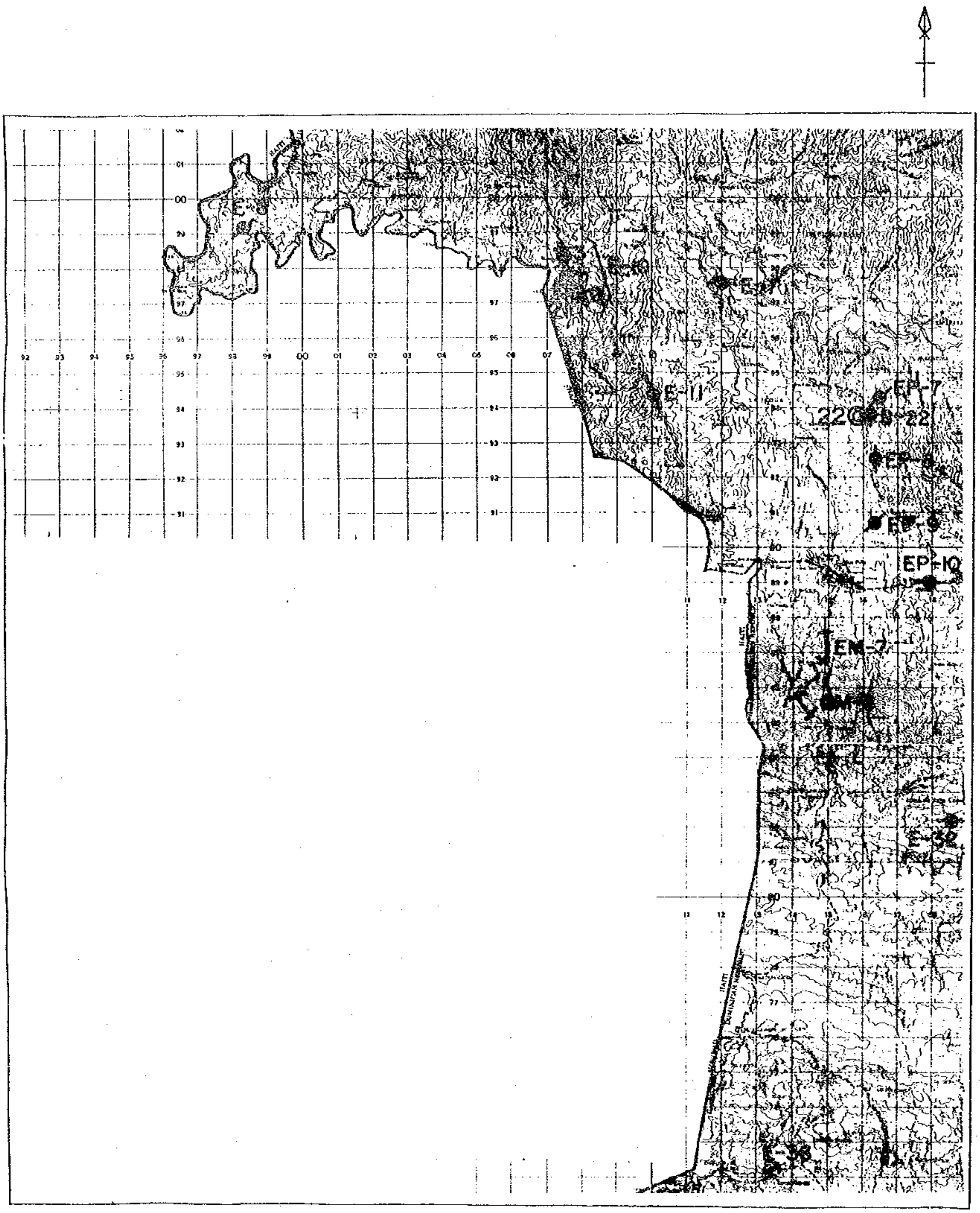
Electromagnetic Sounding

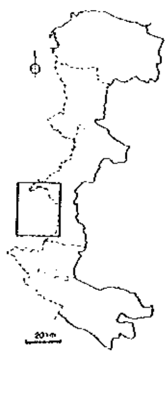
D-46 surveyed line and it's number

16 Test Drilling and it's number

2 1 0 1 2 3 4 5 Km

Figure 5.1.2 Location Map of Geophysical Prospecting Sites (7)





Vertical Electrical Sounding

D-13 surveyed point, direction and it's number

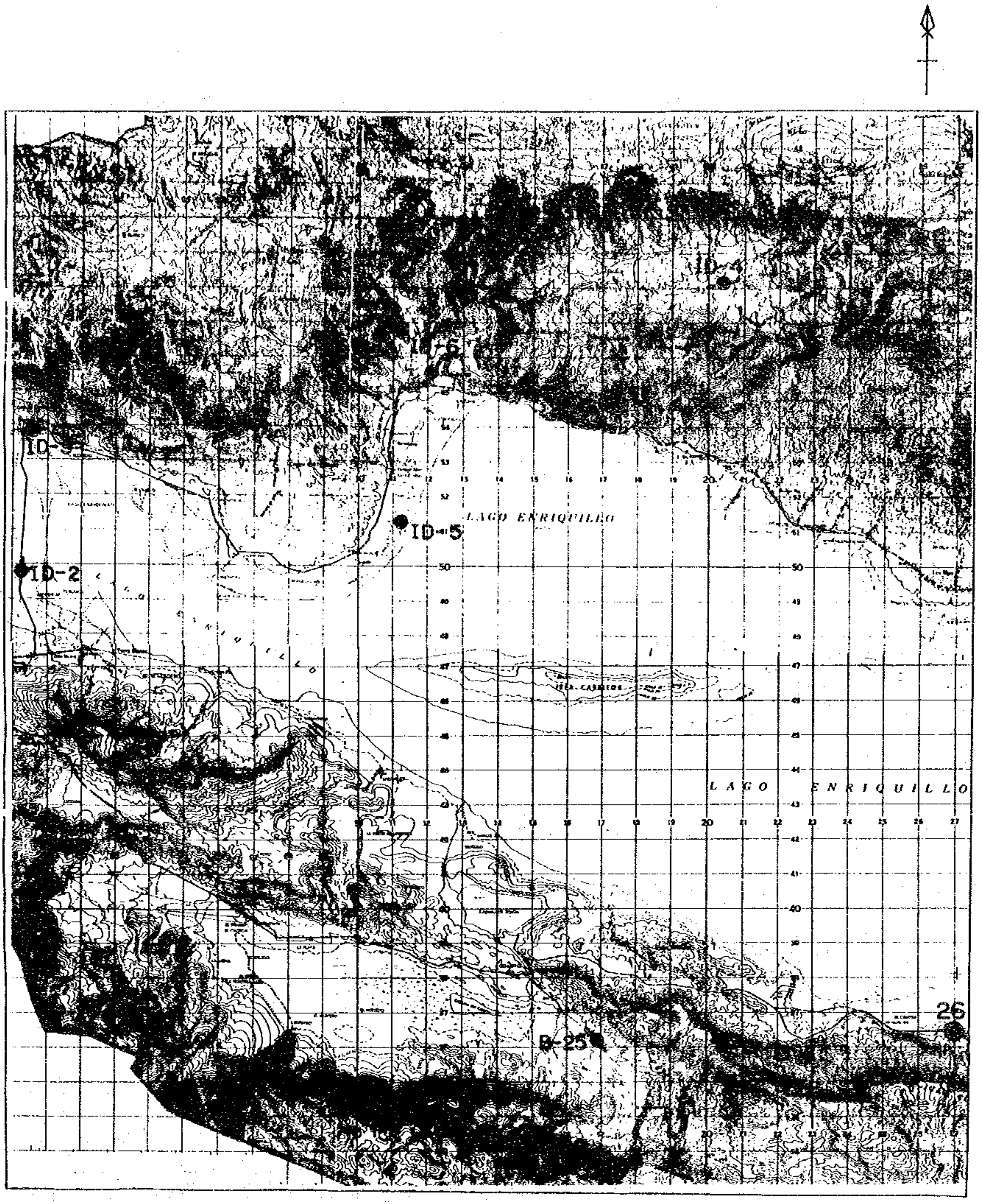
Electromagnetic Sounding

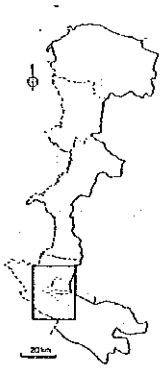
D-46 surveyed line and it's number

16 Test Drilling and It's number

2 1 0 1 2 3 4 5 Km

Figure 5.1.2 Location Map of Geophysical Prospecting Sites (8)





Vertical Electrical Sounding

D-13 surveyed point, direction and it's number

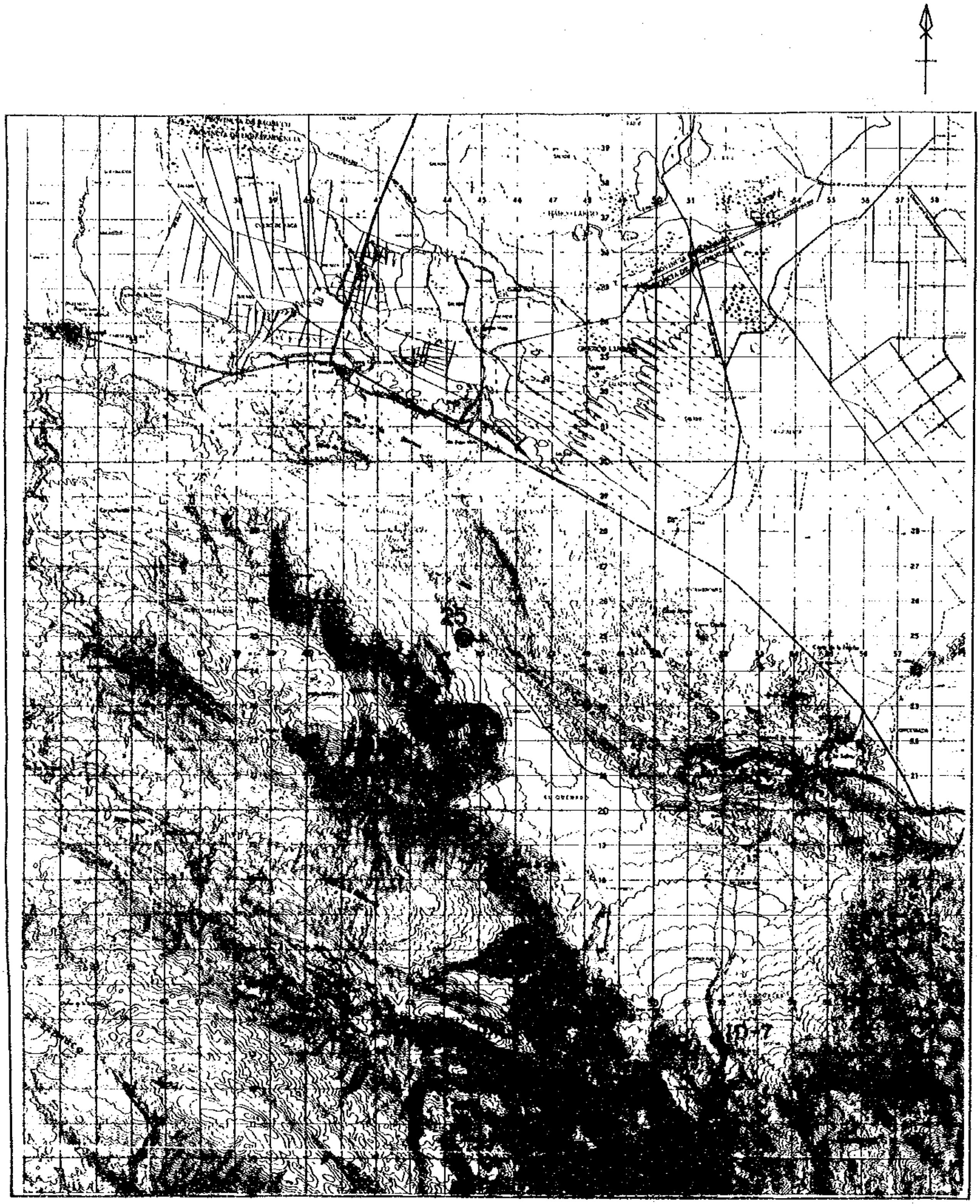
Electromagnetic Sounding

D-46 surveyed line and it's number

16 Test Drilling and it's number

2 1 0 1 2 3 4 5 Km

Figure 5.1.2 Location Map of Geophysical Prospecting Sites (9)



Vertical Electrical Sounding

D-13 surveyed point, direction and it's number

Electromagnetic Sounding

D-46 surveyed line and it's number

16 Test Drilling and it's number

2 1 0 1 2 3 4 5 Km

Figure 5.1.2 Location Map of Geophysical Prospecting Sites (10)

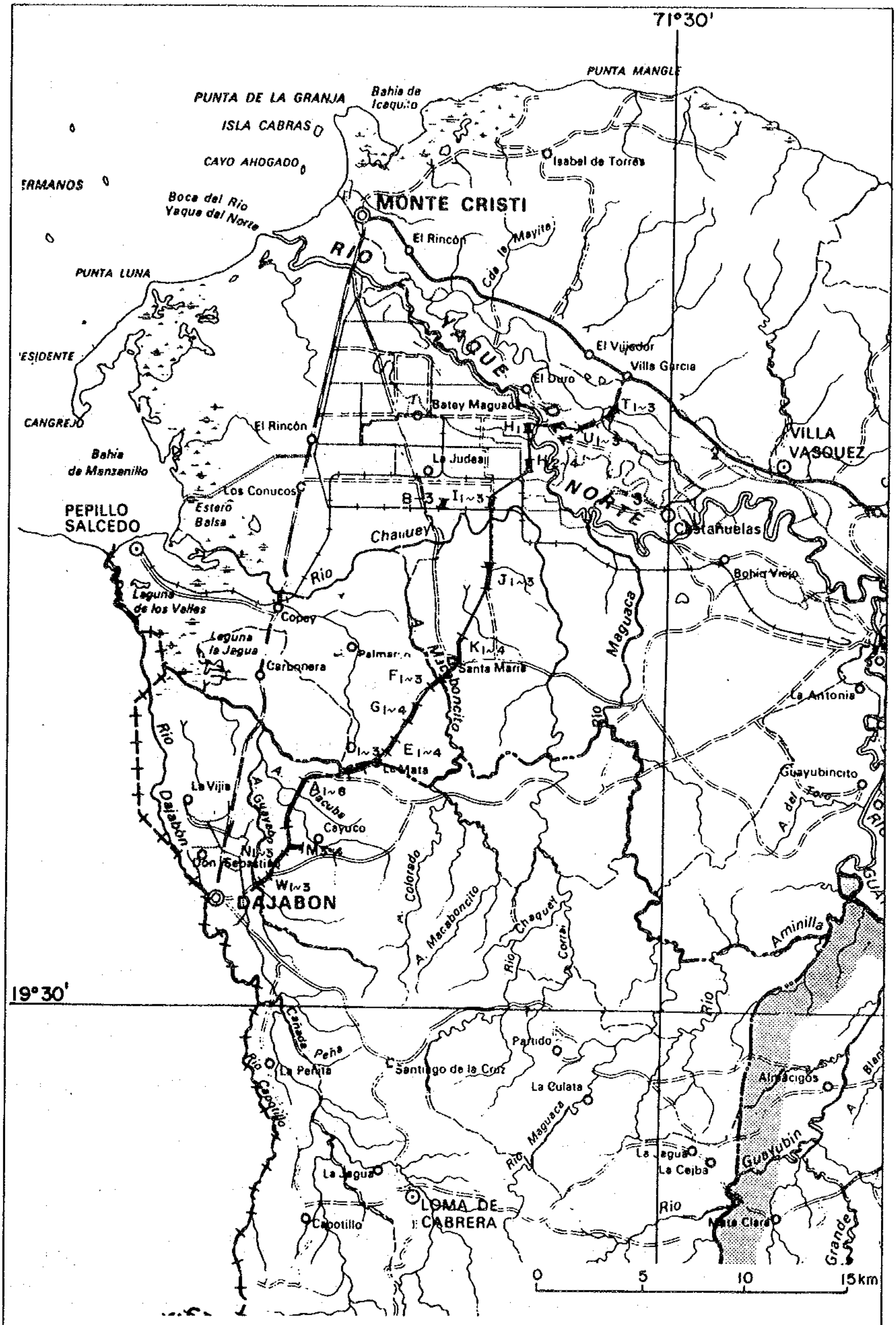


Figure 5.1.3 Location Map of Traverse Line (1)

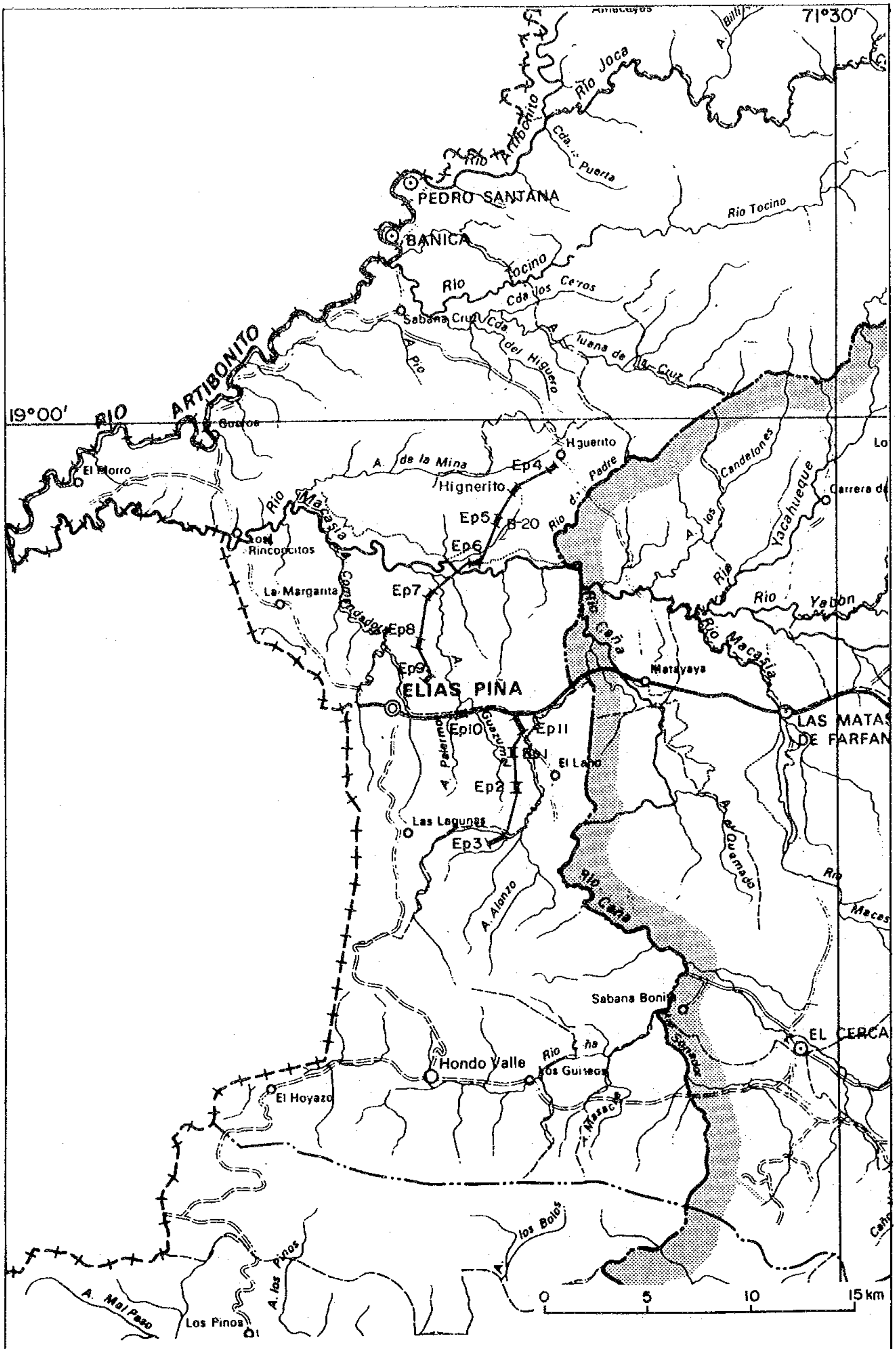


Figure 5.1.3 Location Map of Traverse Line (2)

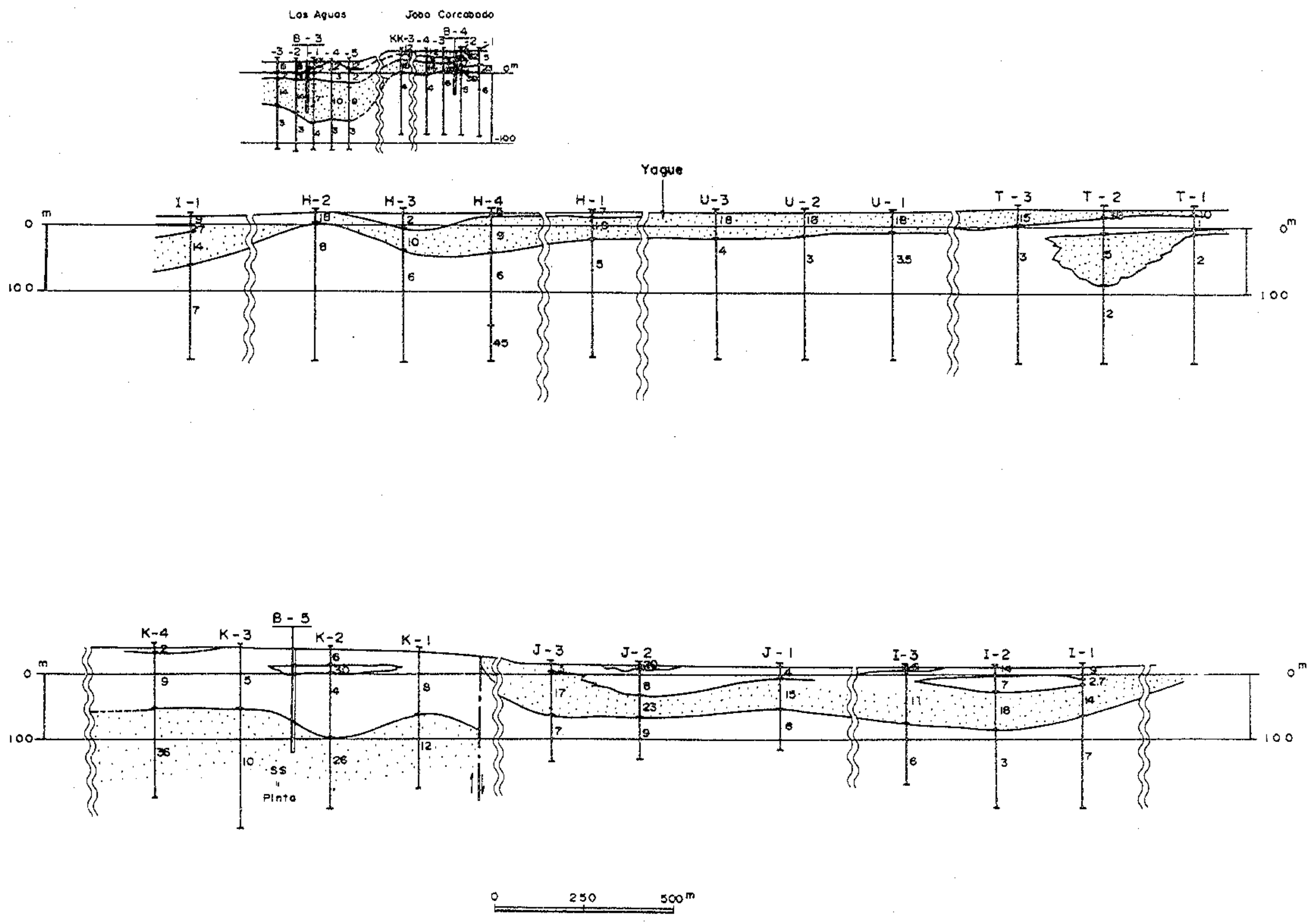


Figure 5.1.4 Resistivity Section (1)

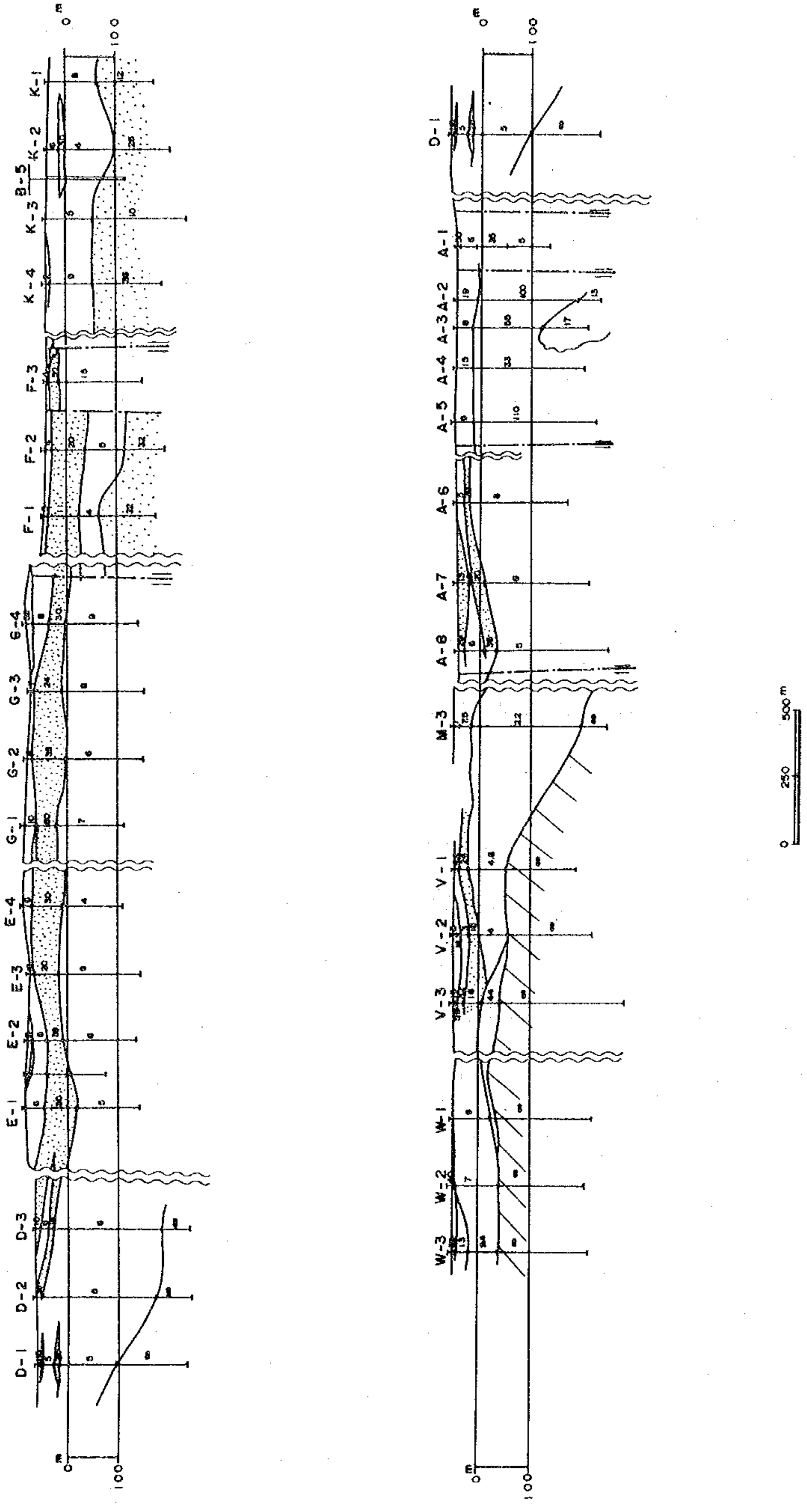


Figure 5.1.4 Resistivity Section (2)

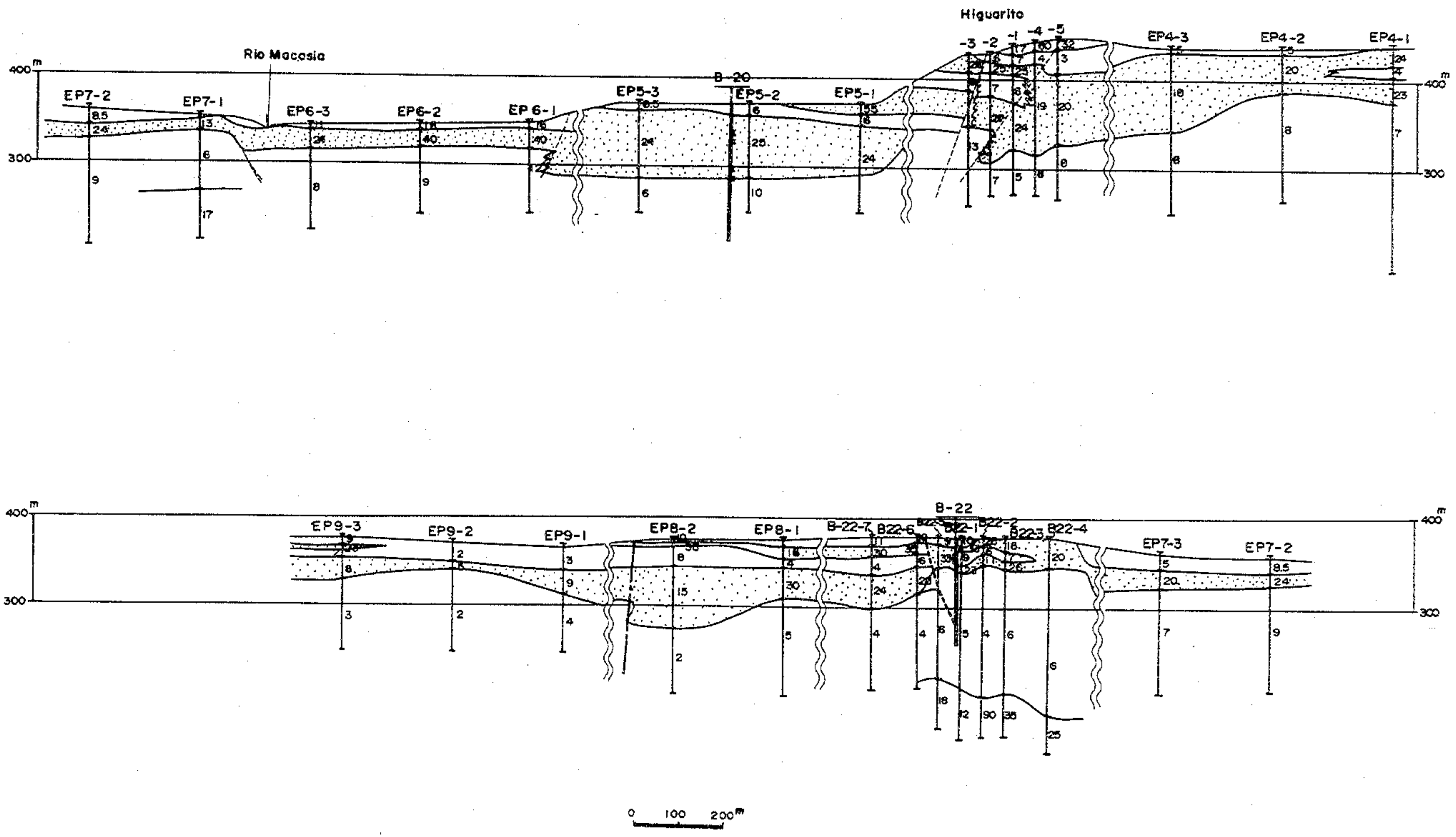


Figure 5.1.4 Resistivity Section (3)

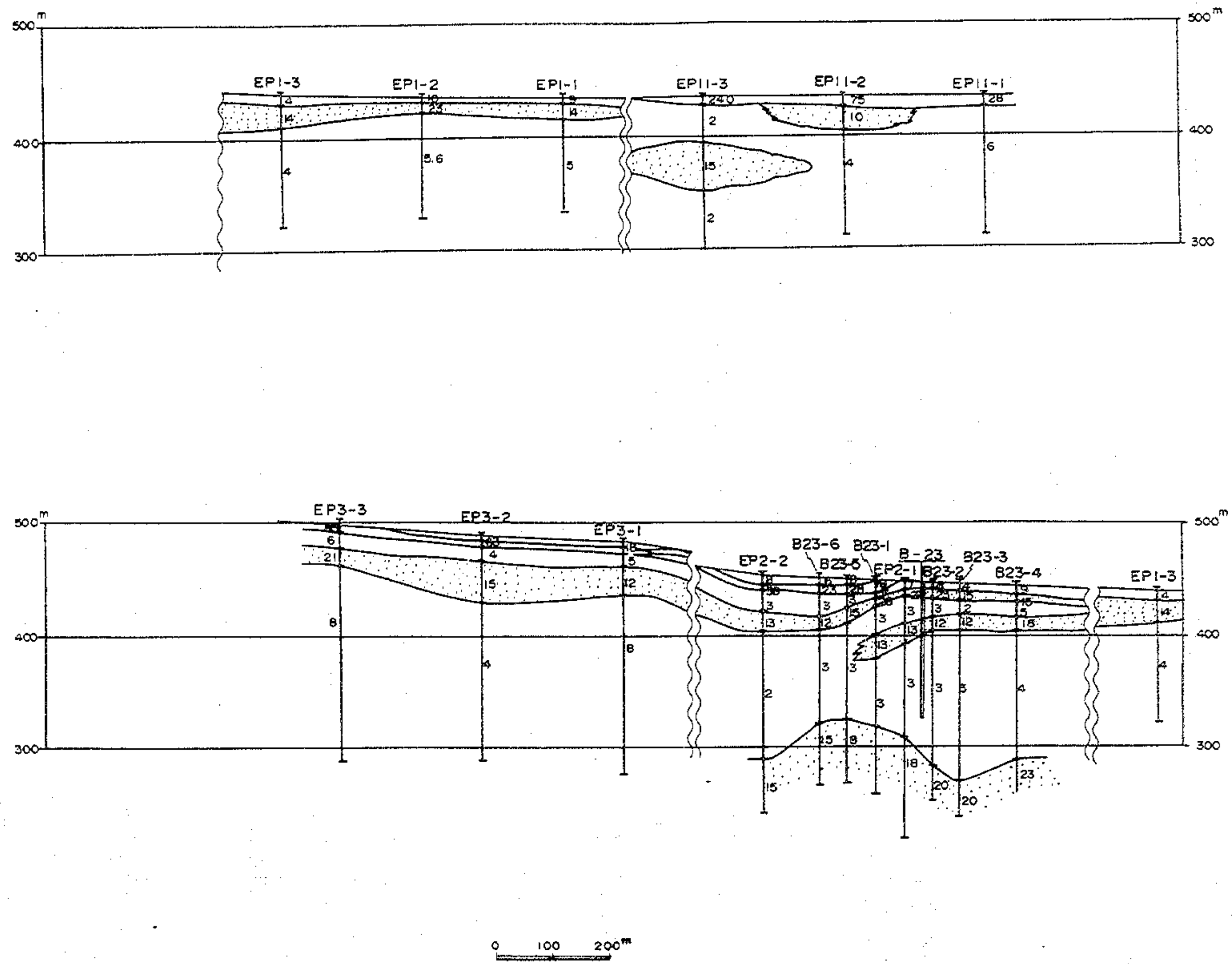


Figure 5.1.4 Resistivity Section (4)

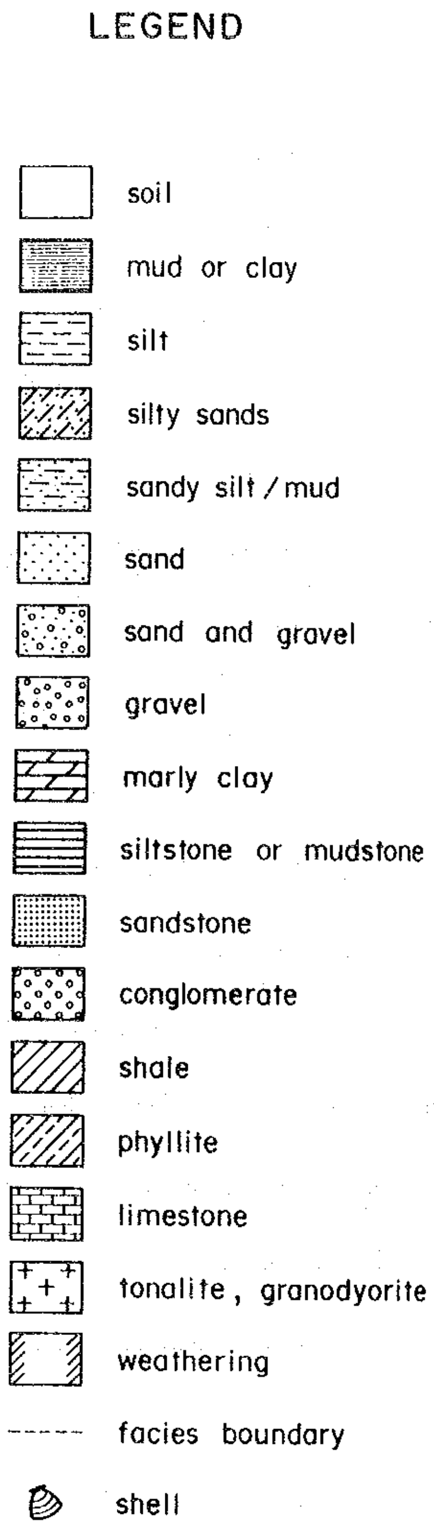


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (1) - (24)

No. 1. El Manantial

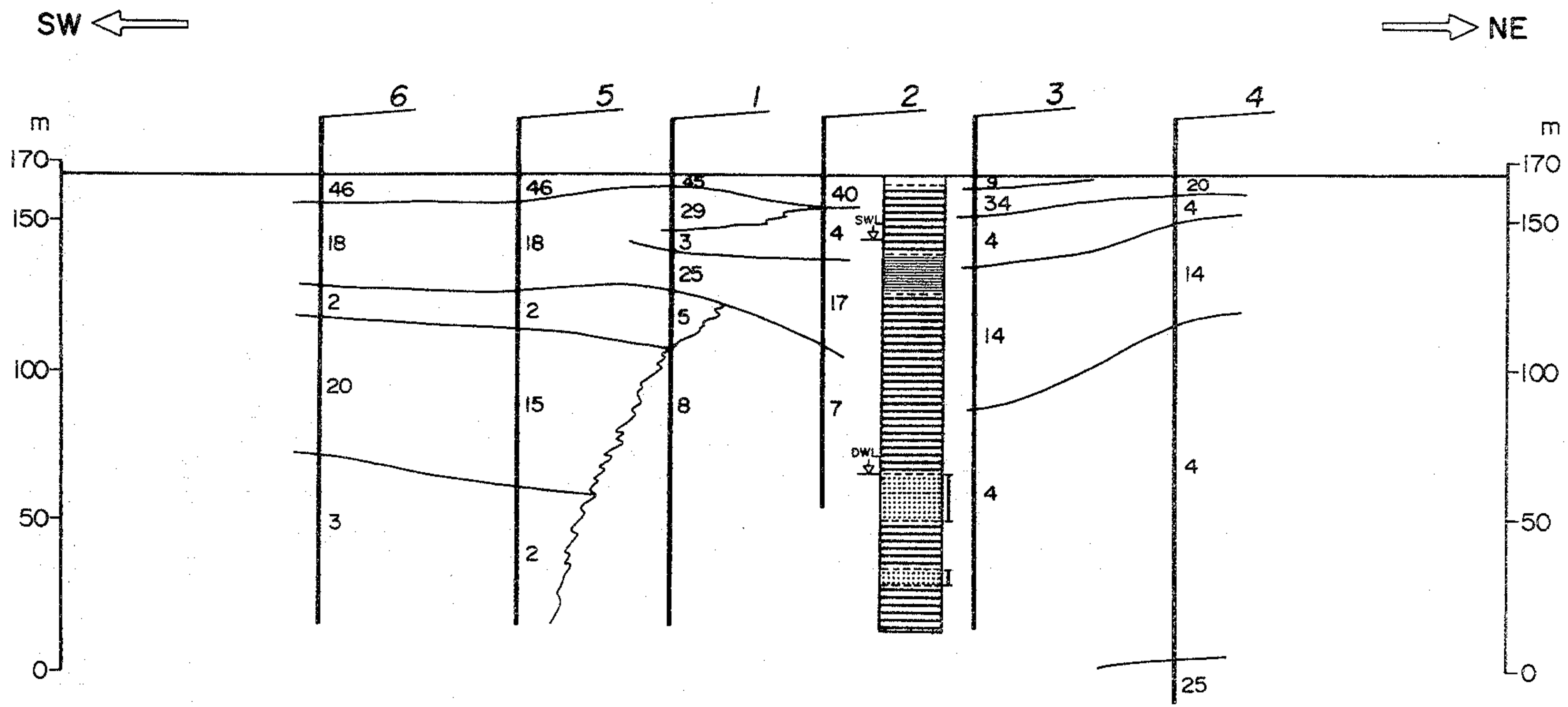


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (1)

No. 2. El Guayo

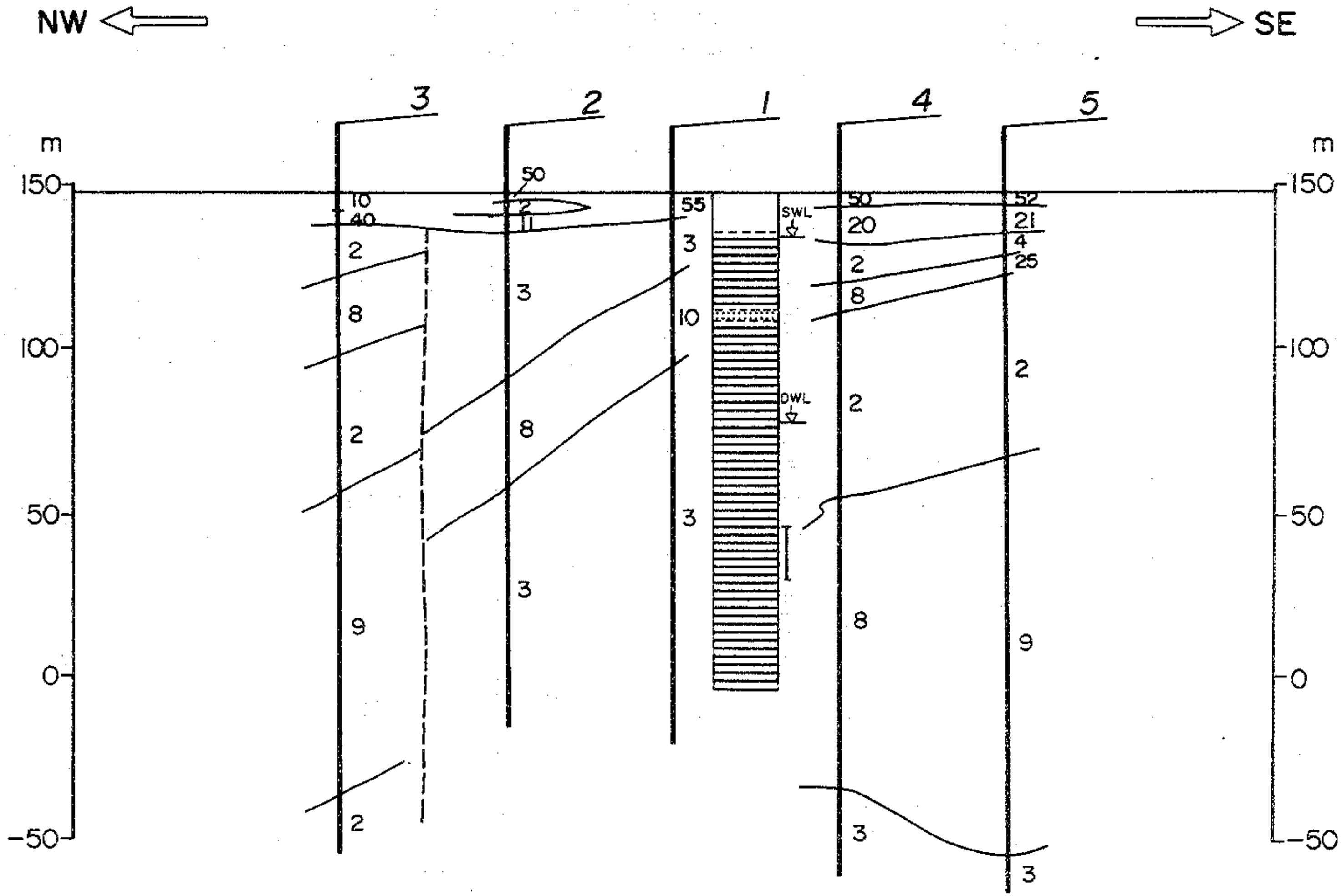


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (2)

No. 3. Las Aguas

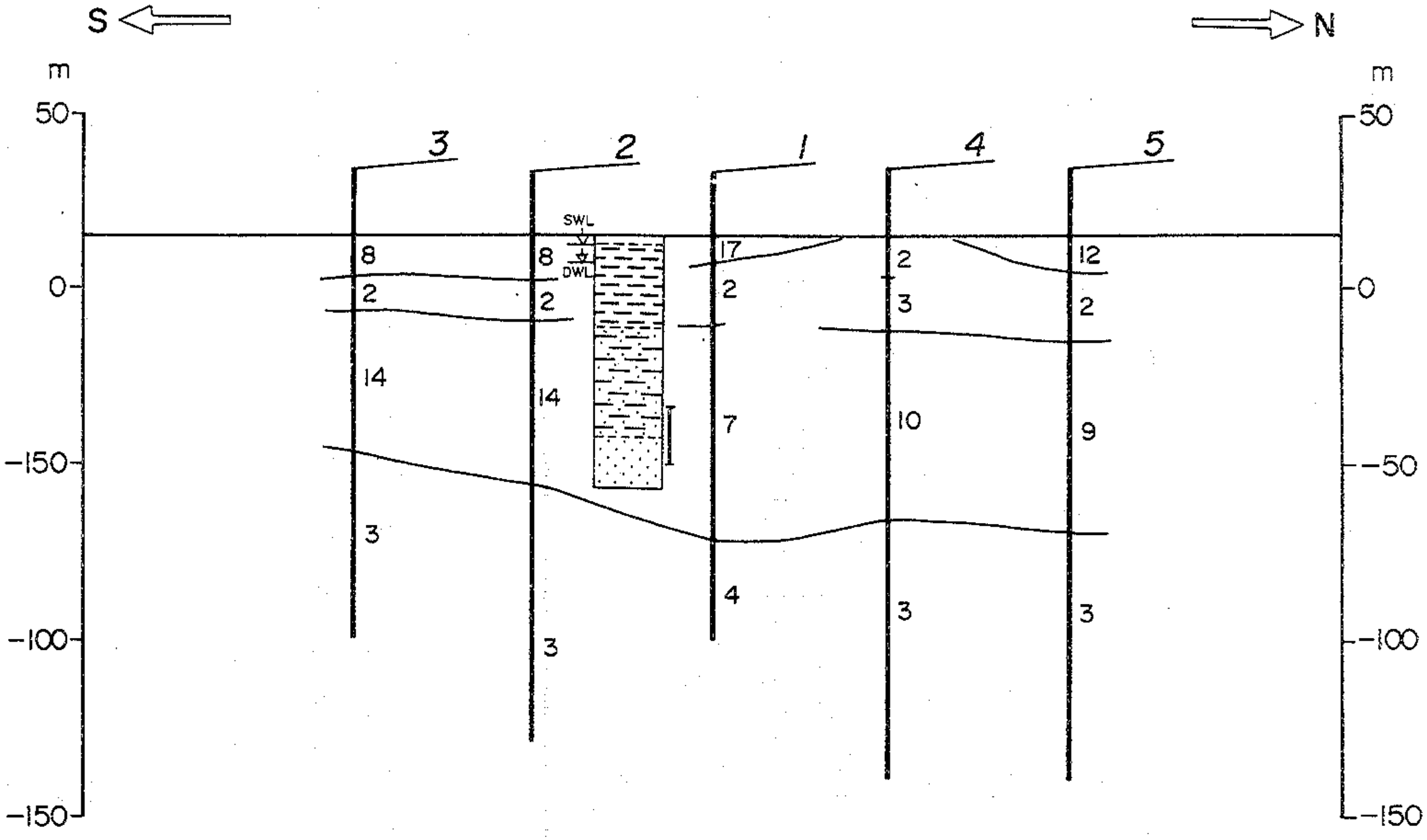


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (3)

No. 4. Jobo Corcobado

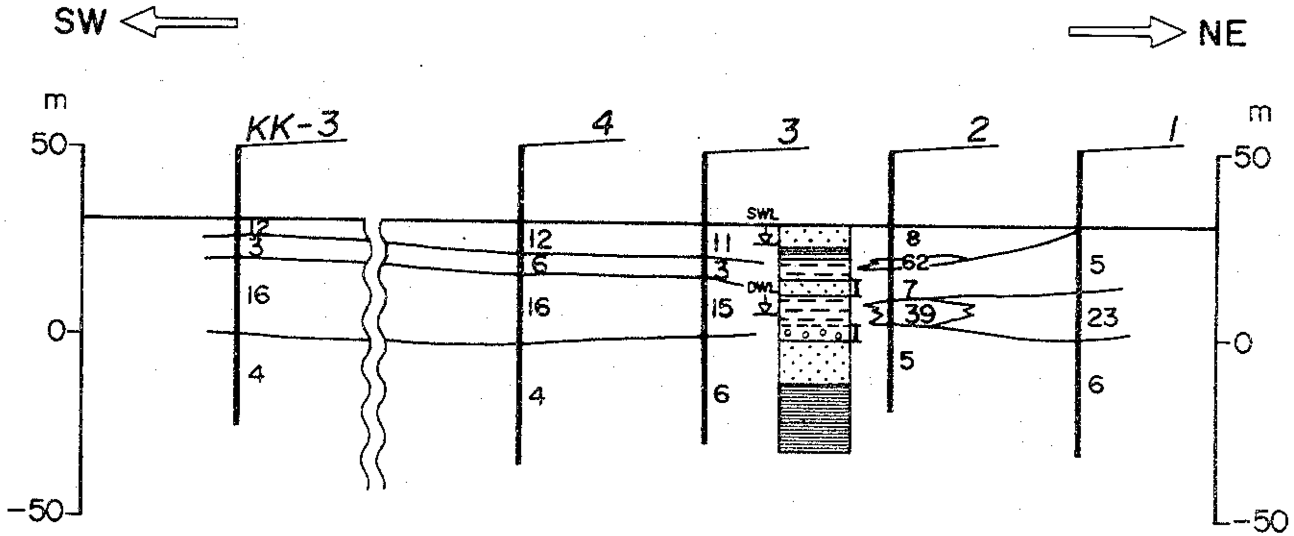


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (4)

No. 5. La Pinta

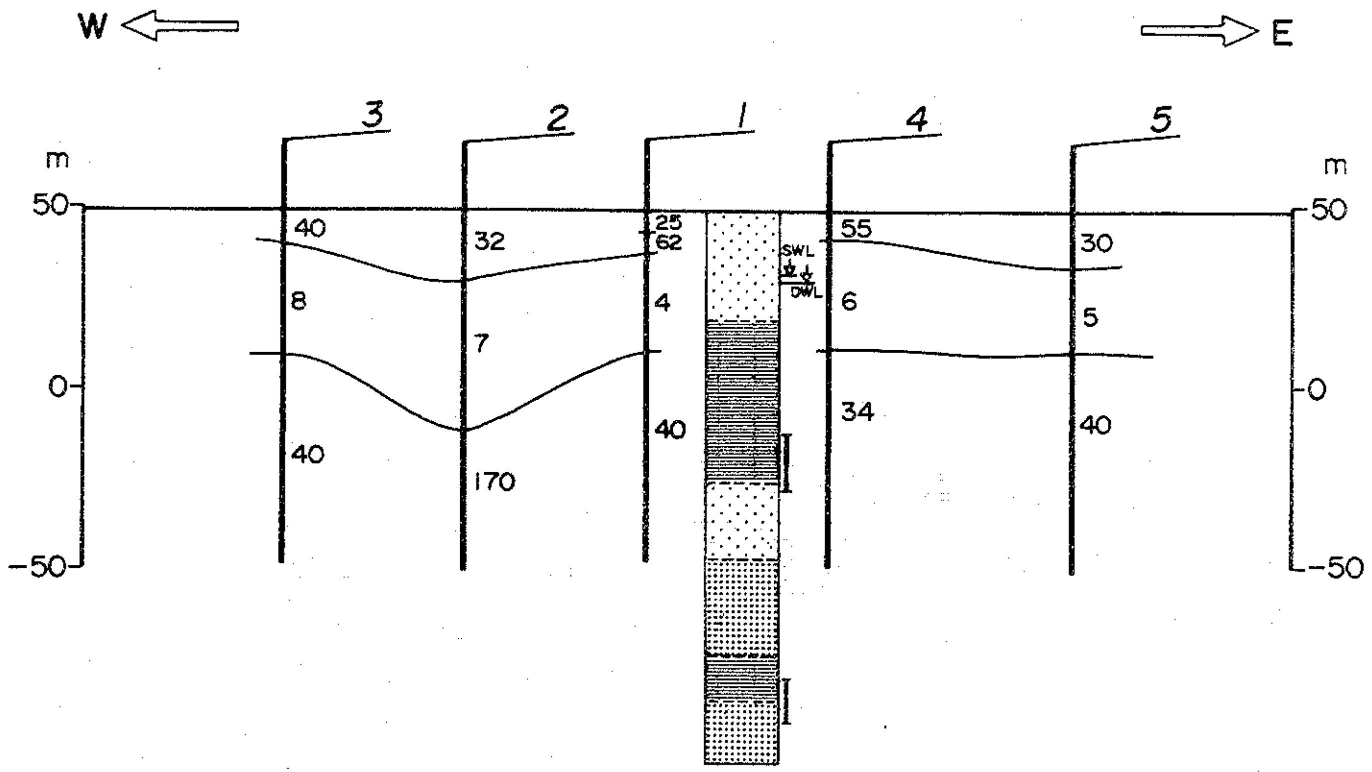


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (5)

No. 6. Ranchadero

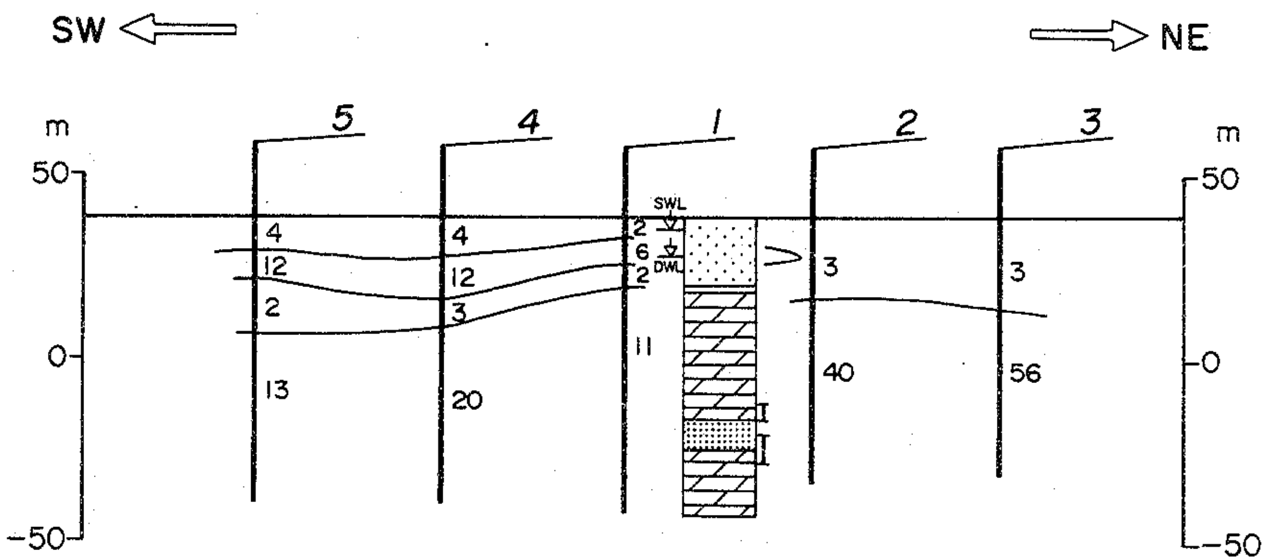


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (6)

No. 7. Guayubincito

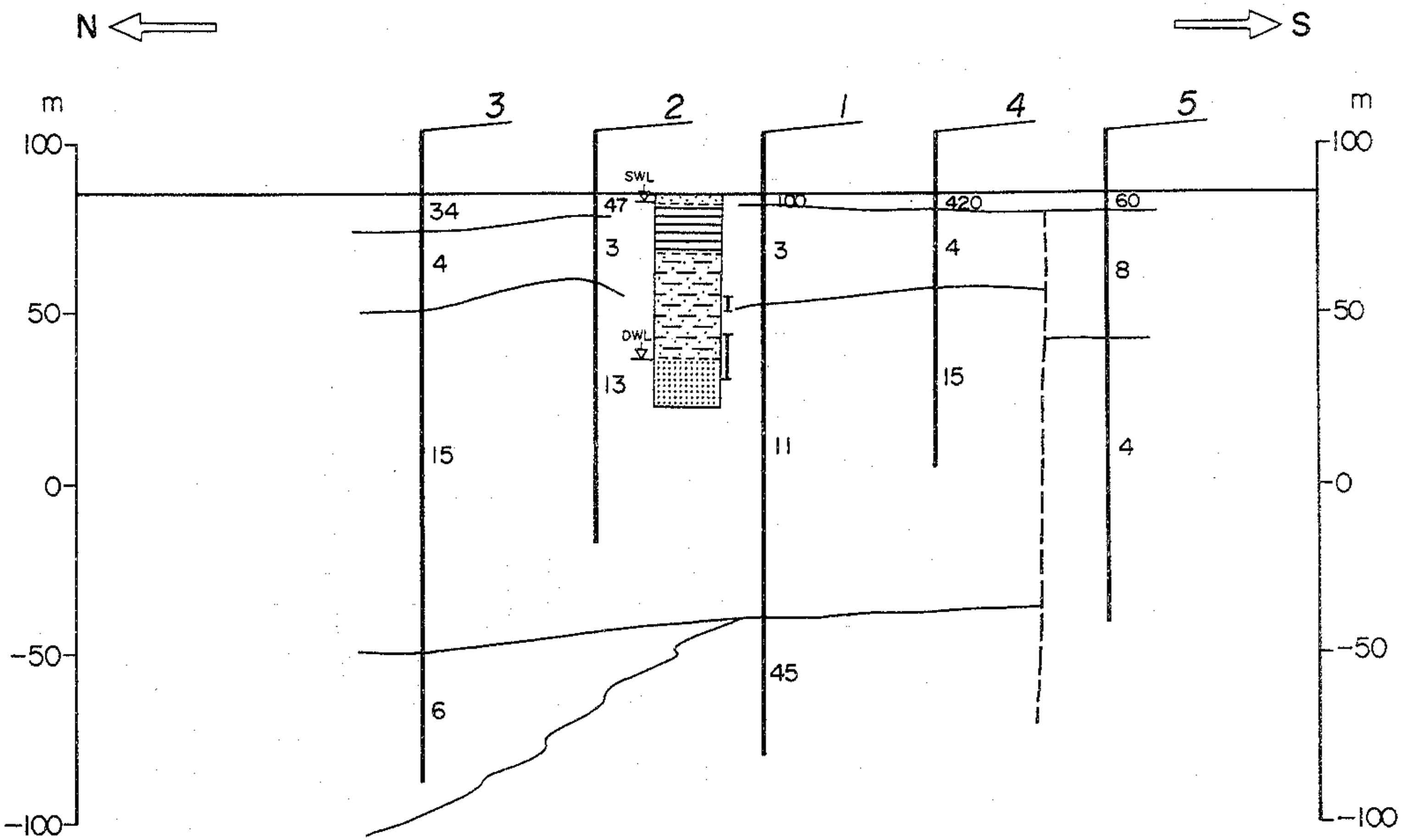


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (7)

No. 8. Cabeza de Torro

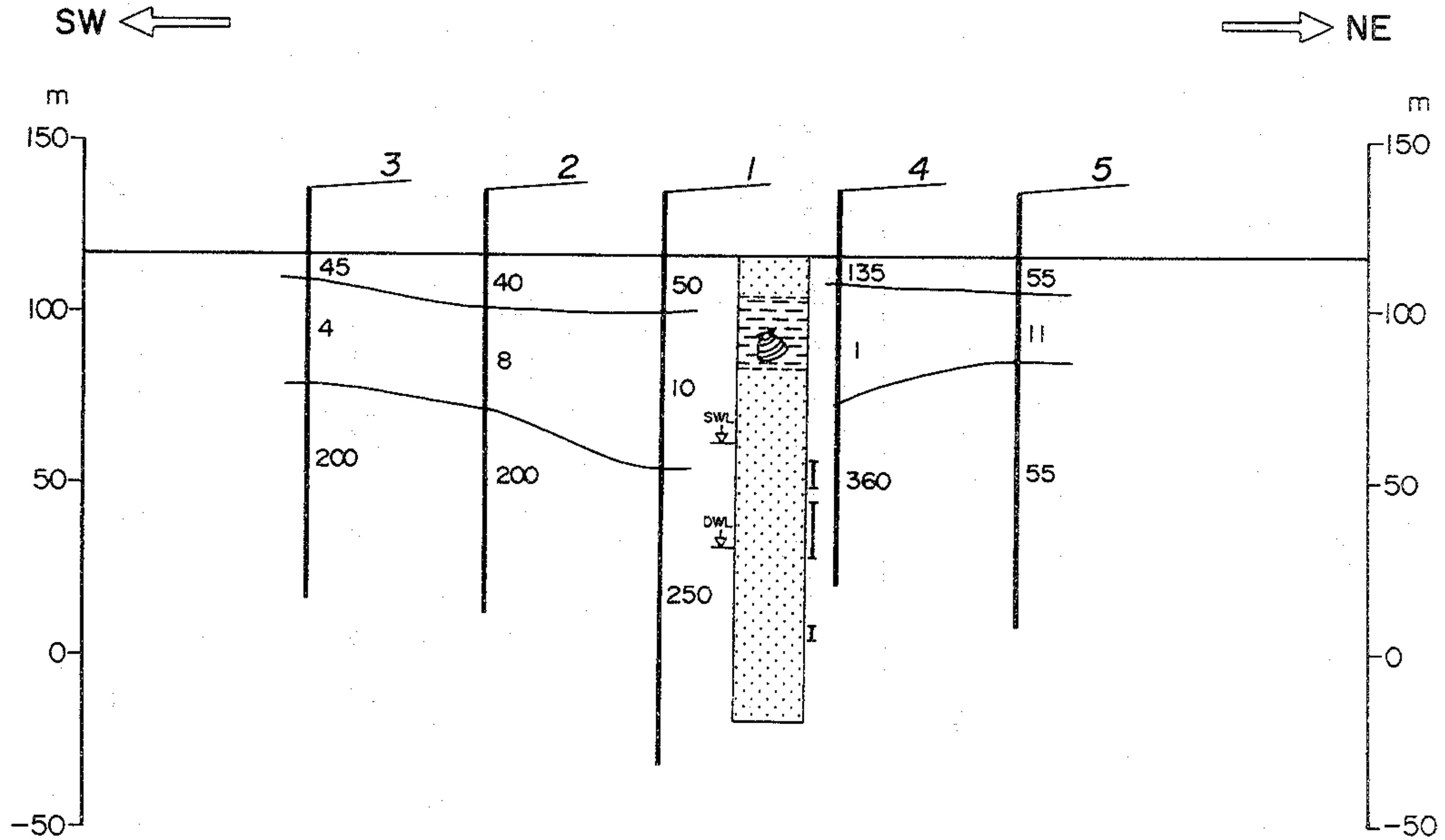


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (8)

No. 9. Palo Blanco

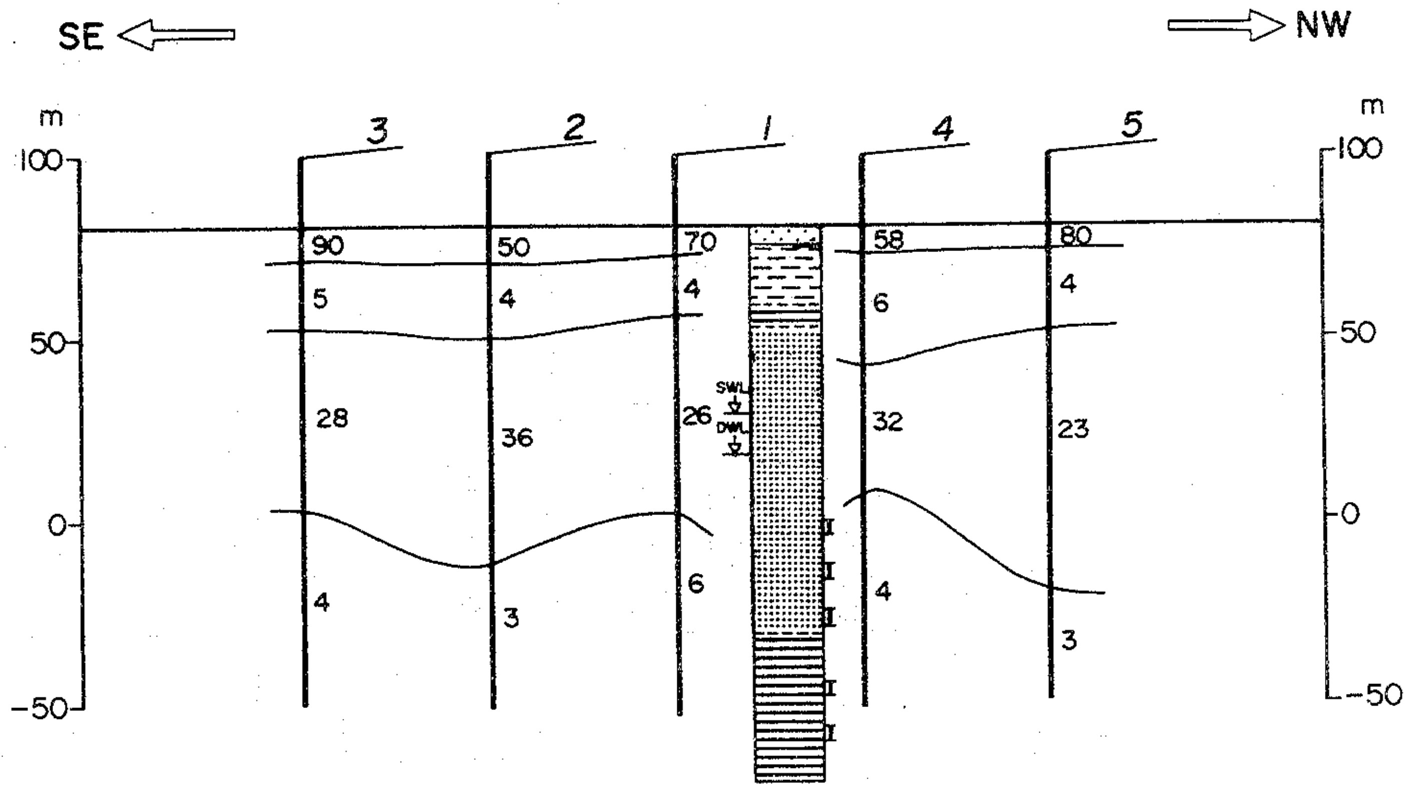


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (9)

No.10. La Vigia

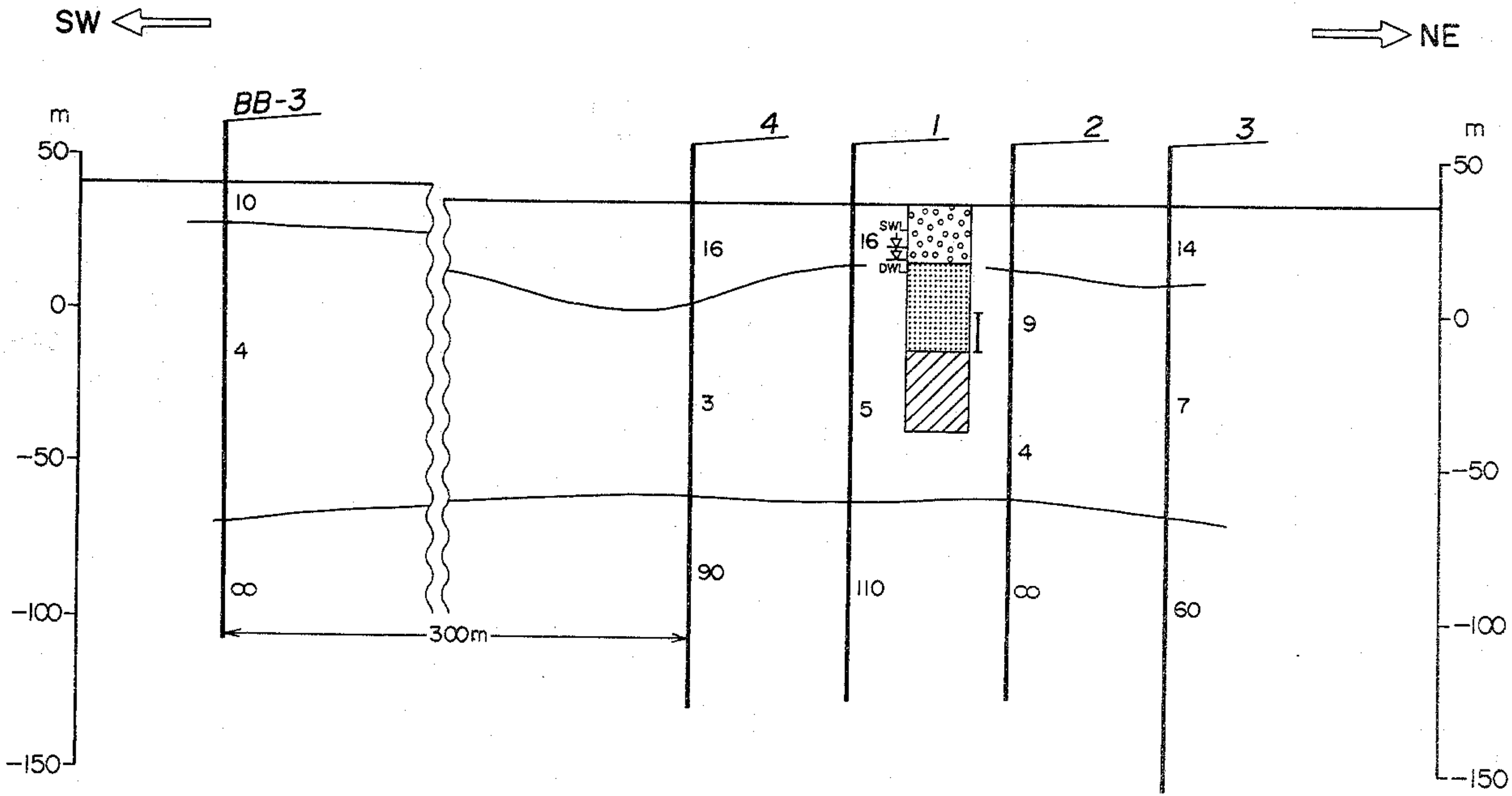


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (10)

No.11. Esperon II

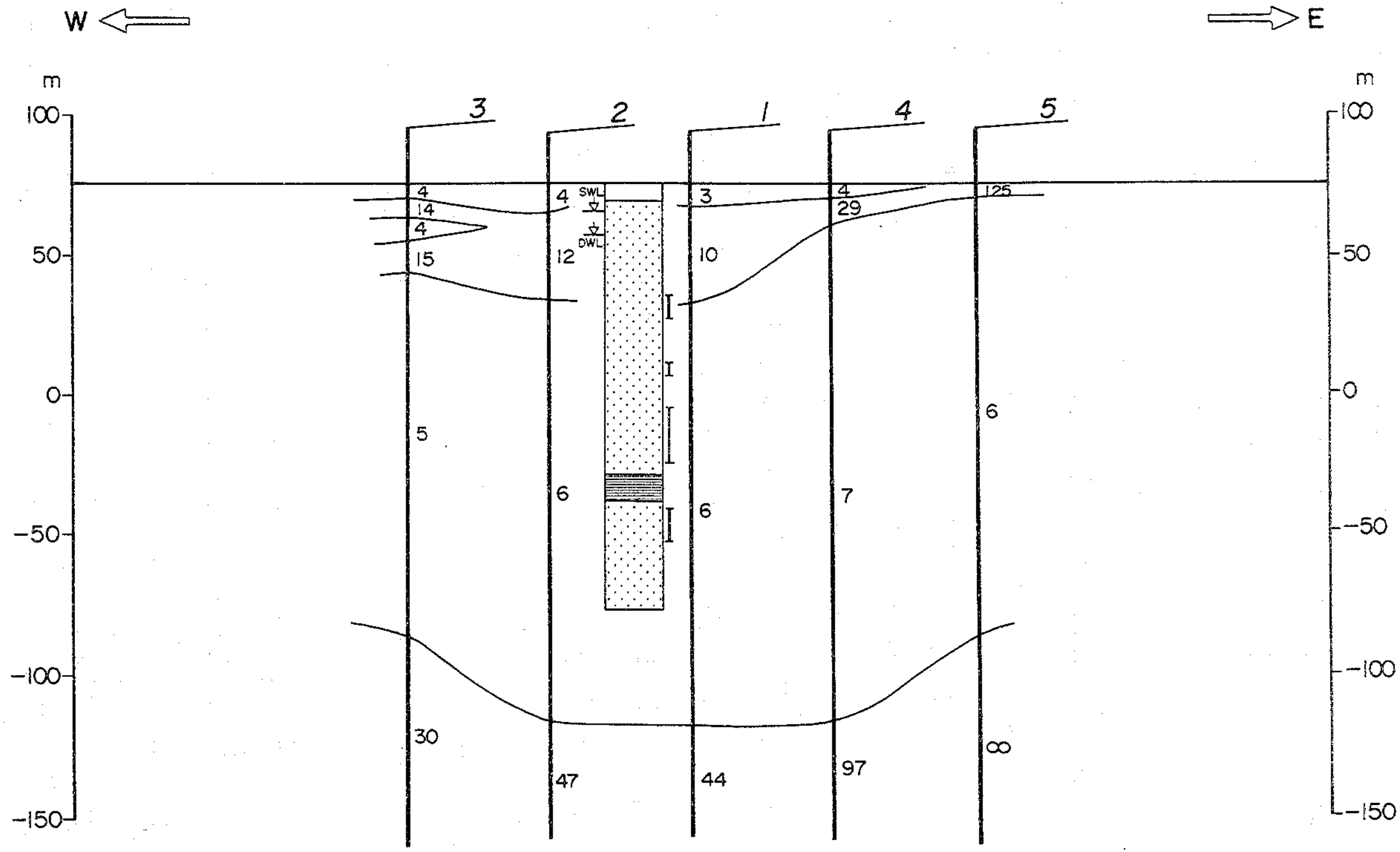


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (11)

No.12. Chacuey II (Canderon)

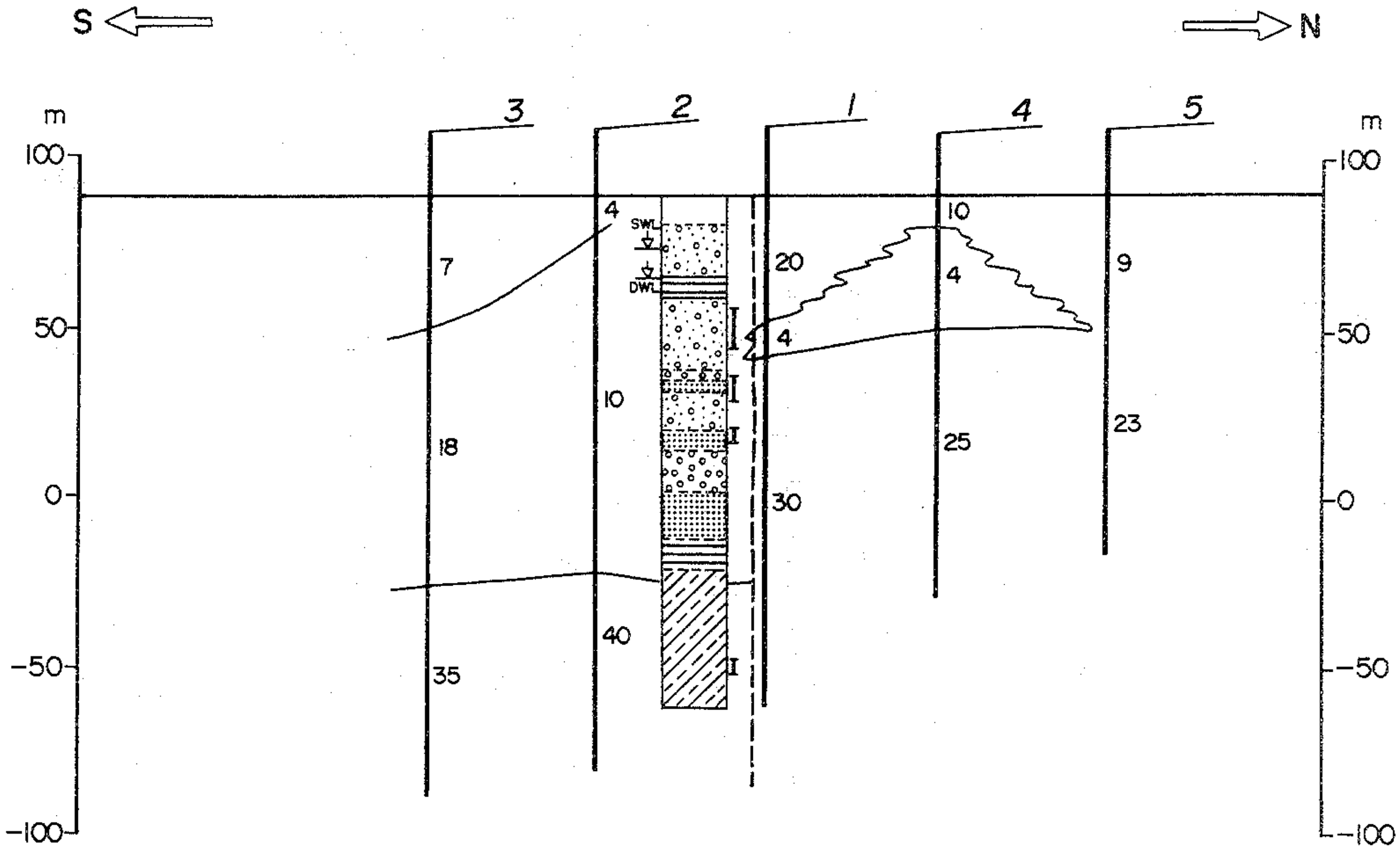


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (12)

No.13. Los Arroyos

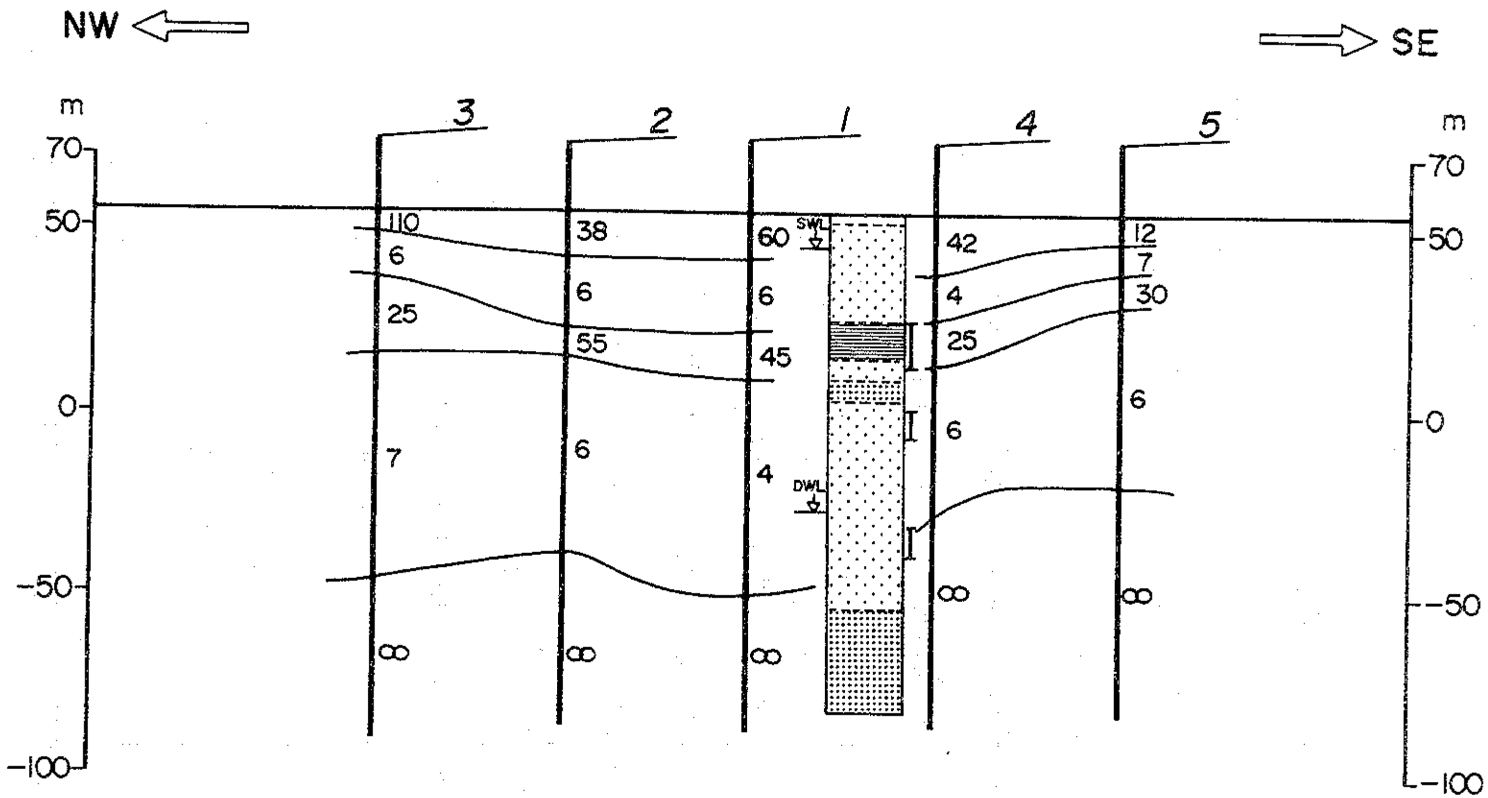


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (13)

No.14. La Gorra

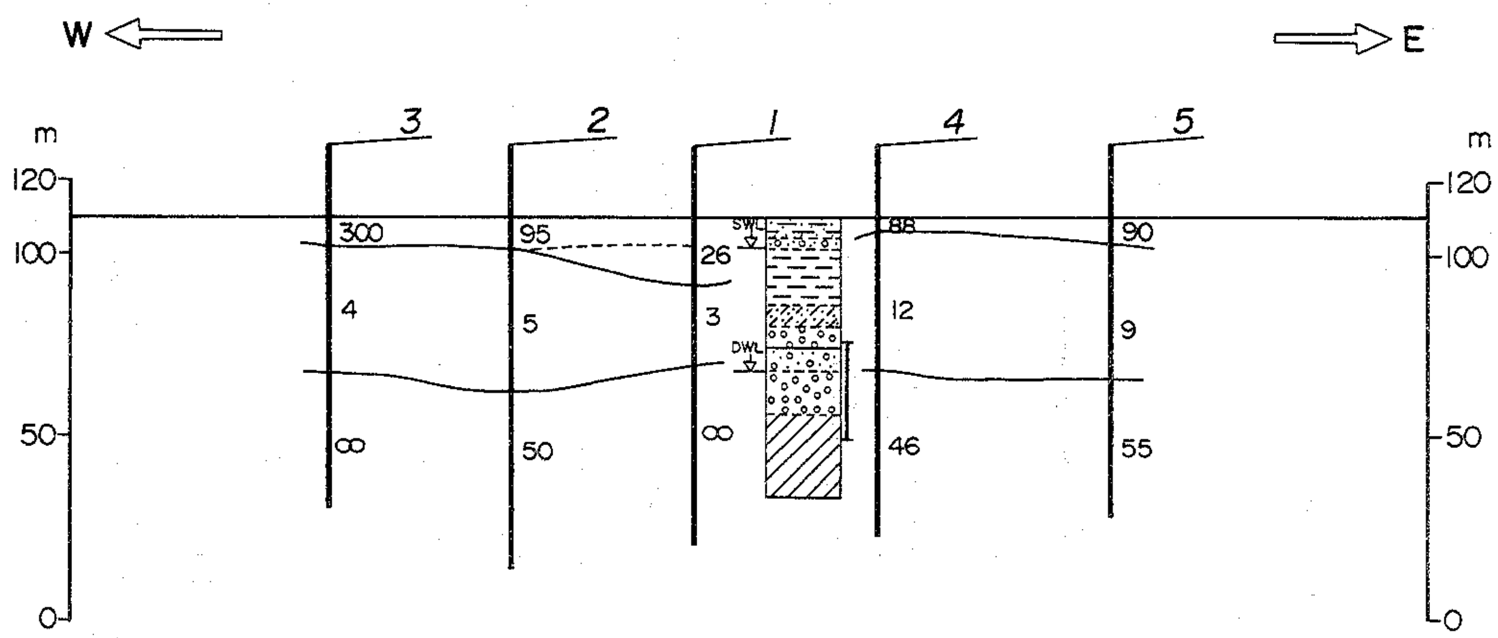


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (14)

No.15. Buen Gusto

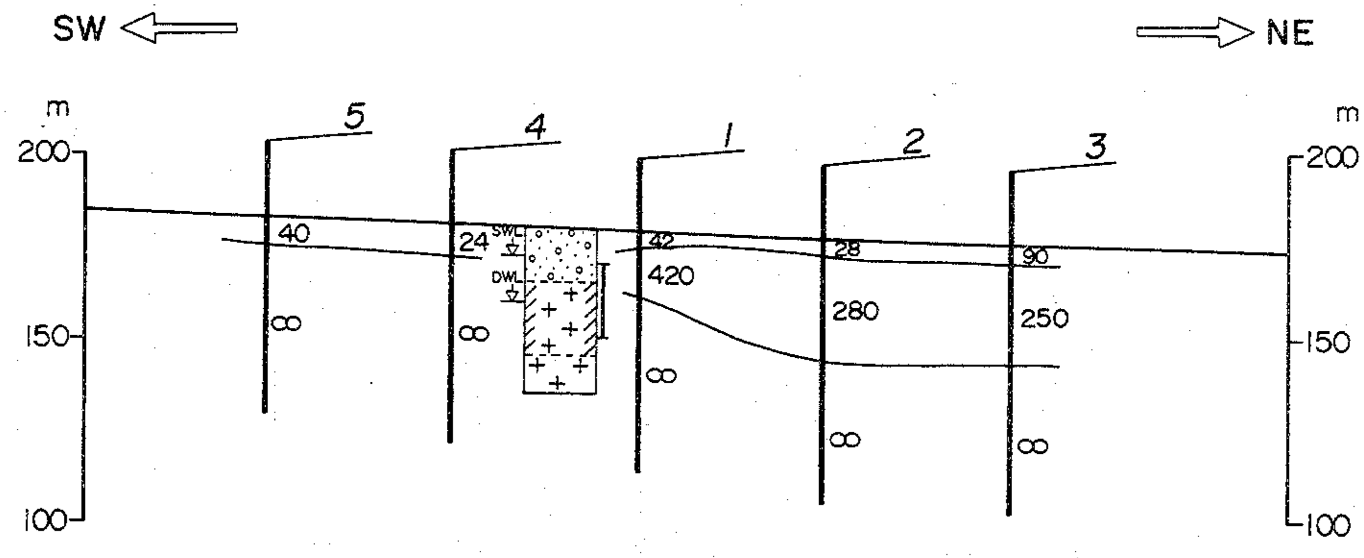


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (15)

No.16. La Peñita Abajo III

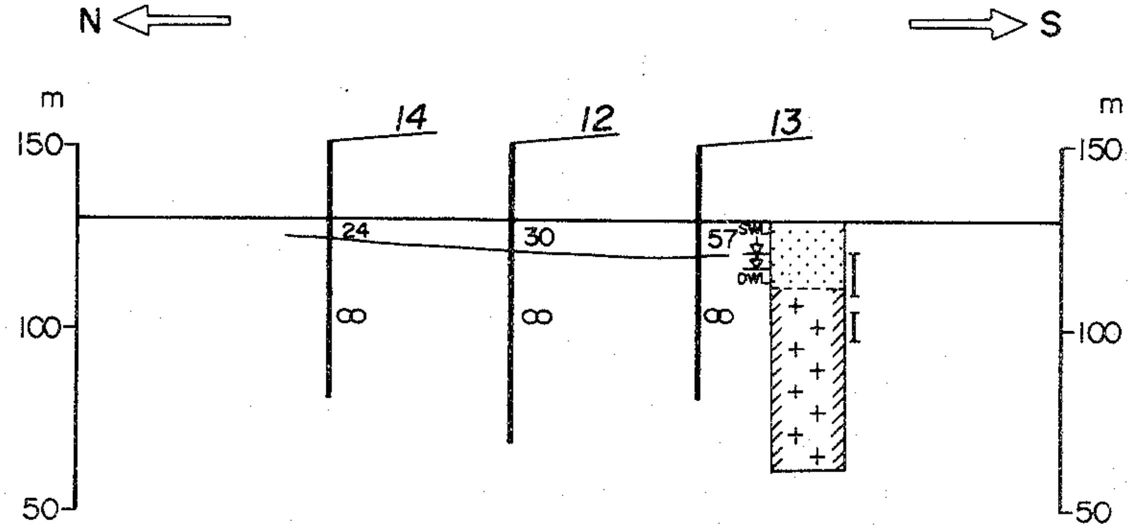


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (16)

No.17. La Peñita Arriba

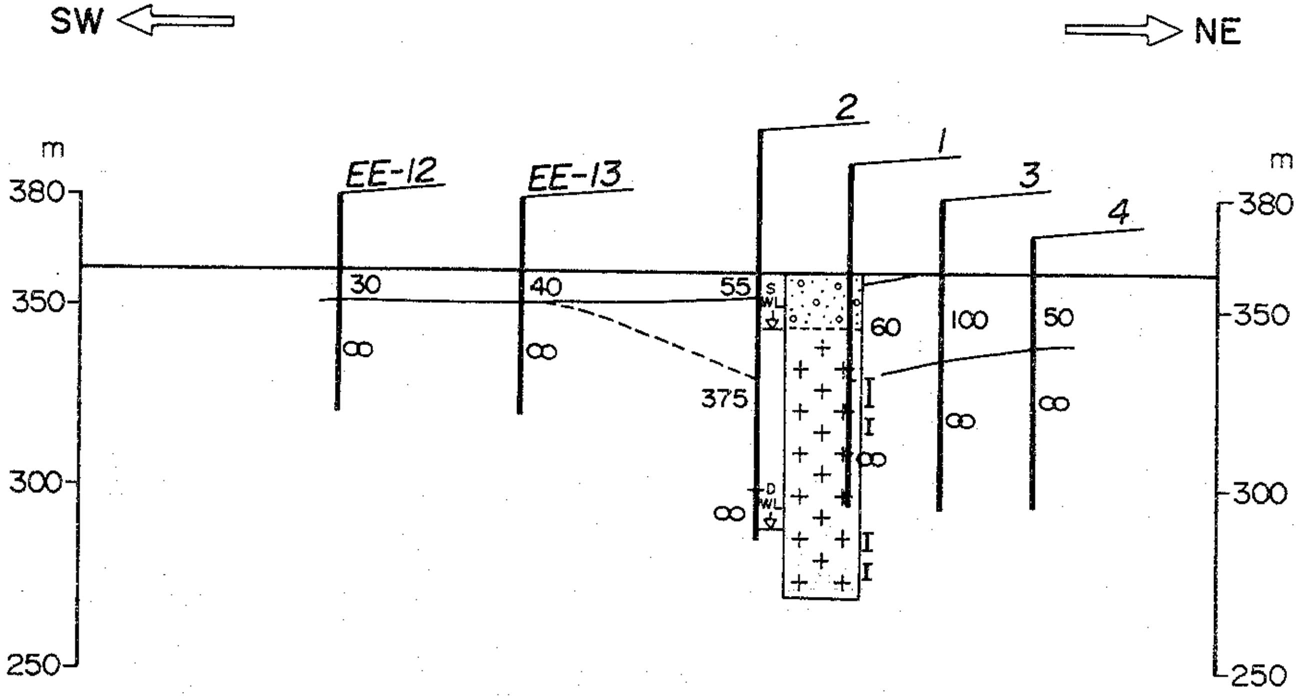


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (17)

No.18. Cruce de Mariano Cestero

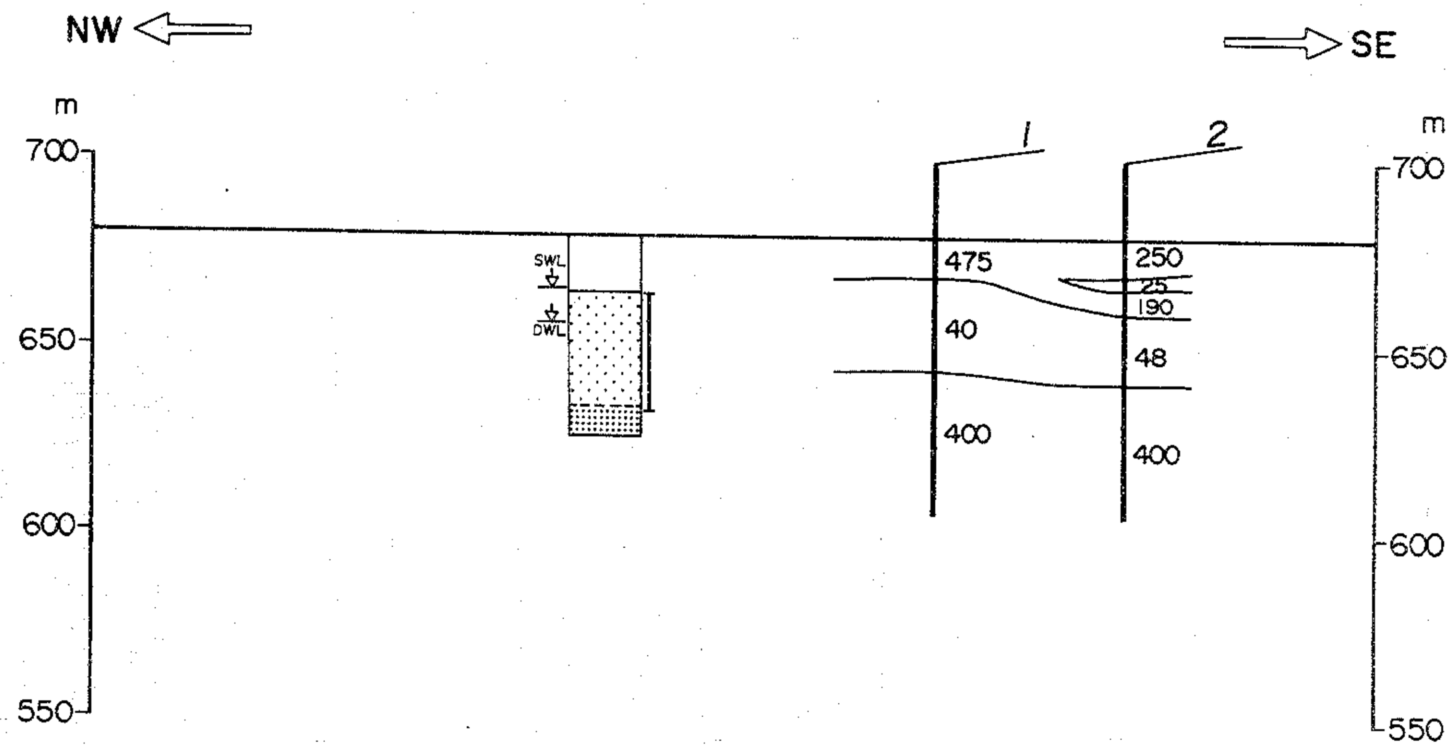


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (18)

No.19. El Mamoncito

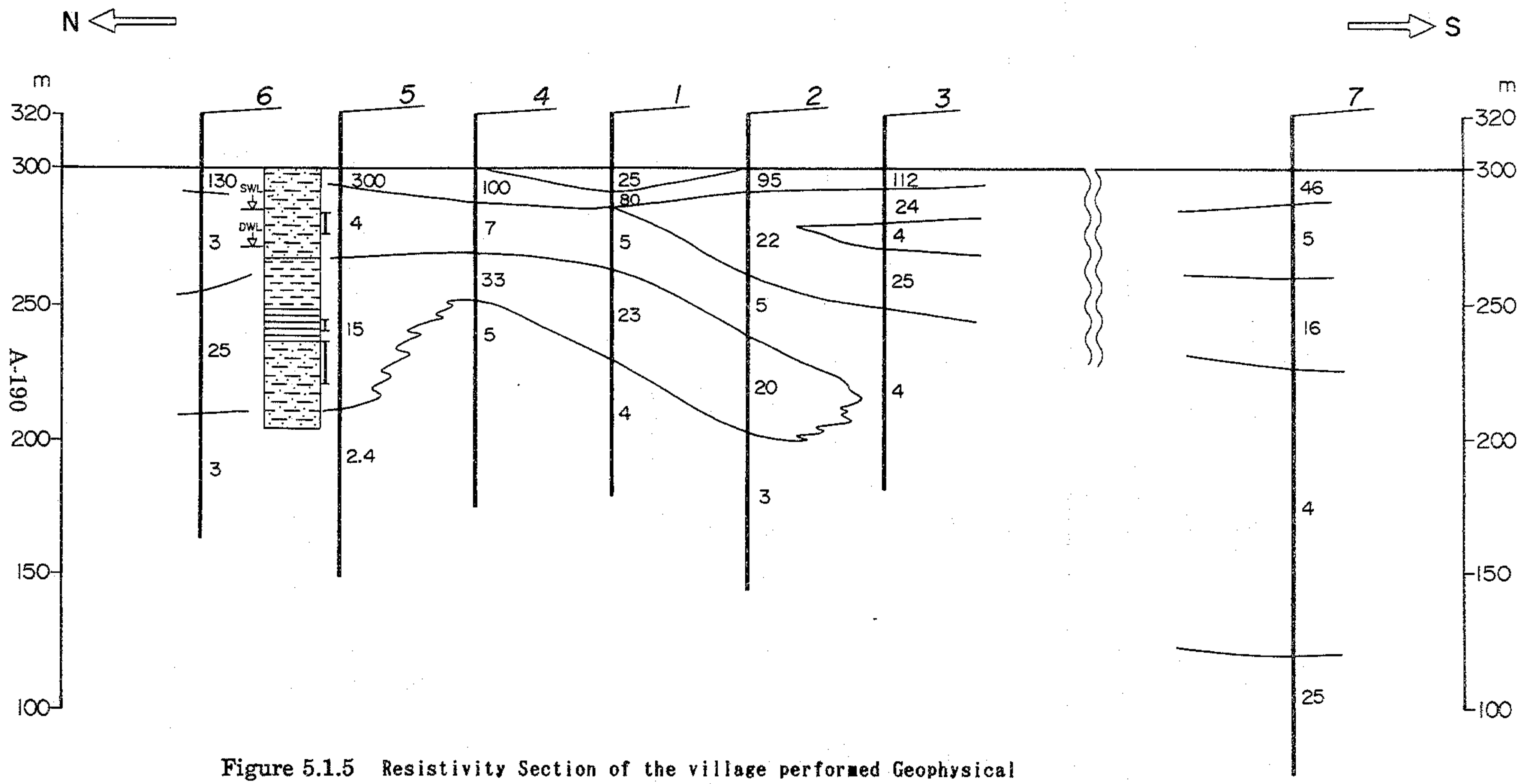


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (19)

No.20. Las Rosas

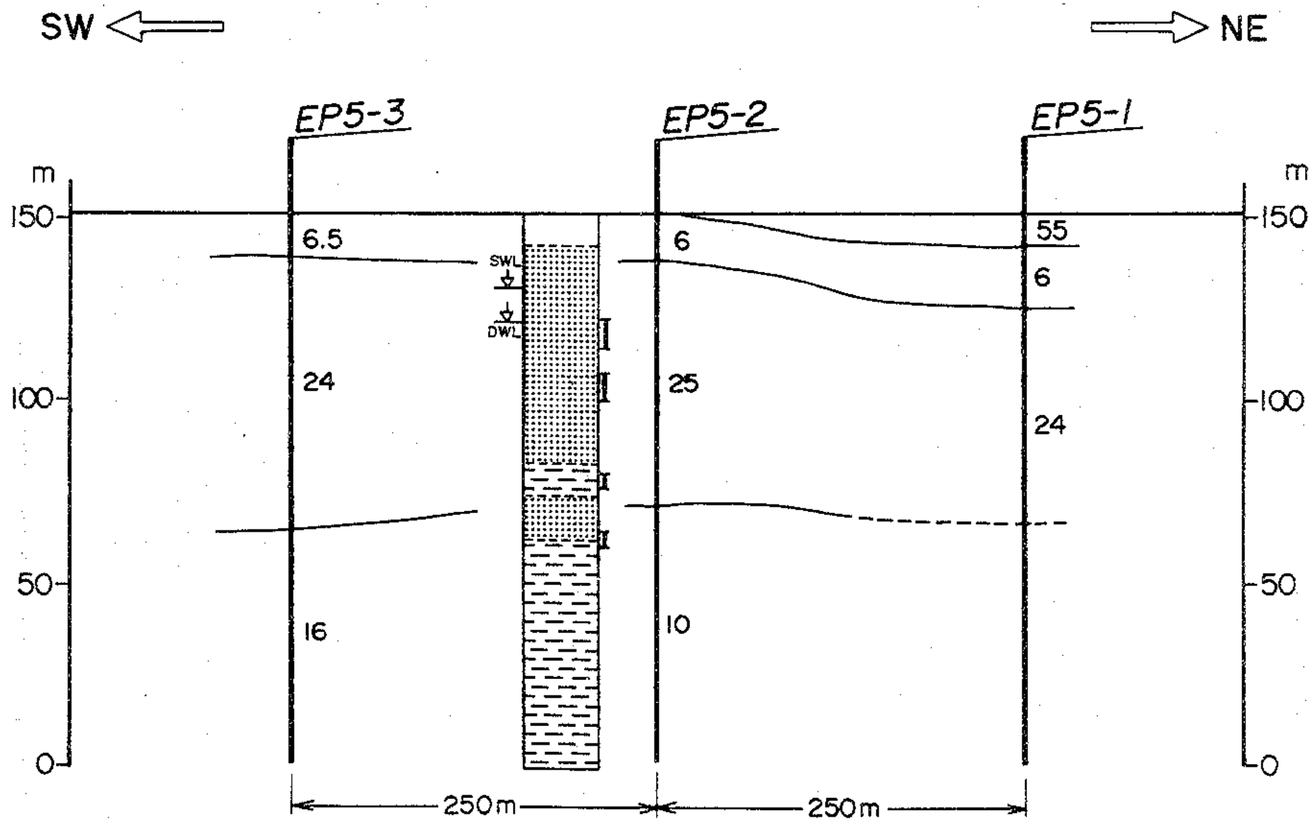


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (20)

No.21. Lamesdero I

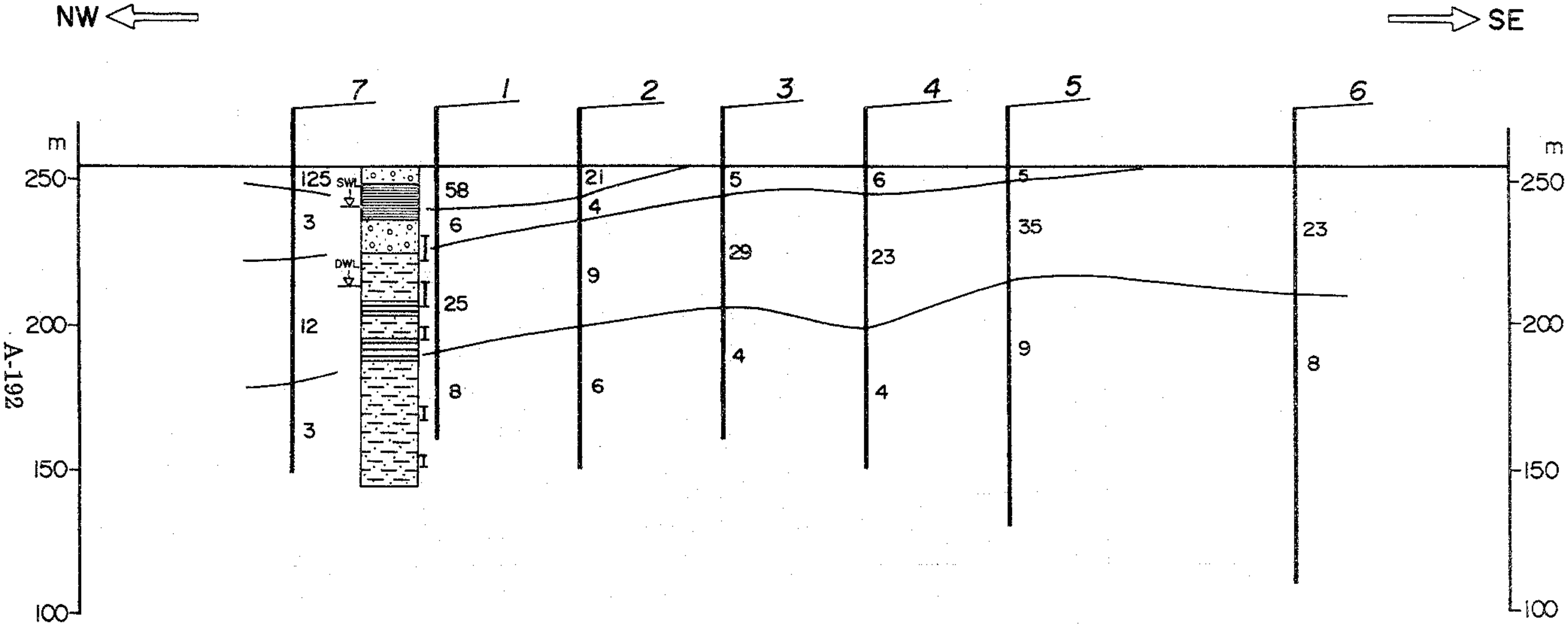


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (21)

No.22. Los Corvanos

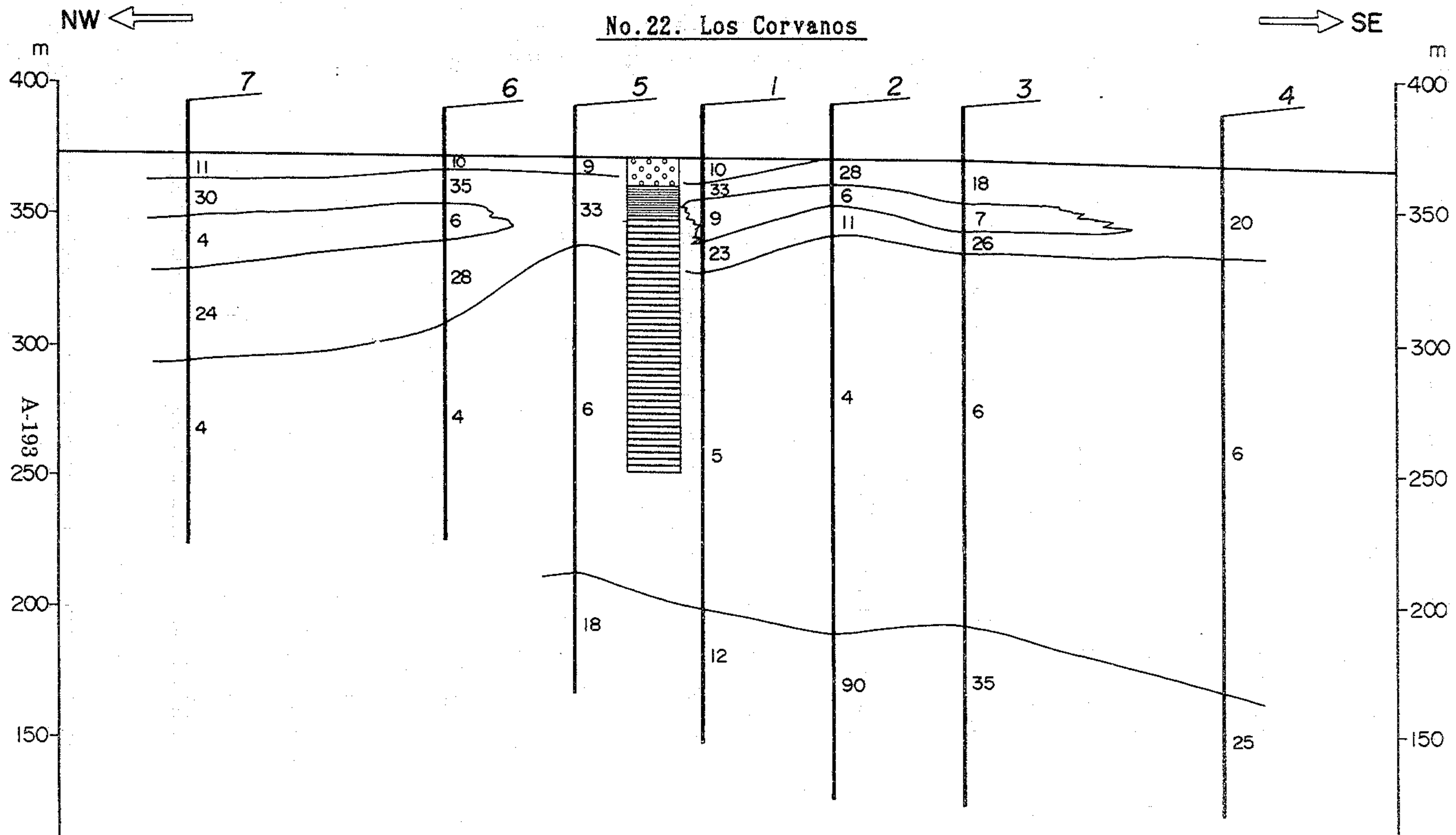


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (22)

No.23. Palo Seco

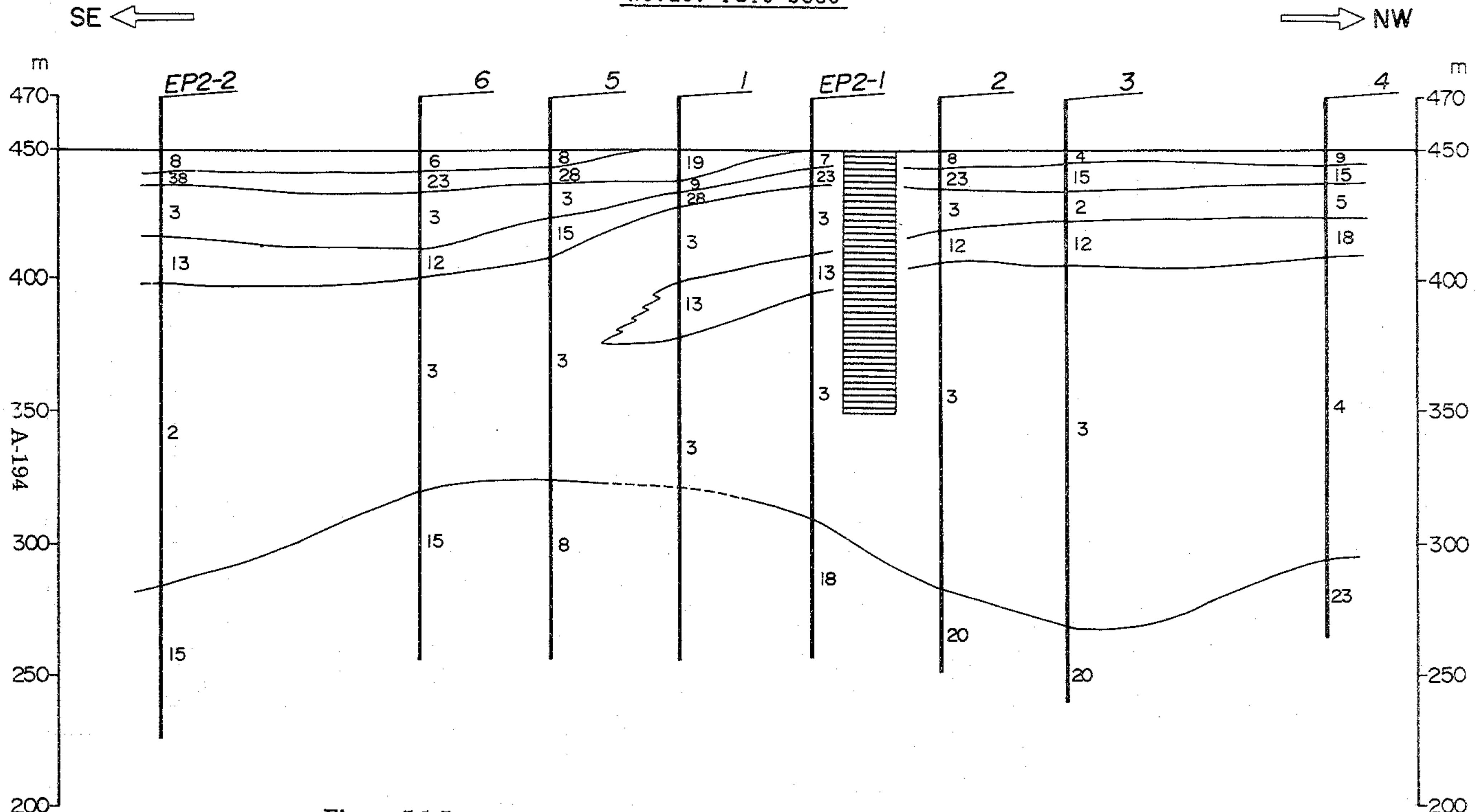


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (23)

No.27. Mariano Cestero

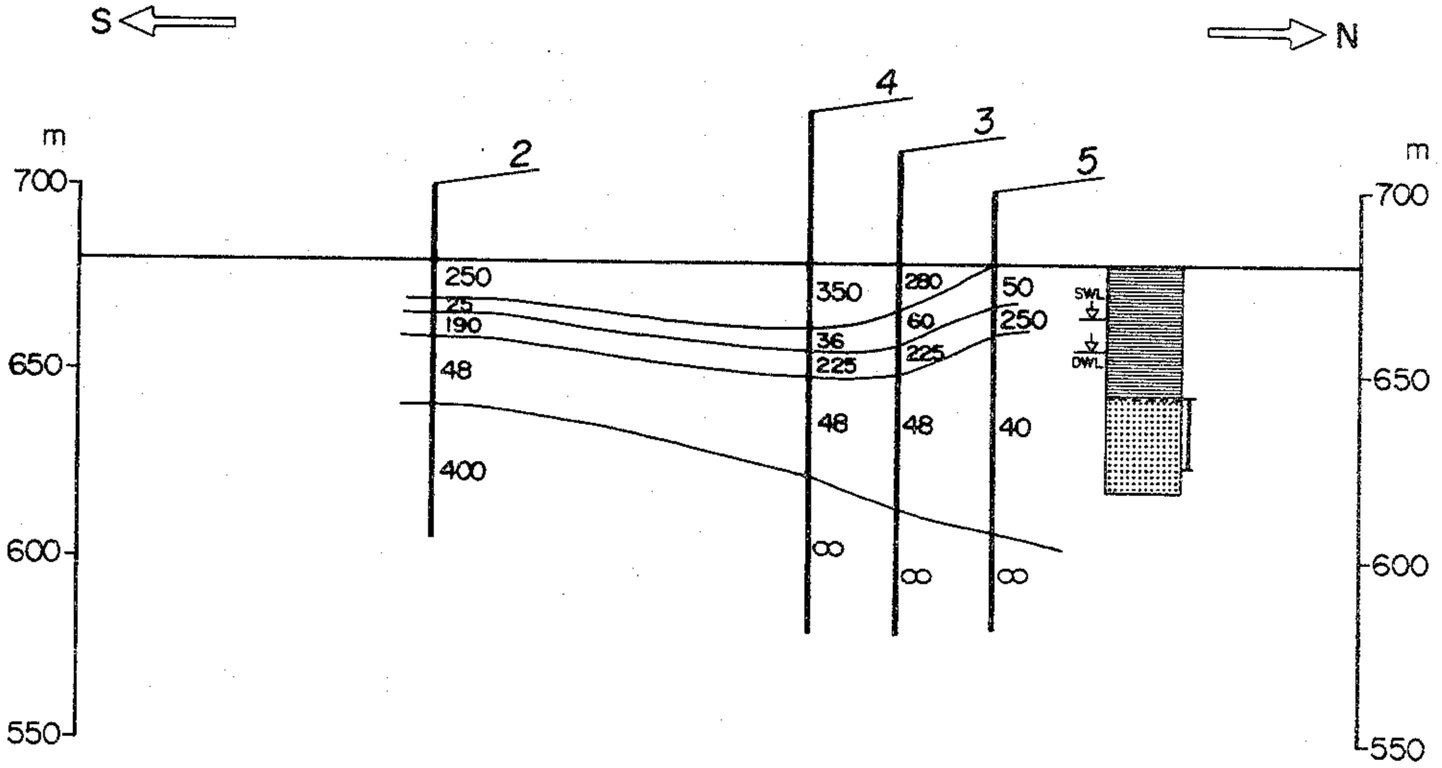


Figure 5.1.5 Resistivity Section of the village performed Geophysical Prospecting and Drilling (24)

D-18
El Cajuil
Electrode Spacing 10m
Station Interval 10m
Exploration Depth 15 m

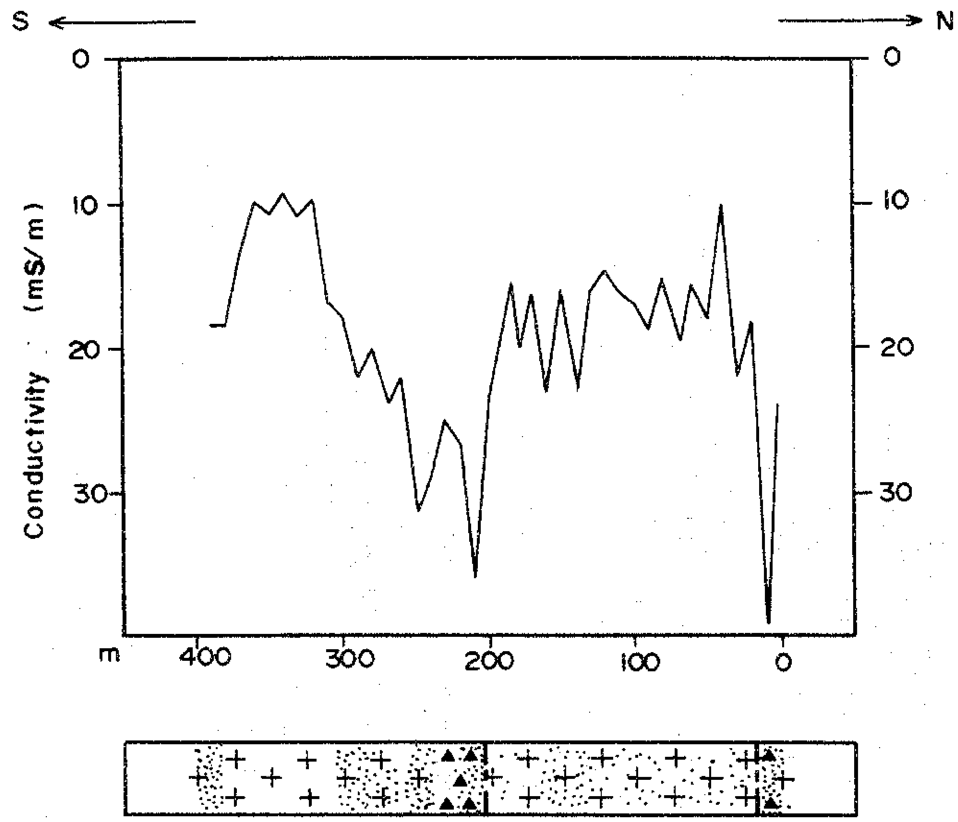


Figure 5.1.6 EM Profile (I)

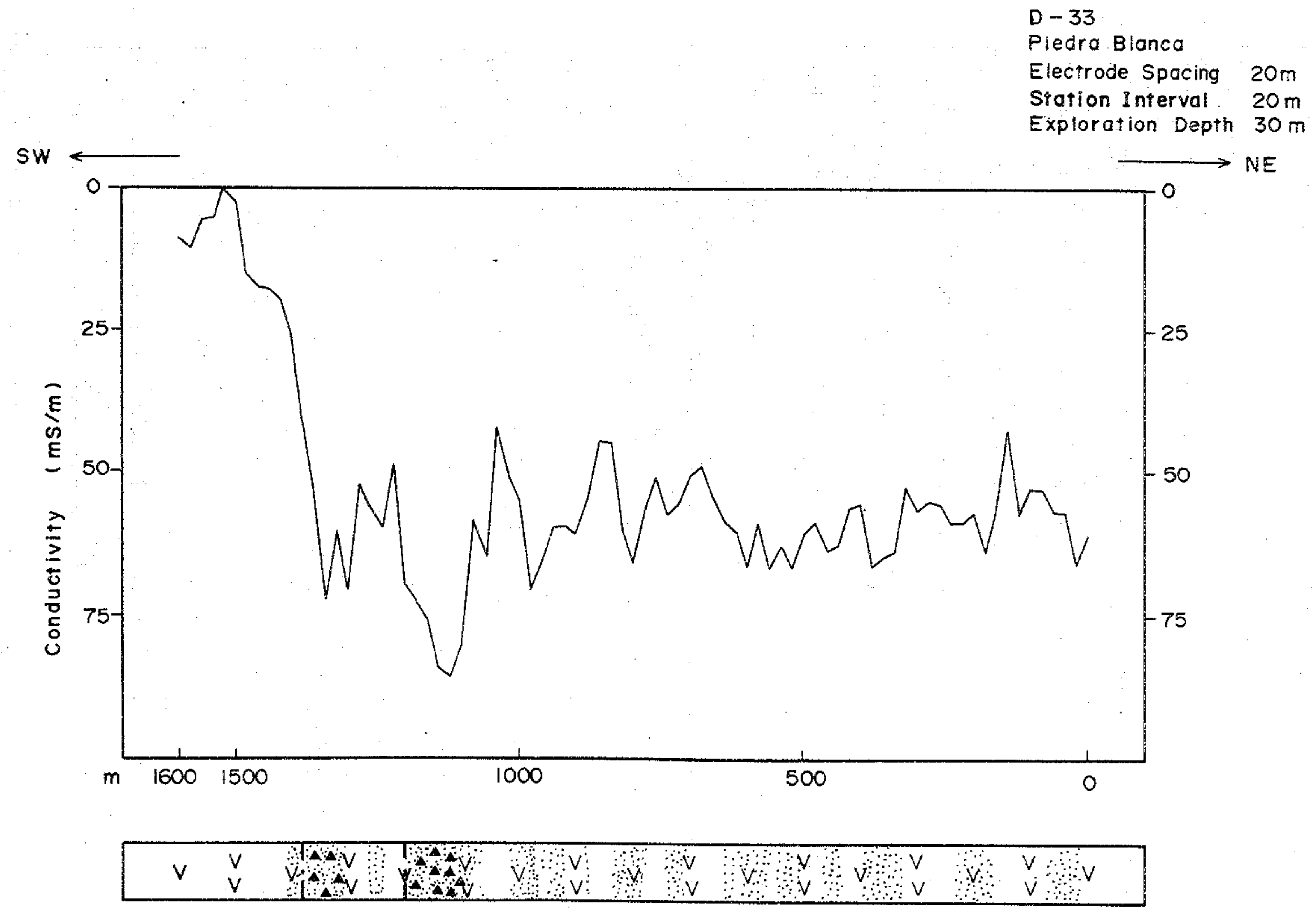


Figure 5.1.6 EM Profile (2)

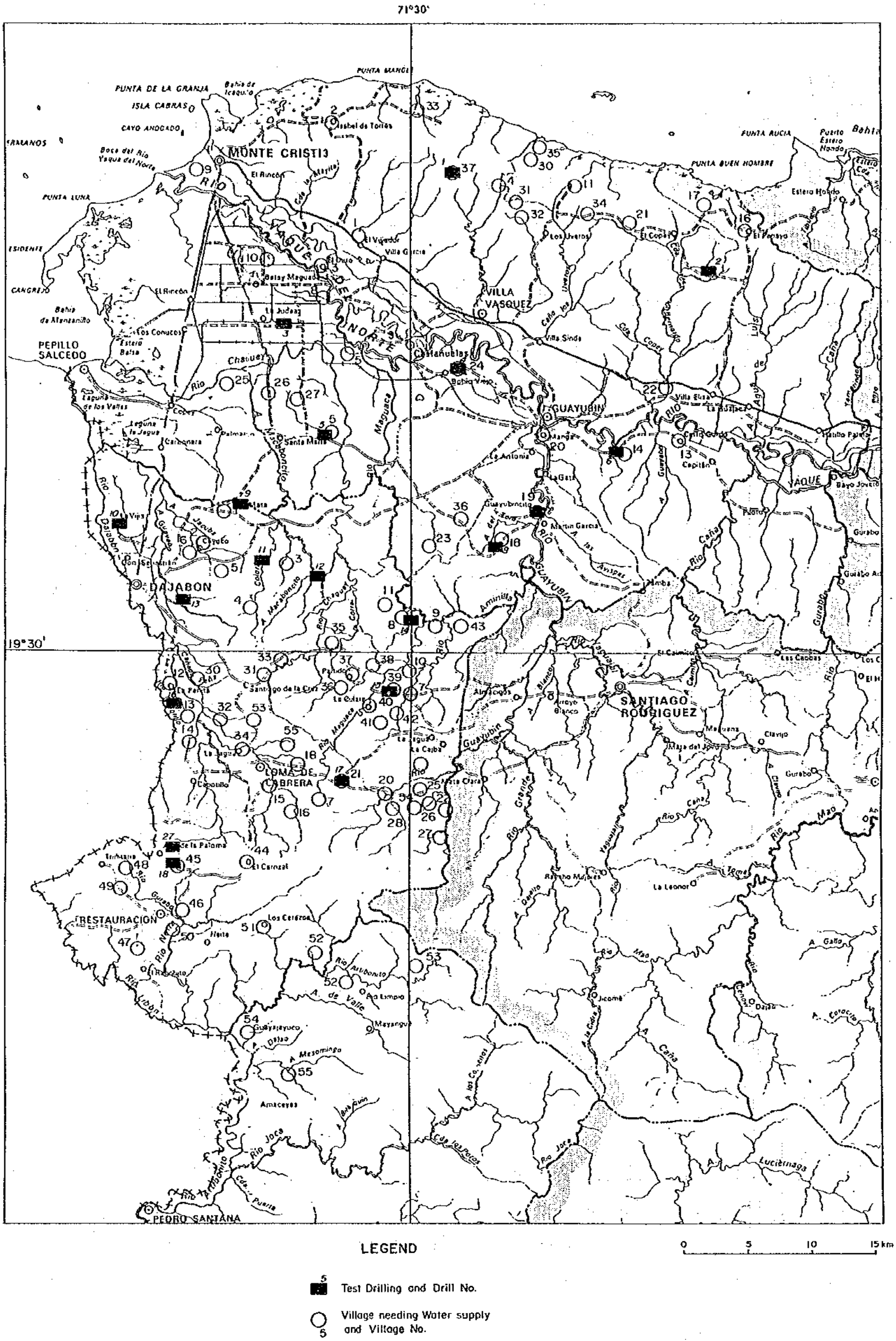


Fig.5.2.1 Location Map of Drilling Sites (1)

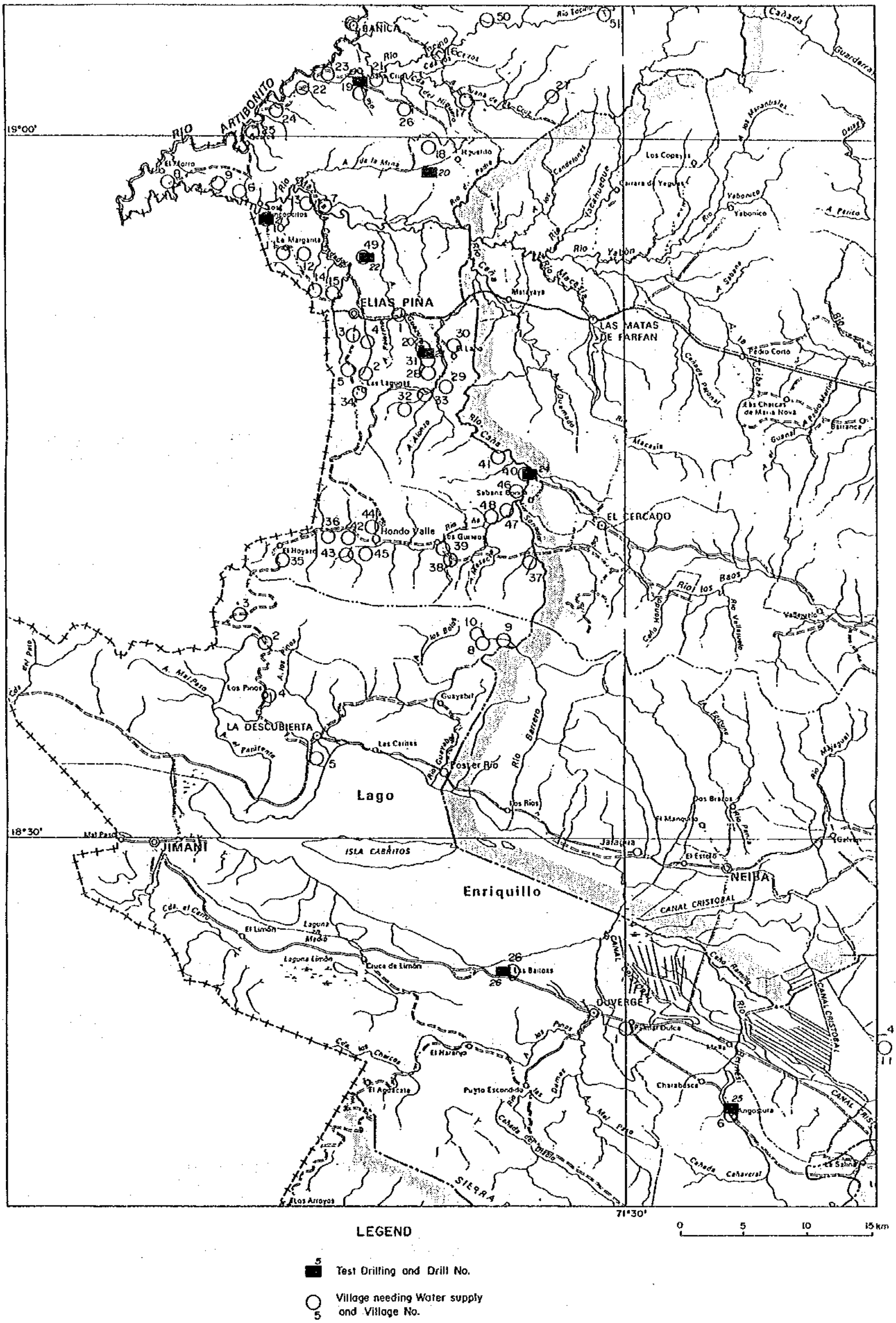


Fig.5.2.1 Location Map of Drilling Sites (2)

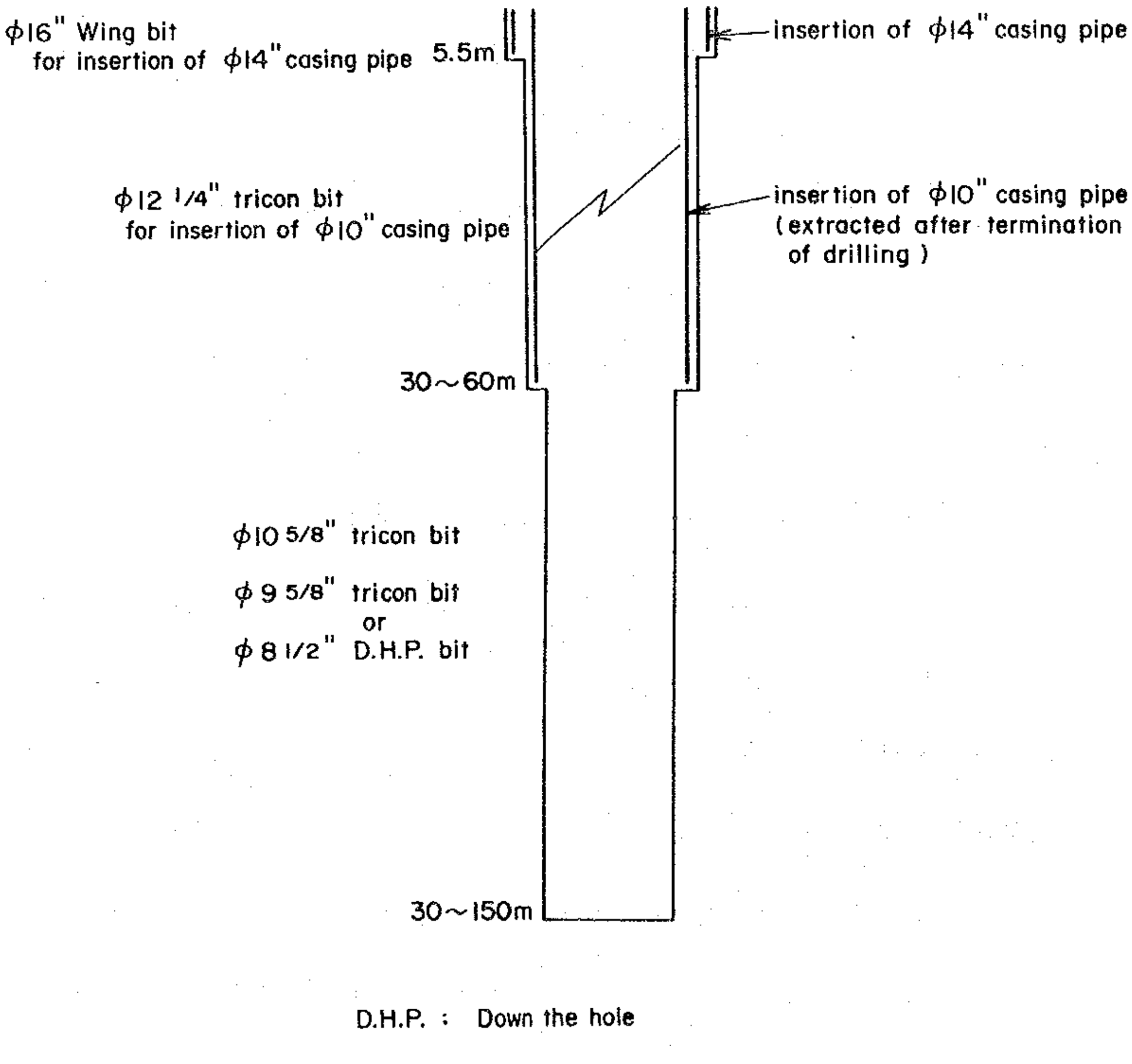


Fig.5.2.2 Casing Program for Test Drilling

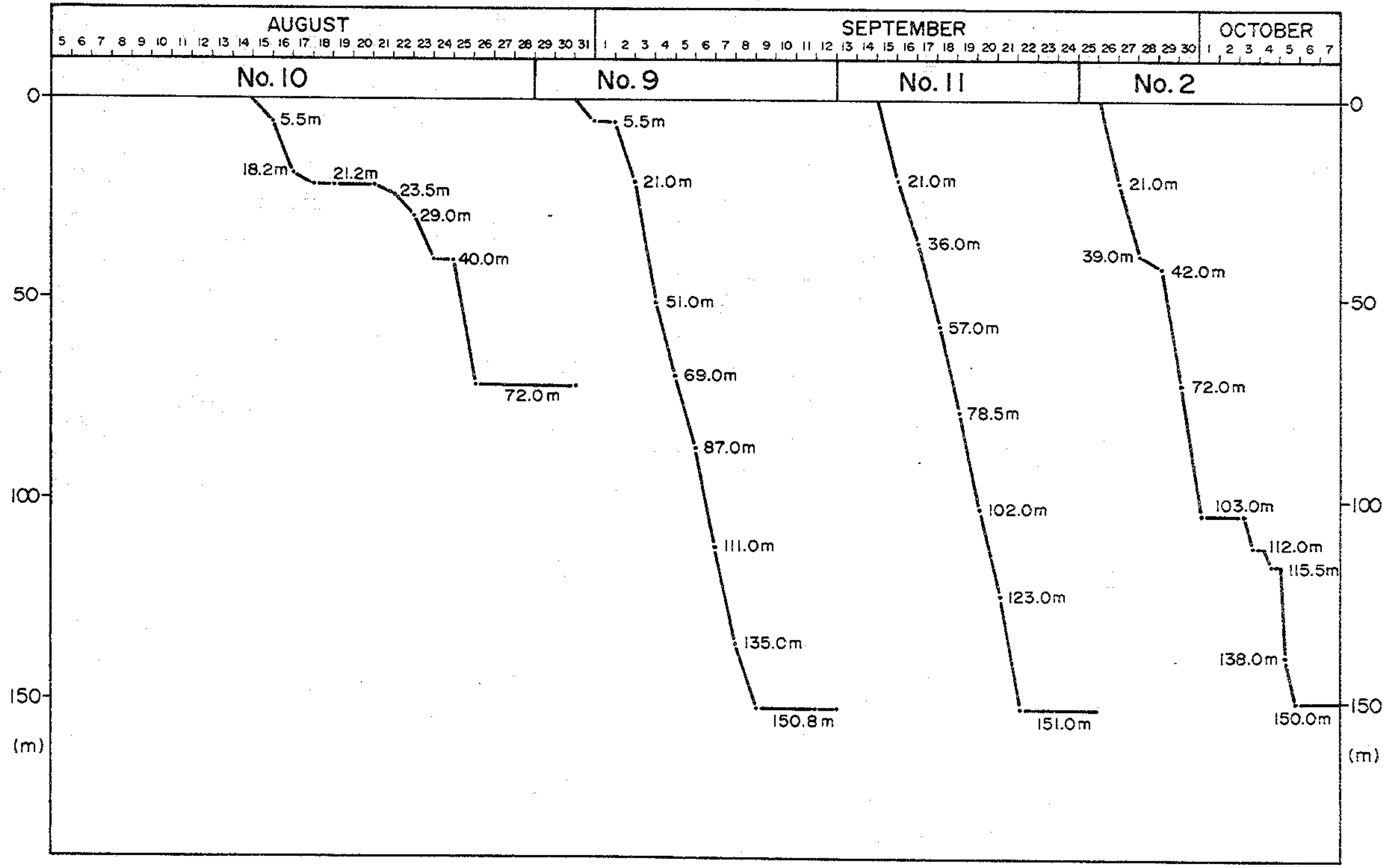


Fig.5.2.3 Process of Drilling Work about the JICA Machine (1)

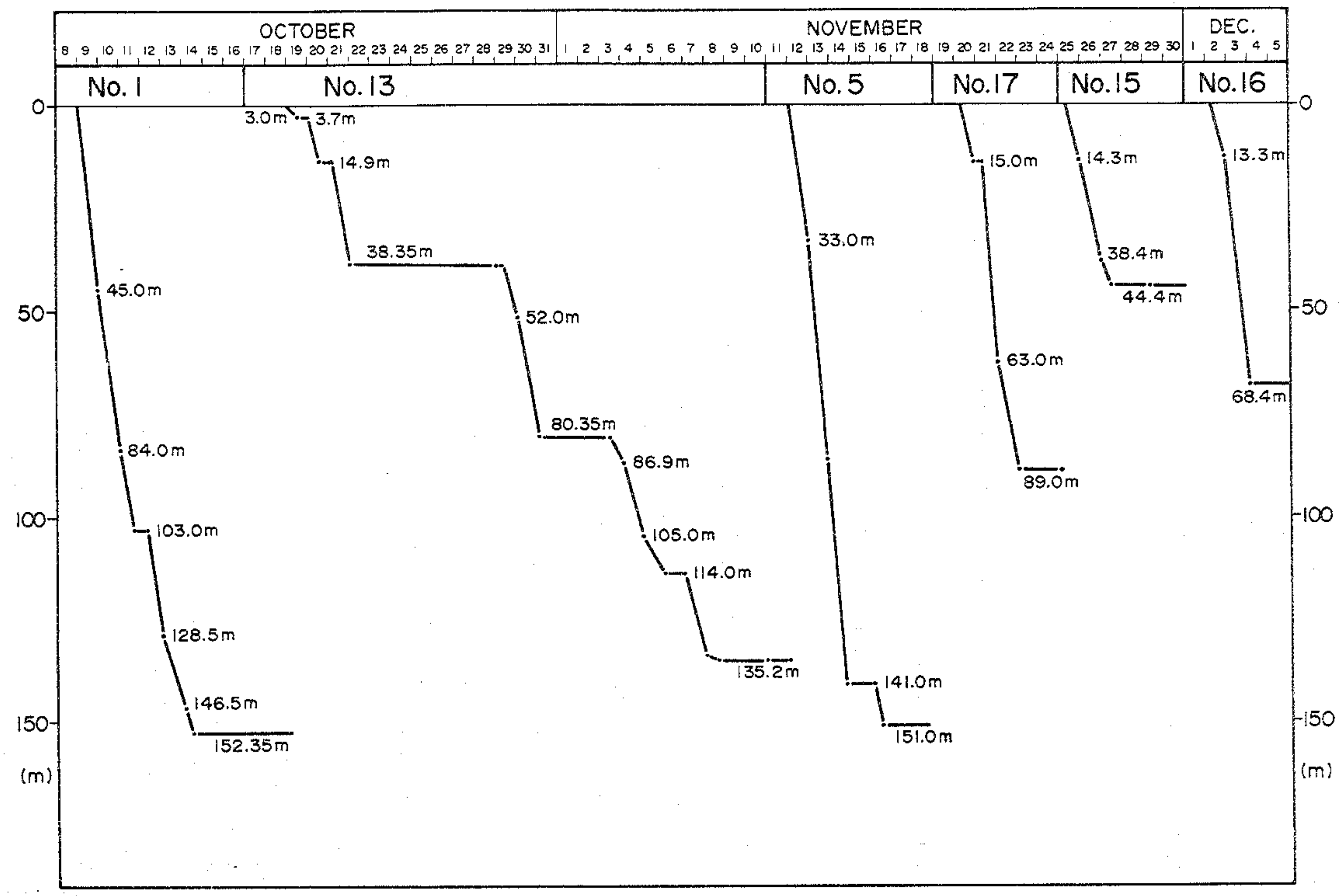


Fig.5.2.3 Process of Drilling Work about the JICA Machine (2)

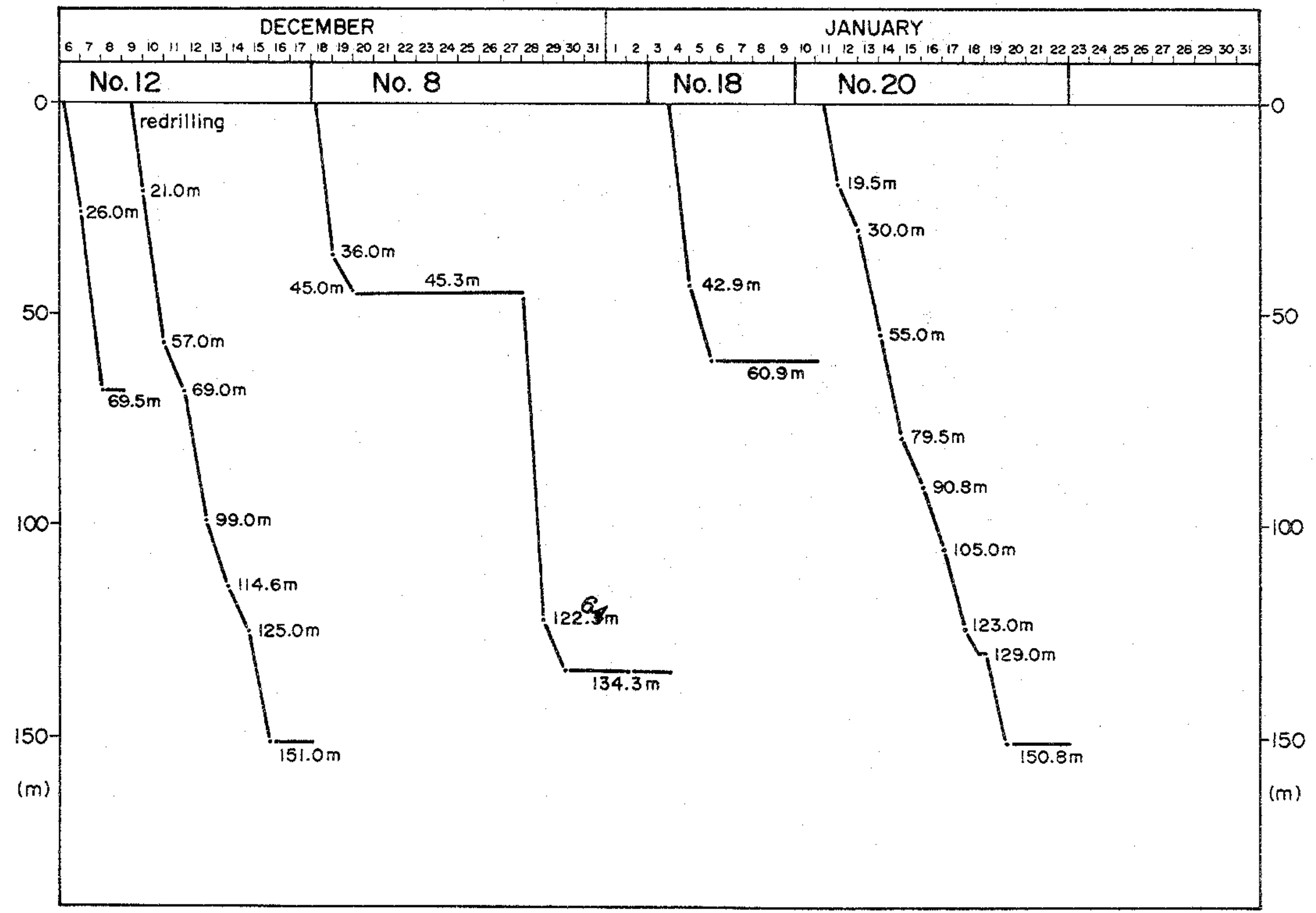


Fig.5.2.3 Process of Drilling Work about the JICA Machine (3)

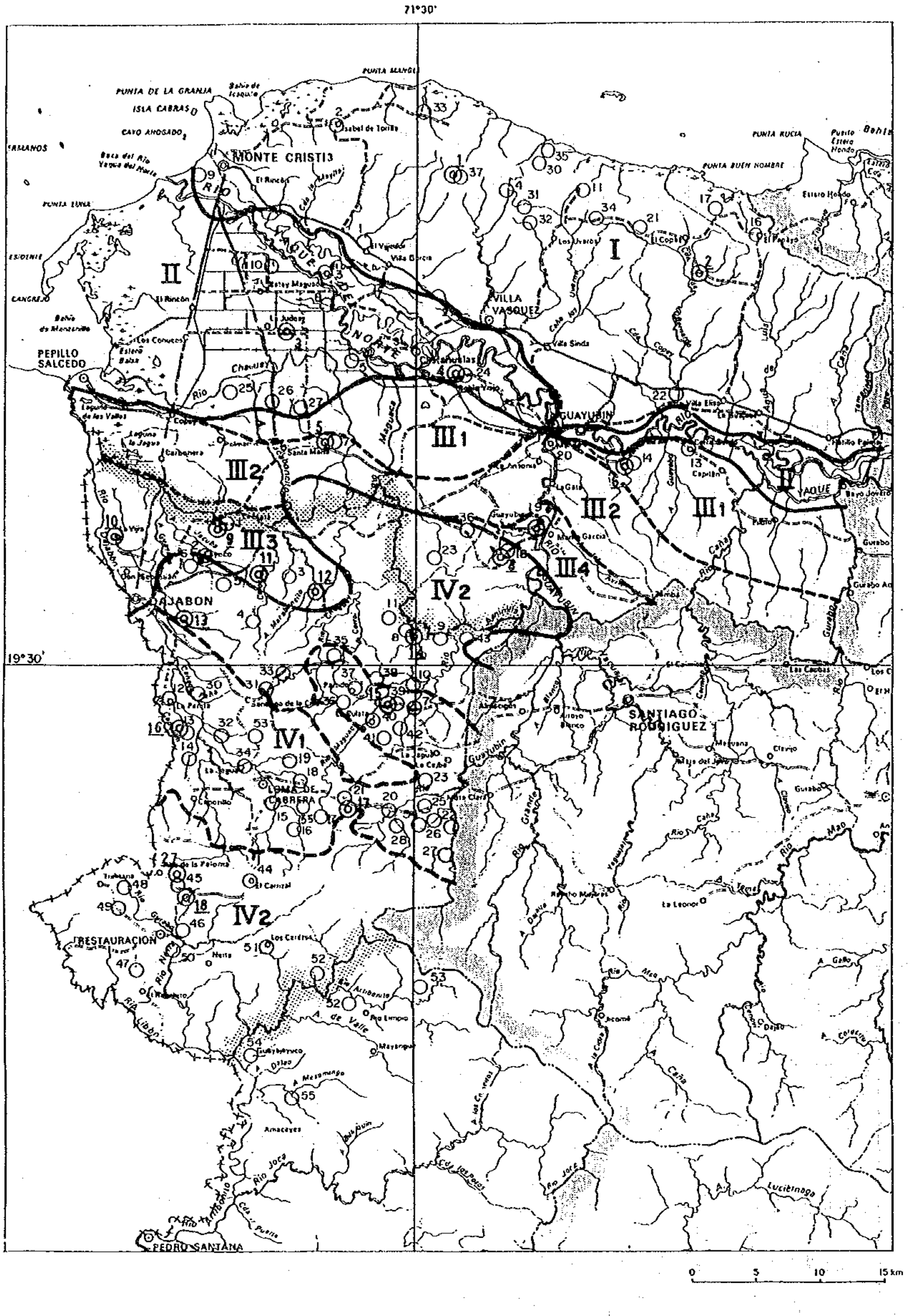


Figure 5.3.1 Classification of the Hydrogeological Province (1)

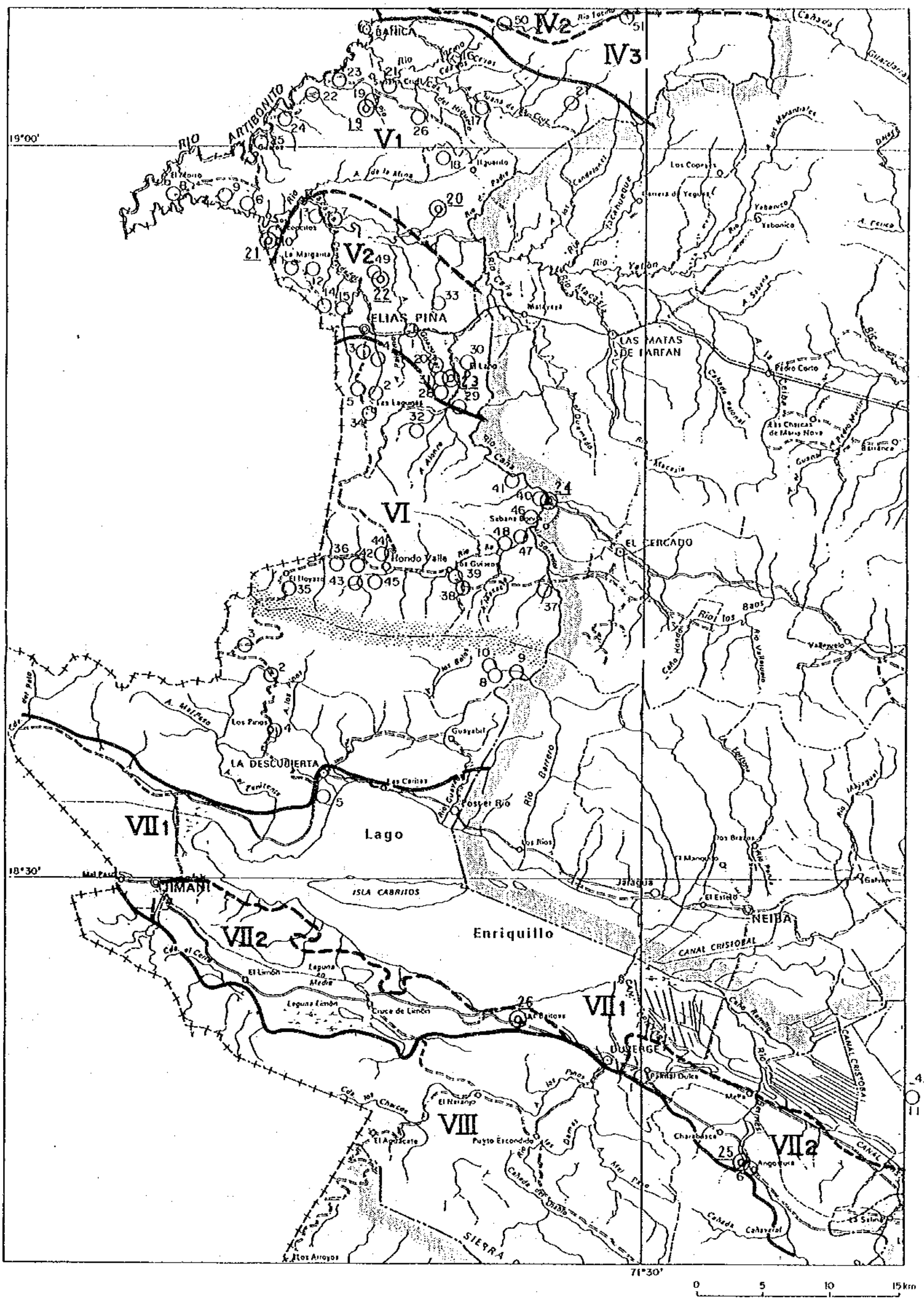


Figure 5.3.1 Classification of the Hydrogeological Province (2)

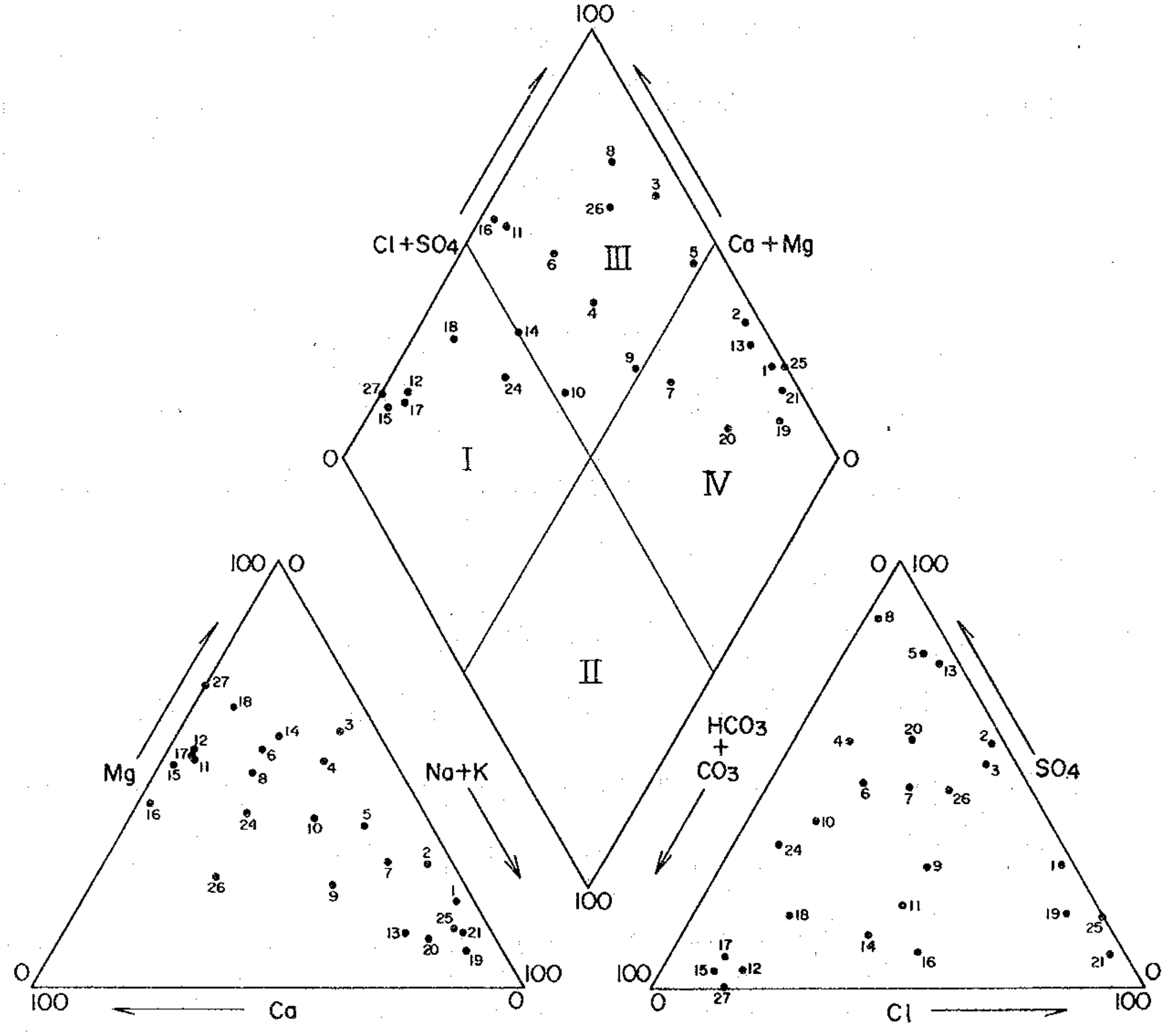


Figure 5.3.2 Piper's Diagram

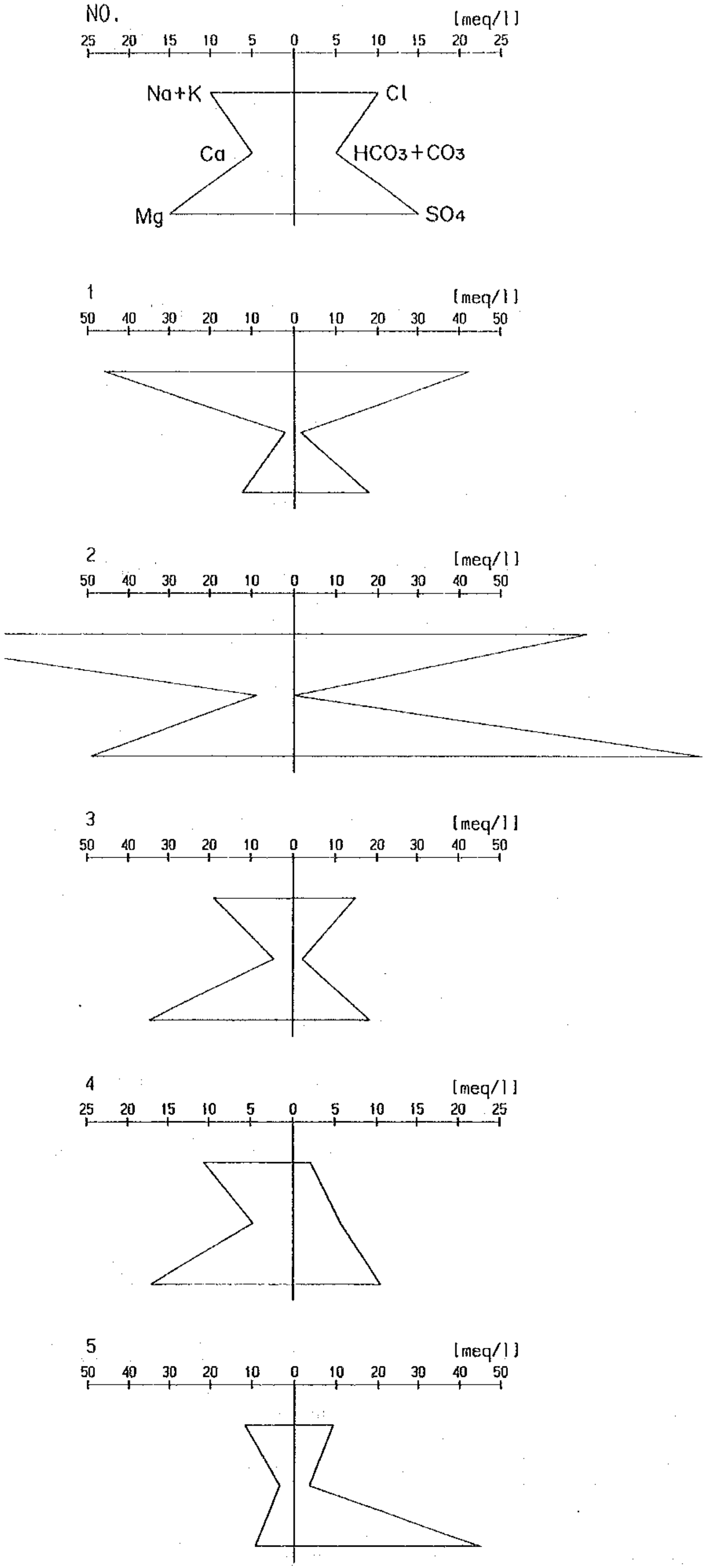


Figure 5.3.3 Hexadiagram (1)

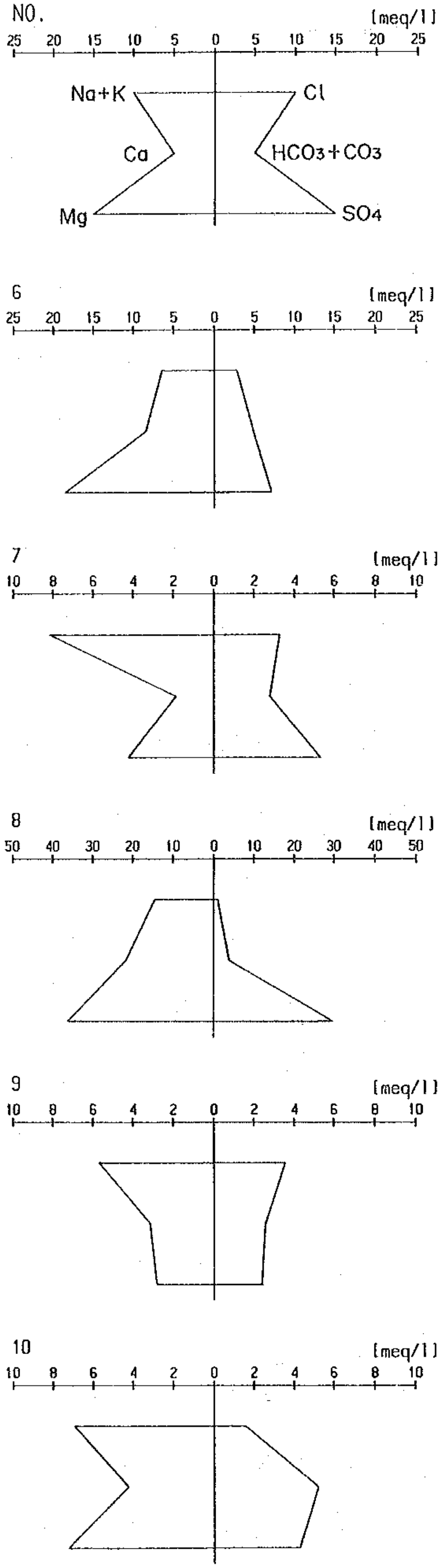


Figure 5.3.3 Hexadiagram (2)

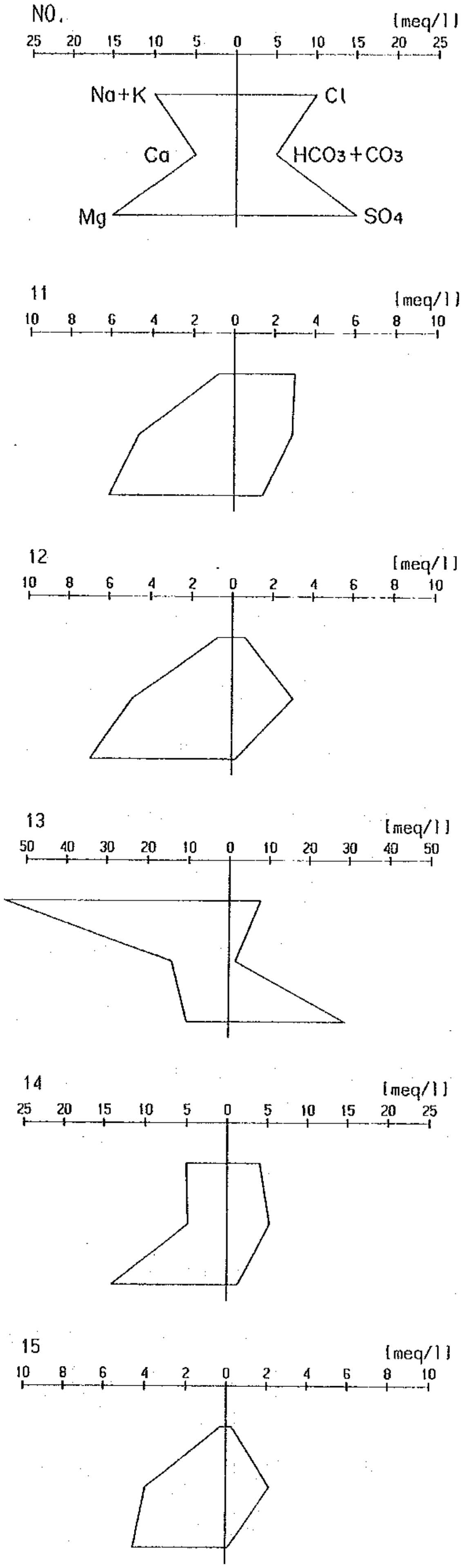


Figure 5.3.3 Hexadiagram (3)

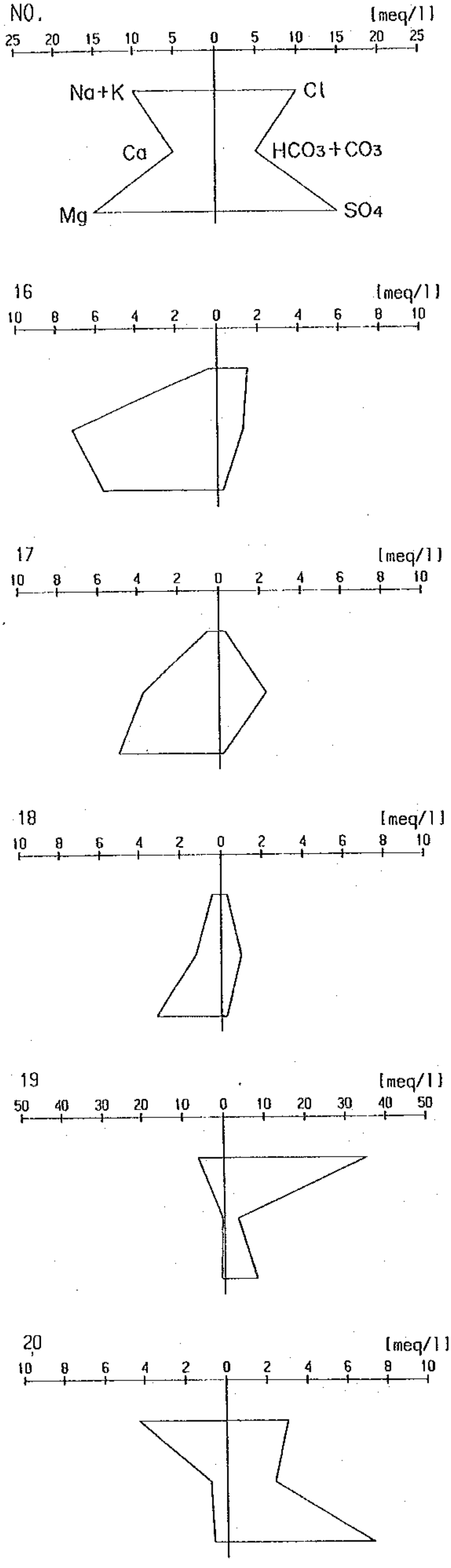


Figure 5.3.3 Hexadiagram (4)

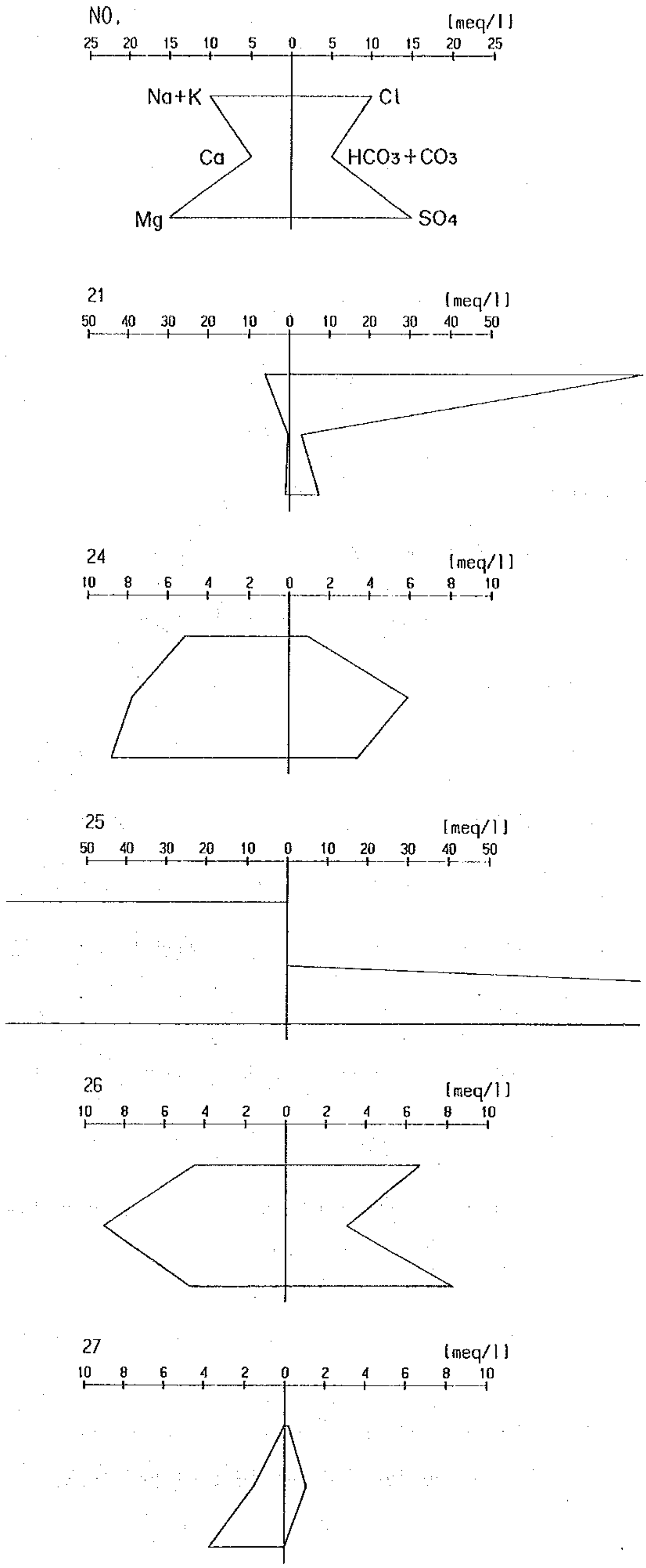
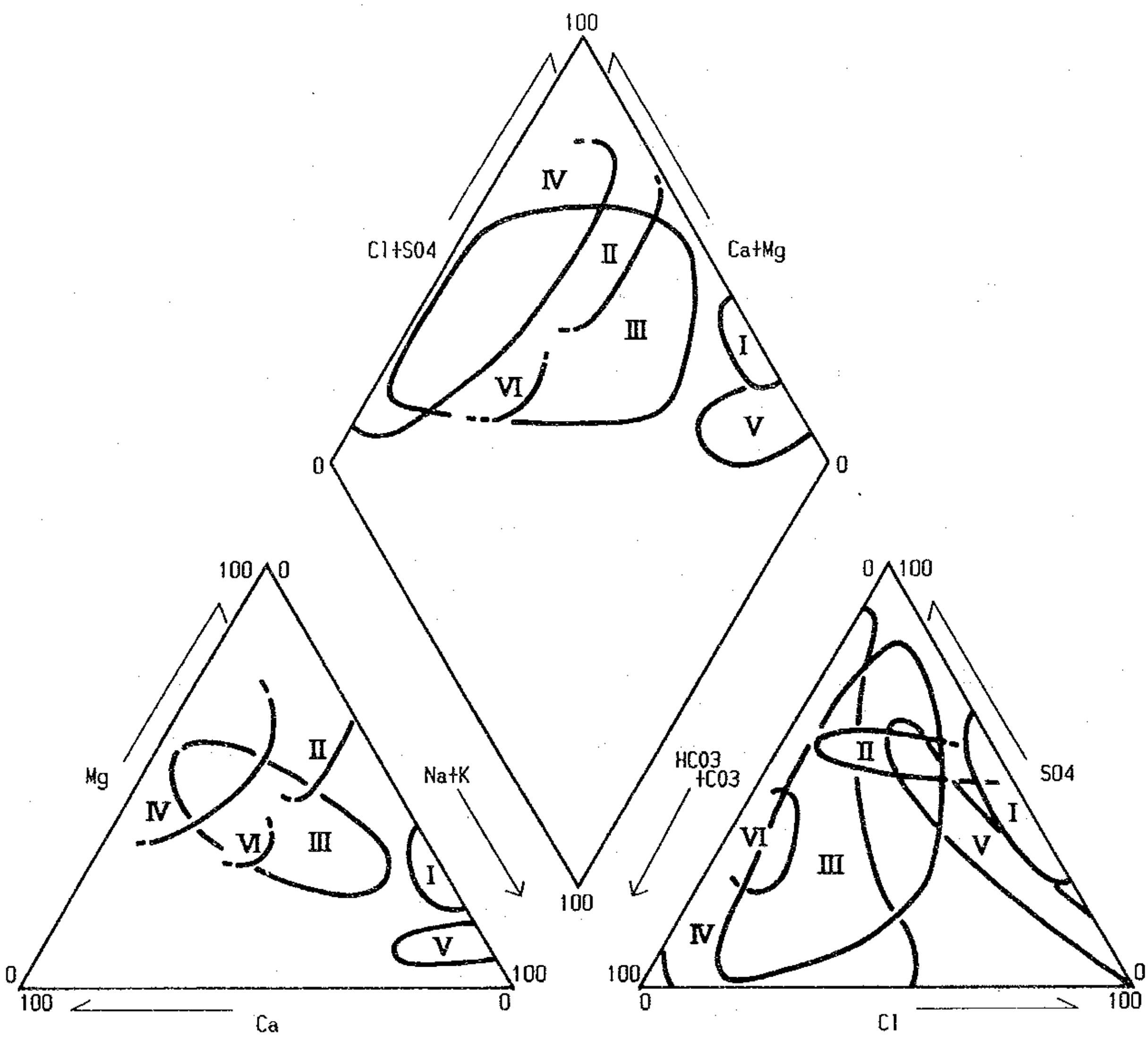


Figure 5.3.3 Hexadiagram (5)



* Province VII : Scattered Data – No apparent trend

* Province VIII : No Samples

Fig.5.3.4 The General Propensities of Ion Content Value in respective Hydrogeological Provinces

D 1	Super-high productive aquifer (Q= 300, partly Q >= 500) existing between 60 ～ 120 m in depth
D 2	High to Super-high productive aquifer (200 > Q >= 100, partly Q >= 3000) existing between 30 ～ 60 m in depth
D 3	High productive aquifer (Q >= 100, partly Q >= 1000) existing between 60 ～ 90 m in depth
D 4	Intermediately to High productive aquifer (Q = 100, partly Q >= 500) existing at shallow part of less then 60 m in depth
D 5	Intermediately productive aquifer (Q = 100) existing between 60 ～ 90 m in depth
D 6	Low to Intermediately productive aquifer (60 > Q >= 10) existing between 30 ～ 60 m in depth
D 7	Low productive aquifer (20 > Q >= 5, partly Q >= 300 ～ 500) existing between 30 ～ 60 m in depth
D 8	Lack of high available aquifer up to the basement situated at 60 m in depth (Q < 5)
D 9	Lack of high available aquifer up to the basement situated at 90 m in depth (Q < 5)
D10	Lack of available aquifer within 120 m in depth (Q < 5)
D11	Lack of available aquifer within 150 m in depth (Q < 5)
D12	no datum
D13	Salt marsh, Mangrove

Fig.5.4.1 Groundwater Potentials

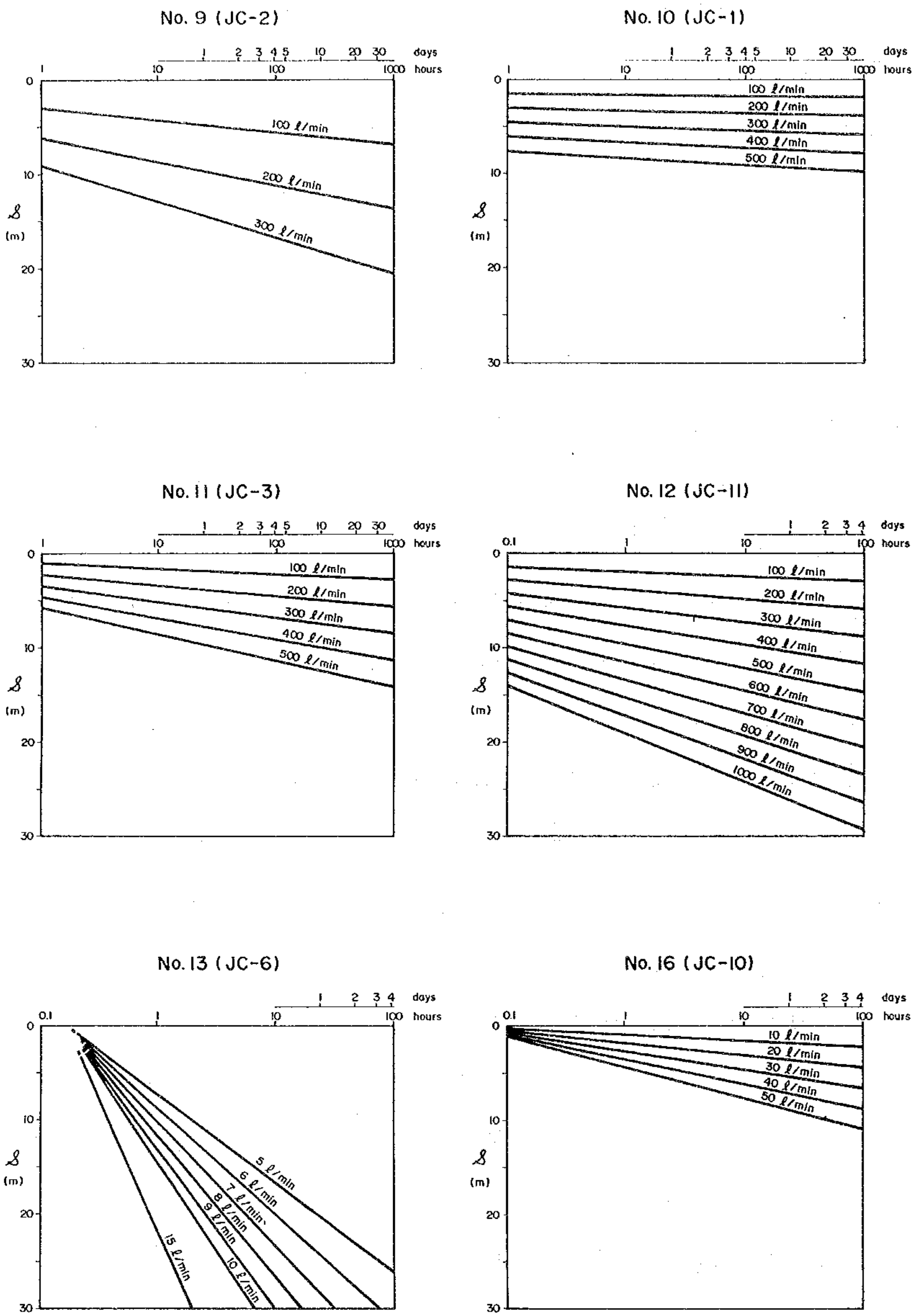


Fig.5.4.2 Reration between Time Hour and Drawdown

SUPPORTING REPORT B

ASSESSMENT OF SURFACE WATER

SUPPORTING REPORT B

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CHAPTER I

INTRODUCTION

1.1 Study Objectives

The objective of the Study is to evaluate the development potentiality of the surface water as defined River flow, Mountain stream, Lake and Marshes, Spring and Rainfall itself as alternative supplemental water resources in the Study Area located at the western border of the Dominican Republic.
The development potentiality of surface water for the proposed Water Supply Plan was formulated on the basis of hydrometeorology, surface runoff characteristics, geographical conditions, present conditions of river development, water quality and required development costs estimated by the Study.

1.2 National Background

1.2.1 Location

The Dominican Republic occupies 74% of the eastern part of the Hispanida Island located in a northern latitude from 17°-36' to 19°-58', and a western longitude from 68°-18' to 71°-45' with a total territory area of 48,422 km^2.
The Dominican Republic is bordered by the Atlantic Ocean to the north, the Caribbean sea to the south, the Mona passage to the east separating it from the neighboring island of Puerto Rico, and the Republic of Haiti to the west (Ref. Fig. 1.1.1).

1.2.2 Topography

Principally, four mountain ranges traverse the country. The first one is the Cordillera Central runs from Haiti through the central territory and reaches to the south with the highest peak in the Antilles (Pico Duarte, 3,175 m). The second is the Cordillera Septentrional which runs parallel to and north of the Cordillera Central separating Cibao Valley from the Atlantic Coast. The third is the Sierra de Neiba which runs parallel to the Cordillera Central forming the San Juan Valley, and the last is the Sierra de Baoruco in the southern part of the island. The Enriquillo Basin, of the salty Enriquillo Lake which is 40 m below sea level, is located between Sierra de Neiba and Sierra de Baoruco.

1.2.3 Hydrological Basin

The National Institute of Hydrological Resources (INDRHI) divides the Dominican Republic into 14 major hydrological basins. The main basins are formed by the Rio Yaque del Norte, the Rio Yaque del Sur, the Rio Yuna, the Rio Nizao, the Rio Ozama and the Rio Artibonito (see Fig. 1-1-1). The Study comprises parts of the Yaque del Norte River Basin, Dajabon River Basin, Artibonito River Basin and the Enriquillo Lake Basin.

The Rio Yaque del Norte flows westward, then into the Atlantic Ocean. The Rio Yuna flows eastward, then into the Bay of Samana. However, most of the river flow to the south, then into the Caribbean Sea.

1.2.4 Climate

The Dominican Republic is an island country isolated from the continent. Topographic undulation causes the regional differences in the climate conditions, however, as the trade wind comes continously from the Atlantic Ocean all year long, the mean annual temperature varies slightly from 24.4°C in February to 28.2°C in September.

1) Precipitation

The mean annual rainfall in the Dominican Republic is approximately 1,400 mm with occurrence of 110 days/year. However, amount of rainfall and days vary annually and regionally.

Mean annual rainfall in the Study Area is as follows:

- Catchment basin of the Rio Yaque del Norte, Llanura de Azua: 400 mm (less than 50 days)
- Rio Yaque del Norte, Lowland area of Rio Yaque del Sur, and Neiba Valley: 660 mm (less than 100 days)
- • Rio Bajabonico, head stream basin of Rio Yasica;
  • Yabon, Jovero, of the Samana Peninsula;
  • Head Stream basin of Rio Ozama and Isabela;
  • Cordillera Central, and headstream basin of Yuna, Yaque del Norte, Bao, Mao, Artibonito rivers;
  • Baoruco Mountains: 2,000 mm (150 days)

According to the collected data, minimum annual rainfall was recorded at Azua in 1957 (242 mm), while maximum annual rainfall was recorded at Restauracion in 1960 (4,652 mm).

A 24 hours maximum rainfall occurred in June 16, 1972 at Batey

Santa Elina with 653 mm/day; maximum rainfall intensity was recorded in August 31, 1979, at Guayabal and Padre Las Casas, with 80 mm/hr.

Although the season cannot be clearly distinguished, the rainy season is from May to October while the dry season is from November to April. It is quite hot from April to October, and considerably cool from November to March due to the breeze coming from the Atlantic Ocean. Hurricanes and tropical cyclones hit the country during the rainy season.

2) Temperature

Temperature is generally high all year round, but milder in mountain regions. Maximum temperature occurs in August, and minimum temperature in January and February. Fluctuations depend on latitude, altitude and oceanic influence. Temperature lowering rate in mountainous and hilly areas is 0.55~0.65°C every 100 m of altitude; in 1959, a minus 3.5°C temperature was recorded in the Central Mountain plateaus.

3) Miscellaneous

Mean annual humidity in the subject Area is ranged from min. 69.3% to max. 87.4%.

Evaporation is exceeding 2,000 mm in the Yaque del Norte River Basin, the Neiba Mountains and the Azua plateaus. The monthly evaporation generally ranges from 40 to 130 mm. The mean wind velocity is 10 km/hour. However, according to the observations, the strongest wind velocity of 320 km/h was recorded in 1969 during Hurricane Flora.

CHAPTER II

STUDY AREA

2.1 General

The Area covers four provinces, - Monte Cristi, Dajabon, Elias Pina, and Independencia, - that is four of the five which are bordered on the west by the Republic of Haiti. This Area is situated at about 300 to 400 km west from the Capital City. The Project covers 158 selected villages scattered in these 4 provinces.

The Study Area extends in a northern latitude from 18°20' to 19°55' and in an eastern longitude from 71°10' to 71°45'. It is bounded on the west by the Dajabon and Artibonito rivers, flowing along the Dominican and the Haitian border; on the east by a vast rugged region extending up to the Pedernales, Barahona, San Juan, Santiago, Valuerde and Puerto Plata provincial boundaries; and on the north by the Atlantic Ocean.

According to the 1981 census, population of the Study Area is 252,425, i.e. 4.4% of the overall population. Population density is 39 inhab./km^2, which is only 30% of the country's average density.

2.2 Topography and Vegetation

The Study Area, western region of the Dominican Republic, is made up of mountain ranges extending from a northwest to a southeast direction, and plains alternating systematically from north to south. From the north, these mountains and plains are the Northern Mountains, Yaque del Norte River Alluvial Plain, Central Mountains, Western San Juan Basin, Neiba Mountains, Enriquillo Lowland Areas and the Baoruco Mountains.

The Northern Mountains faces the Atlantic Ocean forming long and narrow hilly-mountainuous districts with 200~300 m elevations above sea level.

The Study Area is scare of rainfall throughout the year and has poor land cover like cactus mostly used for pasture, and partly used for tobacco production.

The Central Mountain is the largest in the Republic, extending from the Republic of Haiti to the Santo Domingo area, the capital city of the Republic. There are 23 mountains in the Republic with an elevation of more than 2000 m above sea level. The Pico Durante Mountain is the highest one in the Republic with 3175 m in elevation.

The elevation is comparatively low in the ridge of Bernar River flowing to north (with Dajabon river in the downstream) and Rio Artibonito flowing south. Both rivers forming the boundary of the Republic of Haiti. Roads are constructed across these ridges of lower parts, with small towns and villages are along the road.
The mountains of Neiba and Baoruco are the southeast extensions of the Haiti Mountains. The ridges of these mountains have more than 2,000 m elevations. The geology of both mountains are composed of limestones, while the tectonic valleys ascribed to the fault activities and the karst landforms are clearly observed.

Rio Yaque del Norte alluvial plain is located between the Northern and Central Mountains. Rio Yaque del Norte flows west and forms wide plain of about 50 m in elevation at the basin. Rio Masacre, Chacuey, Maguaca and Guayubin are main tributaries of Rio Yaque del Norte distributing at the north slope of the Central Mountain. Large scale of plantation is managed in Yaque del Norte basin as the leading granary region of the Republic.

The Western San Juan Basin is located between the Central and Neiba Mountains. Rio Macasia joints with the rivers of the southern and northern mountains and flows west to the central area. The basin of Rio Macasia is formed by wide plains and hills surrounding the plains. The plain is mainly used for cultivation and pasture. Furthermore, the hills of 300~400 m in elevations are mainly used for pasture in 200~300 m of elevation,.
Between the mountains of Neiba and Baoruco, there exists Lago Enriquillo, in a graben area made by tectonic movement. The side of the mountains facing the graben forms a steep slope. Due to this, many rivers flowing down from both mountains form large alluvial fans at the exit of the graben.

2.3 Meteorology

2.3.1 General

The Study Area extends in a northern latitude form 18°20' to 19°55', and in a western longitude from 71°10' to 71°45'. The Area is located in a subtropical zone with a locally varing climate.
Meteorological Data are obtained from INDRHI. Although duration of observation was different, as shown in the Table 1.2.1, various records were collected. However, most of the stations is located in the urban area

without covering the entire Study Area because of the access difficulty to the local sites.
JICA Study Team collected supplemental data on rainfall and wind velocity by the installed gauges to review detailed meteorological conditions.

As shown in Fig. 1.2.1, there are more than 20 established meteorological stations with valid long term rainfall records.
The location, observation period, and the available records items are indicated in Table 1.2.1 and 1.2.2.

2.3.2 Precipitation

The mean annual rainfall in the Study Area varies locally from 500 mm to 2,000 mm.
Two lowland zones of both south and north, Cibao Valley extends over the downstream basin of Rio Yaque del Norte and Neiba Valley forms Lake Enriquillo basin, locate in arid and semi-arid zones with 500~700 mm mean annual rainfall.
The Central and Neiba mountain ranges are located in humid zone with heavy rainfall, with a mean annual rainfall of 1,500 - 2,000 mm. On the other hand, the hills and plateaus spread on the skirts of these mountain ranges are located in semi-humid zone with a mean annual rainfall of 100 - 1500 mm (Refer to Fig. 1-2-2).
Although the monthly rainfall distribution is slightly different locally, there is little rain from December to March/April during the dry season. Rest of the year is wet, but the monthly rainfall of July is considerably less than 50% of other months.
The rainfall distribution in the Monte Cristi area, a semi-arid zone, is different from the patterns in other areas, the rainy season starts from October and ends December with 40~50% of annual rainfall.
The distribution pattern of monthly rainfall is shown in Fig. 1.2.3. Generally, the maximum rainfall is occured in June, October and/or September. The mean monthly and annual rainfall at each station is shown in Table 1.2.3.
The automatic rainfall recorders were installed in order to supplement the rainfall records of existing stations and to analysis the rainfall distribution pattern in the local area.
According to this records, it was found, the rainfall intencity is very high in all the Study Area. The following data have been recorded at the Loma de Cabrera Station: August, 17, 1991:

One-hour rainfall (from 14:30 to 15:30): 89 mm
(from 15:30 to 16:30): 86 mm

Amount of rainfall observed in one-year (December 1, 1990~November 10, 1991) at this station is 2123 mm, 83 rain-days were recorded, and classification of days according to the rainfall amount and accumulated rainfall are shown below.

Daily Rainfall Amount	Rain-Days	%	Rainfall Amount	%
P<5	18	23	28	1
P<10	14	17	93	5
P<20	15	18	178	8
P<30	8	10	194	9
P<50	14	17	519	24
P<70	5	7	474	23
P<100	6	7	462	22
P>101	1	1	175	8

Daily rainfall amount exceeding 30 mm/day represents about 80% of the total amount of rain (2123 mm), while, rainfall doesn't exceed 1 or 2 hours a day. Rainfall shows a 30 mm/hour intensity in many cases. This tendency is noticed in most of the stations.

Location of the installed gauges, and observation records are shown in Table 1.2.4.

2.3.3 Temperature

The mean annual temperature in the Study Area is 21°C~30°C. The mean monthly temperature, excluding the mountain plateaus, ranges between 22°C and 30°C. The monthly mean temperature in each area changes, not more than 3°C~6°C.

In the mountainous regions, temperature gets lower in relation to the altitude; temperature lowering rate in winter is 0.55 - 0.65°C every 100 m difference of elevation.

The temperature is generally low from December to February, and high from May to September. The mean monthly temperature in each station is shown in Table 1.2.5.

2.3.4 Relative Humidity

Humidity in the area is comparatively high. Mean annual humidity is 74% in the semi-arid lowland zone of Monte Cristi, and 84% in the mountainous area of Restauracion.

In general, relative humidity is high during the rainy season and low during the dry season. (Refer to Table 1.2.6.)

2.3.5 Evaporation and Evapotranspiration

The annual evaporation in the Study Area ranges from 1400 mm to 2800 mm with remarkable regional variation. It varies in accordance with the amount of rainfall; it is high in dry zones where there is little rain, and low in humid zones.

The mean annual areal evaporation in the subject area exceeds the mean annual areal precipitation.

The potential evapotranspiration estimated in 1979 is shown in Table 1.2.7.

2.3.6 Direction and Velocity of the wind

There are few wind records with direction and velocity. As the Study Area is undulated, the existing data cannot cover whole area. The mean annual wind velocity in the Project Area is from 0.8 to 5.3 m. The mean annual wind velocity and wind direction recorded at 3 stations are as follows (Ref. Table 1.2.8):

Observatory	Area	Mean Wind Velocity	Wind Direction
Monte Cristi	Northern Lowland	10 km/hour	Northeast
Dajabon	Mountain Foot	5~6 km/hour	Northeast and East
Jimani	Southern Lowland	10 km/hour	East and East-Southeast

2.3.7 Duration of Sunshine and Insolation

The mean daily maximum insolation does not exceed 12 hours, and average is approximately 8 hours. The insolation increases from February to August and maximum monthly insolation is recorded in July and minimum insolation in December.

Mean annual insolation is estimated between 2,545 up to 3,400 hours (See Table 1.2.9).

2.4 Hydrology

2.4.1 General

The proposed Study Area is formed of various hydrological basins with remarkable local characteristic affected by the precipitation, topography, vegetation, land use, etc.
River water in the Study Area is generally used for the irrigation and domestic water supply. Water resources development, management of river water, observation of river discharge and preparation of recorded data are carried out by the responsibility of the Institute National de Recursos Hidraulicos (INDRHI).

2.4.2 Hydrological Basin

The hydrological basin in the proposed Project area can be divided into six (6) zones which are delineated by the topographic divide of each catchment area; Dajabon river Guayabo/Laguna Saladilla, Chacuey River, Yaque del Norte river, Artibonito river and Lake Enriquillo basins consisting of several small rivers and the coastal zone of Atlantic Ocean.
The six hydrological basins and major rivers in the Study Area are presented in Fig. 1.2.4. The surface area of each basin is as follow: (excluding the coastal zone of the Atlantic ocean coast area)

Name	Catchment Area	Dominican Catchment Area	Catchment Area in the Study Area	Rivers
1. Dajabon River Basin	380km2	230km2	230km2	Dajabon, Masacre Capotillo, Bernar
2. Guajabo/ Lake Saladilla Basin	172	172	172	Guajabo, Lag. Saladilla
3. Chacuey River Basin	397	397	397	Chacuey
4. Yaque del Norte River Basin	7,044	7,044	2,366*	Yaque del Norte, Amina, Mao, Gurabo, Cana, Guayubin, Maguaca
5. Artibonito River Basin	9,000	2,614	2,614*	Artibonito, Libon, Jaco, Tocino, Macasia, Cana
6. Lake Enriquillo Basin	3,193	3,193	1,861	Guayabal, Pibtzo, Barnesi, Majayual, Las Damas

*: Includes a outside of the Study Area

The total catchment area of the rivers is estimated at 20,186 km^2, 67.6% (13,650 km^2) of which is Dominican territory: However, the Project covers only 9,909 km^2 of the catchment area (49.1% of the total catchment basin area, 72.6% of the catchment area in the Dominican territory).

2.4.3 River Discharge

The discharge of each river in the Study Area varies locally, seasonally and annually corresponding with the rainfall intensity, distribution, and other precipitation characteristics. Additionally, other factors like topography, geological features, vegetation, land use and socio-economical development conditions are also important to evaluate the discharge.

There are many observation records provided by INDRHI on the major rivers in the Study Area.

However, observation period of them is always very short because their works were limited by project-base for agricultural development, etc.

The location of the gauge stations, observation periods and the annual and monthly discharges are as shown in Table 1.2.10 and 1.2.11. There are no data on the rivers at the Lake Enriquillo basin.

The discharge of each river slightly differs as a result of the regional and seasonal rainfall variations. May, June, September to November are generally high water seasons where 60~70% of the total annual discharge is observed. October and November, on the other hand, are especially high water seasons and 25~30% of the total discharge is observed from this period. The low water season is from January to March or April in some areas. The droughty water season occurs in February or March. Moreover, due to decreased rainfall in July, the river discharge extremely decreased in August.

The monthly discharge variations of the rivers Yaque del Norte, Mao, Dajabon, Macasia and Artibonito are shown in Fig. 1.2.5. The drought discharge and the specifically estimated discharge at the existing gauging stations are shown in Fig. 1.2.6.

2.4.4 Spring Water

Many springs called Cachones are scattered at the alluvial fan of the northern Lake Enriquillo basin, discharging good quality groundwaters cultivated in the Neiba Mountain zone.

The spring waters of La Descubierta (26.1 ℓ/s), Tierra Nueva (0.9 ℓ/s), and Vengan a Ver (2.1 ℓ/s), etc., are developed as the water sources of the INAPA public water service system.

The principal springs and the corresponding amount of discharge according to the INDRHI survey are as indicated below:

Names of Spring Water	Spring Outflow (m^3/s)
Las Marias	0.2~0.4
Las Barias	0.4~1.0
Llamado la Zurag	0.26
Roberto en Baitos	0.09
La Chorrera en Baitos	0.04
Merigildo en Baitos	0.17
Grande en Baitos	0.54

Furthermore, the springs in Hondo Valle in Elias Pina province are used by INAPA to supply water to the residents of Hondo Valle and Rancho la Guardia village. In addition to this, many springs are scattered in the ravine areas of the Central Mountain range, and these springs provide the local residents with good and essential domestic water resources.

2.4.5 Present Conditions of Surface Water Development and Utilization

Surface water has been used all the year round as water sources for irrigation water, domestic water, and industrial water by the local residents.

1) Domestic Water

In principle, domestic water supply for the local inhabitants is carried out under the responsibility of INAPA.
According to the INAPA data, though various systems, methods and levels of water supply can be found, there are more than 30 water supply systems making use of surface water as their source. Furthermore, 34.6 million m^3 of surface water, including spring water, are supplied annually to about 100,000 local residents for their daily use.
The water supply volume of each river system is summarized below:

River System	Annual Supply Amount of Water
Dajabon River (Masacre/Capotillo)	$1.4\times10^6 m^3$
Guajbo River (Lake Saladillo)	$1.6\times10^6 m^3$
Yaque del Norte River (Maguaca, Guayubin, Cana, Garabo Mao, Inaje and canal Amina)	$23.4\times10^6 m^3$
Artibonito River (Neyta, Valle Juelo, Macasia, and canal Las Carreras)	$3.3\times10^6 m^3$
Lake Enriguillo basin (Los Damas, El Manguito, Arroyo Yerba Buena, Canal Jimani, Los Rios, and La Sabilla)	$4.9\times10^6 m^3$
Total	$34.6\times10^6 m^3$

Furthermore, the INAPA is presently executing the water supply development project, so that water supply volume of the surface water is increasing year by year.

2) Irrigation Water

Water resources development in the Dominican Republic is supervised by the INDRHI. According to INDRHI's data, a lot of the surface waters are developed for irrigation water use in and outside of the Project Area.
In 1986, 1,500 million m^3/year (47.8 m^3/s) of irrigation water has been diverted from the Yaque del Norte river system, and from Dajabon and Gurabo rivers. Out of the 1,500 million m^3/year, 660 million m^3/year of water is developed from the rivers in the Study Area.
Besides, 50~80 million m^3 of irrigation water are developed annually from the Artibonito river basin, and about 35~82 million m^3 of river and spring waters from the Lake Enriquillo basin irrigation use.

2.5 Water Quality

During the study period, samples for water quality analysis were collected from the major rivers, lakes, irrigation/drainage canals, reservoirs and springs in the Study Aarea were collected. The results of water quality analysis of the surface water commissioned to INAPA's Laboratory are presented in the Data Book.
In addition, data were collected from INDRHI, which were classified the river water in the Study Area with use of a SAR-Electric Conductivity Diagram.

According to the both data, pH is more or less than 8 in all river systems. However, the salinity contents, electric conductivity and turbidity, show different values. Some tributaries of the Rio Yaque del Norte: Amina, Mao, Guayubin and Rio Masacre have an excellent water quality. On the other hand, the remaining tributaries of Rio Yaque del Norte: Rio Maguaca, Cana as well as the mainstream of Rio Yaque del Norte, contain a large amount of salt in comparison with those mentioned above.

Water quality of the mainstream of Rio Artibonito, its tributary Cana, and the left bank branch rivers of the Rio Macasia is excellent. The river water of Rio Macasia and the right bank branch rivers of Rio Yachueque are relatively inferior in quality to the former.
Water quality of all the rivers which flow into the Lake Enriquillo: Majaqual, Barrero, Manquito, Guayabal rivers, and canal water taken from the springs, of Duverge, Puerto Escondido, La Descubierta and Neiba can be classified as medium.
The salinity content of the Bermesi river and canal Cristobal is not high, but alralinity value is relatively high compared with river waters in the vicinity.
Pattern diagram of the water constituents of the river flow water was drawn up according to the analysis results of the collected water samples from the major rivers and is shown in Fig. 1.2.7.
In general, the river water is rich in Mg and HCO_3, but does not exceed the maximum permissible level of 150 and 400 mg/liter. However, the maximum permissible level of Ca (200 mg/liter) for drinking water is exceeded in most of the rivers. Colour of water is exceeding the maximum permitted value for drinking water in half of the analysed waters.

CHAPTER Ⅲ

PRELIMINARY EVALUATION

3.1 Precipitation Analysis

3.1.1 General

1) Data Collection

Available information on precipitation in the Study Area were collected from INDRHI.

- 25 established meteorological stations with long term observed monthly rainfall records.
- Daily rainfall over a 4 year period (1985~1988) recorded in 4 stations : Don Miguel, La Antona, Auinigua, and Partido.
- Collection of records observed in 6 rain gauge stations, installed by the Study Team, for almost 1 year from November 1990.

Besides, it was referred to other available data collected in the Study Report of the "Plan de Desarrollo de la Zona Fronteriza" completed in 1987 by the Secretariado Tecnico de la Presidencia Oficina National de Planificacion.

2) Rainfall Pattern

(1) As stated in the foregoing chapter, rainfall amount in the Study Area shows annual, seasonal and local variations.
The mean monthly rainfall in the eastern region of Lake Enquirillo is the lowest with 500~700 mm. The Cordillera Central, Sierra de Bahoruco and Neiba mountain ranges are very humid zones characterized by heavy rainfall, with an annual mean of 1600 to 2000 mm.

On the other hand, the Artibonito river basin and the hilly area of Dajabon are located in semi-humid zones with a mean annual rainfall of 1000to 1500 mm, while the eastern lowland area of Yaque del Norte and the western zone of the Neiba Valley shows a mean annual rainfall of about 750 mm.

The mean annual rainfall observed over 50 years (from 1939 to 1989) at Restauracion, located on a tableland of the Cordillera

Central with an altitude of 594 m, is 1719.9 mm. The maximum annual rainfall was observed 4652 mm in 1960, and 3760.9 mm in 1952, which is twice as much as the mean annual amount. On the other hand, the minimum annual rainfall was recorded in 1941 with 716 mm, then 904 mm in 1976, represents 37% and 52% of the average amount, and 15% of the maximum year.
Accumulated rainfall during the dry season, from December to March, is about 15% of the annual rainfall amount. Accumulated rainfall in the 5-month rainy season (May, June, August, September, October) is about 63% of the annual rainfall (See Table 1.3.1).
As for the monthly mean rainfall, the maximum rainfall is observed in September with 239.6mm, and the minimum rainfall in February with 52.7 mm. According to the data of the observation period, the maximum rainfall was 658 mm on August, 1959, and the minimum rainfall was 0 mm in the dry season.

The rainfall distribution of the Monte Cristi area (altitude 7m), a semi-arid zone, is different from the one of the southern areas. According to data observed from 1934 to 1989, the mean annual rainfall is 667.7 mm. The rainy season in this area is from October to March (6 months) with about 63% of the annual rainfall. About 50% of the annual rainfall falls between October and January. Records are as follows:

Observed maximum annual rainfall :
(1969) 1061.3 mm ; 159% of the average
Observed minimum annual rainfall:
(1976) 315.4 mm ; 47% of the average
Mean monthly rainfall :
(Minimum rainfall) July, 21 mm
(Maximum rainfall) November, 99.3 mm
Observed maximum monthly rainfall :
(1968) 507 mm ; 50% of the annual rainfall
Observed minimum monthly rainfall :
March, April, May, July, 0.0 mm.

24-hour rainfall of 575.4 mm was recorded on June 16, 1972, at the Tamayo Station (No. 0684). Heavy rains caused by hurricanes are frequently observed in the southern zones.

The maximum 24-hour rainfall observed at the Duverge Station (0001) is 444.5 mm (1st), and 263.2 mm (2nd), and a maximum rainfall is 217.4mm at the Jimani Station (0797).

In general, the maximum values of a 24-hour rainfall does not differ very much in the humid or arid zones. Though 285.1mm and 268.0 mm were recorded at the Don Miguel Station (0101), the average roughly ranges around 200mm.
The maximum rainfall intensity of 80 mm/hr, was observed at Hurricane David on August 31, 1979. Moreover, according to the records of automatic rainfall recorder installed at Loma de Cabrera the rainfall intensity observed on August 13, 1991, between 14h30~15h30 and 15h30~16h30 was respectively 89 mm/hr and 86 mm/hr. In other places, the gauges frequently measured intensity ranges of 60~70 mm/hr and 30~40 mm/0.5hr (Ref 1.2.9).
Rainfall duration in the hilly and mountainous zones of Cordillera Central is 130 - 150 days; 95~115 days in the Dajabon area and 90~100m days in the Elias Pína region. In the Neiba Valley rainfalls 80~100 days in the western zone but the number of days are reduced to about 50 days in the eastern zone. In the Monte Cristi region and lowland area of Yaque del Norte, number of rainy days observed is 70~90 days.

(2) The Project Area is a vast area endowed with diverse topographic features and elevations, extending from the Yaque del Norte and Lake Enriquillo Lowland areas with less than 10m elevation to 2000m elevated mountainous lands of Cordillera Central, Sierra de Baoruco, and Neiba.

The meteorological stations are distributed at various altitudes, Barahona Station at 4m and Pepillo Salcedo at 5m are the lowest, and Hondo Valle at 890m is the higest.
Fig. 1.3.1 presents the relationship between the annual rainfall and elevation, based on data collected from observatories located at different altitudes. Nevertheless, it seems difficult to deduce the fluctuation values from the relation of rainfall with the difference of elevation.

The correlation of rainfall amount was examined in the 3 stations, Restauracion, Elias Pina and Hondo Valle located in