Table B-3-12 DEGREE OF IRRIGATION PROBLEM OF WATER QUALITY (FROM GROUNDWATER)

Location name	Esperanza Baja Underdrainage			Chancayllo			La Huaca		
Sample number	1	1 - 2	1 - 3	2	2 - 2	2 - 3	3	3 - 2	3 - 3
Sampling date	3/8	7/6	7/30	3/8	7/6	7/30	3/9	7/7	7/30
Salinity									
ECW	△	△	△	△	△	△	○	○	○
Permeability									
ECW	○	○	○	○	○	○	○	○	○
adj.SAR	△	△	△	△	△	△	○	○	○
Specification toxicity									
Sodium(adj.SAR)	×	×	×	×	×	×	○	○	○
Chloride	○	○	○	○	○	○	○	○	○
Boron	○	○	△	○	○	○	○	○	○
Miscellaneous effect									
NO_3-N or NH_4-N	○	○	○	○	○	○	○	○	○
HCO_3	△	△	△	△	△	△	△	△	△
PH	○	○	○	○	○	○	○	○	○
Synthesis	○	○	△	○	○	○	○	○	○

Where ○: no problem, △: increasing problem, ×: severs problem
(cf. Table B-3-11)

Table B-3-13 DEGREE OF IRRIGATION PROBLEM OF WATER QUALITY (FROM GROUNDWATER)

Location name	Bonos de Boza	Jecuan		Bonos de Granada			Palpa		
Sample number	4	4 - 1	4 - 2	5	5 - 2	5 - 3	6	6 - 2	6 - 3
Sampling date	3/9	7/6	7/30	7/9	7/7	7/30	3/10	7/7	7/31
Salinity									
ECW	×	△	△	×	×	×	○	○	○
Permeability									
ECW	○	○	○	○	○	○	○	○	○
adj.SAR	×	△	△	×	×	×	○	○	○
Specification toxicity									
Sodium (adj.SAR)	×	×	×	×	×	×	○	○	○
Chloride	×	○	○	×	×	×	○	○	○
Boron	×	△	△	×	×	×		○	○
Miscellaneous effect									
NO_3-N or NH_4-N	○	○	○	○	○	○	○	○	○
HCO_3	×	△	△	×	×	×	△	△	△
PH	×	○	○	×	○	×	○	○	○
Synthesis	×	△	△	×	×	×	○	○	○

Where ○ : no problem, △ : increasing problem, ×: servers problem

(cf. Table B-3-13)

Table B-3-14 DEGREE OF IRRIGATION PROBLEM OF WATER QUALITY (FROM GROUNDWATER)

Location name	Cuinch			Torre Blanca			Atauampa (Huaral)		
Sample number	7	7 - 2	7 - 3	8	8 - 2	8 - 3	9	9 - 2	9 - 3
Sampling date	3/10	7/7	7/30	3/10	7/6	7/31	3/10	7/6	7/30
Salinity									
ECW	○	○	△	△	△	△	○	○	△
Permeability									
ECW	○	○	○	○	○	○	○	○	○
adj.SAR	○	○	○	○	○	○	○	○	○
Specificcation toxicity									
SODIUM (ADJ.SAR)	△	△	△	○	○	○	○	○	○
Chloride	○	○	○	○	○	○	○	○	○
Boron	○	○	○	○	○	○	○	○	○
Miscellaneous effect									
NO_3-N or NH_4-N	○	○	○	○	○	○	○	○	○
HCO_3	○	△	△	△	△	△	△	△	△
PH	○	○	○	○	○	○	○	○	○
Synthesis	○	○	○	○	○	○	○	○	○

Where ○ : no problem, △: increasing problem, X : servers problem
(cf. Table B-3-14)

Table B-3-15 DEGREE OF IRRIGATION PROBLEM OF WATER QUALITY (FROM GROUNDWATER)

Location name	Esquivel			Chancay city water			Chancay		
Sample number	10	10 - 2	10 - 3	11	11 - 2	11 - 3	12	12 - 2	12 - 3
Sampling date	3/10	7/6	7/31	3/11	7/6	7/30	3/12	7/6	7/30
Salinity									
ECW	△	△	△	○	○	○	△	○	○
Permeability									
ECW	○	○	○	○	○	○	○	○	○
adj.SAR	○	○	○	○	○	○	○	○	○
Specification toxicity									
Sodium(adj.SAR)	○	○	○	○	○	○	○	○	○
Chloride	○	○	○	○	○	○	○	○	○
Boron	○	○	○	○	○	○	×	○	○
Miscellaneous effect									
NO_3-N or NH_4-N	○	○	○	○	○	○	○	○	○
HCO_3	△	△	△	△	△	△	△	△	△
PH	○	○	○	△	○	○	○	○	○
Synthesis	○	○	○	○	○	○	△	○	○

Where ○ : no problem, △ : increasing problem, ×: servers problem
(cf. Table B-3-11)

Table B-3-16 DEGREE OF IRRIGATION PROBLEM OF WATER QUALITY (FROM GROUNDWATER)

Location name	Aucallama		Casa Blanca		Esperanza Baja				
Sample number	13 - 1	13 - 2	14 - 1	14 - 2	15 - 1	15 - 2			
Sampling date	7/7	7/30	7/7	7/30	7/7	7/30			
Salinity									
ECW	△	△	△	△	△	△			
Permeability									
ECW	○	○	○	○	○	○			
adj.SAR	○	○	○	○	○	○			
Specification toxicity									
Sodium (adj.SAR)	○	○	○	○					
Chloride	○	○	○	○	○	○			
Boron	○	○		○	○	○			
Miscellaneous effect									
NO_3-N or NH_4-N	○	○	○	○	○	○			
HCO_3	△	△	△	△	△	△			
PH	○	○	○	○	○	○			
Synthesis	○	○	○	○	○	○			

Where ○: no problem, △: increasing problem, X: servers problem
(cf. Table B-3-11

Table B-3-17 DEGREE OF IRRIGATION PROBLEM OF WATER QUALITY (FROM CANAL AND RIVER)

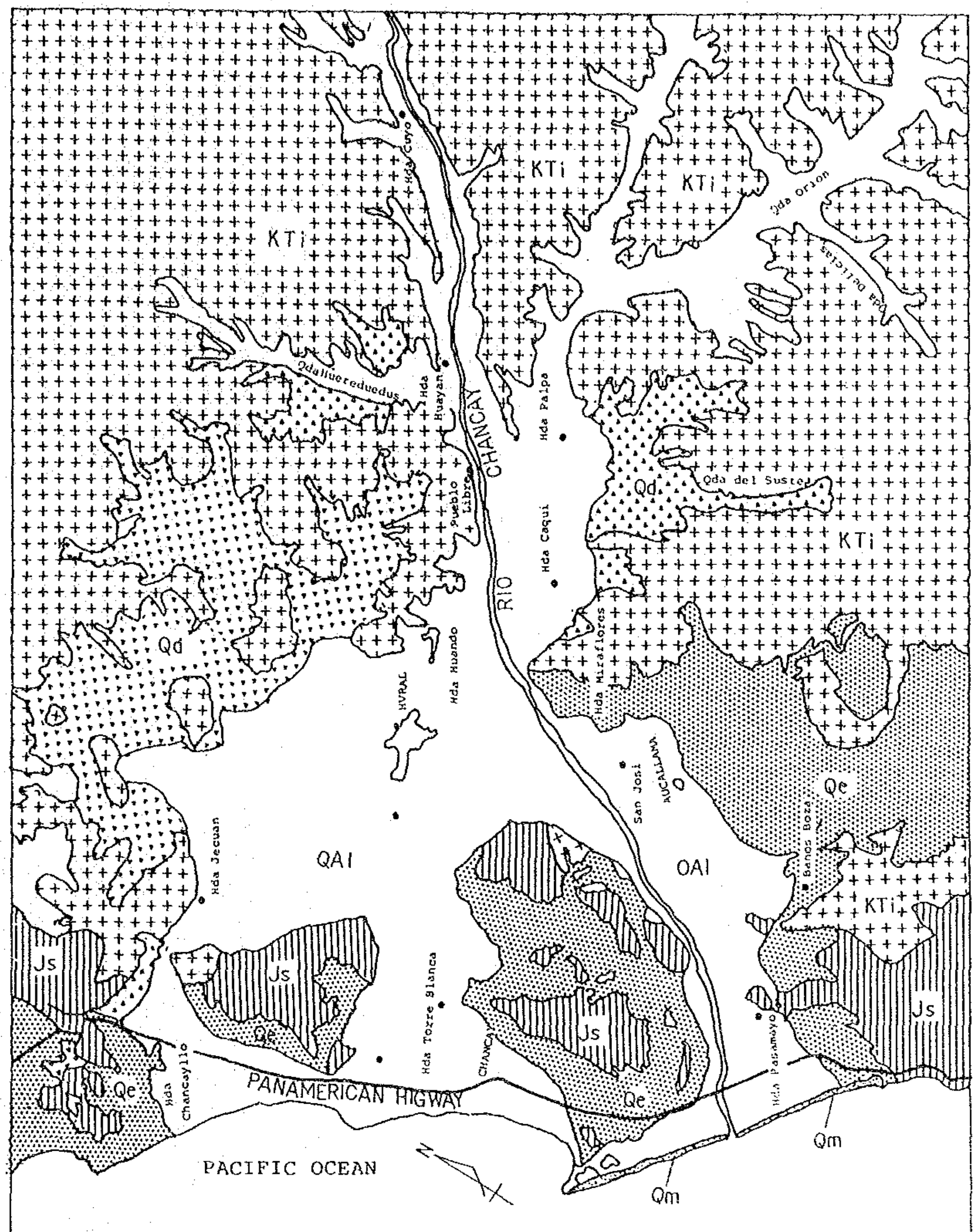
Location name	Palpa Orcon		Quincha - Jecuan			Chancay River Pte. Huaral			Chancay River Pte. Libe
Sample number	-	A - 13	-	A - 14	-	-	A-15-1	-	A-15-2
Sampling date	3/3	7/7	3/8	7/7	7/28	3/8	7/7	7/28	7/7
Salinity									
ECW	○	○	△	△	△	○	○	○	○
Permeability									
ECW	△	○	○	○	○	△	○	○	△
adj.SAR	○	○	○	△	○	○	○	○	○
Specification toxicity									
Sodium (adj.SAR)	○	○	△	×	△	○	○	○	○
Chloride	○	○	○	○	○	○	○	○	○
Boron	○	×	○	△	△	○	○	○	○
Miscellaneous effect									
NO_3-N or NH_4-N	○	○	○	○	○	○	○	○	○
HCO_3	○	△	○	△	△	△	△	△	△
PH	○	○	○	○	○	○	○	○	○
Synthesis	○	△	○	○	○	○	○	○	○

Where ○ : no problem, △ : increasing problem, × : severs problem
(cf. Table B-3-11)

Table B-3-18 DEGREE OF IRRIGATION PROBLEM OF WATER QUALITY (FROM CANAL AND RIVER)

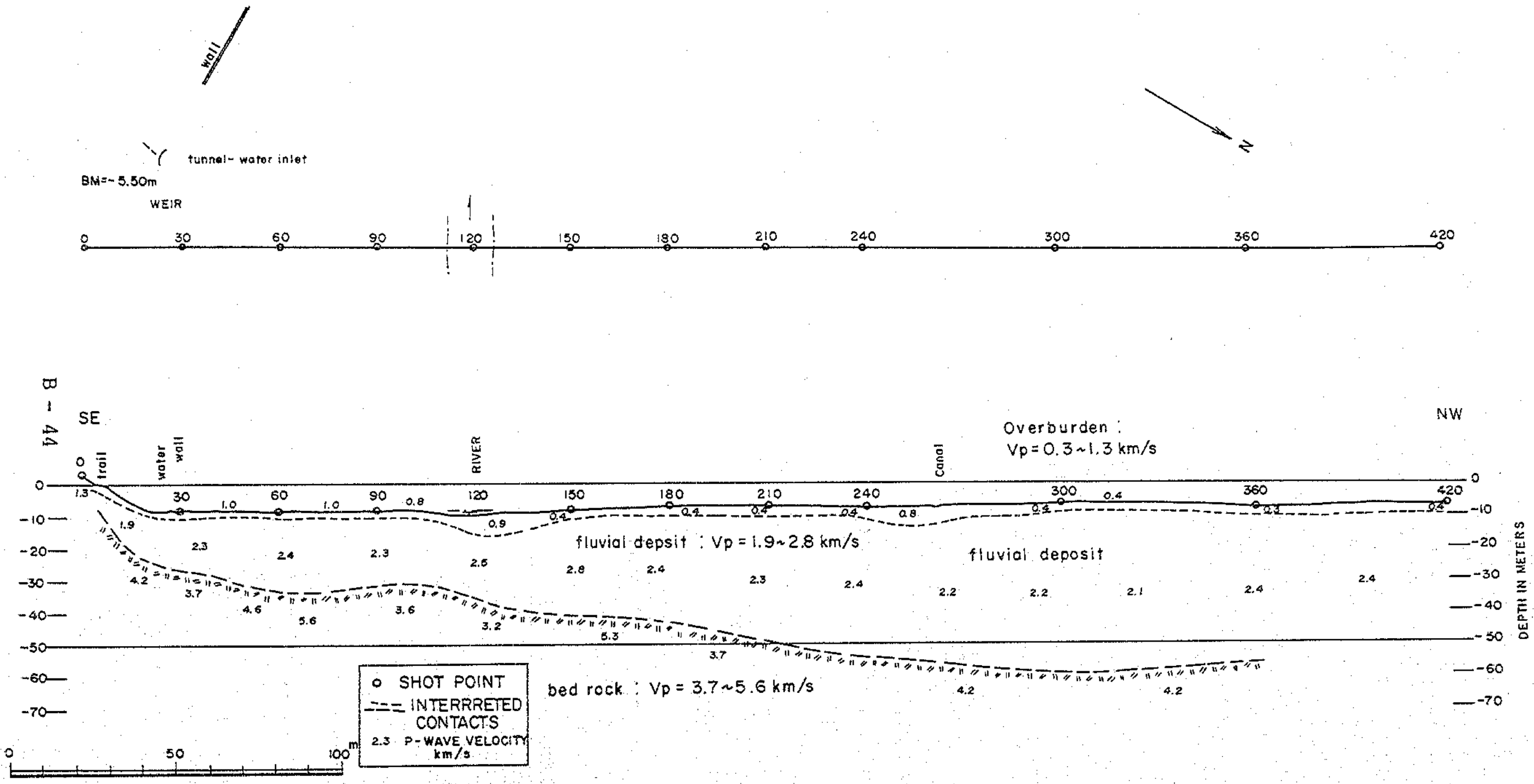
Location name	Los Laureles (canal)			Los Laureles Donoso			Donoso		
Sample number	-	A - 16	-	-	A - 17	-	A - 18	-	
Sampling date	3/8	7/7	7/28	3/8	7/7	7/28	7/7	7/28	
Salinity									
ECW	○	○	△	○	○	○	△	△	
Permeability									
ECW	△	○	○	△	○	○	○	○	
adj.SAR	○	○	○	○	○	○	○	○	
Specification toxicity									
Sodium (adj.SAR)	○	○	○	○	○	○	○	○	
Chloride	○	○	○	○	○	○	○	○	
Boron	○	○	○	○	○	○	○	○	
Miscellaneous effect									
NO_3-N or NH_4-N	○	○	○	○	○	○	○	○	
HCO_3	△	△	△	△	△	△	△	△	
PH	○	○	○	○	○	○	○	○	
Synthesis	○	○	○	○	○	○	○	○	

Where ○ : no problem, △ : increasing problem, × : severs problem
(cf. Table B-3-11)



Qe	Quaternary, eolian dep.	Qd	Quaternary, compound dep.
Qm	Quaternary, marine dep.	Js	Puente Piedro formation (Jura.)
OAl	Quaternary, fluvial dep.	KTi	Diorite (Cretaceous to Tertiary Intrusive rock)

Fig. B-1-1 Geologic Map of The Project Area
(Source ONERN Scale 1/150,000)



PALPA INTAKE

Fig. B-1-2 VELOCITY LAYER PROFILE

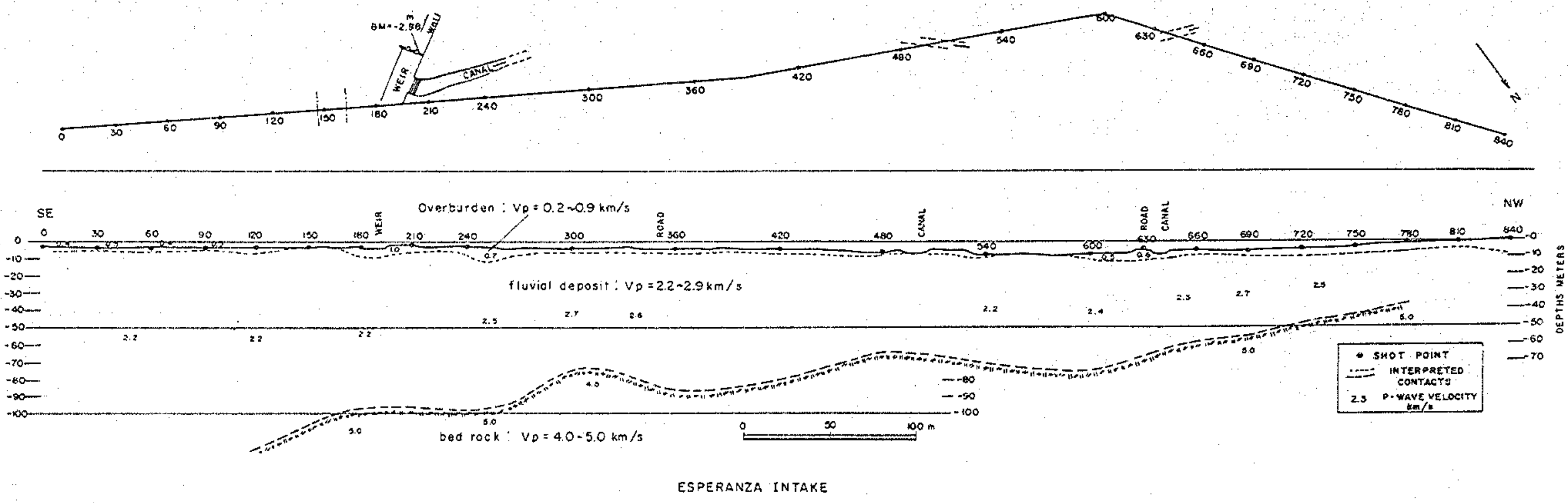


Fig. B-1-3 VELOCITY LAYER PROFILE

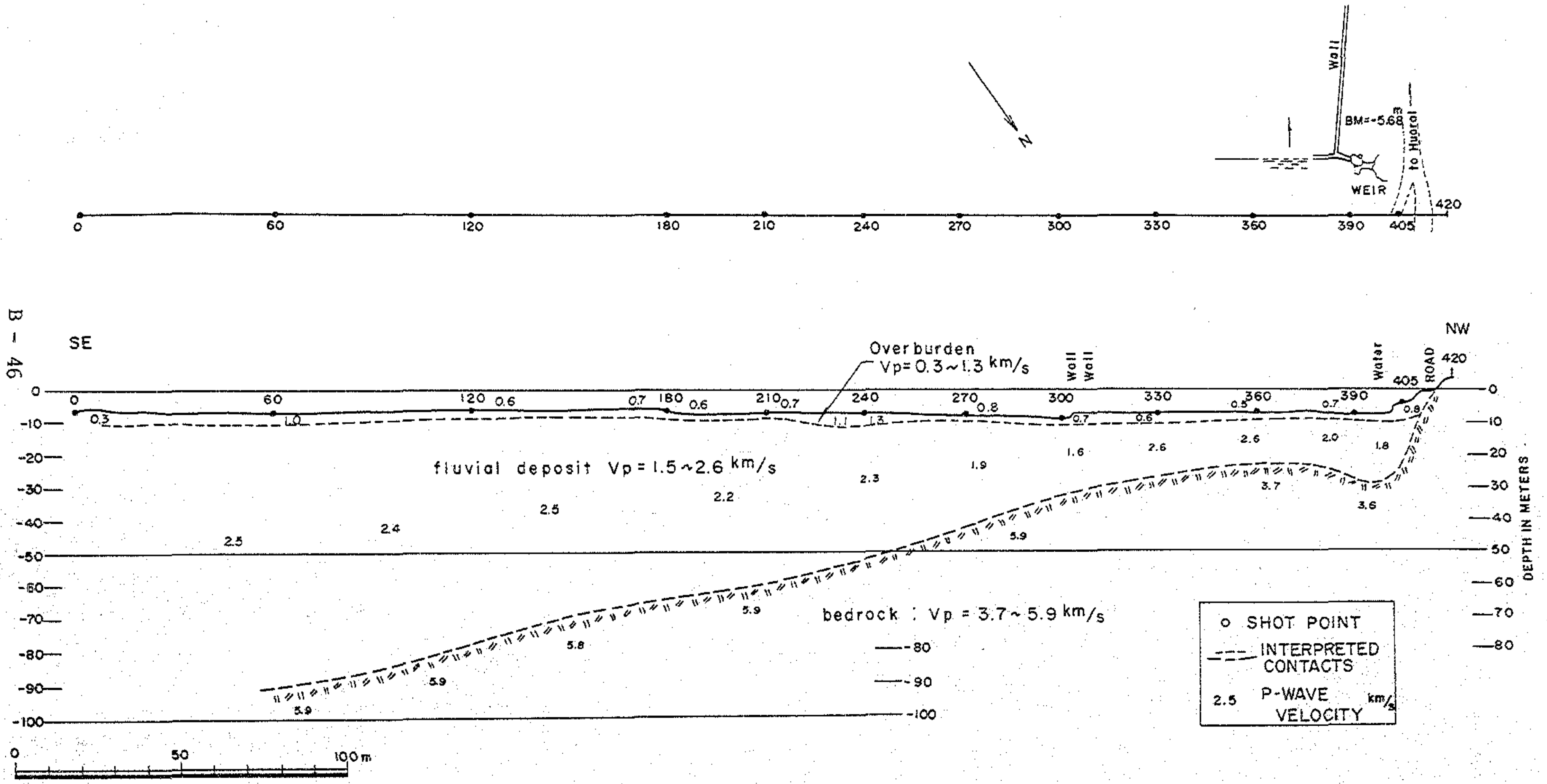


Fig. B-1-4 VELOCITY LAYER PROFILE

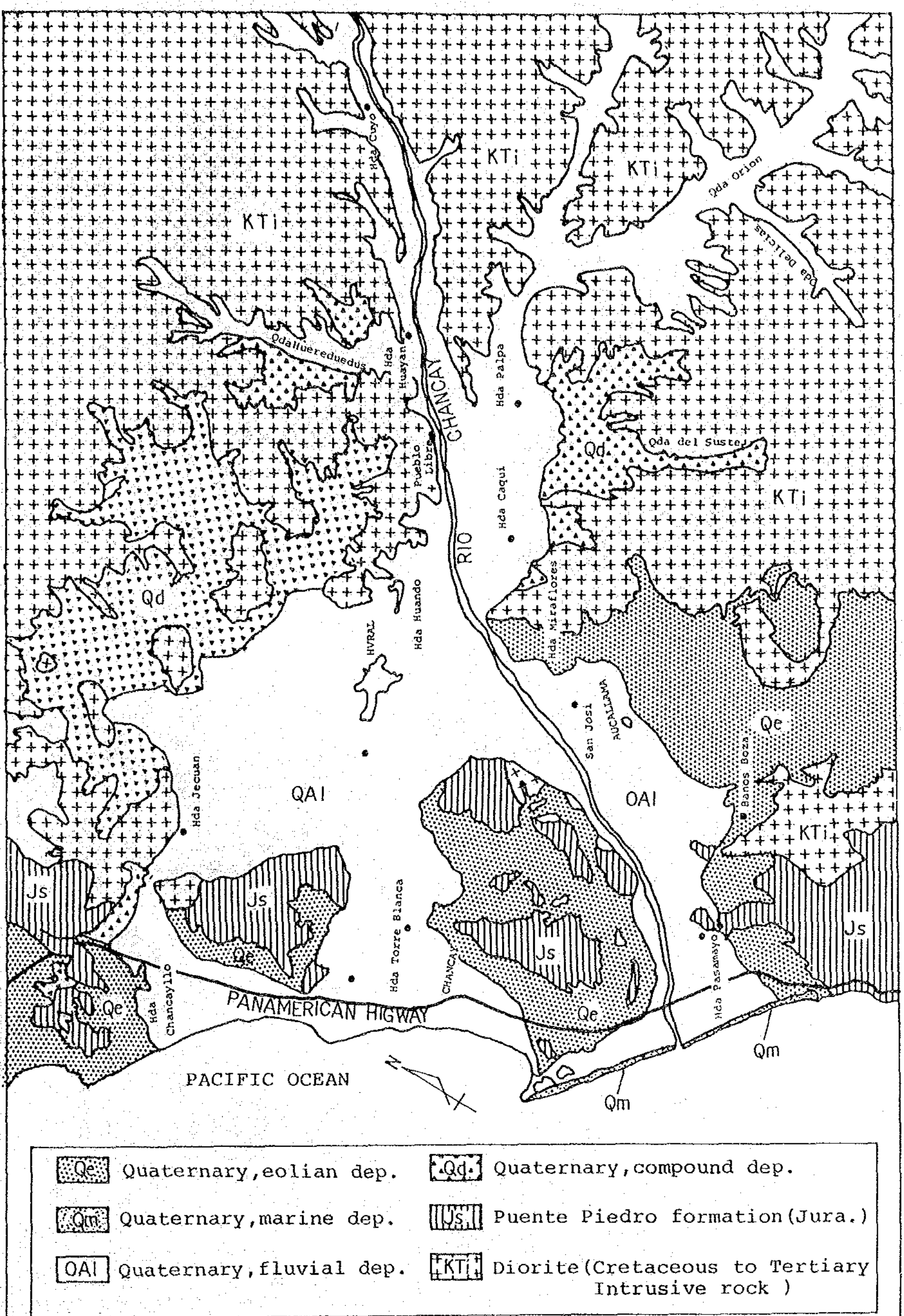


Fig B-2-1 GEOLOGIC MAP OF THE PROJECT AREA
(Source ONERN Scale 1/150,000)

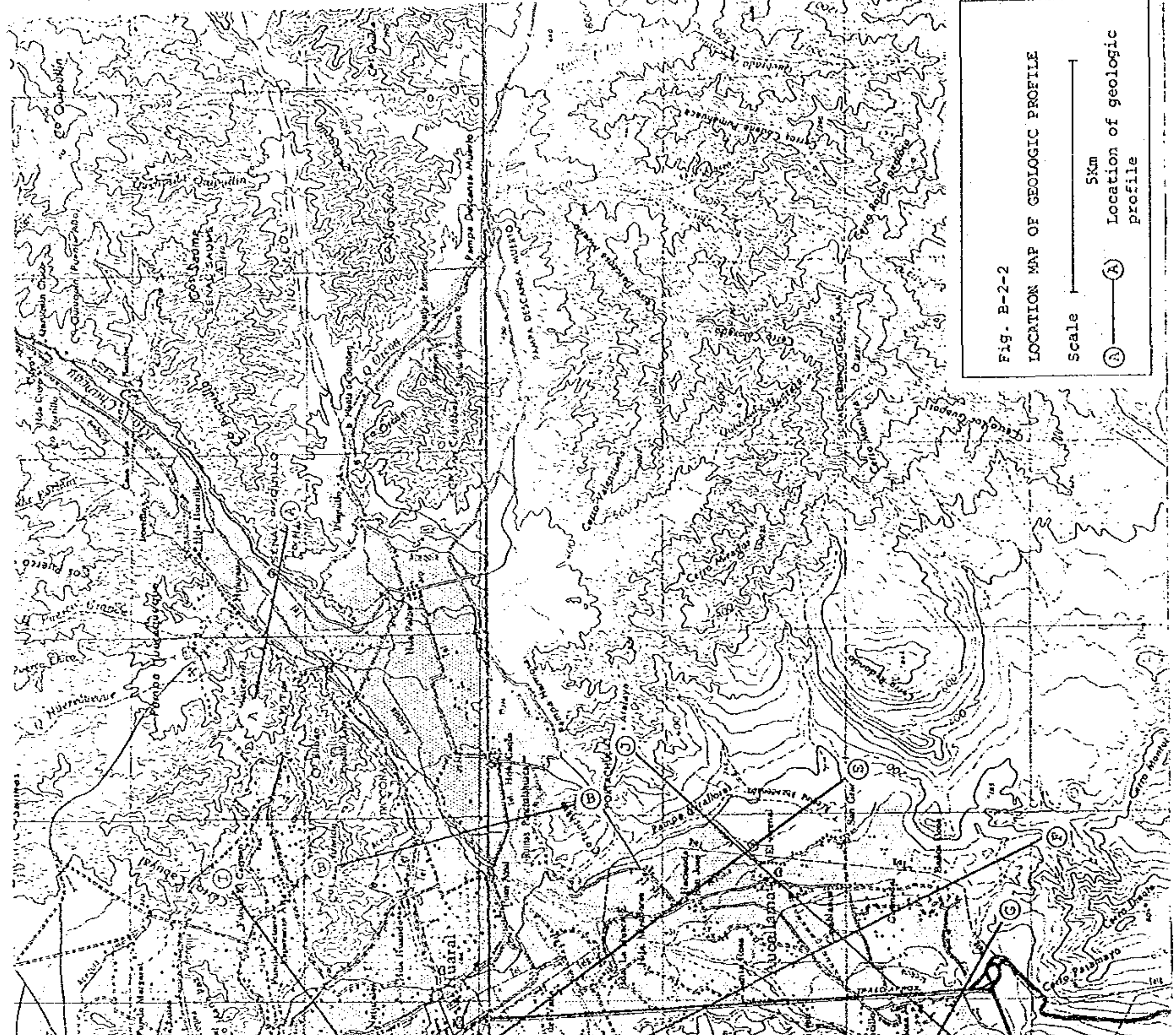


Fig. B-2-2

LOCATION MAP OF GEOLOGIC PROFILE

Scale 5Km

(A)——(A) Location of geologic profile

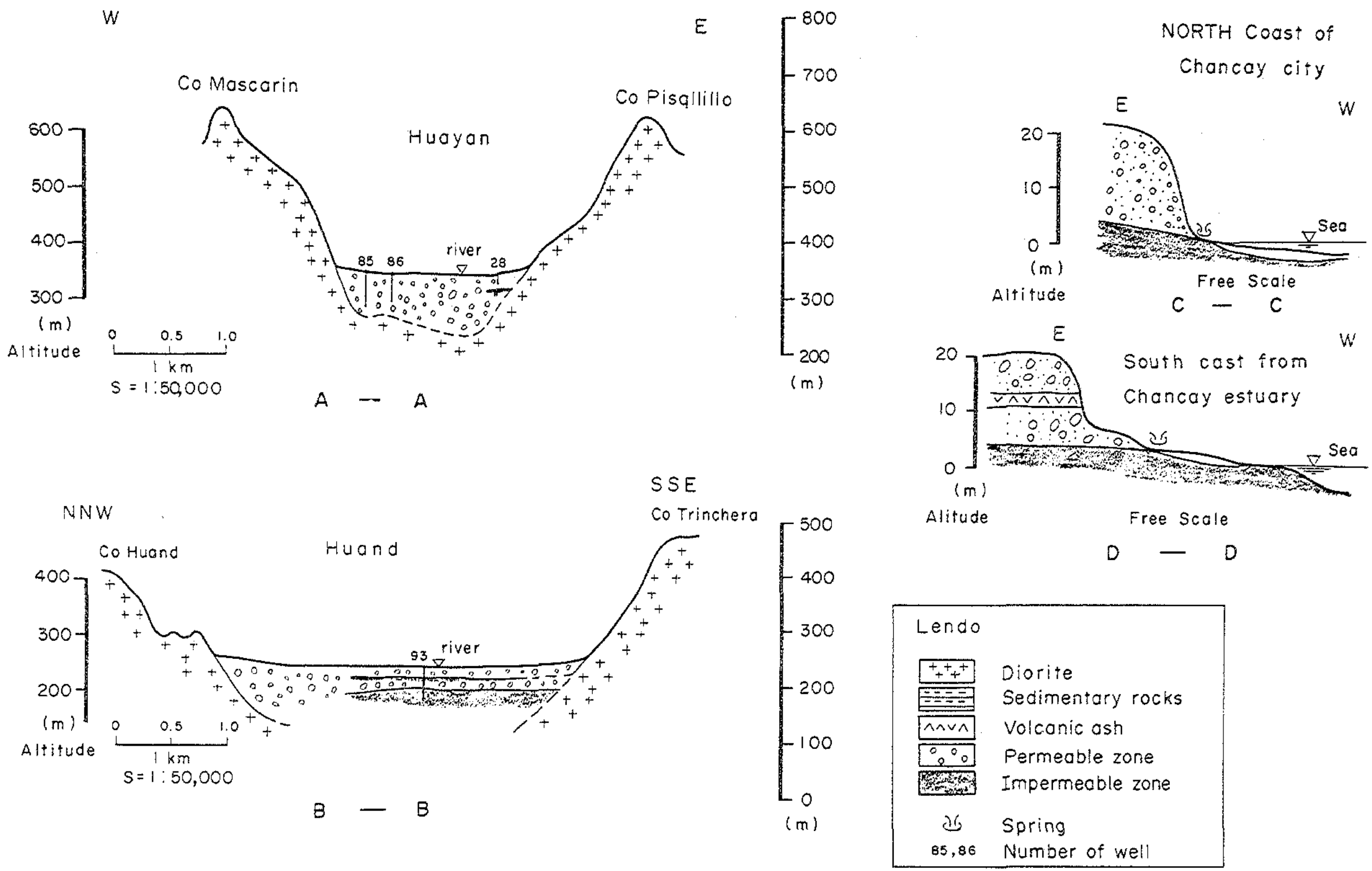


Fig. B-2-3 GEOLOGIC PROFILES

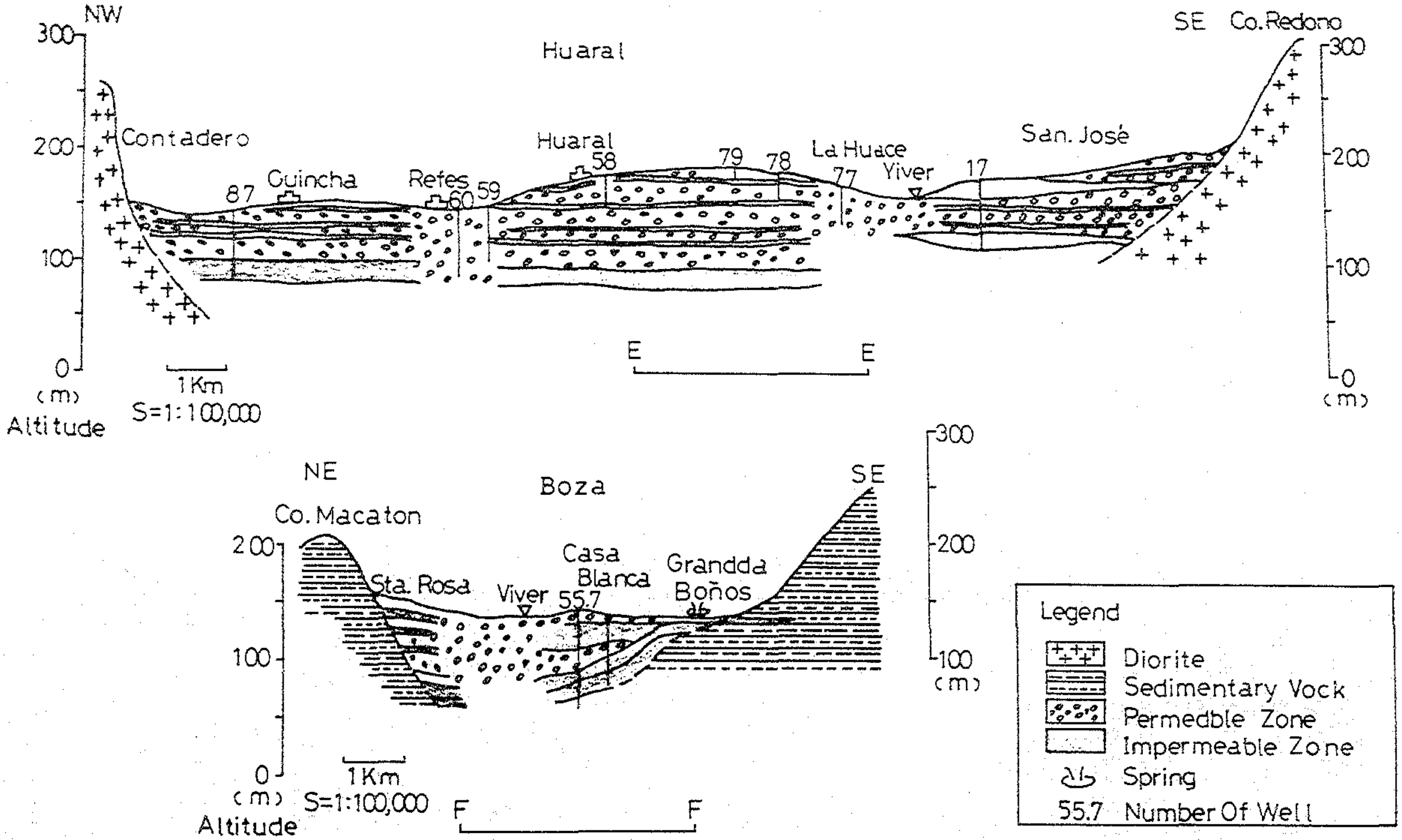


Fig. B-2-4 GEOLOGIC PROFILES

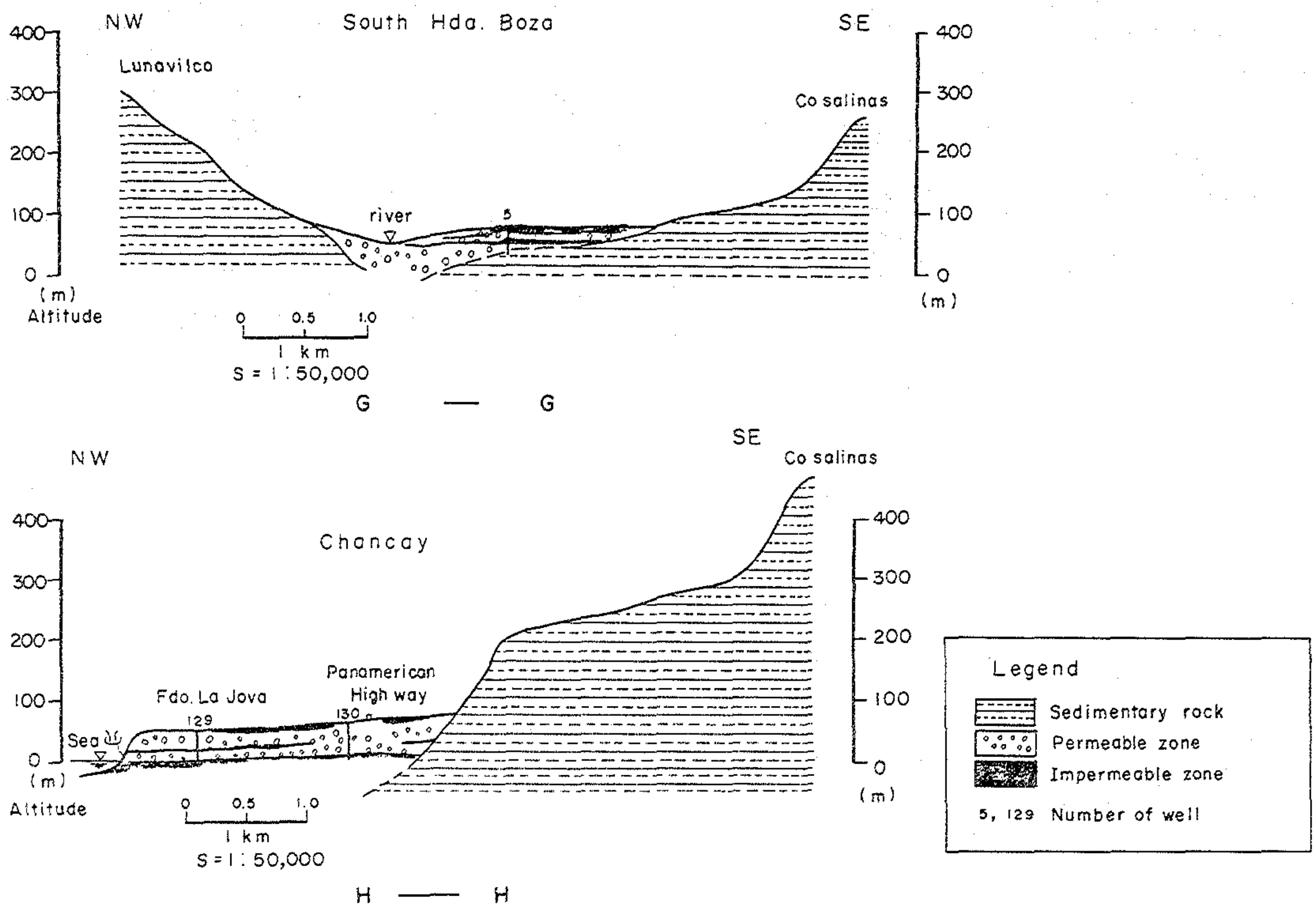


Fig. B-2-5 GEOLOGIC PROFILE

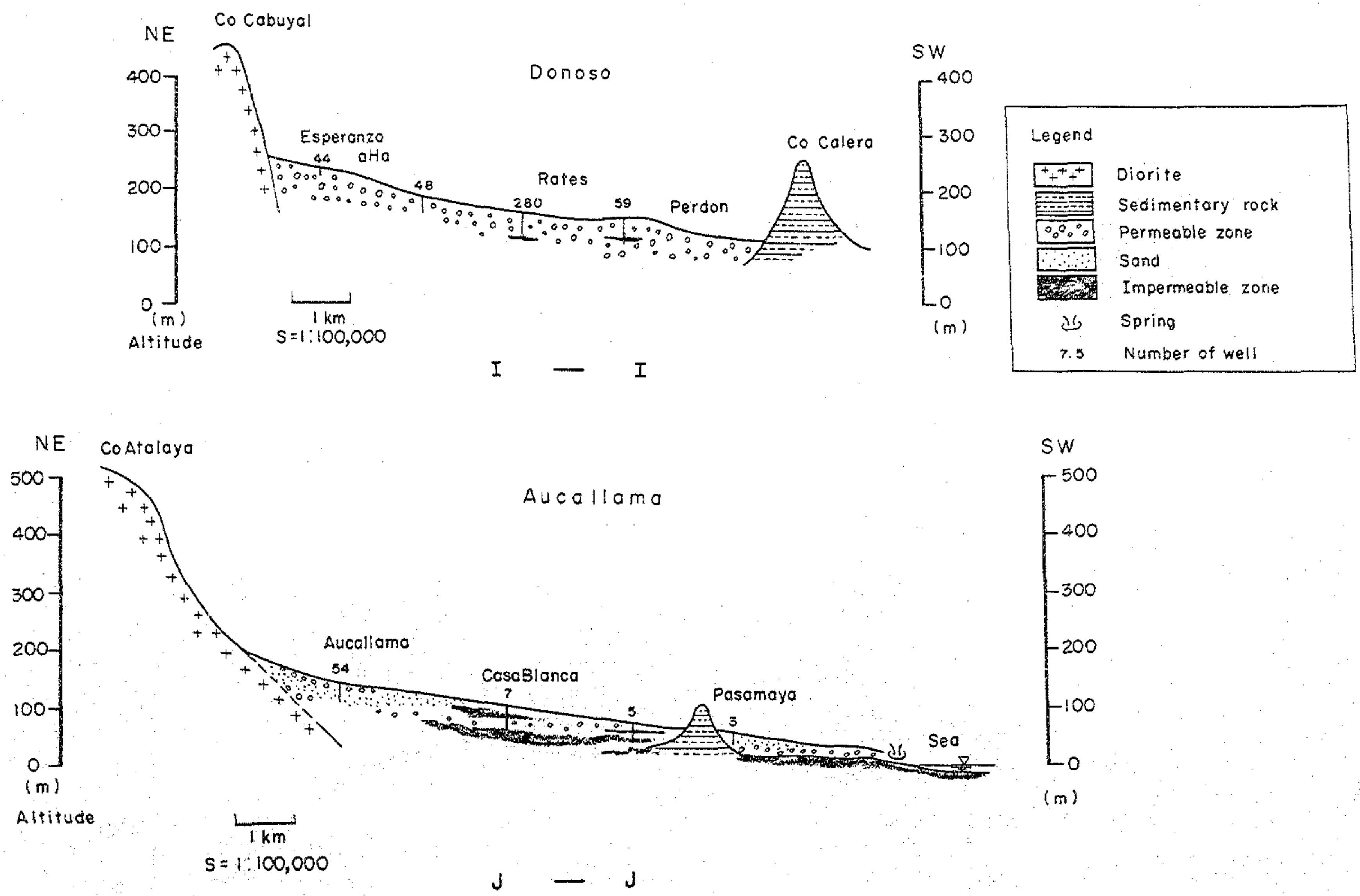


Fig.B-2-6 GEOLOGIC PROFILE

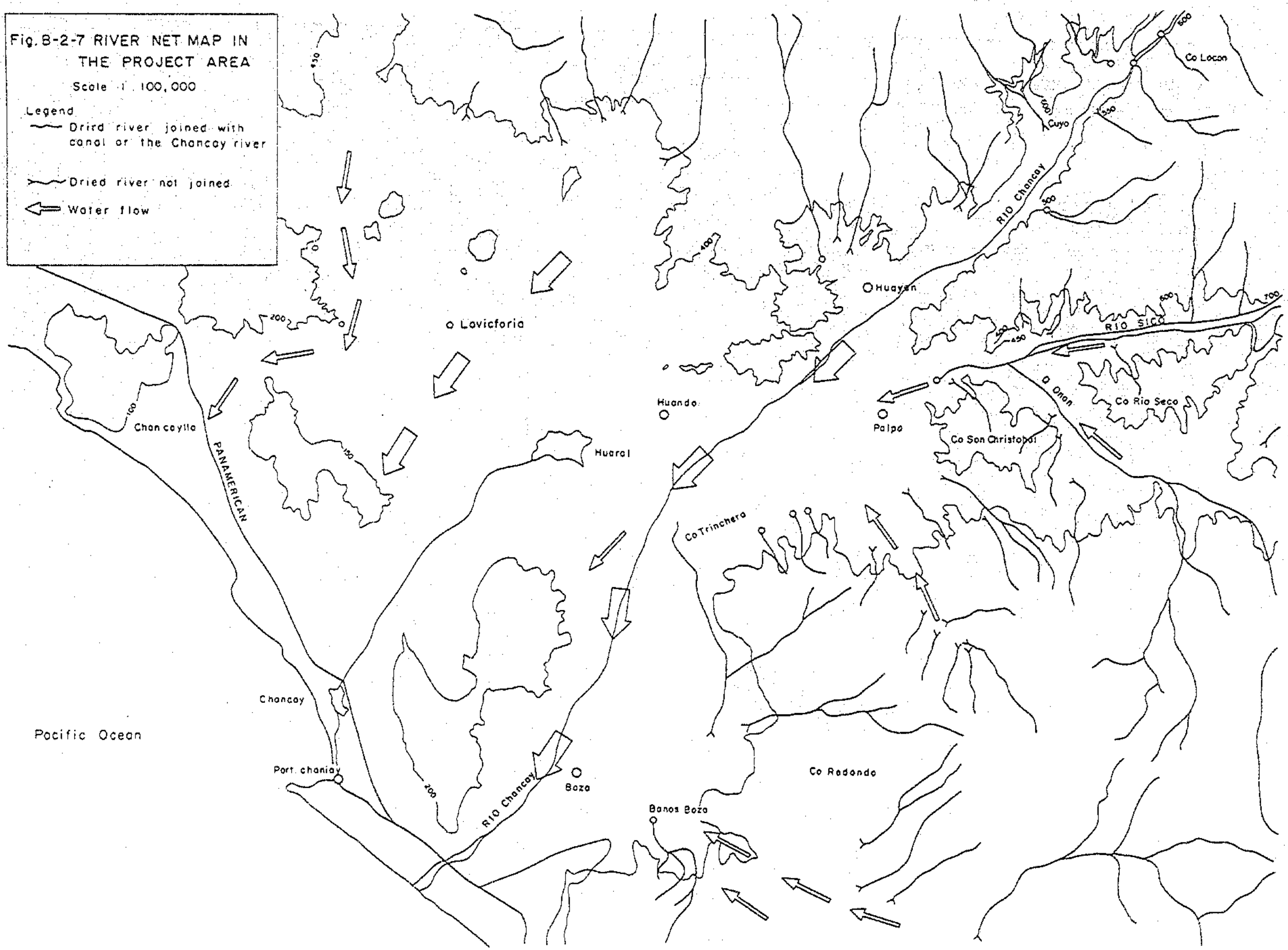


Fig. B-2-7 RIVER NET MAP IN THE PROJECT AREA

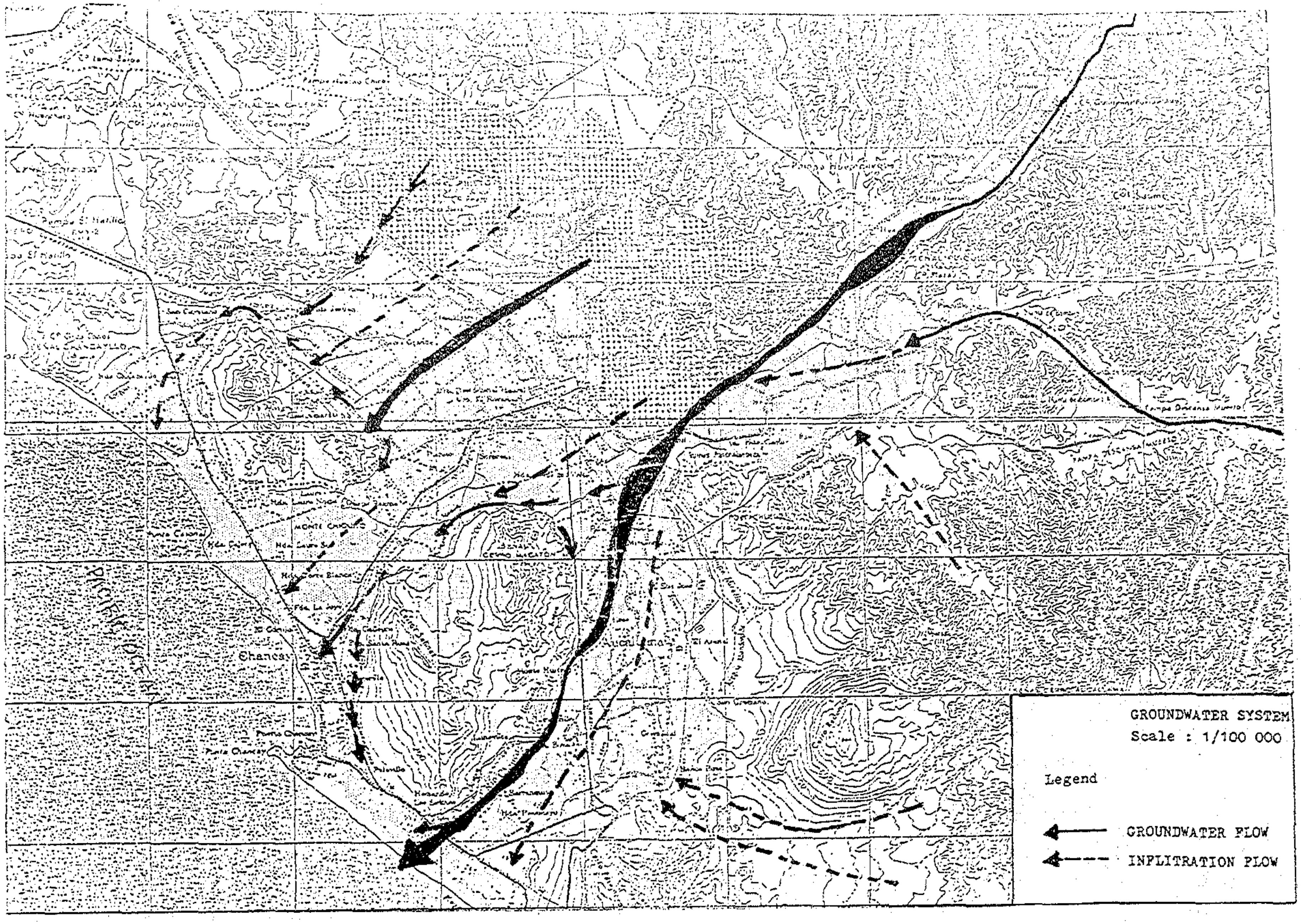


Fig. B-2-8 Groundwater System

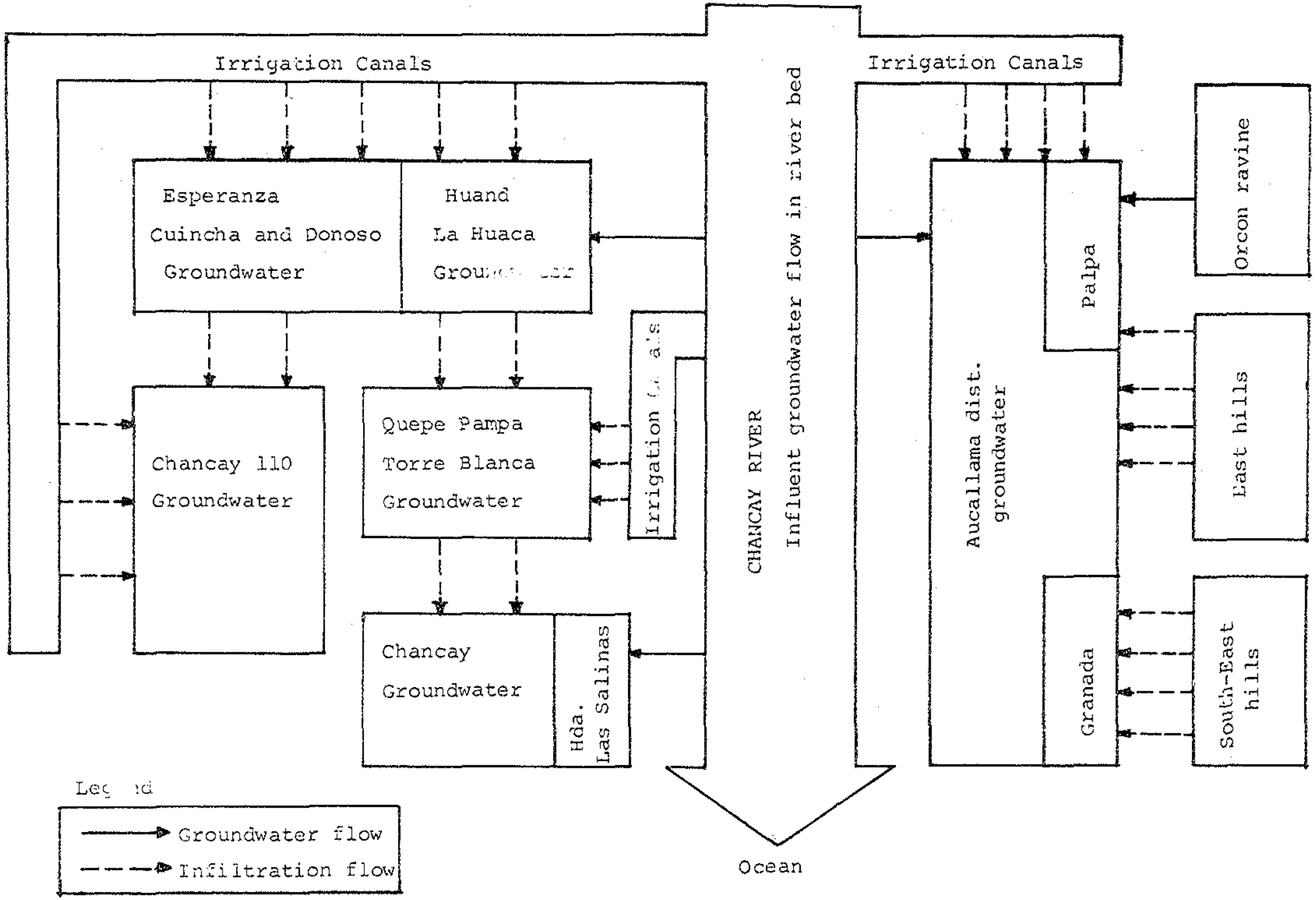


Fig. B-2-9 System of Groundwater in the Project area

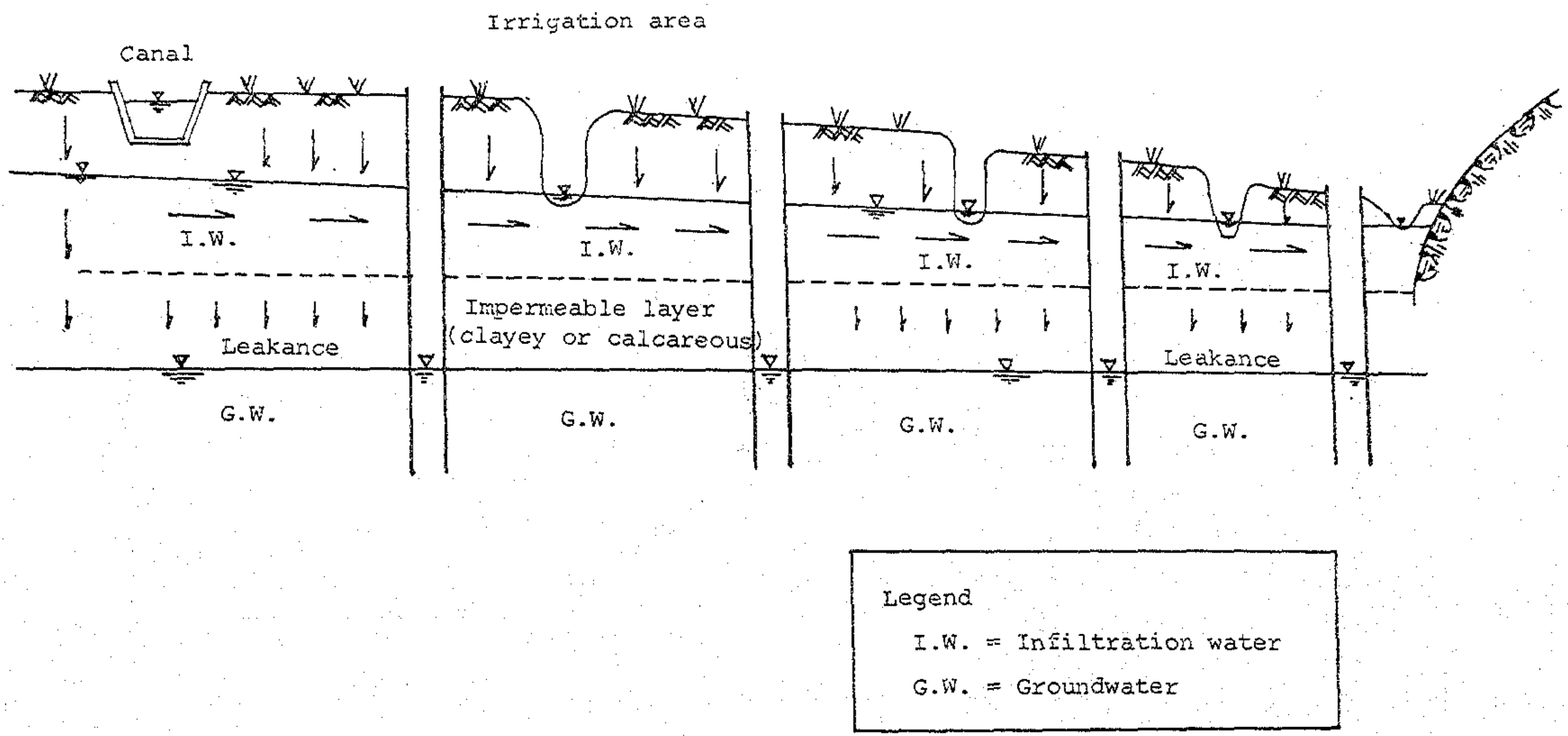


Fig. B-2-10 Classification of Groundwater in poor drainage area (Cuincha and Donoso)

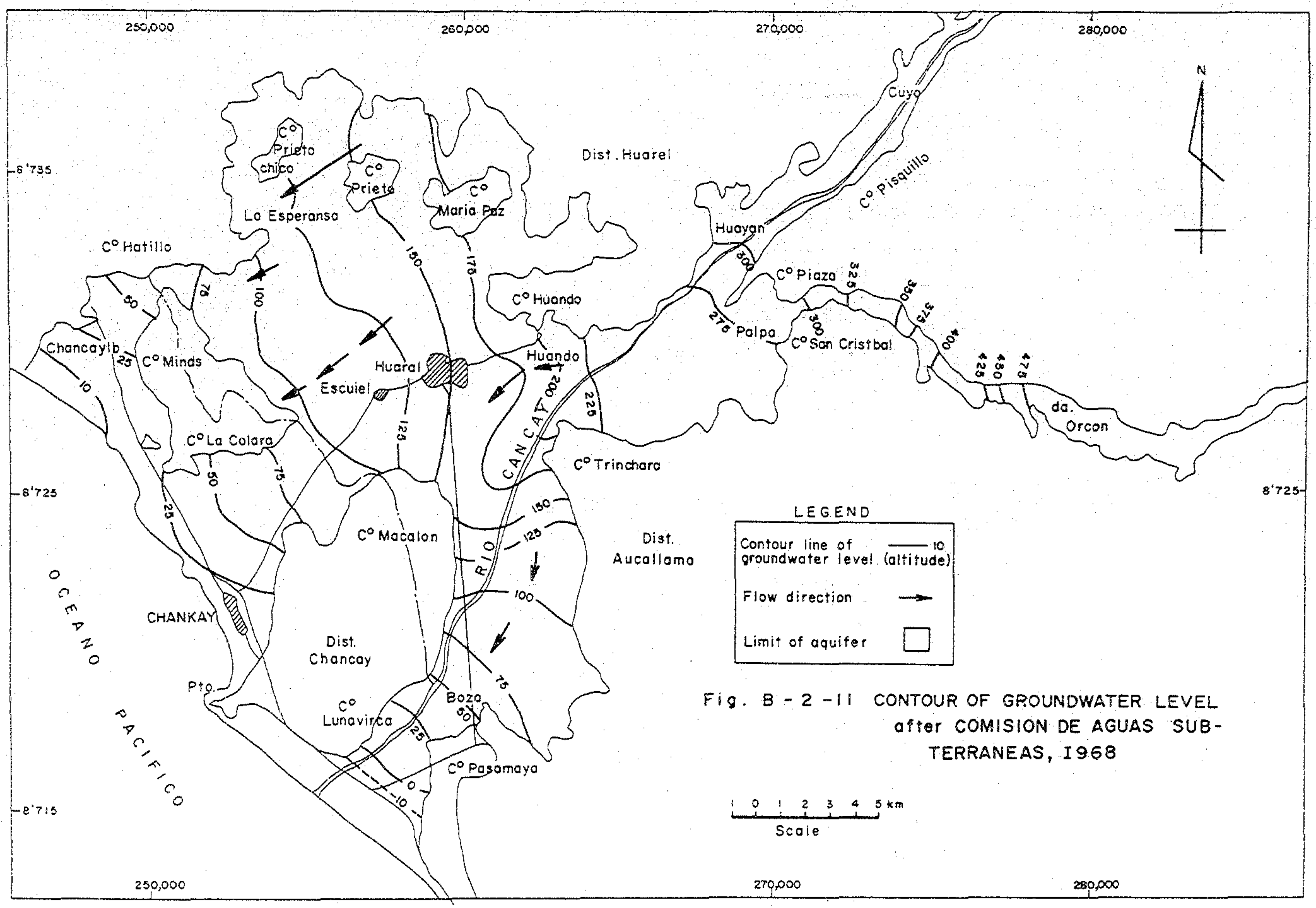


Fig. B - 2 - 11 CONTOUR OF GROUNDWATER LEVEL after COMISION DE AGUAS SUB-TERRANEAS, 1968

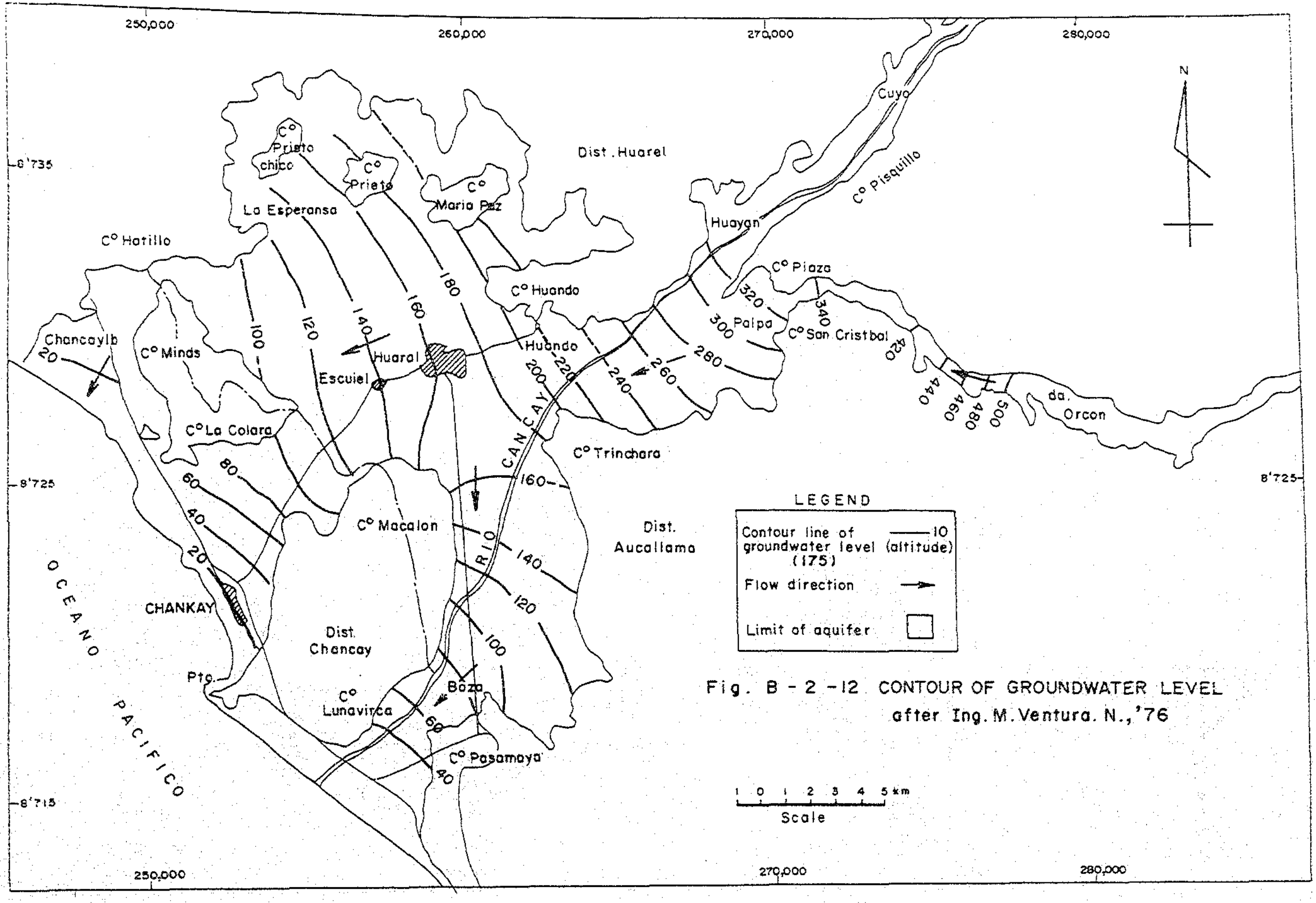


Fig. B - 2 -12 CONTOUR OF GROUNDWATER LEVEL
after Ing. M. Ventura. N., '76

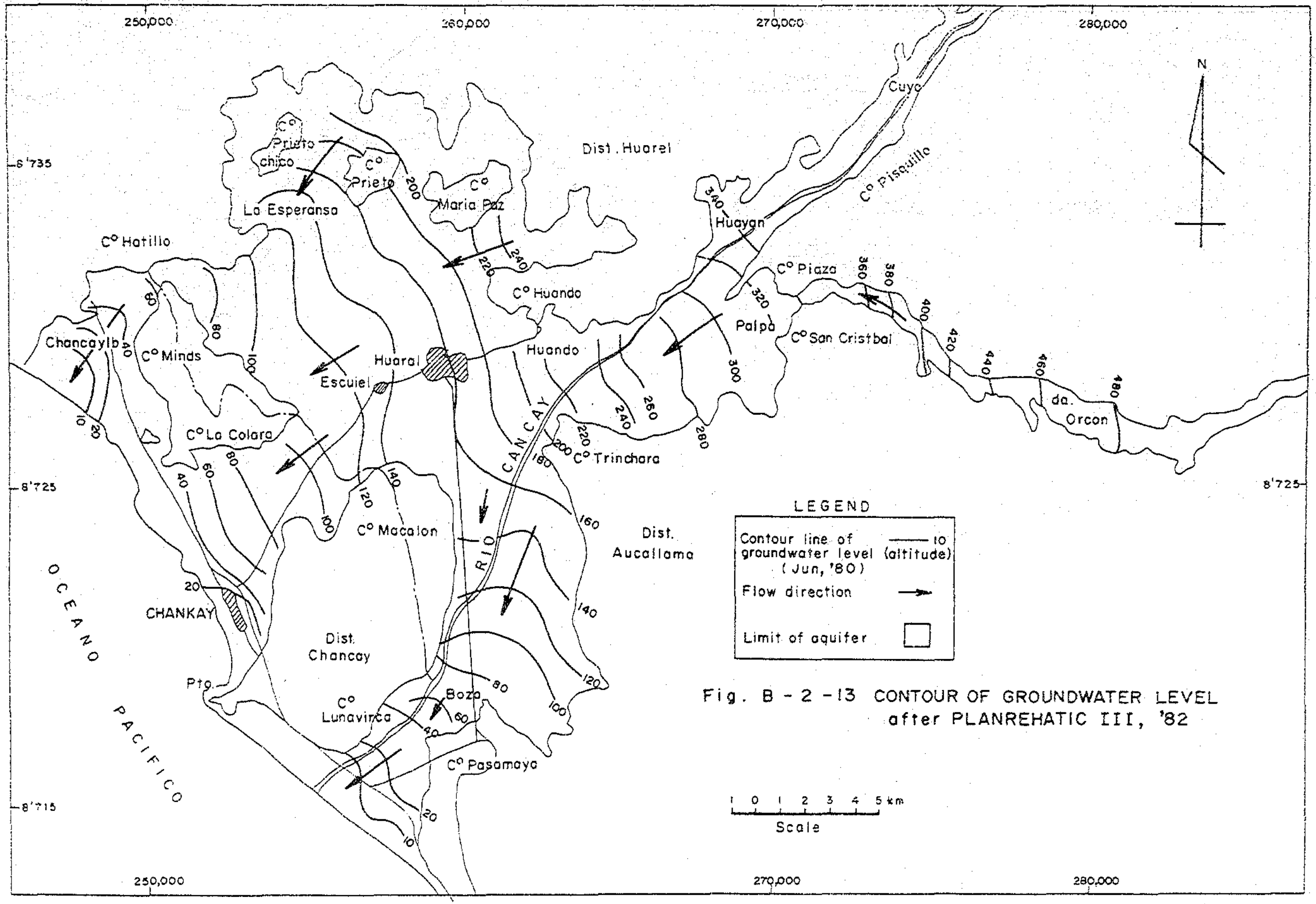


Fig. B - 2 -13 CONTOUR OF GROUNDWATER LEVEL after PLANREHATIC III, '82

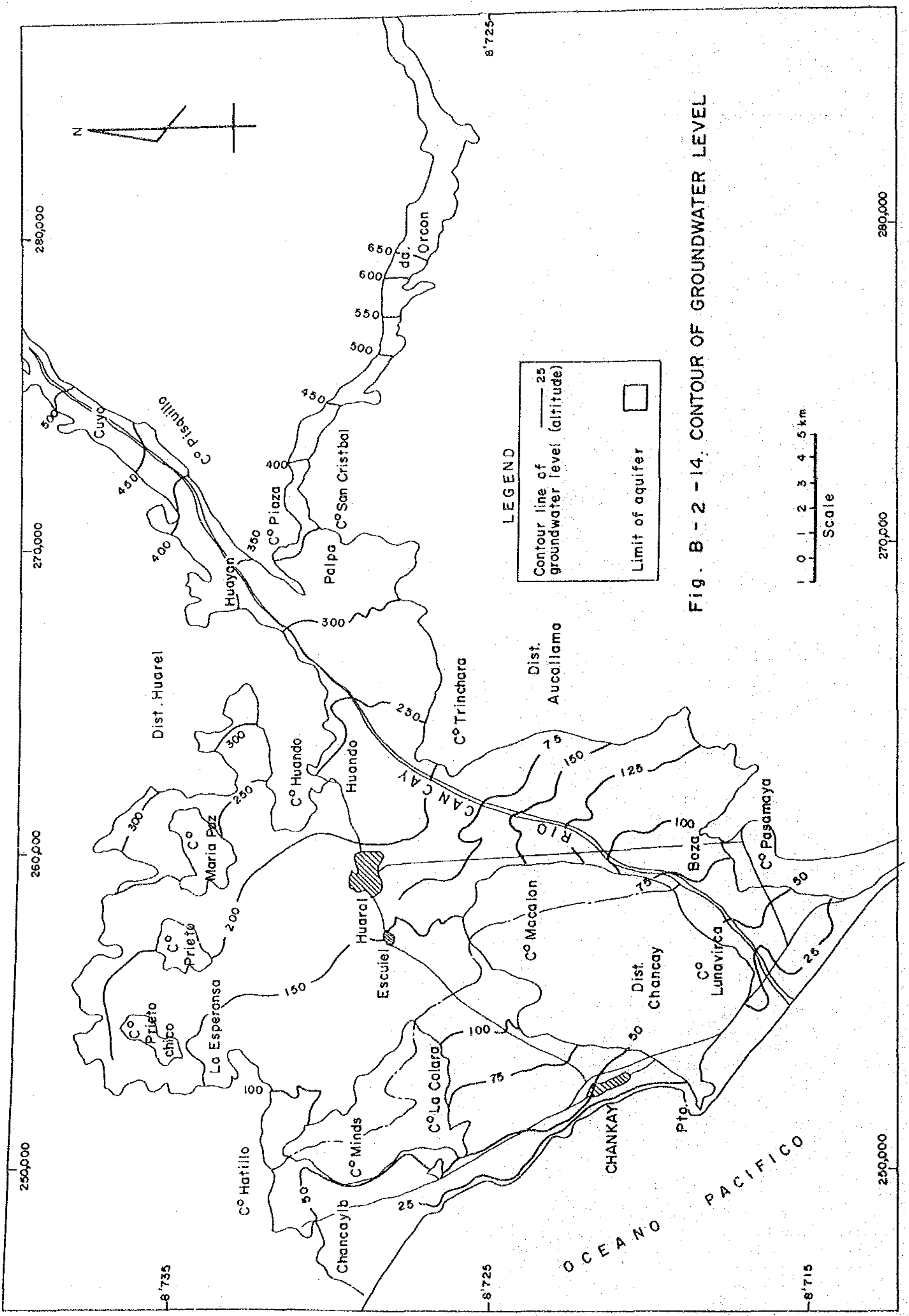


Fig. B - 2 - 14. CONTOUR OF GROUNDWATER LEVEL

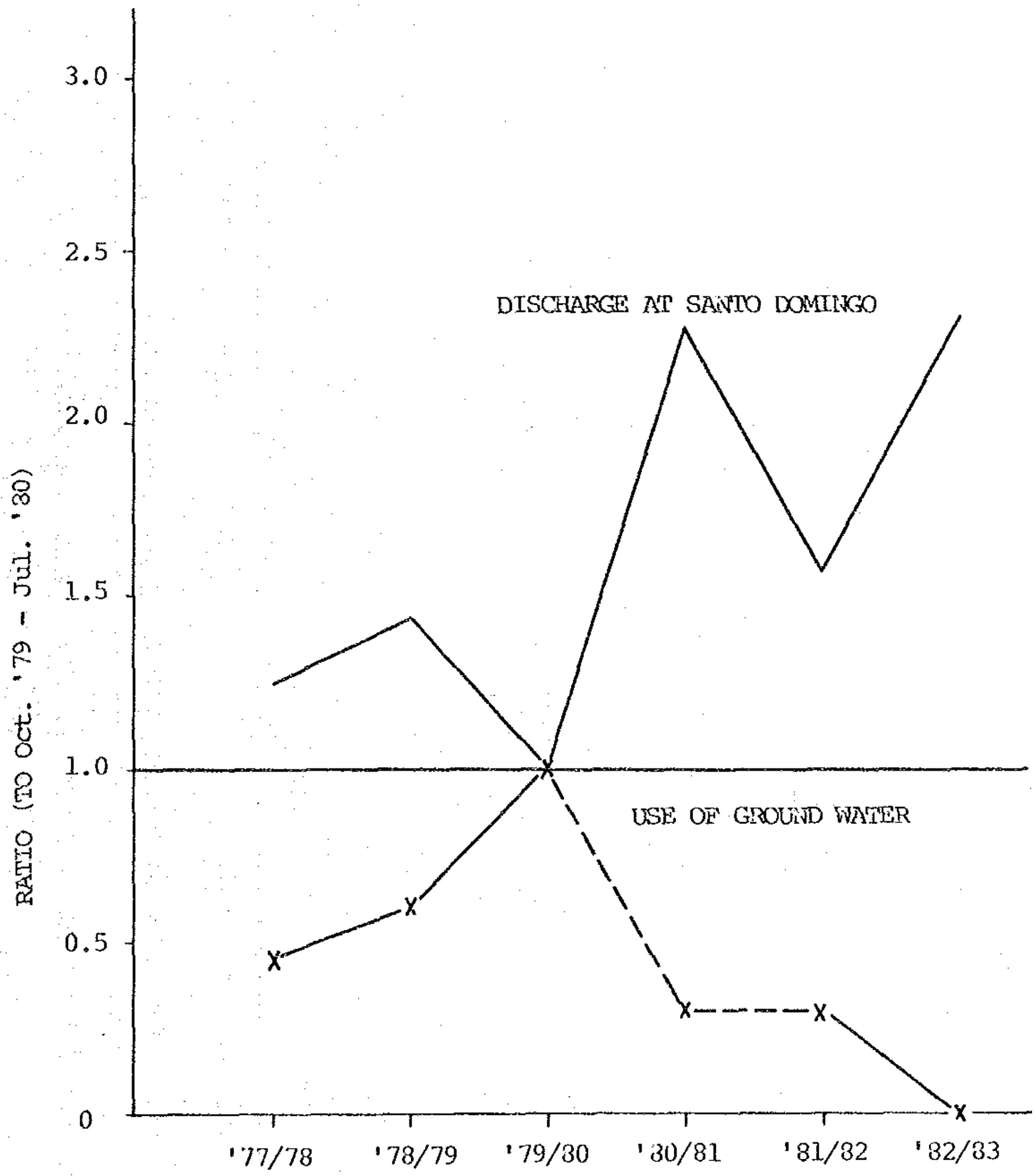


Fig. B-2-15 RATIOS OF DISCHARGE AND USE OF GROUNDWATER PER ANNUM

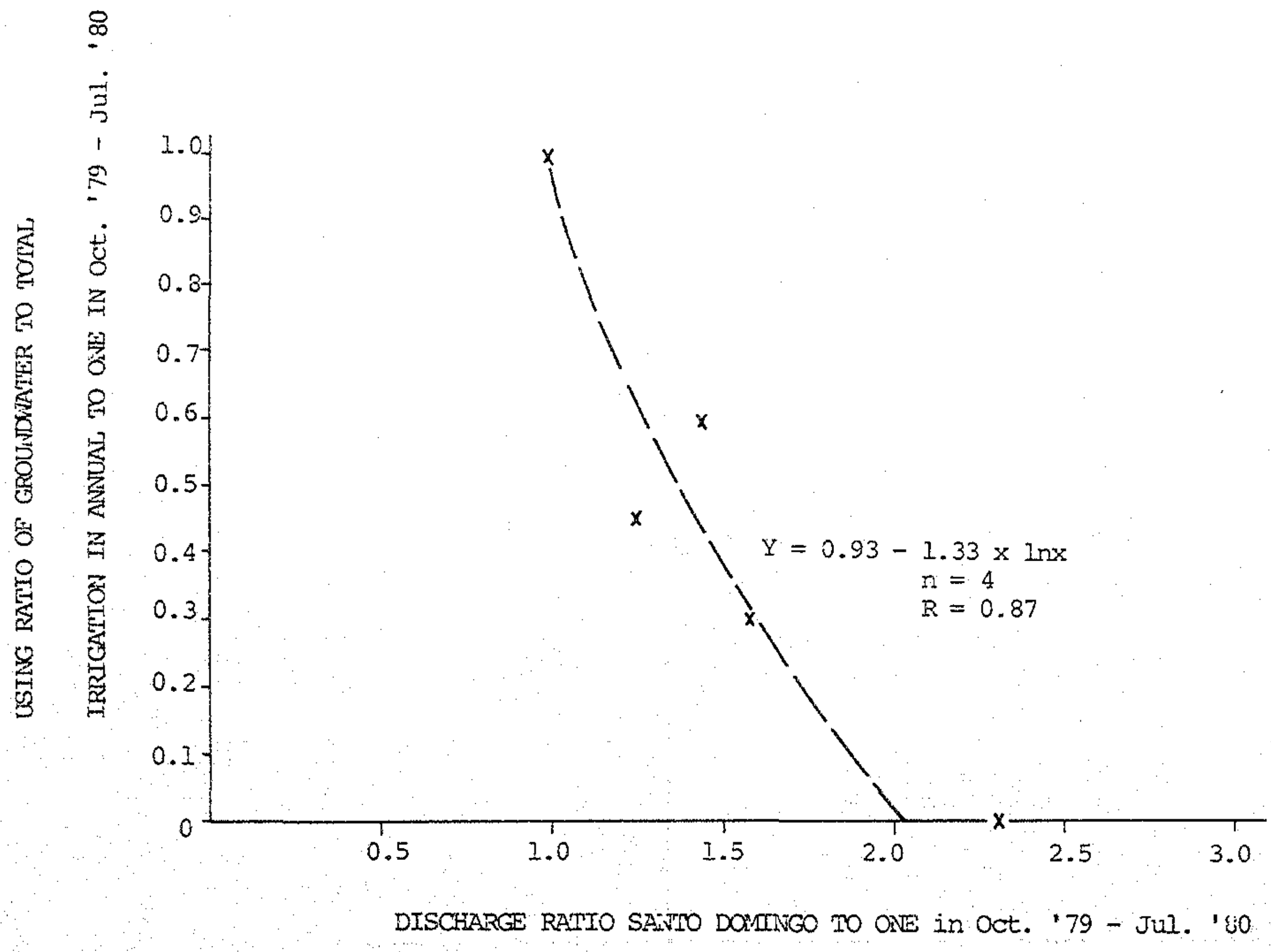


Fig. B-2-16 DISCHARGE RATIO vs. USING RATIO OF GROUNDWATER

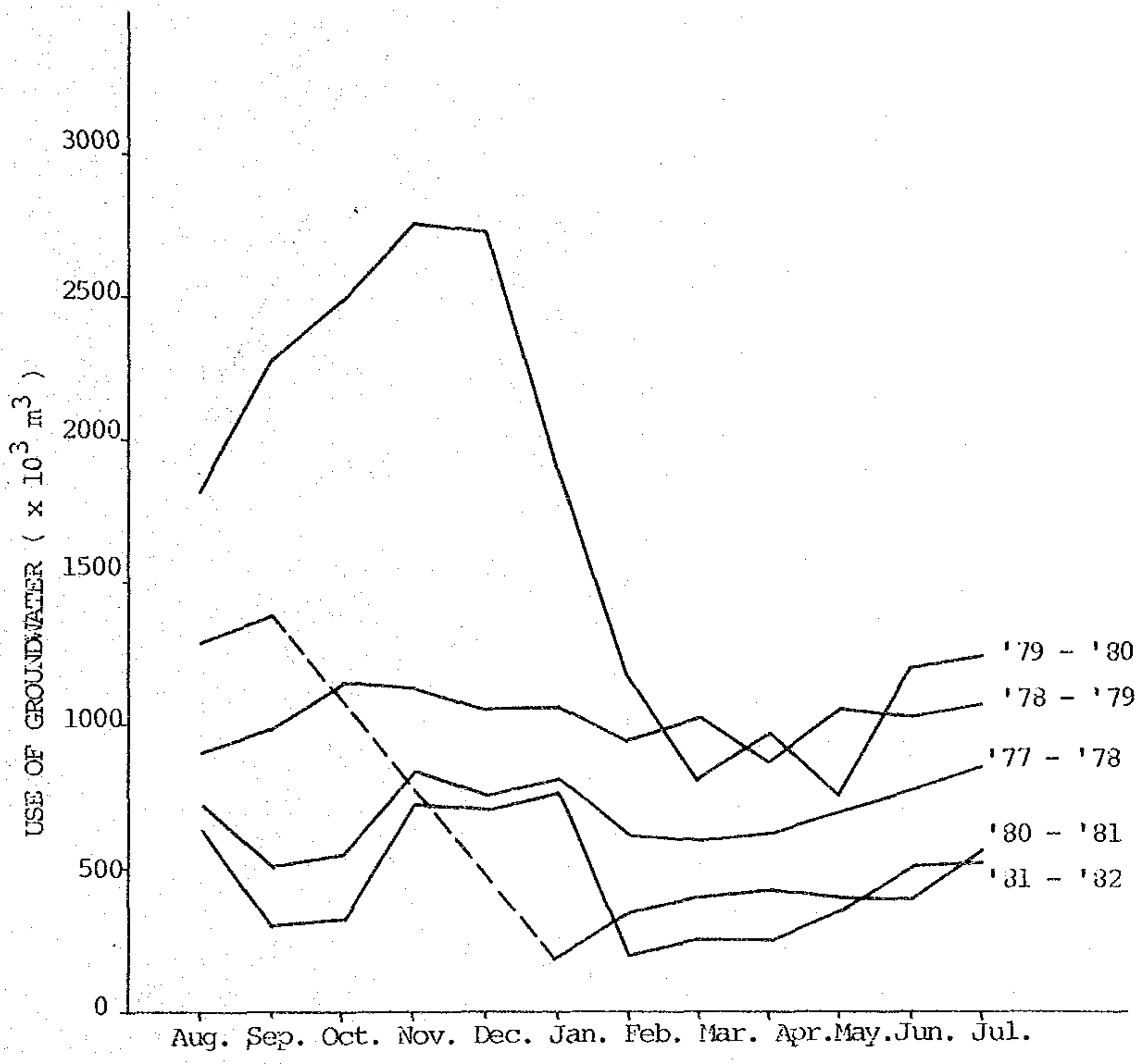
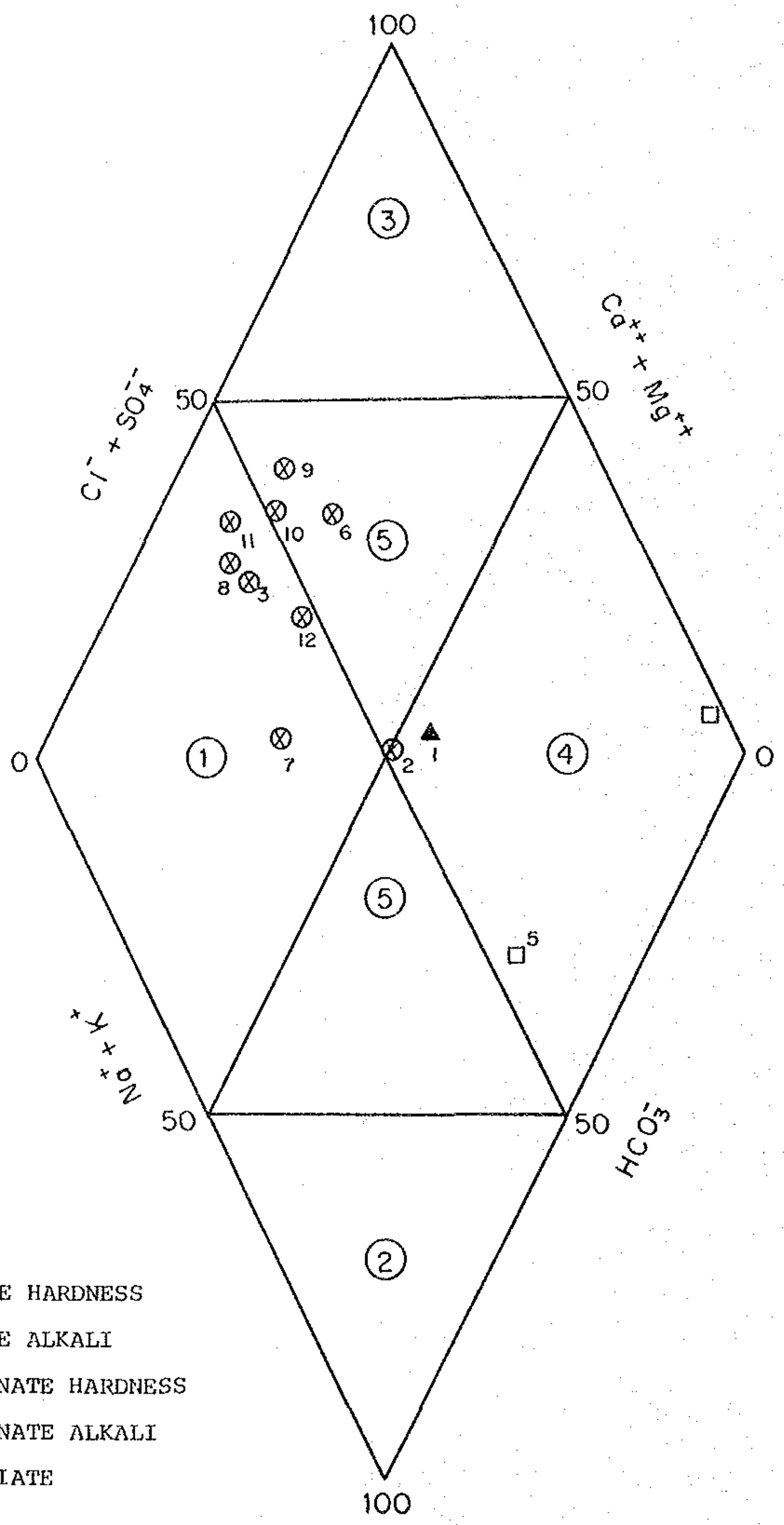


Fig. B-2-17 USE OF GROUNDWATER FOR IRRIGATION PER ANNUM



1. CARBONATE HARDNESS
2. CARBONATE ALKALI
3. NONCARBONATE HARDNESS
4. NONCARBONATE ALKALI
5. INTERMEDIATE

Fig. B-3-1 KEY DIAGRAM For water from wells and spring (sampling date 8-11, Mar., 1984)

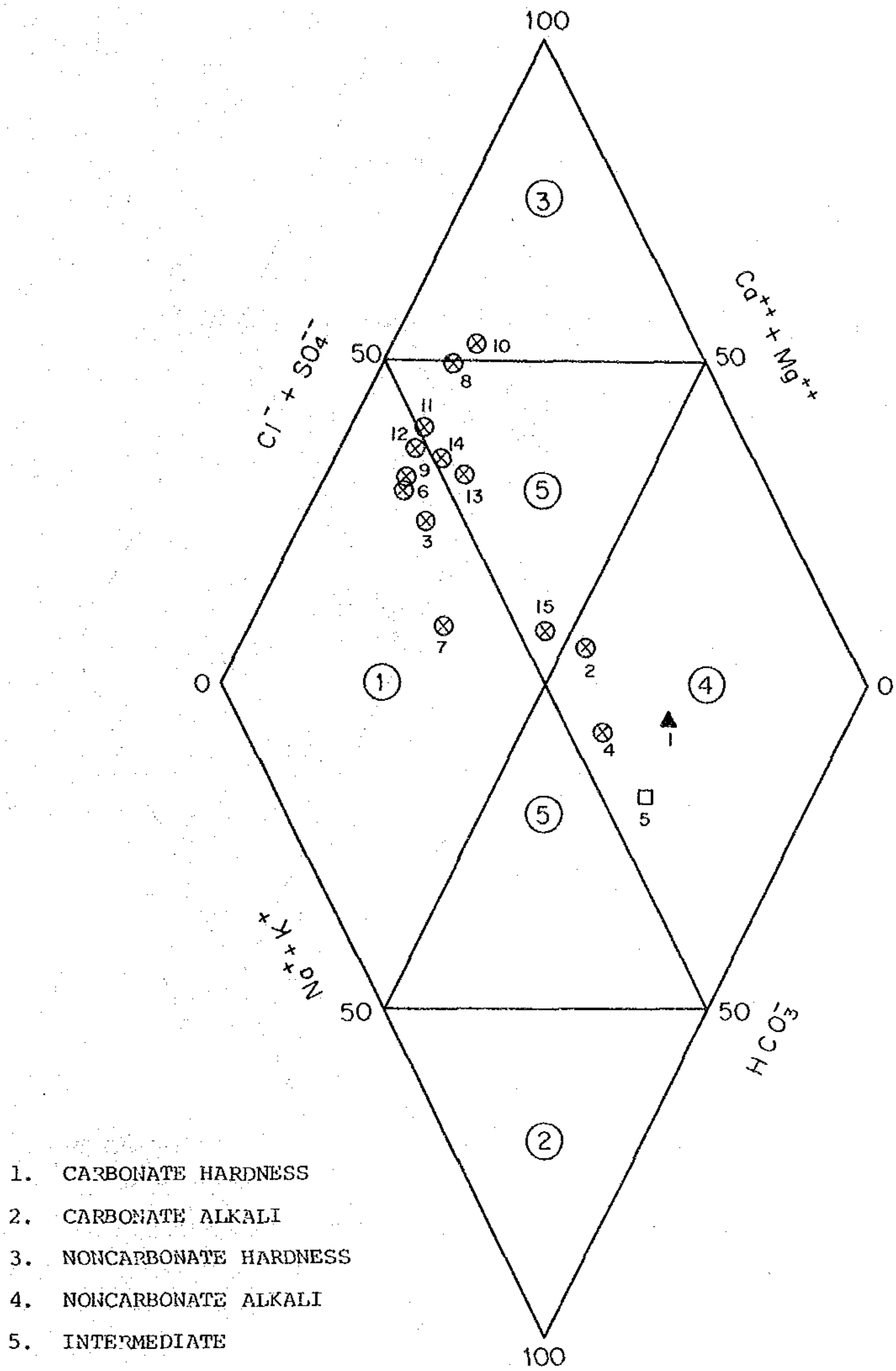
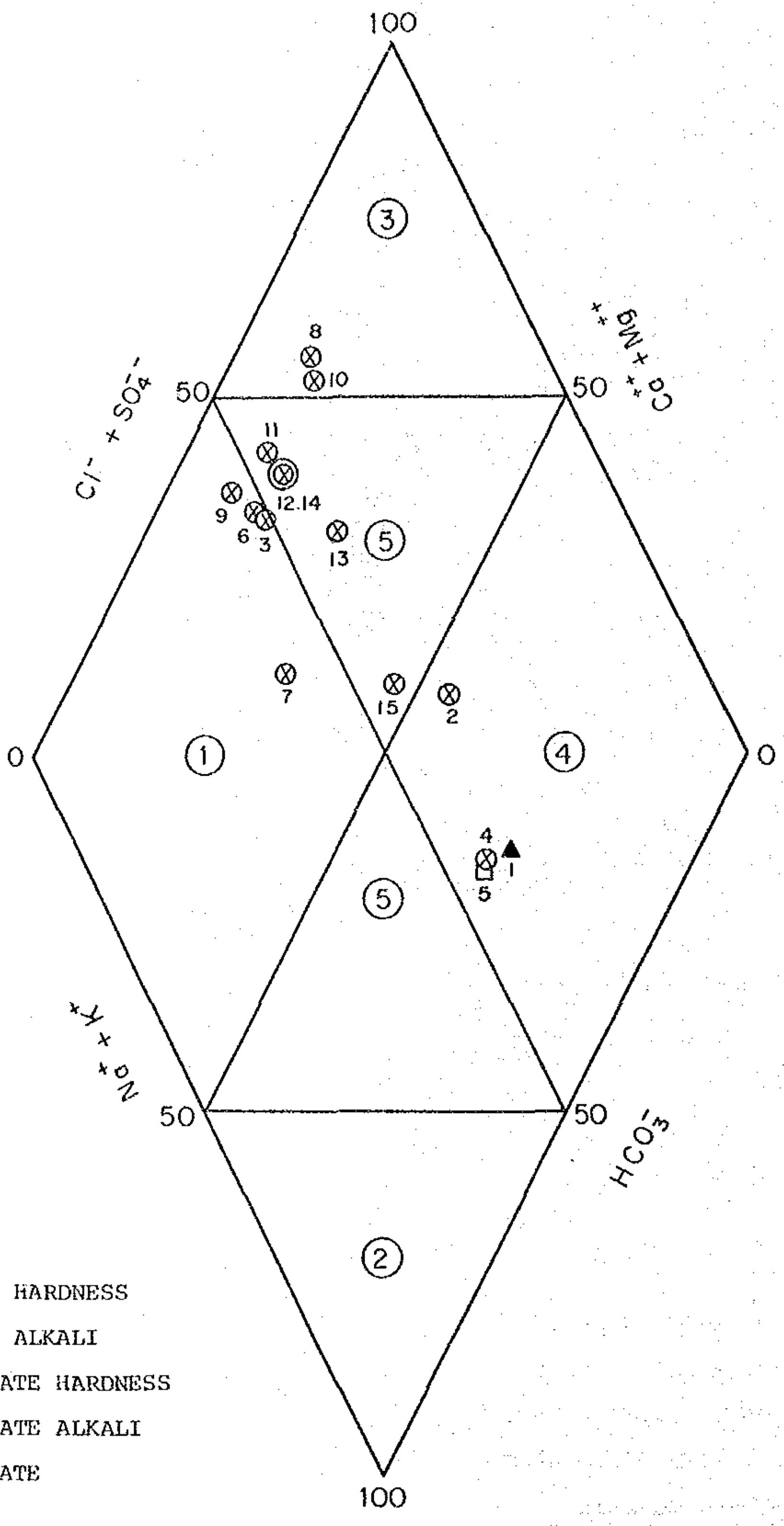
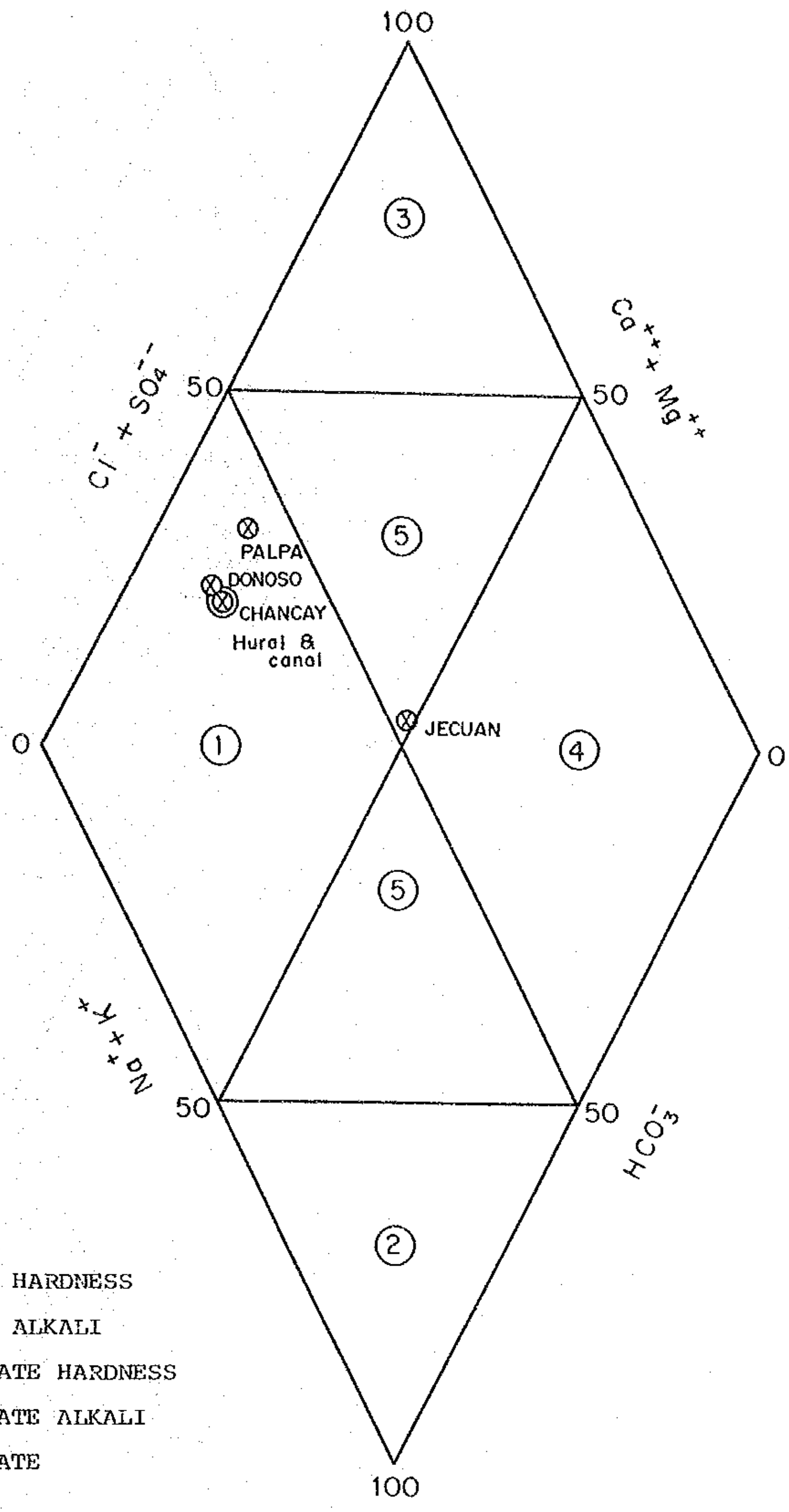


Fig. B-3-2 KEY DIAGRAM For water from wells and spring (sampling date 6-7, July, 1984)



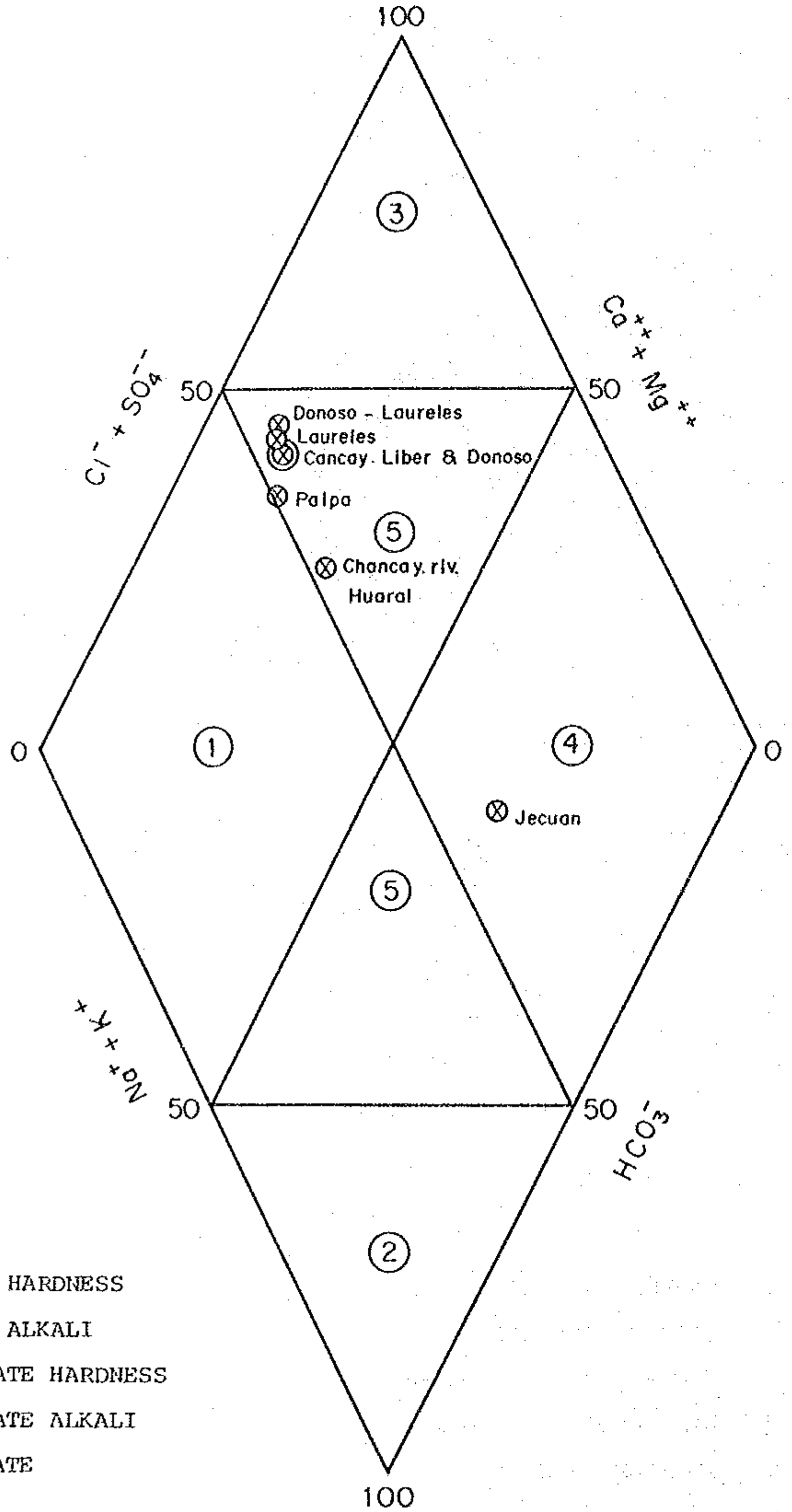
1. CARBONATE HARDNESS
2. CARBONATE ALKALI
3. NONCARBONATE HARDNESS
4. NONCARBONATE ALKALI
5. INTERMEDIATE

Fig. B-3-3 KEY DIAGRAM For water from wells and spring (sampling date 30-31, July, 1984)



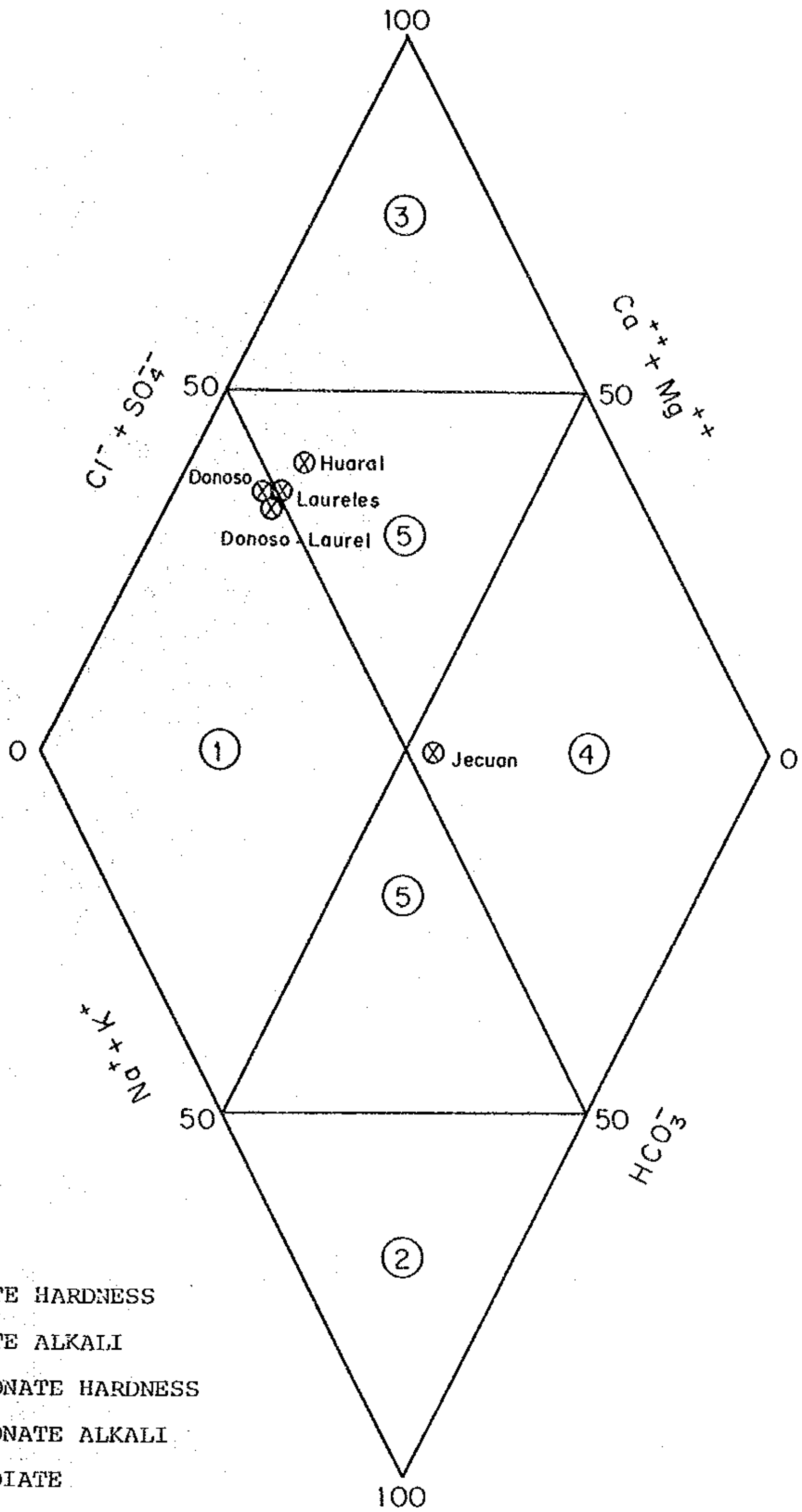
1. CARBONATE HARDNESS
2. CARBONATE ALKALI
3. NONCARBONATE HARDNESS
4. NONCARBONATE ALKALI
5. INTERMEDIATE

Fig. B-3-4 KEY DIARAM For water in canal (sampling date 11, Mar., 1984)



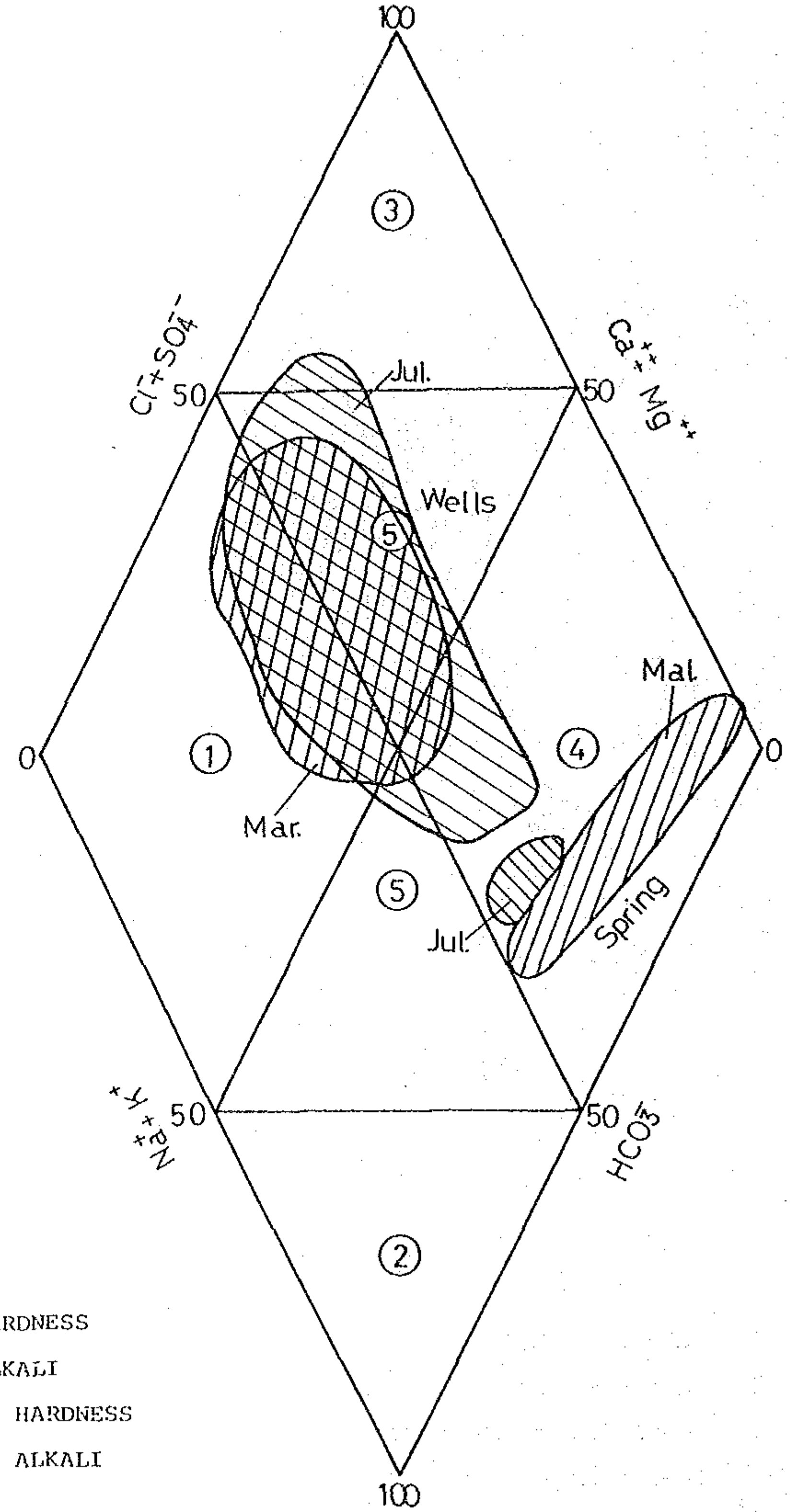
1. CARBONATE HARDNESS
2. CARBONATE ALKALI
3. NONCARBONATE HARDNESS
4. NONCARBONATE ALKALI
5. INTERMEDIATE

Fig. B-3-5 KEY DIAGRAM For water in canal (sampling date 7, July, 1984)



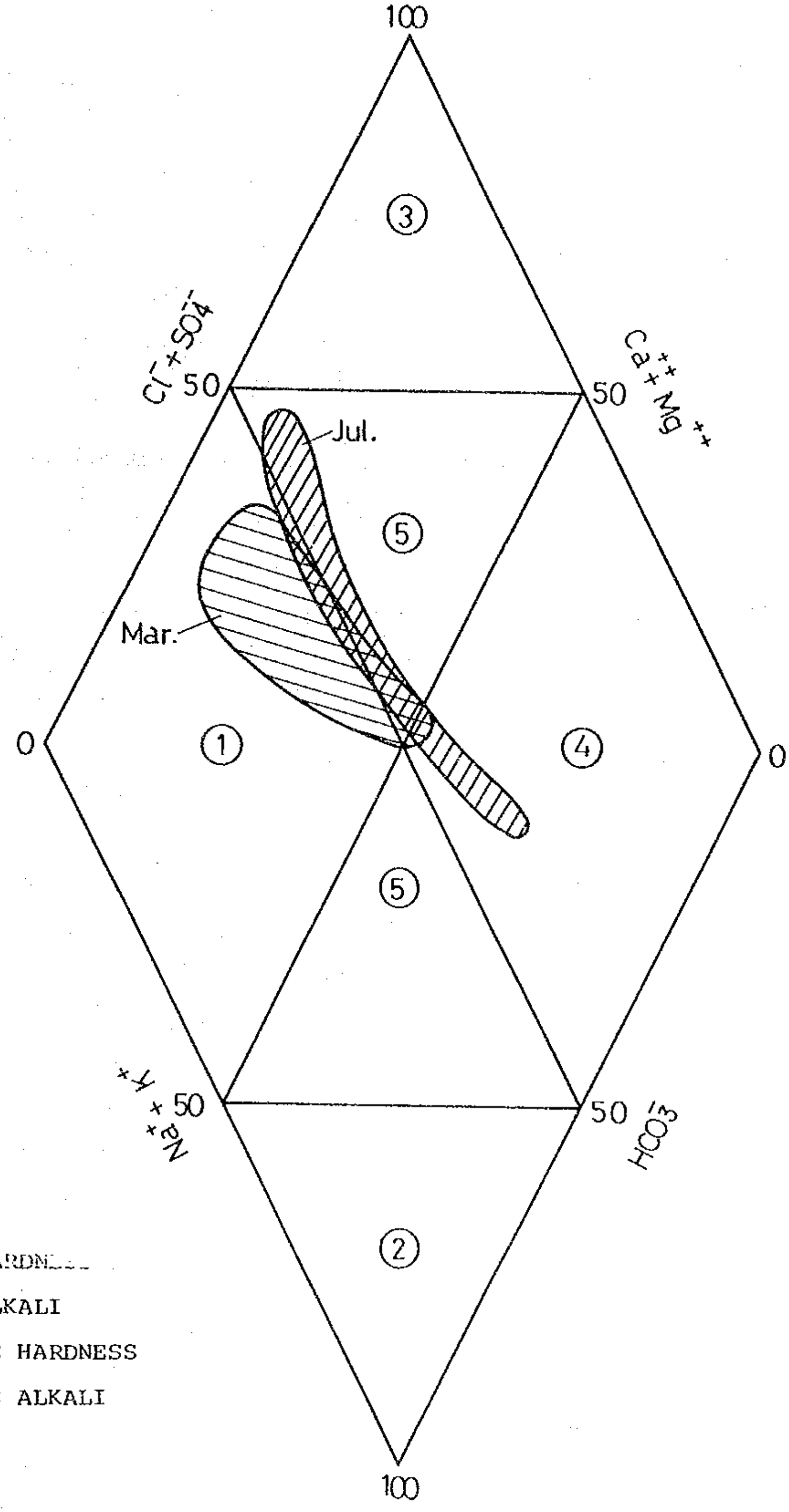
1. CARBONATE HARDNESS
2. CARBONATE ALKALI
3. NONCARBONATE HARDNESS
4. NONCARBONATE ALKALI
5. INTERMEDIATE

Fig. B-3-6 KEY DIAGRAM For water in canal (sampling date 28, July, 1984)



1. CARBONATE HARDNESS
2. CARBONATE ALKALI
3. NONCARBONATE HARDNESS
4. NONCARBONATE ALKALI
5. INTERMEDIATE

Fig. B-3-7 KEY DIAGRAM (water from wells and spring)



1. CARBONATE HARDNESS
2. CARBONATE ALKALI
3. NONCARBONATE HARDNESS
4. NONCARBONATE ALKALI
5. INTERMEDIATE

Fig. B-3-8 KEY DIAGRAM (water from canals)

SEISMIC REFRACTION SURVEY

Contents

1. PURPOSE OF SURVEY

The Seismic Refraction method is adequate for determining the vertical variations of the acoustic impedances of a lithological column affected by waves originating at a shot point. The elastic properties of rocks are defined by the compacity and the density; the wave velocities are, thus, directly related to these factors. Consequently, the unconsolidated sediments are "slower" than rocks.

The refraction seismograms are used to calculate velocities of the layers and there are mathematical procedures to determine their thicknesses. They consist of identifying the first wave arrivals to each geophone of a series located at known distances from the shot point. The time increments and the distances are used to calculate velocities; depths and/or thicknesses are then interpreted using the arrival times and the total lenght times.

The most widely used application of the seismic refraction technique is for delineating the bedrock profile and other elastic contact planes. The velocities are slowed down when the rocks are fractured and it is important to define the seismic sequence for each shot and then establish the correlation between adjacent stations.

The geometric resolution of the seismic method is in the 5% to 10% vertical range, better than with electric resistivity soundings which have 20% to 30% inherent errors. If the seismic technique is applied in a conventional way to obtain depths below each geophone, the horizontal resolution is high, depending on the separation between geophones, usually 5 to 30 meters.

2. THE SEISMIC REFRACTION GEOPHYSICAL METHOD

If an explosive charge is detonated at the surface, the elastic waves travel in all directions with a concentric pattern. The wave fronts have short radii near the shot point but become more straight with increasing distances from it.

The seismic technique uses sensor or geophones located along spread cables with equal separation between contact points. The geophones convert the mechanical variations into electric impulses that are sent to the seismograph where they are amplified and recorded.

The waves caused by an impact or an explosion travel with velocities that are dependent on the acoustic impedances of the rocks. Part of the energy is dissipated as sound in air, at a 0.33 km/s velocity. The remaining energy penetrates the ground following patterns that are changed when contact planes between different rocks are encountered. Some waves are reflected to the surface and are used by the seismic reflection technique. Some others are refracted according to known physical lows and return to the surface to be employed by the seismic refraction method.

The most important feature of a refraction seismogram is its susceptibility to interpretation procedures that give velocities and thicknesses of the elastic horizons. With adequate field techniques a high degree of horizontal resolution is achieved, with depth calculations below each geophone. For this purpose, the reverse shooting field progress is required because two arrival times coming from both ends of the same spread have to be recorded at the same geophone station.

The first step in interpreting a seismogram is the identification of the first wave arrival times to each geophone and the plotting of times versus distances from the shot point. The time-distance curves are formed by segments with slopes that represent the velocities of the elastic media. The two times at each sensor and the total duration of the records are used to compute depths by means of the "plus-minus" or the "delay times" techniques. The large amount of data that is usually available from a seismic survey forces the use of automatic procedures, with desk-top computers or programmable calculators.

Routine refraction surveys are carried out using the first arrivales of the longitudinal wave P, that is commonly clearly shown on the seismograms. The shear or transverse waves (S) are slower but follow the same lows governing the primary ones; these S waves are useful for special purposes in engineering studies but they have to be recorded under appropriate operating conditions, employing "signal enhancement" seismographs with digital stacking that can be monitored by CRT displays.

For our seismic surveys we employ the following equipment:

-<u>Seismographs</u>

a. Nimbus ES-1200, with twelve channels and two timing traces (10-ms intervals), timing lines with intervals regulated by the total duration of the recording cycle (selected between 50 ms and 2000 ms). The starting time of the record can be delayed up to 9999 ms in 1 ms increments. Records are obtained in photosensitive paper. The output signals from the amplifiers are stored in digital memories where they can be optimized by repetitive inputs; each memory stores 1024 discrete samples. A D/A converter is then used to transfer the signals to a graph recorder in analog form.

   Accessories: -CRT display monitor.
   -Cassette recorder (RS-232 format).
   -240-Volt blaster.

b. Geo Space GT-2A with 12 seismic channels plus time-break, timing lines every 10 ms, individual amplifiers, integrated blasting circuit (90 V), continuity test circuit, instant developing records, galvanometers of 125 Hz.

-Geophones

- ·14 vertical units, 14 Hz, for P waves.
- ·14 vertical units, 8z, for P waves.
- ·14 horizontal units, 14 Hz, for S waves.
- ·Borehole pick, 50 mm diameter, 50-meter long cable.

-Spead cables

- ·60, 120 and 240 meters in length.

-Blasting cables

- ·Lenght of 40, 120, 240, 480, 960 and 1200 meters.

3. INTERPRETATION

The seismograms were analized to obtain the first arrivals of the P waves in milliseconds (ms). This procedure is relatively simple for geophones close to the shot point but become more difficult at increasing distances because of the normal attenuation of the higher frequencies and the predominance of long wavelenghts. This problem is normal and under favorable conditions the high frequency waves arrive at the farthest sensors.

The enclosd plates that contain the interpreted seismic sections also show the time-distance curves on the upper part. Those curves are prepared with the arrival times of the seismograms. The shot points are the origin of segments, thus, they can readily be identified. The reverse shooting technique employed is evident when comparisons are made for curves beginning at the extremes of selected sections along a line.

For the present survey we have employed the "plus-minus" computation technique developed by Hagedoorn (1959) based on theoretical work by Thornburgh (1930). Cummings (1979) published the programs that we have adapted to a Hewlett-Packard 97 desk top calculator and to a HP-41CV hand calculator for the field evaluations.

The "delay times" computation technique is also widely used. It is based on theoretical work by Redpath (1973) but the operation is somewhat slower as compared to the "plus-minus" one. Therefore, we apply the "delay times" program adapted to the HP-97 and HP-41CV calculators only for occassional checks.

The first step of the calculation consists of obtaining an adequate average for the velocity of the surface layer (usually the overburden) by means of the direct wave arrivals. Appropriate segments of the time-distance curves are then selected to determine the second layer velocity and depths to the first contact plane. The velocities are used to compute the scale factor that multiplies the time relations assigned to each geophone station.

For the second contact plane and the velocity of the third layer the process is similar but longer time-distance curves have to be utilized. In this case it is necessary to employ a correction factor involving the effect of the first thickness. As there are two elastic (scale) factors determined for pairs of layers above and below the contact planes, it is much greater the inherent error of the second depth calculations.

All seismic interpretations are based on the assumption that ideal physical and geometric conditions are present, which is not the case in Nature. On the other hand, it is not possible to predict either the intensity or the quality of variations in velocities and structures. In seismic refraction surveys the accuracy of interpretations is defined by the degree of homogeneity of the elastic properties within a particular "layer", by the contrast in acoustic impedances and by the relative uniformity of the contact planes.

Furthermore, a basic requirement for the total refraction to occur along a contact plane is that the seismic velocities should increase with depth. If this is not the case, the "blind" layers would be occurring and they could not be detected. Fortunately, the geological setting of unconsolidated sediments over bedrock is the common situation in engineering projects, because higher velocities are directly related to age.

The results of calculations for each geophone station are plotted on topographic sections thus permitting the correlation between adjacent depth-points, separated by relatively short distances, usually 20 meters or less. It has to be noted that some smoothing has to be performed between sections of profile calculated for selected reversed time-distance curves, because average velocities for each section do not necessarily represent the true values. This is a minor drawback that has to be accepted in order to get a high resolution seismic profile. The smoothing is normally not required for the first contact plane so the overburden can be traced with high accuracy.

The seismic velocities that are shown as part of the interpreted sections are the harmonic averages of corresponding reversed slopes of the time-distance curves. These averages provide valuable information about the mechanical properties of the ground, especially regarding bedrock fracturation and/or alteration.

4. FIELD WORK

The shooting diagrams shown on the following page are clearly indicative of the operating system that was employed for the present survey. It can be seen that although 60 meters between shot points were applied as a general rule, more detail was looked after by means of some intermediate shot points at 30-meter intervals; these were especially programmed for areas near the valley margins.

A total of 130 seismograms were obtained with the following characteristics:

-Palpa weir : 1 line, 420-meter long, 28 seismic shots.

-La Esperanza weir : 1 line, 840-meter long, 74 seismic shots.

-Huando weir : 1 line, 420-meter long, 28 seismic shots.

As proposed on June 25, 1984, a 10-meter interval between geophones and a 12-channel seismograph meant that the basic geophone spread had 120 meters in lenght, with 12 takeouts. This initial spread was good for 20 to 40 meters of effective depth penetration. Accordingly, extension spreads from 120 to 240 meters and from 240 to 360 meters were employed where survey line lenghts permitted.

As a general rule, the following explosives were used:

-0 to 120-meter spreads : 1 electric cap with 75 grams of 45% strenght dynamite.

-120 to 240-meter spreads : 1 electric cap with 150 grams of 45% strenght dynamite.

-240 to 360-meter spreads : 1 electric cap with 300 grams of 45% strenght dynamite.

The amout of explosives consumption was:

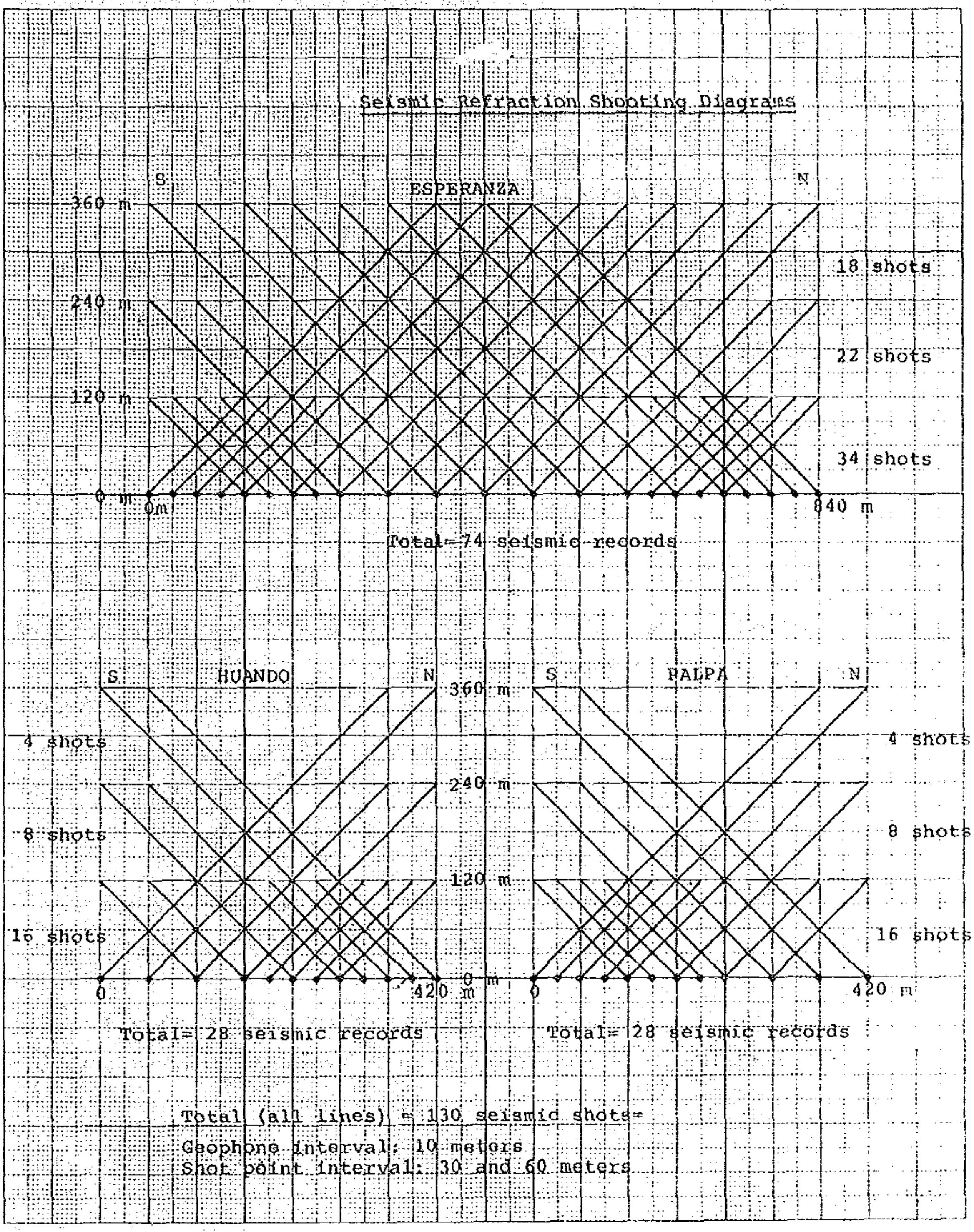
- -130 electric blasting caps.
- -18450 grams of 45% strenght dynamite.

The remaining explosives purchaed were disposed of in the following manner:

- -14 electric caps for repeated shots.
- -2000 grams of dynamite for repeated shots.
- -6 electric caps fired at the end of survey.
- -89550 grams of dynamite burned at the end of survey.

The geophones and shot point locations were controlled by a topographic survey using the existing concrete structures of the diversion weirs as references, with arbitrarily assigned elevations, as shown on the 1:1000 scale maps of Plates P2, E2 and H2.

Although all the equipment described on page 4 was available either in Huaral or at our office in Lima, the GT-2 Geo Space seismograph, with a 120-meter spread cable, 14-Hz vertical geophones and 480 meters of shooting cable were employed at all times.



Seismic Refraction Shooting Diagrams
S
ESPERANZA
N
360 m
240 m
120 m
0 m
0m
840 m
18 shots
22 shots
34 shots
Total=74 seismic records
S
HUANDO
N
360 m
240 m
120 m
0 m
4 shots
8 shots
16 shots
0
420 m
S
PALPA
N
0
420 m
4 shots
8 shots
16 shots
Total= 28 seismic records
Total= 28 seismic records
Total (all lines) = 130 seismic shots
Geophone interval: 10 meters
Shot point interval: 30 and 60 meters

5. GENERAL INTERPRETATIVE CONSIDERATIONS

The geological conditions of the Peruvian coastal valleys imply that radical changes in compacity and grain size has to be expected for the alluvial fill. The river sediments are mostly composed of heterogeneous material ranging in size from silt to boulders. Gravels presently observed on the river bed are normally not representative in view of the many changes in river courses along the geological history of the erosional and depositional cycles.

The area comprising the Palpa, La Esperanza and Huando diversion weirs lies at a valley section where chaotic events have occurred many times in the past. The local mud and stone flows known as "huaycos" have built up a valley fill with complex constitution, with generalized coarse material likely to be found throughout the area. Some electrical measurements that we performed in 1981 indicated that high resistivity sediments prevail in the entire unconsolidated valley fill, down to bedrock.

Agriculture is carried out on areas where soil is partially generated through years of cultivation. At shallow depths, the "unaltered" silt-sand-gravel-boulder sediments can be found everywhere. The distribution of the finer (silt) sediments and large boulders is highly irregular, thus presenting a general mass with strong porosity variations although keeping high permeability and groundwater transmissivity.

As a result of the above described lithological features, the elastic properties of this ground are irregular in short distances but reveal strong generalized resistance to deformation. Although we do not have measurements of S-waves, the P-wave velocities are high in materials below the overburden, thus presenting good mechanical characteristics for engineering foundations.

The soil cover gives P-wave velocities in the 0.2 to 1.0 km/s (kilometers per second) range, typical of loose material. The same values apply to agricultural soil and to surface river gravels and sands. The overburden is relatively thin, reaching only few meters in depth.

Just below the overburden the alluvial material has P-wave velocities in the 2.0 to 2.8 km/s range, with only exceptional deviations away of those margins. The water saturation has certainly some influence because the ground water level is shallow, probably coincident with the contact "plain" between overburnden and alluvial fill. However, the water saturation does not have a significance of higher than 20% in this kind of silt-sand-gravel-boulder complex, and the 2.0 to 2.8 km/s elastic mass has strong mechanical properties, either dry or saturated. A good proof of this fact is evidenced where uncased holes are dug to obtain clear water for human consumption; the walls remain in good condition for long time, casing being required only for the overburden.

The bedrock velocities are high; we have determined values from 3.3 to 6.0 km/s, with prevailing 4.5 to 5.0 km/s. This rock mass must be considered as strong, only with slight fracturation and/or alterration at limited areas.

6. GEOPHYSICAL RESULTS

The interpretation of the seismic records has provided the first arrival times, at each geophone station, of the P-waves generated at the shot point locations. Consequently, a plot is prepared for each shot point, with distances to geophones on the abscissa and times on the ordinate. The resulting graphs are called "time-distance curves" and they are presented on Plates P1, E1 and H1, corresponding to Palpa, La Esperanza and Huando, respectively.

There are two time-distance curves for the same geophone spread, generated at the ends of it. The direct and reverse curves give clue to the elastic behavior of the ground affected by the explosions and represent the refracted arrivals at the geophones. They provide true average velocities for the three typical materials or "layers" encountered: overburden, alluvial fill and bedrock.

Taking into account the arrival times, to a single geophone, of waves coming from opposite directions, the seismic calculations are performed, usually with automatic programs, to determine the thicknesses of the overburden and of the alluvial fill. Depth to bedrock is then easily computed by adding the two results.

Although the theoretical process is relatively simple, the Peruvian coastal valleys give irregular time-distance traces, as it can be seen on plates P1, E1 and H1. Furthermore, the upper contact (overburden-alluvial fill) is roughly parrallel to the surface but the lower contact (alluvial fill-bedrock) has an unpredictable shape. This is the reason why it is customary to obtain time-distance curves with large overlaps, up to 83% in the present survey, in order to get several arrivals from several shot points.

All calculations were performed to obtain:

1. Velocities of the overburden, near the shot points.

2. Average velocities of the alluvial fill.

3. Average velocities of the bedrock.

4. Thickness of the overburden at each geophone station.

5. Thickness of the alluvial fill at each geophone station.

All five parameters have been processed to prepare the interpreted seismic sections of Plates P2, E2 and H2. The extremes where bedrock is becoming deeper, near the center of the valley, "loose" some 60 meters of bedrock control, due to the inherent characteristics of the reverse shooting refraction technique. As the survey was programmed with 360 meters in maximum length of geophone spreads, a 60 to 100-meter depth reach had to be expected; on the SE extreme of the La Esperanza seismic section, bedrock depths in excess of 100 meters were found, thus precluding the possiblity of thickness calculations there.

-<u>Palpa Diversion Weir</u>

As it was said before, Plate P1 contains the time-distance curves utilized for the seismic analysis. Plate P2 includes the topographic control references and the interpreted seismic section. The water intake tunnel at the Palpa weir has two cement columns with irregularly shaped crowns; the easternmost one has been used as bench-mark with an assigned elevation of -5.50 meters. There is a cement wall, E-W oriented, that can serve to define the survey line position.

The shot point at 0 distance lies on the hillside, where talus material was dug to bury the explosive charges. Shot point at distance 120 lies in water.

The overburden has 0.3 to 1.3 km/s and thicknesses in the 2 to 7-meter range. The overburden has poor mechanical compactness and at the SE extreme could in part represent the weathered zone of the rock mass.

The alluvial fill has 2.1 to 2.8 km/s of P-wave velocity, fairly uniform and revealing a strong degree of compactness and density. A high proportion of coarse grained sediments should be expected for this horizon.

Bedrock profile indicates a scarp at the SE margin, a smoothly deepening bottom of the alluvial fill to the NW. Velocities of 3.7 to 5.6 km/s are typical of hard and solid rock.

-La Esperanza Diversion Weir

As it can be seen on Plate E2, the topographic control has been referred to the top of the two cement supports of the foodgate, with an assigned elevation of -2.98 meters. The diversion canal was crossed between 480 and 540 and between 630 and 660. The sections between 0 and 90 and from 660 to 840 were surveyed over cultivated land.

The overburden along the La Esperanza seismic section shows lower velocities, due to soft soil, between 660 and 840, with velocities in the 0.2 - 0.4 km/s range and thicknesses up to 7 meters (at 840). This overburden pinches out near 150 and between 540 and 600. P velocities are somewhat higher SW of shot hole 300.

The alluvial fill of the second seismic horizon has velocities varying from 2.2 to 2.9 km/s that indicate predominance of compact coarse material down to bedrock, and for more than 100 meters in the SE end of the survey line.

Bedrock relief undulates with a general increase in depth to the SE, from a minimum of some 36 m below 780 to more than 100 m between 0 and 120. P velocities of this dense and hard rock varies in the 4.0 - 5.0 km/s range.

-Huando Diversion Weir

Plate H2 shows the topographic control references and the interpreted seismic section. The B.M. was chosen at the concrete structure of the weir itself and an arbitrary elevation of minus 5.68 meters was given to that point, also marked with red paint. The survey line goes parallel to the water fall and at 17 meters of distance; the cement wall orientation gives a good directional reference.

The originally planned shot point at 420 could not be used in view of the closeness to the road where traffic could be affected by throwing debris of explosions. Therefore, an special shot point at 405 was used to complete the line. This proved to be appropriate as a result of the strong inclination of the erosional scarp, as shown on H2.

The Huando weir area presents a more uniform overburden, as compared to the Palpa and La Esperanza zones. At Huando, the velocities are from 0.3 to 1.3 km/s with prevailing 0.6-0.7 km/s. The thickness of the low velocity "layer" is also more regular, typically from 2 to 4 meters.

The intermediate seismic horizon, the alluvial fill, has velocities in the 2.0-2.6 km/s range, with a "strange" low area below shot hole 300 where 1.5 km/s was measured and interpreted as containing a higher proportion of silt. In general, the alluvial fill behaves in a manner similar to that encountered at the other survey zones: mostly coarse material, very dense and compact.

Bedrock becomes smoothly deeper towards the SE where some 85 meters were computed below station 60. Between 390 and 405 it appears that a "pocket" with 1.8 km/s material is perhaps indicative of a probable fracture zone; this deduction is supported by the fact that slightly lower velocities were found for bedrock at the same location. From 60 to 300, bedrock P-wave velocities are high, 5.8 to 5.9 km/s, evidence of unaltered solid rock.

7. CONCLUSIONS

The seismic survey has defined a general elastic picture made up of three horizons: overburden with typically less than 1.0 km/s, alluvial fill with an average of 2.7 km/s and bedrock with some 5.0 km/s or higher where unaltered.

The overburden is generally thin, with no more than 7 meters found at few places only, and 2 to 4 meters as a rule. The 0.2 to 1.3 km/s velocities are representing loose material easily rippable with mechanical excavating devices.

The alluvial fill has a strong elastic contrast with the overburden. It has velocities higher than 2.0 km/s, evidence of coarse material with probable boulders that could present some troubles to earth-moving equipment. In any case, it is unconsolidated and the relatively high velocities are mostly due to the denser fractions (pebbles, cobbles and boulders) compacted with silt.

Bedrock is highly dense and hard.

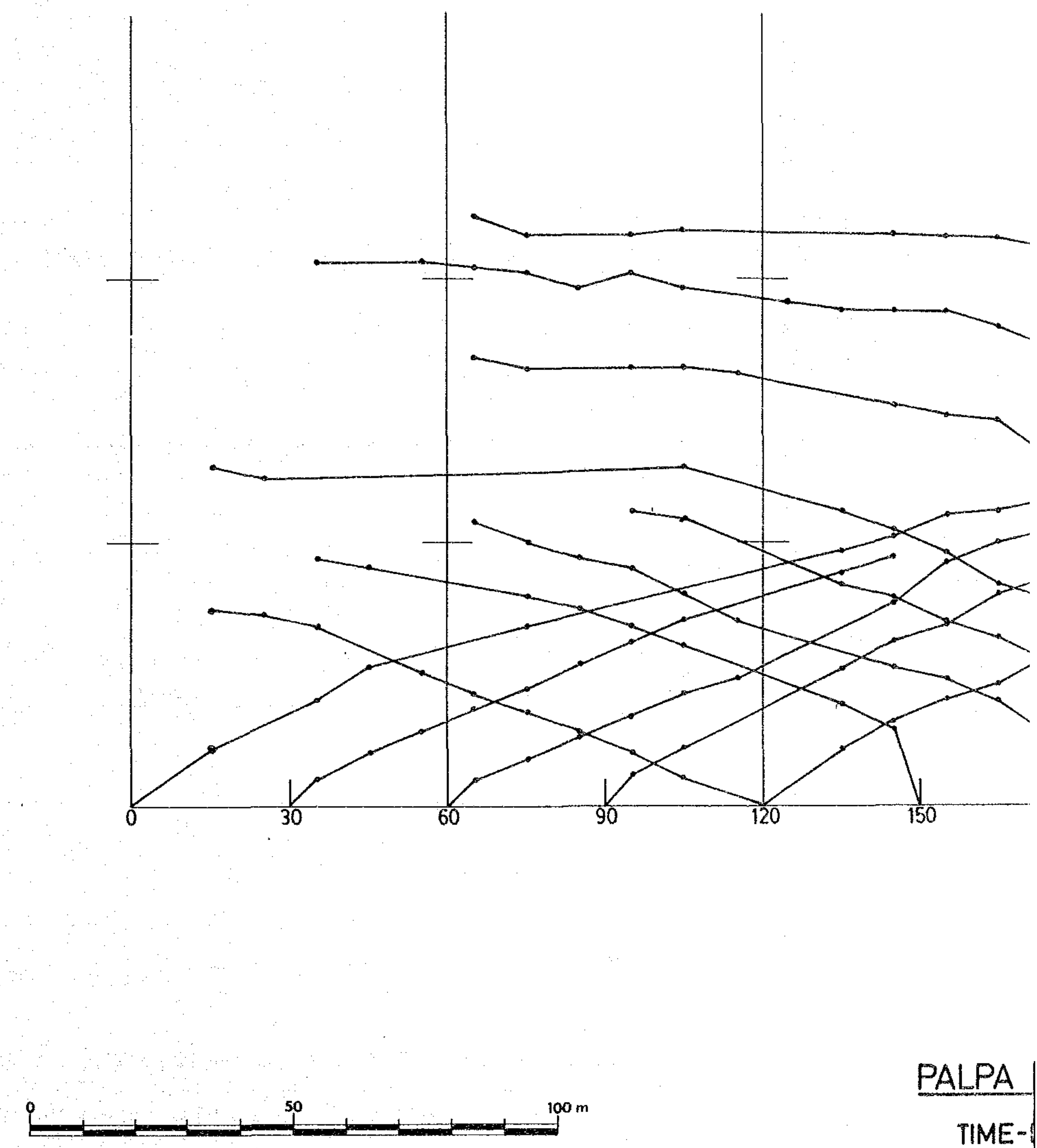
8. RECOMMENDATIONS

In view of the required shallow knowledge for structure design, the thick and compact material found as alluvial fill, below the overburden, provides excellent foundation conditions as a general feature. On the other hand the marginal areas at the left (Palpa) and right (Huando) have complex morphology that should be studied to analyzed for possible seismic resonance conditions close to bedrock. It is then advisable to determine the local natural ground vibration periods at the Palpa and Huando weir sites.

Some shallow open holes that should penetrate the overburden plus some meters in the alluvial fill are recommended to verify the accuracy of the seismic interpretation. A field geological evaluation of the selected well sites in conjunction with the geophysical data would be most desirable.

August 23, 1984

José E. Arce



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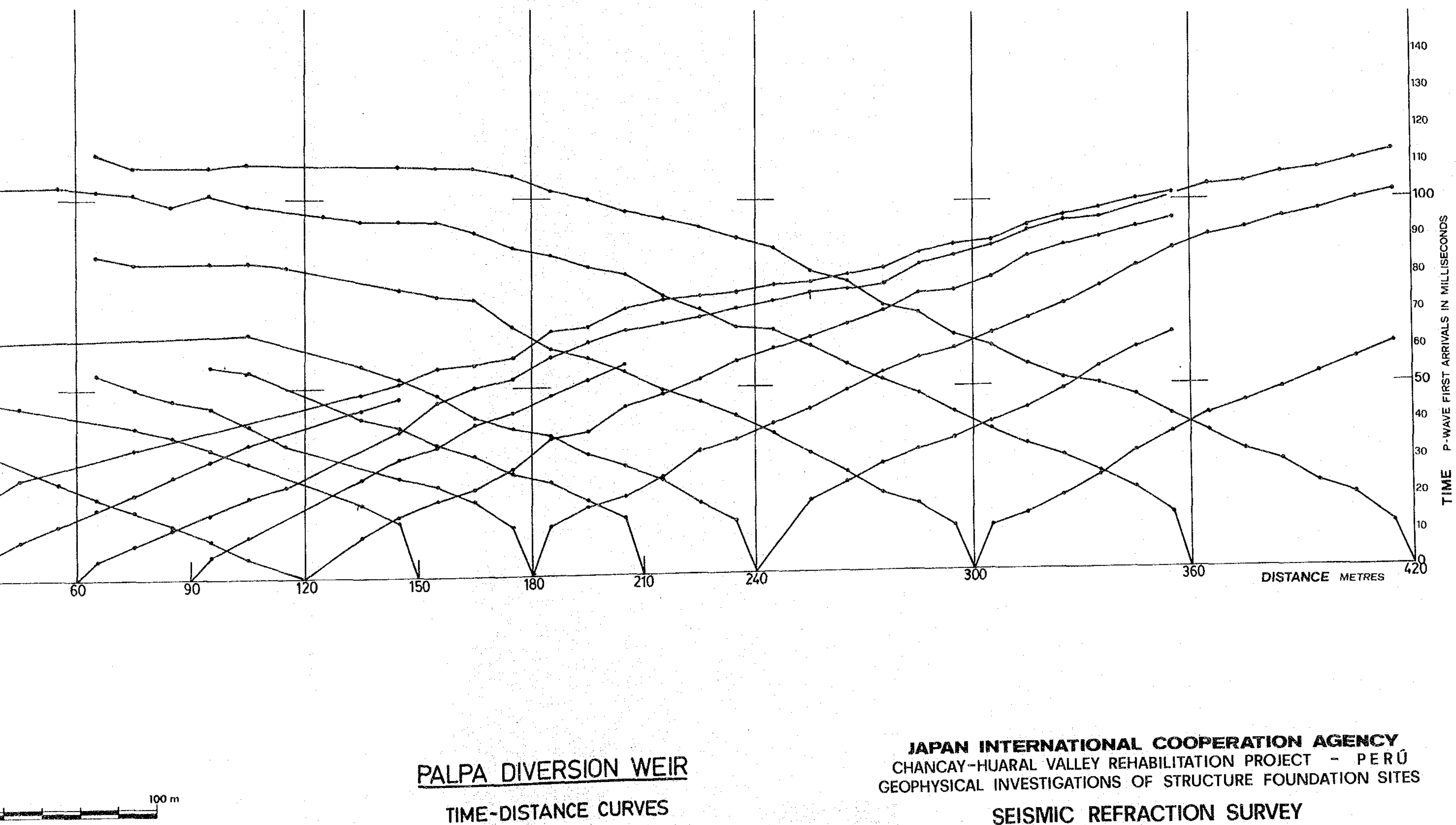
TIME-



PALPA DIVERSION WEIR

TIME-DISTANCE CURVES

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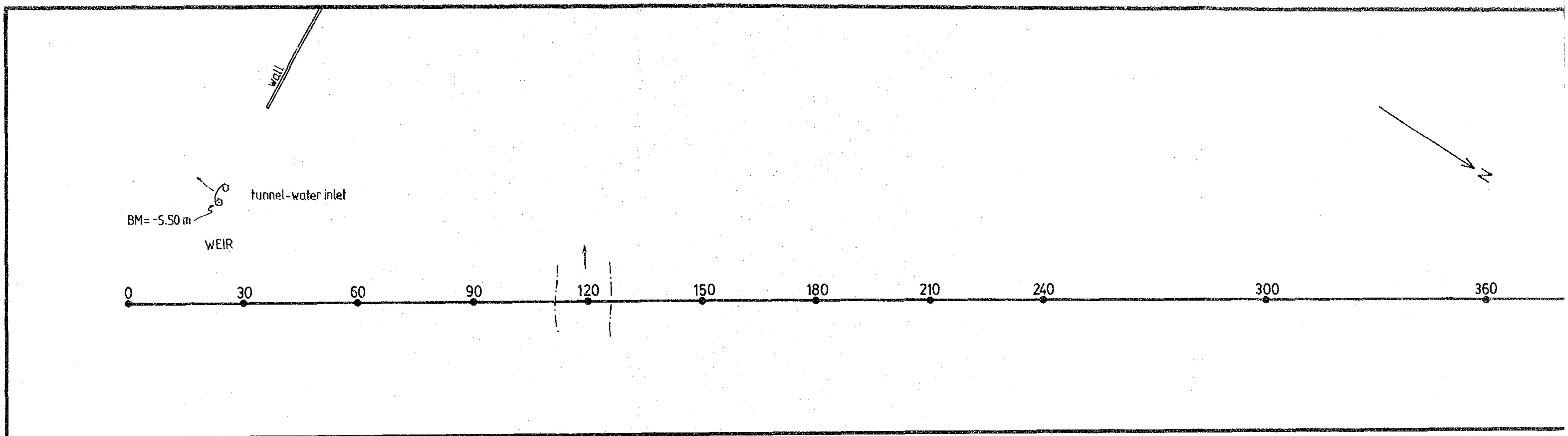
GEOPHYSICAL INVESTIGATIONS OF STRUCTURE FOUNDATION SITES

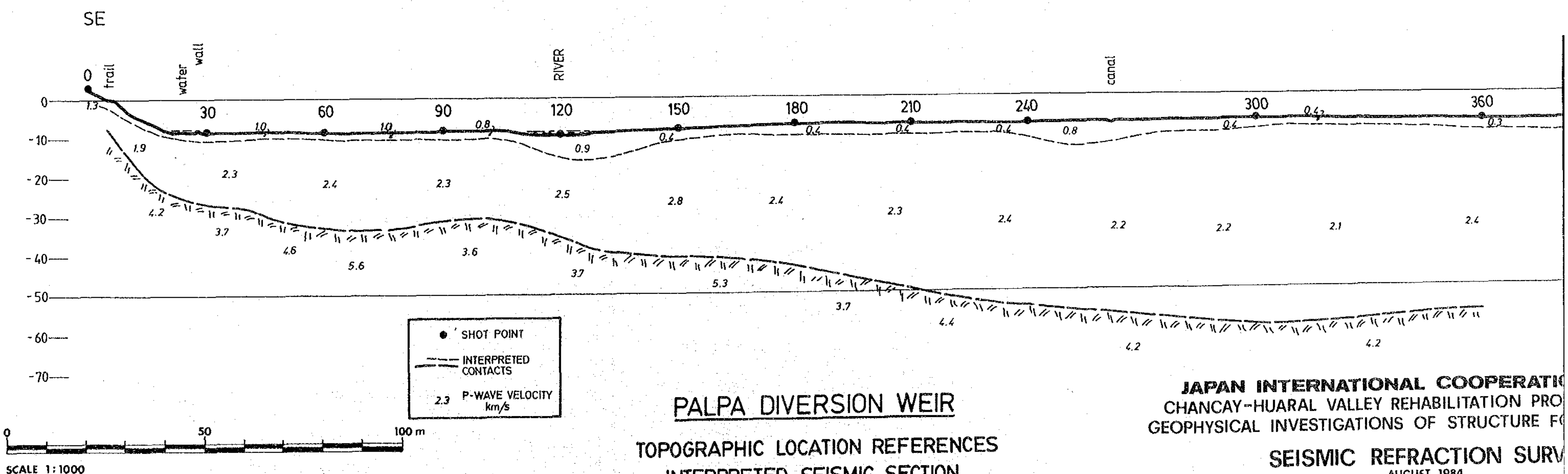
SEISMIC REFRACTION SURVEY

AUGUST 1984

JOSÉ E. ARCE HELBERG   Exploration Geophysicist, Lima - Perú   Nº 295-84

PLATE Nº P1





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TOPOGRAPHIC LOCATION REFERENCES
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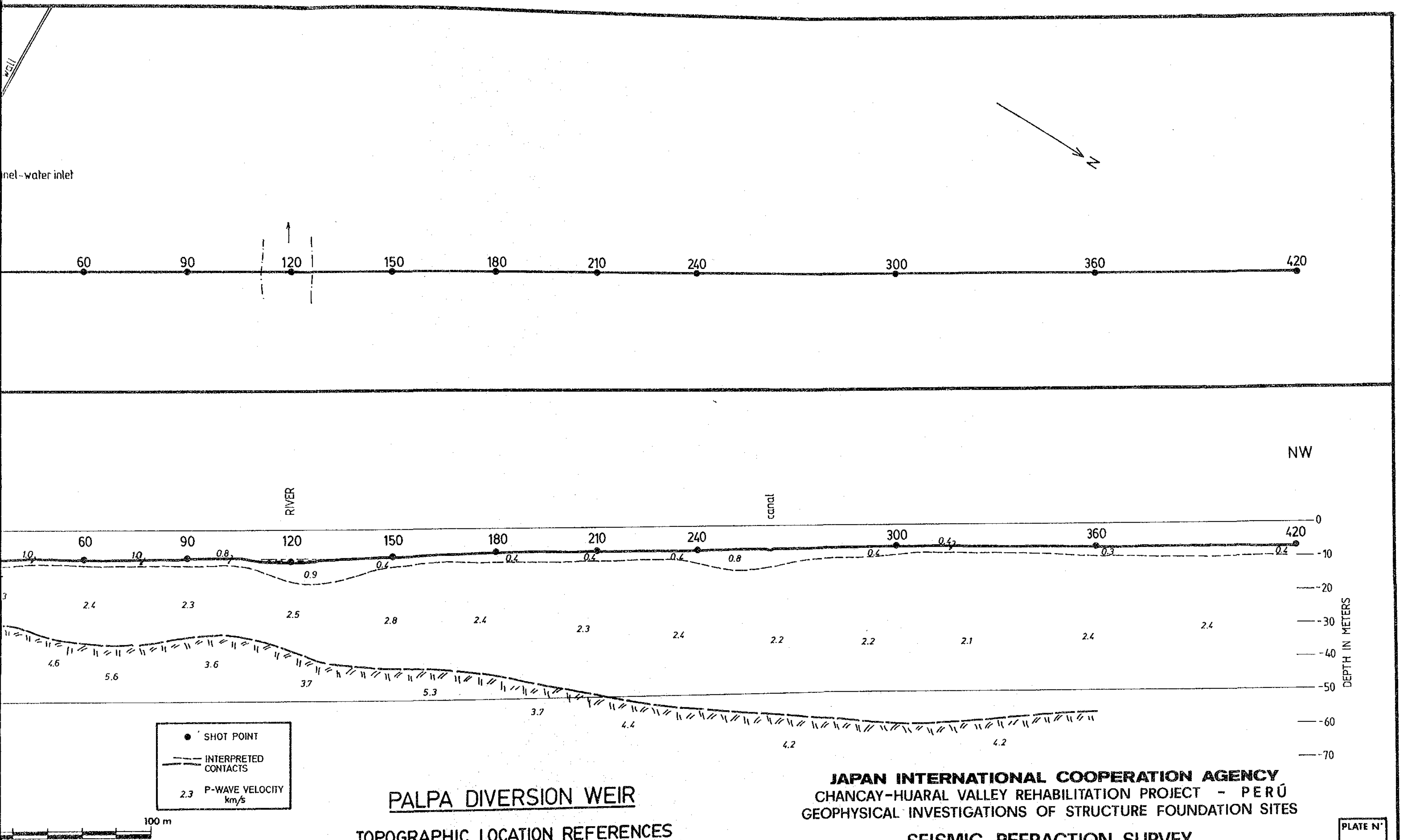

PALPA DIVERSION WEIR

TOPOGRAPHIC LOCATION REFERENCES
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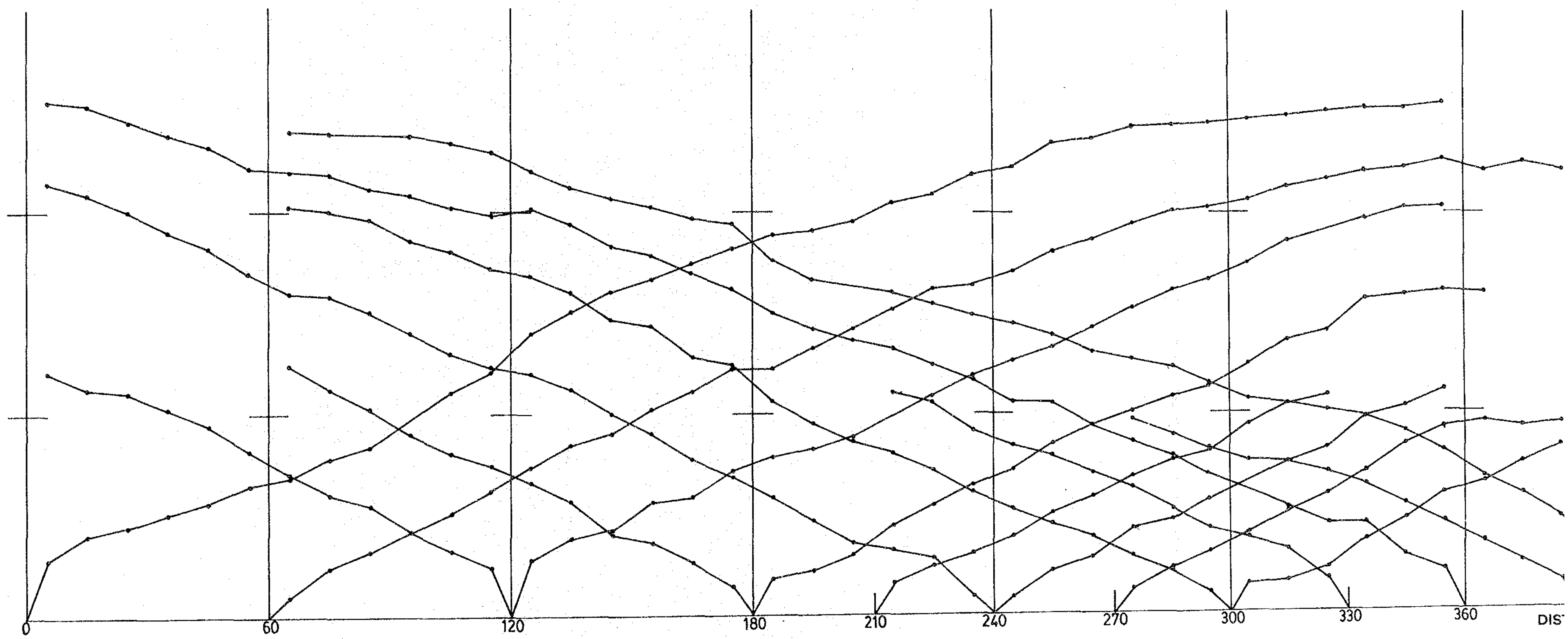
PLATE Nº P 2



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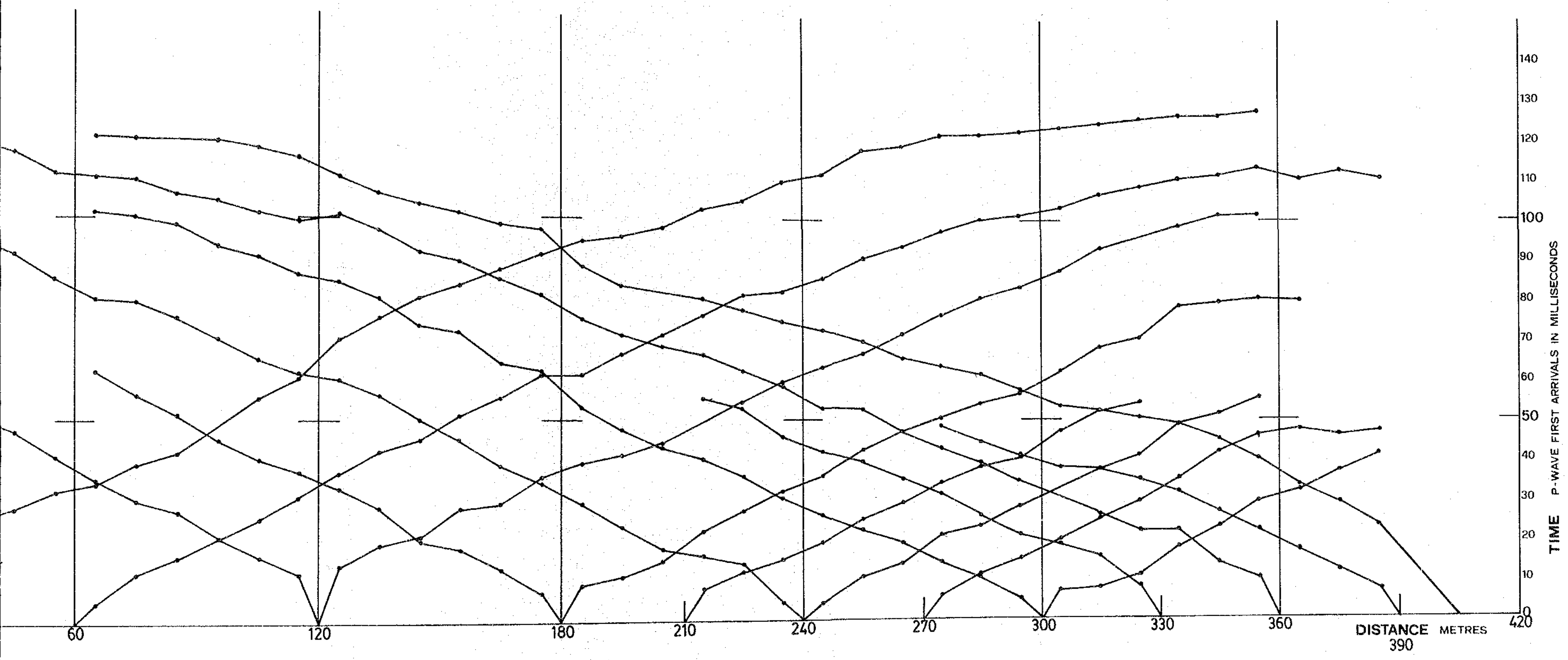

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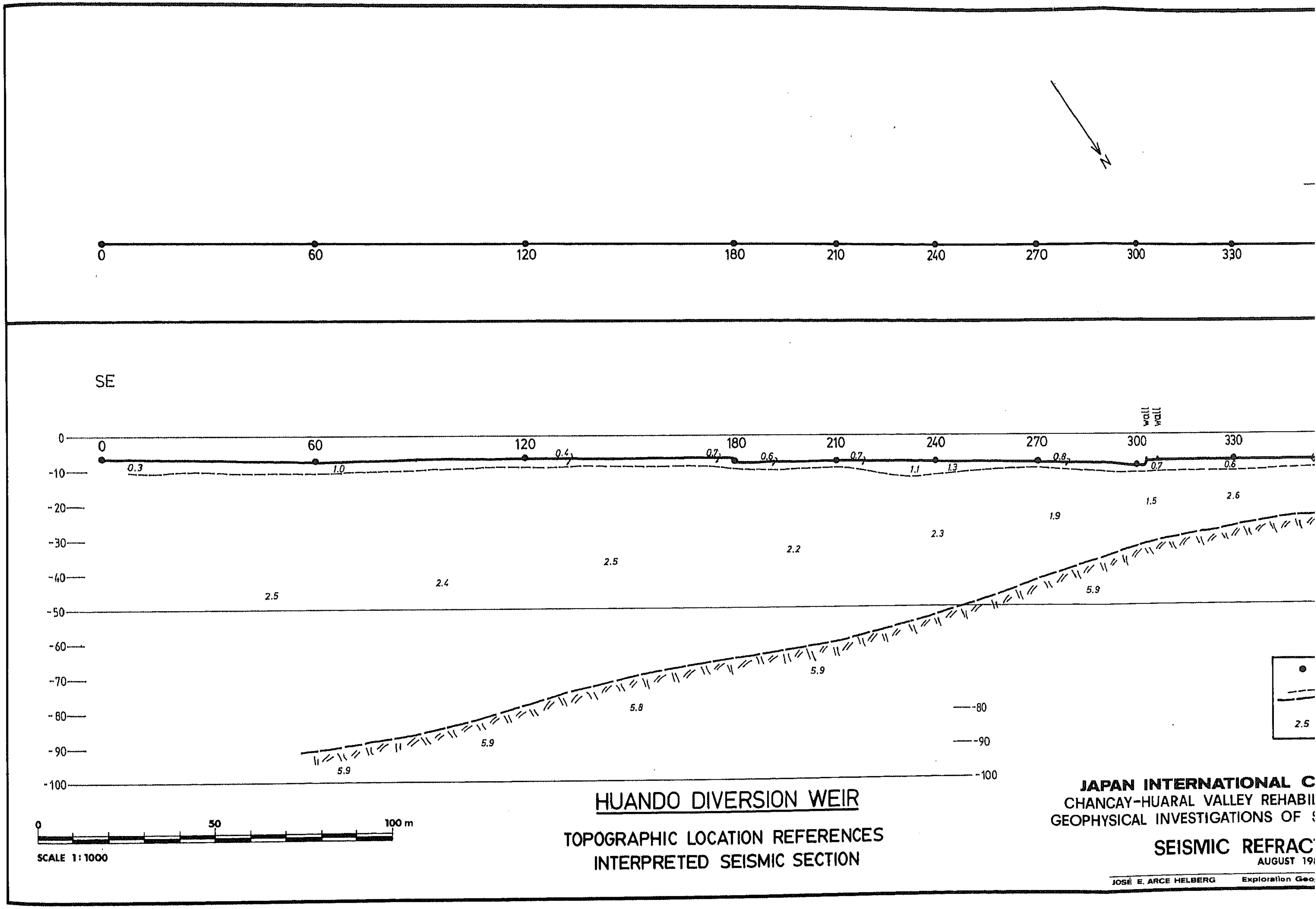
PLATE Nº H 1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SE
wall
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0.3
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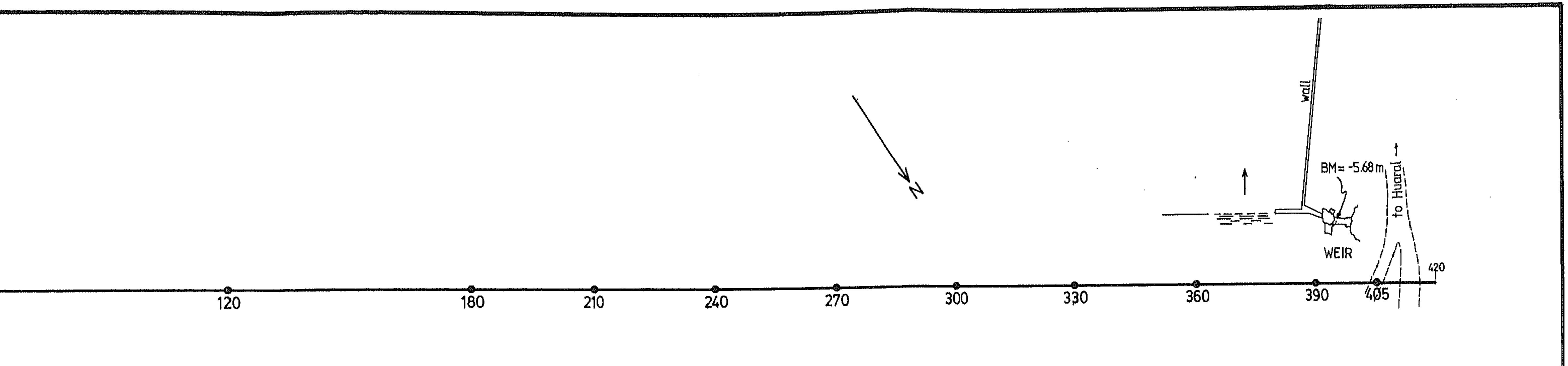
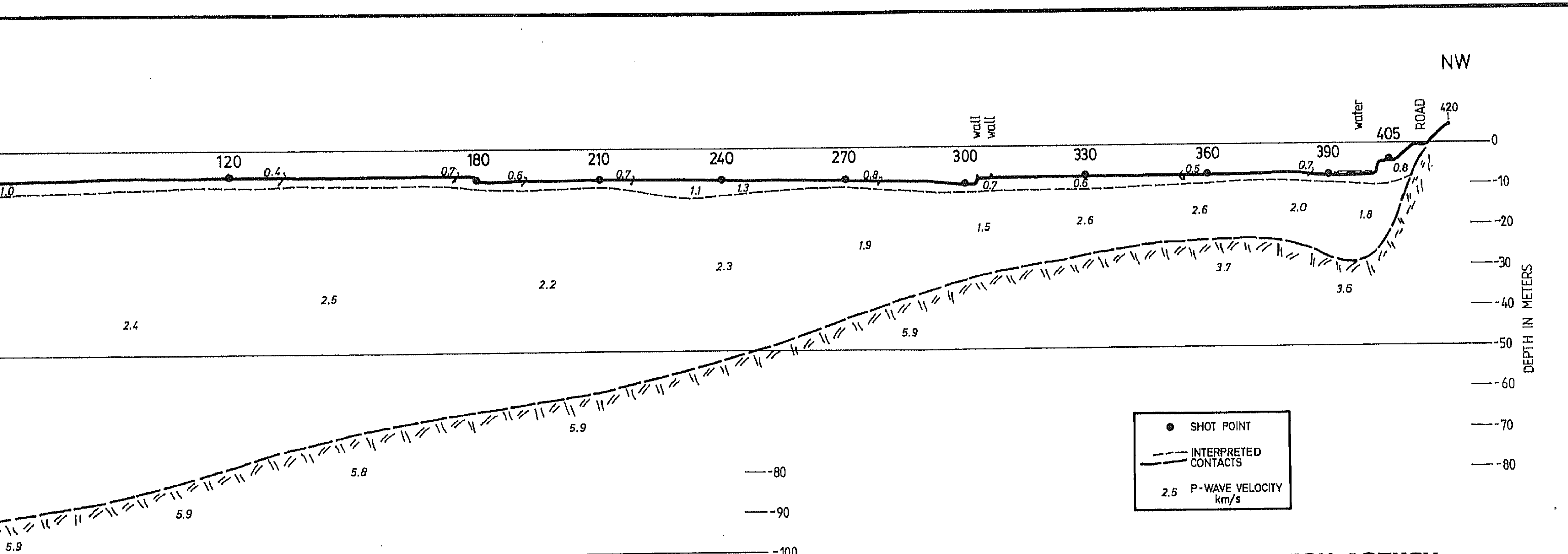
Exploration Geo





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TOPOGRAPHIC LOCATION REFERENCES
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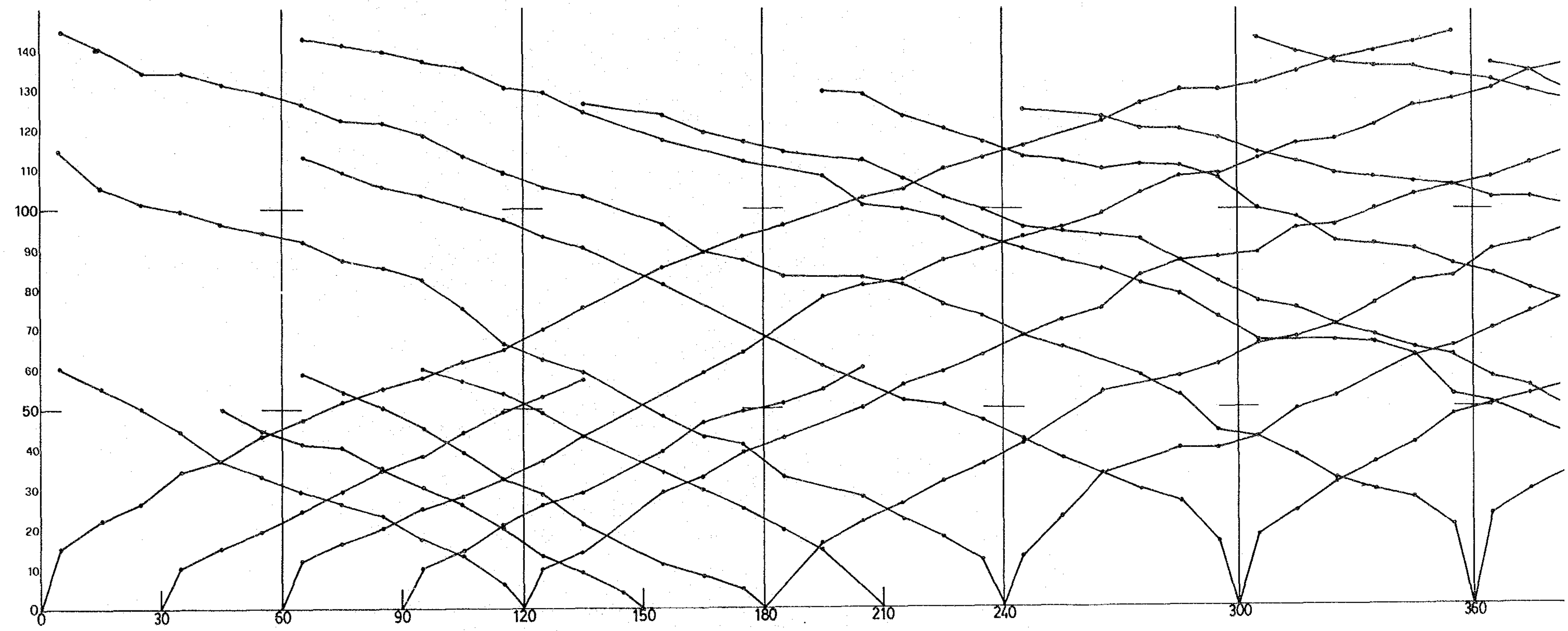
PLATE Nº
H 2



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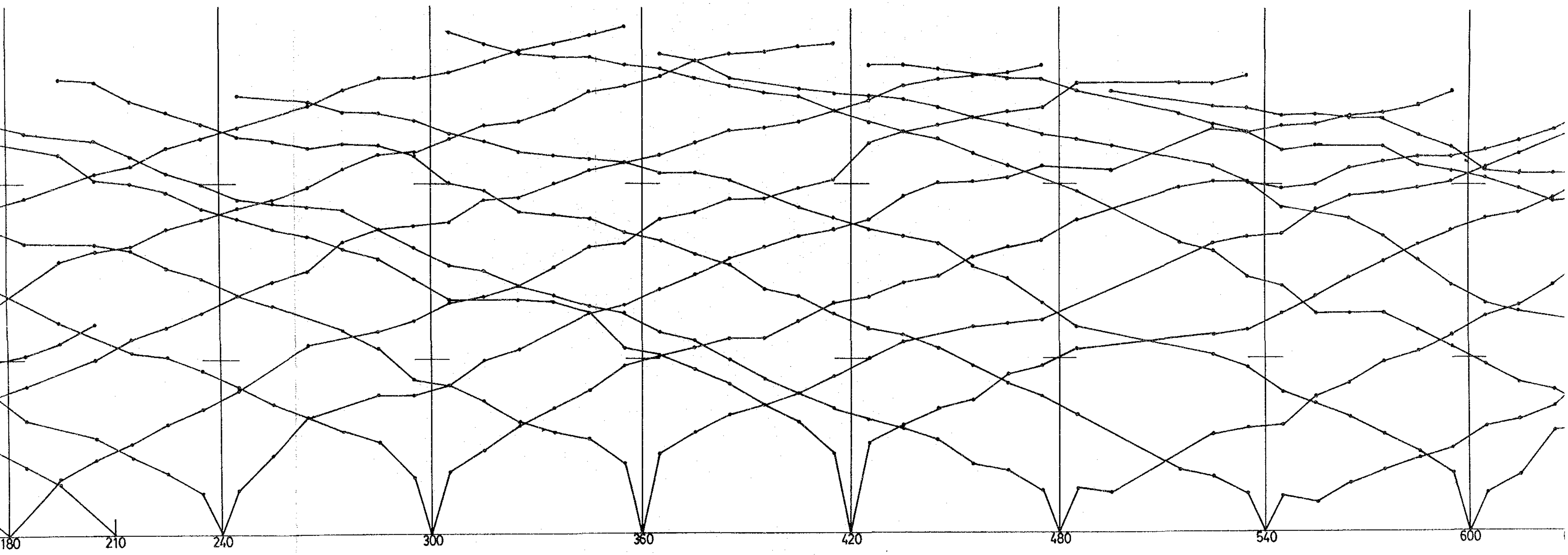

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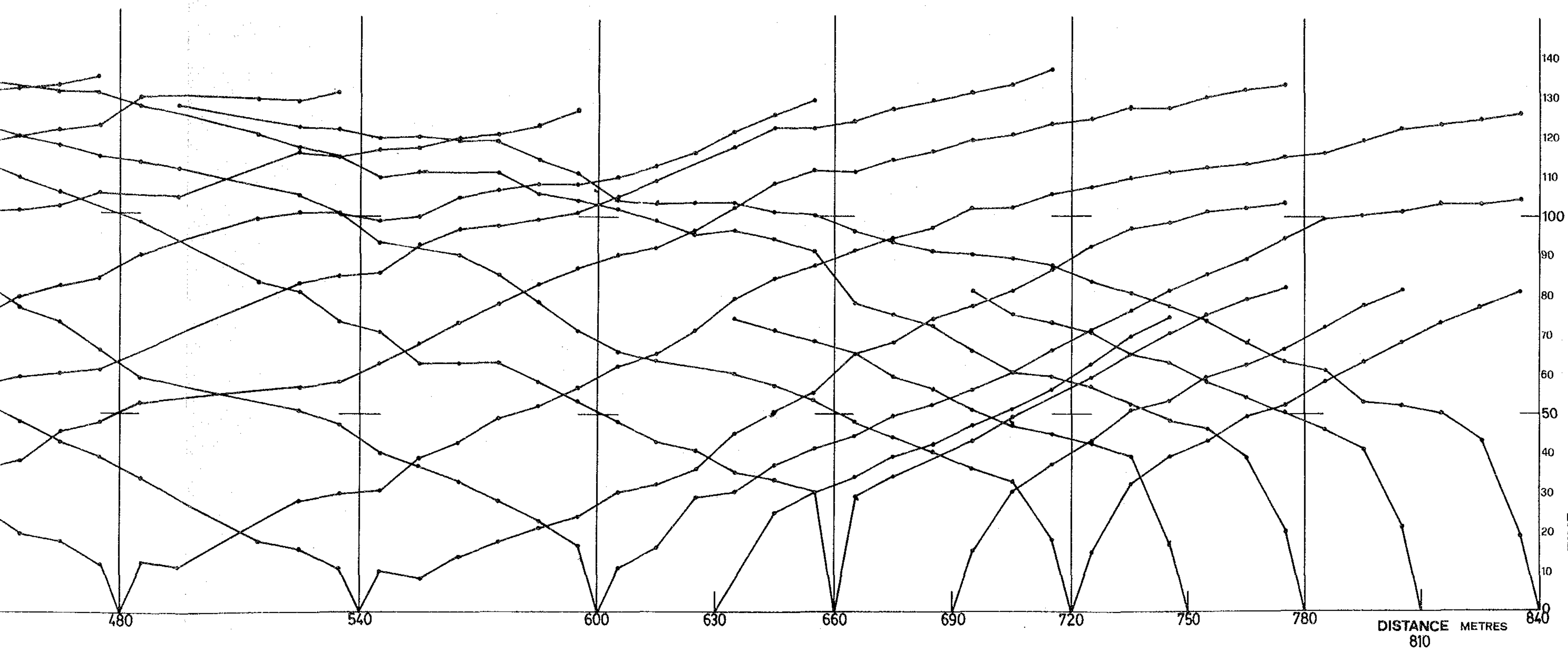
LA ESPERANZA DIVERSI

TIME-DISTANCE CUR



LA ESPERANZA DIVERSION WEIR

TIME-DISTANCE CURVES

JAPAN INTERNATIONAL COOPERATION AGENCY

CHANCAY-HUARAL VALLEY REHABILITATION PROJECT - PERÚ

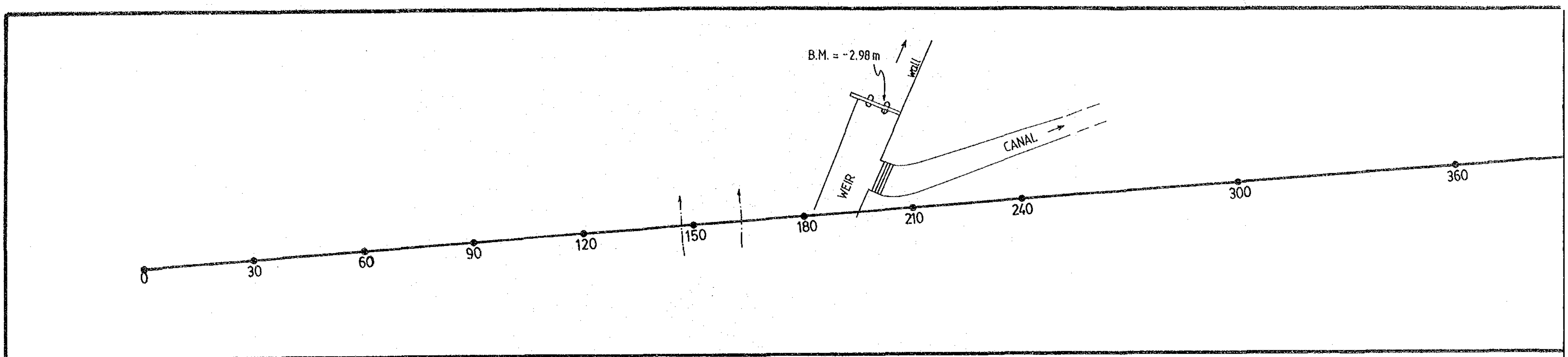
GEOPHYSICAL INVESTIGATIONS OF STRUCTURE FOUNDATION SITES

SEISMIC REFRACTION SURVEY

AUGUST 1984

JOSÉ E. ARCE HELBERG Exploration Geophysicist, Lima - Perú Nº 295-84

PLATE Nº E1



B.M. = -2.98 m
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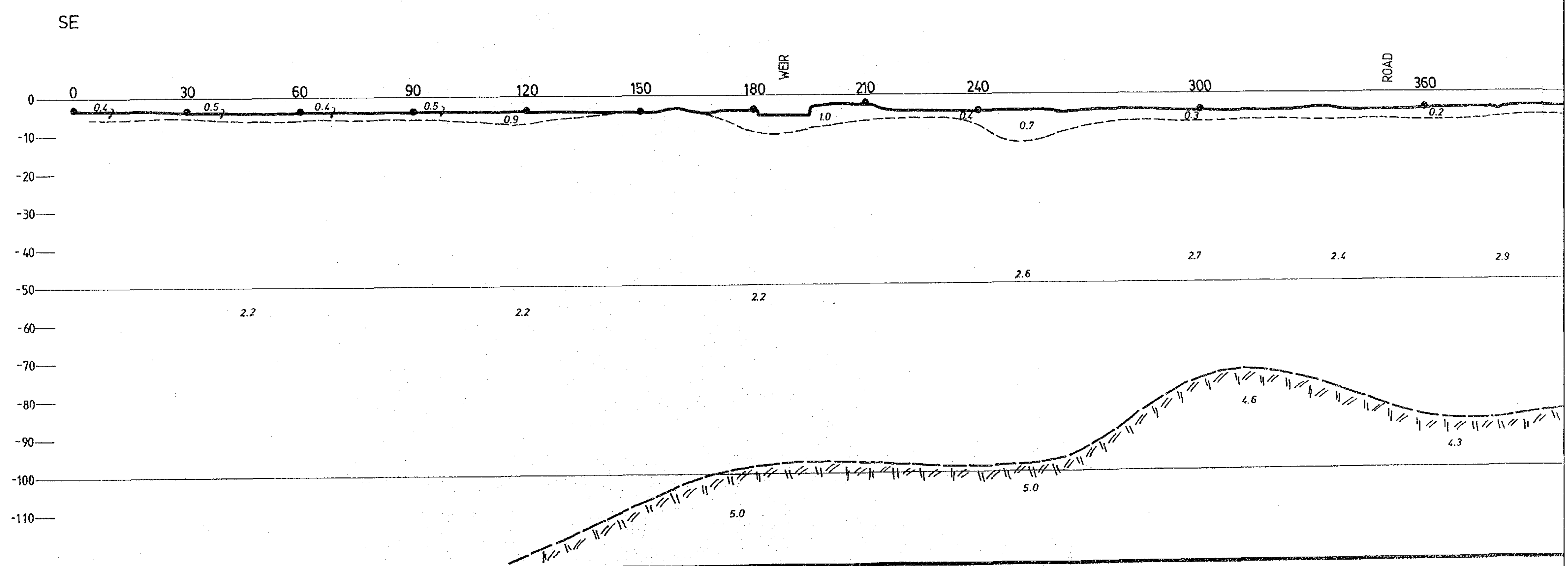

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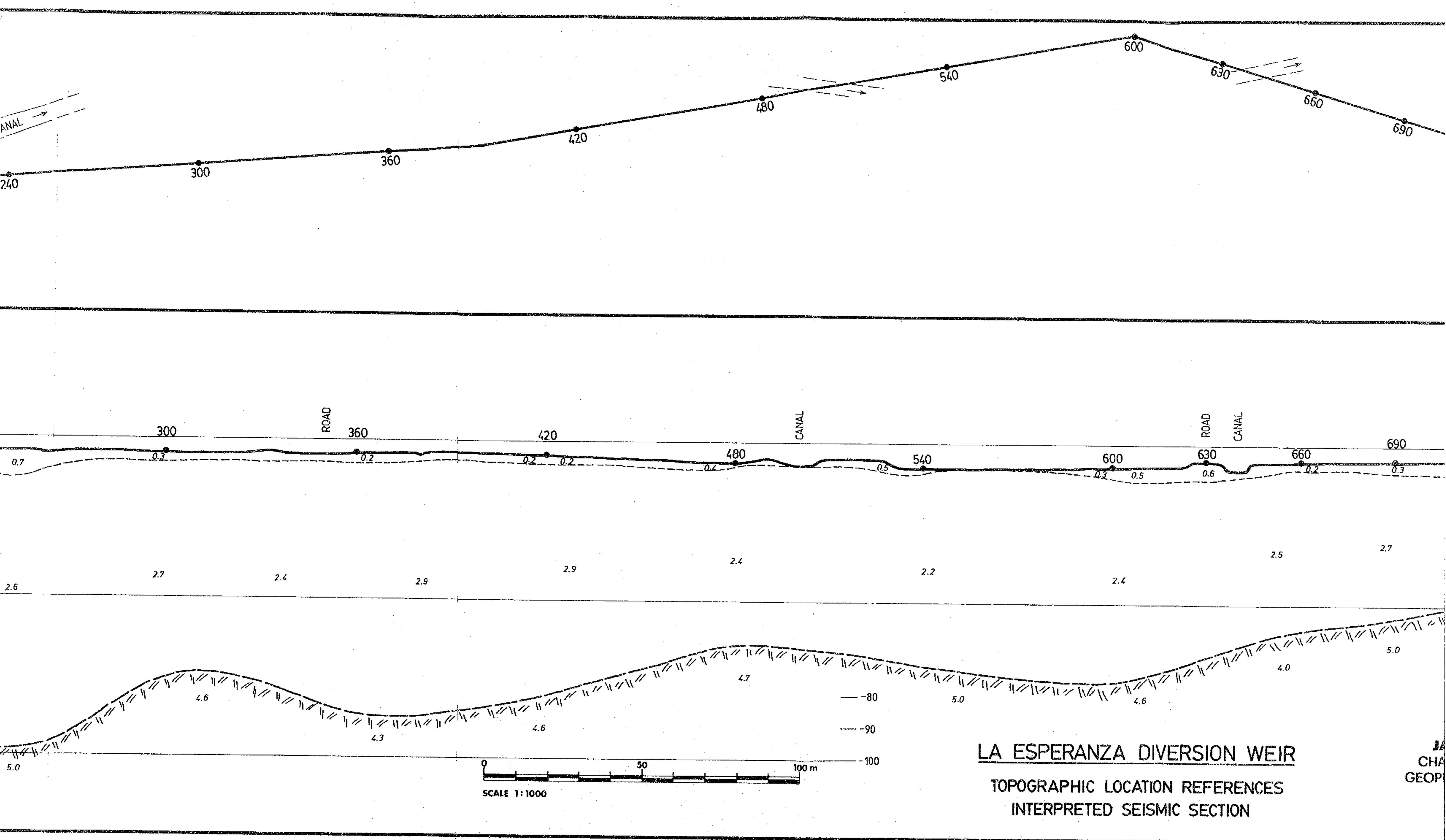

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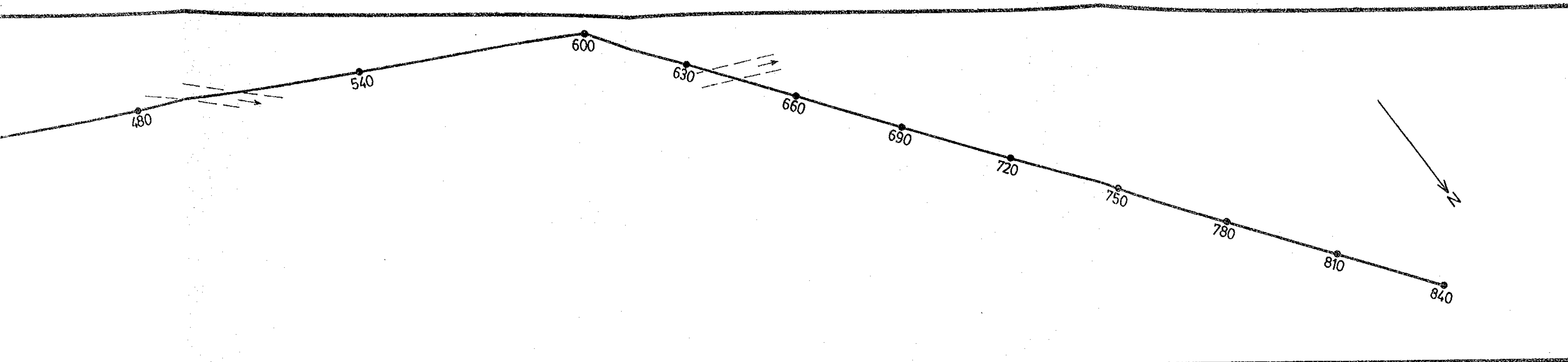

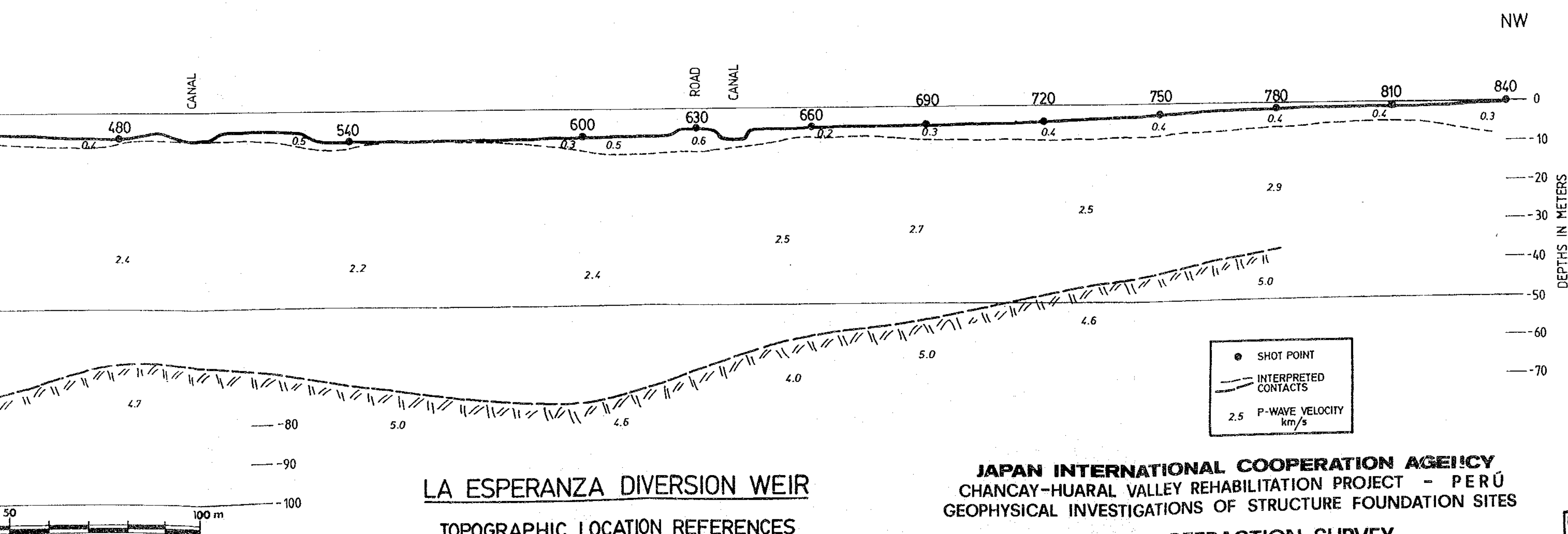

LA ESPERANZA DIVERSION WEIR

TOPOGRAPHIC LOCATION REFERENCES
INTERPRETED SEISMIC SECTION

JAPAN INTERNATIONAL COOPERATION AGENCY
CHANCAY-HUARAL VALLEY REHABILITATION PROJECT - PERÚ
GEOPHYSICAL INVESTIGATIONS OF STRUCTURE FOUNDATION SITES

SEISMIC REFRACTION SURVEY

AUGUST 1984

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PLATE Nº
E 2

ANNEX C

SOIL AND LAND CLASSIFICATION

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ANNEX C SOIL AND LAND CLASSIFICATION

1. General

The soil study was carried out with the following objectives:

a) to review and identify characteristics and distribution of soil groups;

b) to identify problem soils and distribution of the same;

c) to clarify land qualities and evaluate land qualities for irrigation farming (land classification)

The study was based on data obtained from the field surveys and from the following sources:

- "Estudio Argologico Detallado Y Zonificacion Climatica De Cultivos Del Valle Chancay-Huaral", Direccion General De Aguas, Suelos Y Irrigacion, Ministerio De Agricultura, 1974.
- "Estudios De suelus Con Fines De Riego En Cada Uno De Los Ocho Valles Del PLAN REHATIC III", Asociasion De Consultora Ingeniera (ACE), 1982.
- "Diagnostico Nuevas Areas - Margen De Recha Rio Chancay-Huaral" PLAN REHATIC, 1983.
- "Diagnostico De Los Valles - Volumen III", PLAN REHATIC, 1983.
- "Inventario, Evaluacion Y Uso Racional Los Recuros Naturales De La Costa - Valle Chancay-Huaral", ONERN, 1969.

During the field survey, soil profile and boundary were studied and the distribution of salt accumulated soils was carefully surveyed. The soil map with a scale of 1:20,000 prepared by Director General of Water, Soil and Irrigation was used as the base map. Chemical and physical soil analyses were conducted by the Laboratory of Soil and Water Analysis, Director General of Water, Soil and Irrigation.

Soil pits were used for profile observations and soil chemical and physical analyses were conducted for the resultant representative profiles. Laboratory analyses on salinity (EC) and alkalinity (ex.-Na%) were carried out on samples collected in course of the field survey on the distrubution of salt accumulated soils. The results of soil analysis are shown in Table C-1-1, C-1-2, C-3-3 and C-4-2.

The soils in the Project area have been classified into soil phases on the basis of the results of field survey and the finding of past studies mentioned earlier. Land irrigability classes for irrigation farming have been examined based on the suitability of land qualities of each soil unit for irrigation farming. The results of soil study are summarized in the soil map and the land classification map (Fig. C-5-1 and, presented in ANNEX M).

2. Outline of Soil Distribution

The distribution of ten soil series has been identified in the Project area. These soil series are classified into four groups on the basis of texture classes of surface soil (0-30cm) and the origin of parent materials as shown in Table C-2-1. The outlines of distribution and formation of these soil groups are explained in the following sections.

(1) Coarse-textured Soil/Alluvial & Colluvial Deposits

Coarse-textured soil derived from alluvial deposits of the Chancay River and colluvial deposits of neighbouring hills is distributed widely in the rightbank-upper irrigation block. In particular, in the irrigation subsector Esperanza, the distribution of this soil group is found exclusively. The topography ranges from gently sloping with undulation to nearly flat. The soil is characterized by a coarse-textured surface layer, coarse-textured to gravelly subsoil and immature with no prominent morphological development.

(2) Coarse-textured Soil/Alluvial & Eolian Deposits

Other coarse-textured soil is found along the isolated hills located in the lower part of the Project area and on gently sloping areas at the foot of Cerro Hatillo, Cerro Arana and Cerro Pasamayo.

Eolian deposits have significant influence in formation of the soil, although the primary parent material is alluvial deposits from the Chancay River. The soil is characterized by nearly uniform horizons of fine sand in a complete profile. Morghological development of the soil profile is not clear. The topography is gently sloping to nearly flat.

(3) Medium-textured Soils/Alluvial Deposits

In the alluvial plains with nearly flat to flat land forms which occupy the greater part of the Project area, medium-textured soils developed on alluvial deposits are distributed throughout most of the area. This soil group is subdivided into two subgroups; i) soil series with a coarse-textured horizon or hirzons in soil profile (0-1.5m): Tucume, Esquivel-Trujillo, Clemencia, Huaral, and ii) soil series with no coarse-textured horizon in soil profile: Mochumi, Ocuaje, Lambayeque. In both cases, the soils are immature with few morphological characteristics.

(4) Fine-textured Soil/Alluvial Deposits

The distribution of fine-textured soil derived from alluvial deposits of the Chancay River is limited and mainly found in the poorly drained area of Quincha and Donoso. The topography is generally flat with or without slight undulation.

3. Soil Classification

The 10 soil series found in the Project area are subclassified into soil phases based on land characteristics. In the present study, land characteristics presenting significant limitations for irrigation farming in the Project area including: i) ECe of surface soil, ii) coarse fragments in the surface layer, and iii) depth to sandy or gravelly layer; are taken into consideration. Other land characteristics are further evaluated in the classification of soil phases into soil units for land classification.

In the subclassification, the following phases and criteria for land characteristics are adopted:

a) well-drained salt accumulated phase: code SI (salt accumulated soils with good drainage conditions)

land characteristics	ECe (electric conductivity of saturated soil extract at 25°C) of surface soil (0-15cm)
criterion	ECe > 4ms/cm

b) poorly-drained salt accumulated phase: code SII (salt ccumulated soils in poorly drained area)

land characteristics	ECe of surface soil/ > 4ms/cm

c) gravelly surface phase: code C

land characteristics	coarse fragments in surface layer (0-30cm)
criterion	coarse fragment content > 5%

d) shallow phase (code I -- only for Tucume and Esquivel-Trujillo series)

land characteristics	depth to gravelly layer/ depth to sandy layer for Tucume series
criterion	30-60cm

e) moderately deep phase (code II -- only for Tucume and Esquirel-Trujillo series)

land charateristics	same as shallow phase
criterion	60-120cm

f) deep phase

land characteristics	depth to gravelly layer
criterion	>120cm

The principal properties of soil series and soil phases are outlined in the following section. The results of soil classification are presented in the soil map and summarized in Table C-3-1.

(1) Aucallama Series (Code AU)

1) General

The soil series is mainly distributed adjacent to the hilly area as outlined in 3.1.2. Sloping land is commonly utilized for fruit production, while flat land is for annual crop production. In the coastal area, intensive vegetable cultivation is carried out while in the poorly drained area, cotton and maize are predominant.

Soils are immature with no morphological development, and the solum is deep with uniform fine sandy texture (S-LS). Soil drainability is good to excessive while the subsurface water table is deep except in poorly drained areas.

The soil series occupies 2,542ha or about 12.6% of the total arable land in the Project area.

2) Chemical and physical properties

Cation exchange capacity is low while organic matter content is generally low. Potential moisture holding capacity is also low while permeability is rapid. Solid phase % and hardness of subsurface soil are generally high due to compaction, impeding expansion of plant roots.

3) General management practices

A major limitation of the soils for crop production is low moisture and nutrient holding capacity due to the sandy texture. Consequently, crop productivity is primarily dependent on water control. In order to mitigate the adverse effects, the following management practices are proposed.

a) water and fertilizer application should correspond to soil conditions and crop requirement;

b) subsoiling should be carried out to improve physical conditions of subsurface soil and thus promote expansion of root zones; and,

c) application of organic matter should be encouraged.

4) Phases

The soils of the series are subclassified into phases as follows:

a) Deep phase (code AU); this is the typical phase, representing the majority of soils in the soil series, and occupies 1,832ha or 9.1% of total arable land.

b) Well-drained salt accumulated, deep phase (code AUSI); in this soil phase, two soil types are included. One is highly salt accumulated soils (160ha) in Hatillo which requires desalinization for culivation and the other is slightly salt accumulated soil on sloping land presently utilized for fruit cultivation. The soil phase occupies 212ha or about 1% of arable land.

c) Well-drained salt accumulated, gravelly surface, deep phase (code AUSIC); the soil has high coarese fragment and salt content in the surface soil and is only suitable for fruit production. The soil occupies only 97ha or about 0.5% of arable land.

d) Poorly-drained salt accumulated, deep phase (code AUSII); the soil is mainly distributed in the drainage improvement study area in Boza. Salt accumulation varies from slight to high and the greater parts of the highly salt accumulated area are under swampy grassland. The soil occupies 401ha or about 2% of arable land.

(2) Esperanza Series (code EP)

1) General

The soils in this series are mainly distributed in the irrigation subsector Esperanza as already outlined in 2. Almost all land covered with the soils of this series is utilized for fruit cultivation such as citrus and apple. The same account for the greater part of fruit production in the Project area.

The soils are immature with no morphological development and are characterized by a coarse-textured surface layer and limited depth to the gravelly layer. The coarse-textured (medium sand to loamy sand) surface layer of about 30cm depth is underlain by a coarse sandy to coarse sandy gravelly layer. Soil drainability is excessive and the subsurface water table is generally deep due to physiographical position.

These soils cover 4,020ha or about 19.9% of arable land.

2) Chemical and physical properties

Chemical properties of the soils of this series are poor and the potential moisture holding capacity is very low due to soil texture. Permeability is rapid to very rapid while subsoil is generally too compacted to allow root penetration of annual crops.

3) General management practices

As in the case of the Aucallama series, the major limitation for crop production is low moisture and nutrient holding capacities of the soil, although these limitations are more pronouned in the Esperanza Series. In general, sucessful cultivation of annual crops is impossible without intensive water management. In case of fruit cultivation, however, once a fruit tree has established root zones deep in the subsoil, the roots absorb irrigated water which has permeated the subsoil and thus irrigation efficienty is higher than that for annual crop cultivation. However, intensive water managment corresponding to soil moisture conditions is necessary until fruit trees have established expanded root zones in the subsoil. Despite limitations, therefore, the soils of Esperanza series are considered more suitable for fruit production than for annual crop production.

The following management practices are proposed in the Project area:

a) application of organic matter to improve both water and nutrient holding capacity;

b) irrigation water management based on soil moisture characteristics; and,

c) split application of fertilizer.

4) Phases

The soils of this soil series include salt accumulated soils and gravelly surface soils as follows:

a) Shallow phase (code EP); this is the typical phase of the soil series and covers 2,422ha or about 12% of arable land.

b) Well-drained salt accumulated, shallow phase (code EPSI); this soil phase is widely distributed on sloping land adjacent to hilly areas or the desert laying outside the Project area. Salt accumulations is generally slight to moderate and found only in the surface soil and thus does not have a significant effect on fruit production. The soil phase occupies 1,138ha or about 5.6% arable land.

c) Gravelly surface, shallow phase (code EPC); the content of coarse fragments in the surface layer is 5-15% with no significant effect on fruit cultivation. The soil occupies 198ha or about 1% of arable land.

d) Well-drained salt accumulated, gravelly surface, shallow phase (code EPSIC); the content of coarse fragments is 5-15% and salt accumulation is generally moderate. The soil occupies 174ha or about 0.9% of arable land.

e) Poorly-drained salt accumulated, shallow phase (code EPSII); the distribution is found in the drainage improvement study area in Quincha and is limited to 88ha. Salt accumulation is slight to high.

(3) Tuccume Series (code TC)

1) General

The soils of this soil series are mainly distributed on the middle and upper terraces of the Project area. Extensive distribution is found in the irrigation subsector Retes-naturares, Miraflores-San Jose, Boza-Aucallama and Chancay Bajo covering land forms which are slightly sloping to flat with or without undulation.

The soils are utilized predominantly for annual crop production and are characterized by medium-textured (SL-L) surface soil and coarse-textured (S-LS) subsoil to the bottom of the soil profile. The same are subclassied into shallow and moderately deep phases according to the thickness of surface medium-textured soil which varies from 30 to 80cm. Soil drainability is good while the subsurface water table is generally deep.

The soils cover 1,962ha or 9.7% of arable land.

2) Chemical and physical properties

Cation exchange capacities of surface soil and coarse-textured subsoil are low to moderate and low, respectively. Potential moisture holding capacity is moderate or low to moderate depending on the depth of medium-textured soil. Permeability is good and both the solid phase % and soil hardness of subsurface soil tend to be high.

3) General management practices

Compared to the preceding two coarse-textured soil series, limitations for irrigated farming are less significant with the Tuccume series. However, insufficient moisture and nutrient holding capacity still presents limitations for higher crop productivity. A further limitation is the compacted subsurface soil which hinders expansion of plant root zones. The following management practices should be adopted, especially for shallow phase soils:

a) irrigation water management based on soil moisture conditions and crop requirement;

b) split application of fertilizer;

c) application of organic matter; and,

d) subsoiling to improve subsurface soil.

4) Phases

The soils of this series are subclassified into the following soil phases.

a) Shallow phase (code TCI); depth to the sandy subsoil is shallow, in general 30-40cm, although the effective soil depth is deep. The soil occupies 877ha or about 4.3% of arable land.

b) Poorly-drained salt accumulated, shallow phase (code TCISII); the soil is mainly distributed in Quincha and Donoso. Degree of salt accumulation differs from slight to high. The soil occupies 147ha or about 0.7% of arable land.

c) Moderately deep phase (code TCII); the soil has a moderately deep medium-textured soil layer of about 80cm. Management practices mentioned above are recommended. The soil occupies 845ha or about 4.2% of arable land.

d) Poorly-drained salt accumulated, moderately deep phase (TCIISII); the soil is distributed in Quincha and Donoso. Salt accumulation is slight to high. The soil occupies only 93ha or about 0.5% of arable land.

(4) Esquivel-Trujillo Series (code ES)

1) General

This soil series has the largest distribution among soil series found in the Project area. Considerable extension of this series is recognized in the irrigation subsector Jesus Del Valle-Esquivel, Chancay Bajo, Pasamayo, Retes-Naturales and Palpa-Caqui. Land forms vary from flat to sloping with or without undulation, although in general the same are flat to nearly flat. The soils of this series are mainly utilized for annual crop production. In Chancay Bajo and Pasamayo, vegetable cultivation is extensively carried out while in the sloping area, fruit cultivation is predominant.

The soils are immature with no morphological development. Medium-textured (SL-L) surface soil in varying depth is underlain by a sandy-cobbly layer with a cobble content of around 30%. Therefore, the effective soil depth is shallow to moderately deep depending on the depth to the sandy-cobbly layer. In addition, about 40% of these soils have a coarse fragment content in the surface layer of over 5%. The gravelly properties of the soils present limitations for irrigation farming. Soil drainability is good and the subsurface water table is generally deep.

The soils of this series occupy 5,262ha or about 26% of arable land.

2) <u>Chemical and physical properties</u>

Cation exchange capacity of surface soil is low to moderate. Potential moisture holding capacity is moderate to low largely dependent on the depth of medium-textured surface soil and coarse fragments in soil profile. Permeability is moderately rapid.

3) <u>General management practies</u>

Major limitations which some of the soils of this series have for irrigation farming are limited depth to cobbly layer and coarse fragments in the surface layer. The former limits potential root zones for crops while the latter influences workability of the soil. Both limitations are closely related to availability of moisture and natrients for crops. As countermeasures to improve availability of the same, the following management practices are recommended:

a) irrigation water management based on soil moisture conditions;

b) split application of fertilizer; and,

c) in corporation of organic matter to improve water and untrient holding capacity.

As for soils with moderate to high coarse fragment content (over 15%), occasional stone picking which is generally practiced in the Project area, is recommended for annual crop production.

4) Phases

The soils of this series are subclassfied into shallow and moderately deep phases. Both phases include gravelly surface soils and salt accumulated soils.

a) Shallow phase (code ESI); the effective soil depth of the soil is shallow, about 30-40cm. However, this is not detrimental to successful annual crop production, if water management relevant to soil moisture characteristics is practices as previously mentioned. The soil occupies 1,304ha or 6.5% of arable land.

b) Gravelly surface, shallow phase (code ESIC); the soil is mainly distributed in Esquivel and Laureres. Coarse fragment content in the surface layer varies from low to moderate (5-30%). Stone picking is generally practiced in fields with moderate content and is required to improve workability. Agricultural potential is primarily dependent on water management. The soil occupies 1,176ha or about 5.8% of arable land.

c) Well-drained salt accumulated, gravelly surface, shallow phase (code ESISIC); the distribution is limited to sloping areas of the upper terrace in the irrigation subsector Palpa-Caqui. The land is utilized for fruit cultivation. The soil has strong limitations for annual crop production and occupies 153ha or about 0.8% of arable land.

The following two phases are found in poorly drained areas with limited extension and a generally low degree of salt accumulation.

d) Poorly-drained salt accumulated, shallow phase (code ESISII); limited to 47ha or about 2% of arable land.

e) Poorly-drained salt accumulated, gravelly surface, shallow phase (code ESISIIC); limited to 109ha or 0.5% of arable land.

f) Moderately deep phase (code ESII); the soil is widely distributed in the Project area, but mainly in the irrigation subsector Pasamayo and Retes-Naturares. The effective soil depth is moderately deep, in general about 80cm. There is no major limitations for annual crop production; however, management practices to improve availability of both moisture and natrients should be taken to realize agricultural potential. The soil occupies 1,677ha or about 8.3% of arable land.

g) Gravelly surface, moderately deep phase (code ESIIC); the soil is mainly distributed in the irrigation subsector Jesus Del Valle-Esquivel. The coarse fragment content in the surface layer is generally between 5-15%, which does not significantly affect workability. Management practices similar to the moderately deep phase are recommended. The soil occupies 634ha or 3.1% of arable land.

h) Well-drained salt accumulated, gravelly surface, moderately deep phase (code ESIISIC); both the degree of salt accumulation and coarse fragment content are low. The distribution is limited to 32ha or about 0.2% of arable land.

i) Poorly-drained salt accumulated phase (code ESIISII); the distribution is mainly recognized in the drainage improvement study area of Luna Villca. Degree of salt accumulation is moderate in general. The soil occupies 130ha or about 0.6% of arable land.

(5) Clemencia Series (code CL)

1) General

The soils of this series occupy 695ha or about 3.4% of total arable land and are mainly found in the irrigation subsector Pasamayo and Chancay Bajo. The topography is generally flat to nearly flat and the soils are generally utilized for annual crop production.

Morphological development of the soils is not clear. The soil profile is characterized by the stratifications of soil layers with a medium-textured (SL-L) surface layer of 30 to 50cm depth underlain by a coarse-textured (LS-S) soil layer of 30 to 50cm thickness which rests on another medium-textured (SL-L) soil layer. The effective soil depth is deep and soil drainability is generally good. The subsurface water table is deep except in poorly drained areas.

2) Chemical and physical properties

Cation exchange capacity of the surface soil is low to moderate and organic matter content is generally low. Potential moisture holding capacity is moderate and permeability is moderately rapid. Compaction of subsurface soil is generally noticed.

3) Phases

Small patches of salt accumulated soils and gravelly surface soils are included in the soils of this series. The series is subclassified into the following phases:

a) Deep phase (code CL); this phase accounts for the greater part of the soil series. The soil has no major limitations for irrigation farming; however, the following management practices are recommended to increase crop productivity:

- irrigation and fertilization relevant to soil characteirstics
- organic matter application
- subsoiling to improve physical conditions of subsurface soil

The soil represents 603ha or about 3.0% of arable land.

b) Poorly-drained salt accumulated, deep phase (CLSII); distribution is limited to 68ha and is mainly found in the drainage improvement study area of San Luis. Degree of salt accumulation is moderate to high.

c) Gravelly surface, deep phase (CLC); the soil occupies only 24ha. The content of coarse fragments in the surface layer is about 10%.

(6) Huaral Series (HU)

1) General

The distribution of this series is limited in area and is mainly found in the rightbank-central irrigation block. Topography is generally flat, and the land is utilized for annual crop production.

The effective soil depth is moderately deep restricted by an underlying gravelly layer. A medium-textured (SL-L) surface layer of varing depth (30cm in average) is underlain by a fine-textured (CL-SCL) soil layer of varying thickness, in general about 50cm, which is followed by a gravelly layer consisting of gravel and cobble. Soil drainability is moderate.

The soils represent only 309ha or about 1.5% of arable land.

2) Chemical and physical properties

Cation exchange capacity of the surface layer is moderate and organic matter content is moderate to low. Potential moisture holding capacity is moderately high, while permeability is moderate to moderately rapid. Compaction of subsurface soils is generally recognized.

3) Pases

The soils include salt accumulated soils and gravelly surface soils as set in below:

a) Moderately deep phase (code HU); the soil has no major limitations and considerably high productivity is anticipated. Subsoiling and organic matter application is recommended to improve the physical conditions of subsurface soil. The soil occupies 90ha or about 0.4% of arable land.

b) Poorly-drained salt accumulated, moderately deep phase (HUSII); degree of salt accumulation is generally slight. Similar agricultural potential is expected through salinity control measures. The soil covers 165ha or 0.8% of arable land.

c) Gravelly surface, moderately deep phase (HUC); the coarse fragment content in the surface layer is in the range of 5-15%. The soil occupies 54ha or about 0.3% of arable land.

(7) Mochumi Series (code MCH)

1) General

The soils of the series are widely distributed on the middle terrace of the Project area. The relief is generally flat to nearly flat, and the land is predominantly utilized for annual crop production, usually cotton and maize.

The soils generally have homogeneous medium-textured (SL-L) solum. The morphological development of the soil profile is not clear. The effecive soil depth is deep and soil drainability is moderate. The subsurface water table is deep except in poorly drained areas. The soils cover 3,850ha or about 19.1% of arable land.

2) Chemical and physical properties

Cation exchange capacity is moderate and organic matter content is generally low. Potential moisture availability is moderate to high while permeability is moderate. The solid phase and hardness of subsurface soil is generally high. In some areas, the subsurface soil is densely compacted to the extent that it hinders root penetration and, as a result, root zones are limited to the superficial layer.

3) Phases

The soils of this series include salt accumulated soils of limited extension and minute patches of gravelly surface soils. The series in subclassified into the following phases:

a) Deep phase (code MCH); the soil has no major limitations for irrigation farming and has high agricultural potential. Organic matter application and subsoiling are preferable together with adquate water and fertilizer supply so as to ascertain anticipated crop production. The phase occupies 3,158ha or about 15.6% of arable land.

b) Poorly-drained salt accumulated, deep phase (code MCHSII); the soil is mainly distributed in the poorly drained areas of Quincha and Donoso. Degree of salt accumulation ranges from slight to high. For desalinization, both drainage improvement and leaching should be planned. Achievement of agricultural potential similar to that of the deep phase is expected by desalinization. The soil occupies 652ha or about 3.2% of arable land.

c) Gravelly surface, deep phase (code MCHC); distribution is limited to 40ha. The content of coarse fragments in the surface layer is in the range of 5-15%.

(8) Ocuaje Series (code OC)

1) General

Distribution of the soils in this series is limited to 360ha or 1.8% of arable land in the Project area and is chiefly found at Cap Palpa and Cap Huaca. The topography is flat to slightly sloping. Cultivation of cotton is ususally practiced.

The soils have deep effective soil. The medium-textured (SL-L) surface layer of 30 to 60cm depth is underlain by fine-textured (CL-SCL) subsoil of varing thickness (20-50cm) which lies on another medium-textured soil layer. Soil drainability is moderate while the subsurface water table is generally deep.

2) Chemical and physical properties

Cation exchange capacity of the surface soil is moderately high and organic matter content is moderate to low. Potential moisture holding capacity is moderately high, while permeability is moderate to moderately rapid. Compaction of subsurface soil is generally noted.

3) Phases

The soils of this series are subclassified into two phases as follows:

a) Deep phase (code OC); the soil has no major limitations for crop production and high productivity is expected. Management practices such as subsoiling, organic matter application and adequate fertilization are required in order to realize potential productivity. The soil occupy 306ha or 1.5% of arable land.

b) Poorly-drained salt accumulated, deep phase (OCSII); the soil has slight salt accumulation which can be easily removed by leaching if field drainage conditions are improved. The extension of the soil is limited to only 54ha or 0.3% of arable land.

(9) Lambayeque Series (code LB)

1) General

The soils of this series occupy only 605ha or about 3.0% of arable land and are mainly distributed in the irrigation subsectors of Jesus Dell Valle and Palpa-Caqui. Landforms are generally flat to slightly sloping and land is commonly utilized for annual crop production, usually cotton and maize.

The soils have deep effective soil depth while the soil profile is characterized by a moderate to thick medium-textured (SL-L) upper layer and fine-textured (CL-SCL) lower layer up to over 1.5m depth. Soil drainability is moderate and the subsurface water table is generally deep except in poorly drained areas.

2) <u>Chemical and phyiscal preperties</u>

Cation exchage capacity is moderate and organic matter content is moderate to low. Potential moisture holding capcity is moderately high while permeability is moderate to moderately slow. Surface soil is generally very friable and bulk densities of the soils are low. Compacted subsurface soil is generally common with this soil series.

3) <u>Phases</u>

The soils are classified into two phases according to salinity of surface soil and are set in below:.

a) Deep phase (code LB); the soil has high agricultural potential with no major limitations for irrigation farming. However, the existence of compacted subsurface soil will adversely affect crop growth, impeding penetration of roots into the subsoil.

The following management practices are recommended to ensure high crop productivity:

- subsoiling
- organic matter application
- application of fertilizer and water corresponding to crop requirement

The soil of this series occupies 416ha or about 2.1% of arable land.

b) Poorly-drained salt accumulated, deep phase (LBSII); the soil is distributed in poorly drained areas and the degree of salt accumulation is generally slight. Agricultural potential similar to the deep phase is anticipated if adequate salinity control measures are taken. Distribution of the soil is limited to 189ha or about 0.9% arable land.

(10) Quepecaliche Series (code QC)

1) General

Distribution of the soil of this series is nearly confined to the irrigation subsector Jesus Del Valle-Esquivel. The topography is flat to nearly flat with or without undulation and the land is predominantly utilized for cotton and maize cultivation.

The soils have moderately deep fine-textured (CL-SCL) solum. The soil profile is characterized by the existence of continuous to discontinuous caliche layer (vesicular ca-pans) or abundant distribution of fragments of caliche in the subsoil. The caliche layer is generally found at a depth of 80 to 110cm and the thickness is around 10cm. Soil drainability is imperfect to poor depending on the depth, thickness and continuity of the caliche layer. The subsurface water table is generally found within one meter of the ground surface, but varies from superficial (less than 50cm) to deep (over 1.5m) depending on physiographical conditions.

The soils of this series occupy 595ha or about 2.9% of arable land.

2) Chemical and physical properties

Cation exchange capacity is moderately high and organic matter content is generally moderate. Potential moisture holding capacity is moderately high while permeability is moderately slow. Compaction of subsurface soil is generally