3.3 Tank Model

3.3 Tank Model

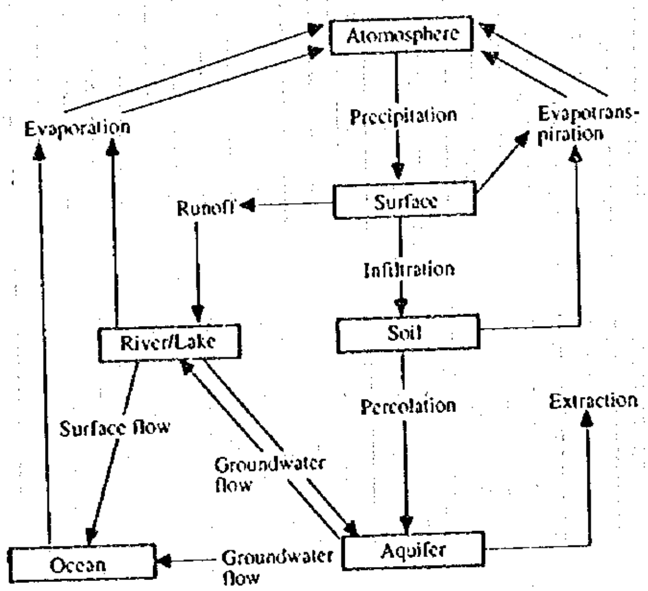
3.3.1 Outline of Water Balance Analysis

(1) Water Balance and Hydrologic Cycle

The following presents an application of water balance analysis for estimation of groundwater recharge, using meteo-hydrological records. Water balance analysis is to clarify a balance of quantity of inflow and outflow in a hydrologic system within a certain period of time. Basically, this is formulated as the following equation.

(Inflow) - (Outflow) = (Change of Storage)

Groundwater flow system is a part of the hydrologic cycle as illustrated below. In general, it is difficult to know a quantity of groundwater recharge by measurement or observation. On the other hand, water entering into a hydrologic system is a sum of precipitation and runoff from a neighboring hydrologic system, and water going out is a total of runoff, evapotranspiration and water extraction from the system. Quantity of these items can be known based on measurement or observation data. Accordingly, groundwater recharge can be estimated based on these data.



Schematic Diagram of Hydrologic Cycle

(2) Water Balance Equation

A basic equation for unconfined groundwater balance can be expressed as follows :

$$\underbrace{P + Ri + Gi}_{\text{inflow}} = \underbrace{E + Ro + Go + \Delta Ws + \Delta M + m\Delta H + Qd}_{\text{outflow}}$$

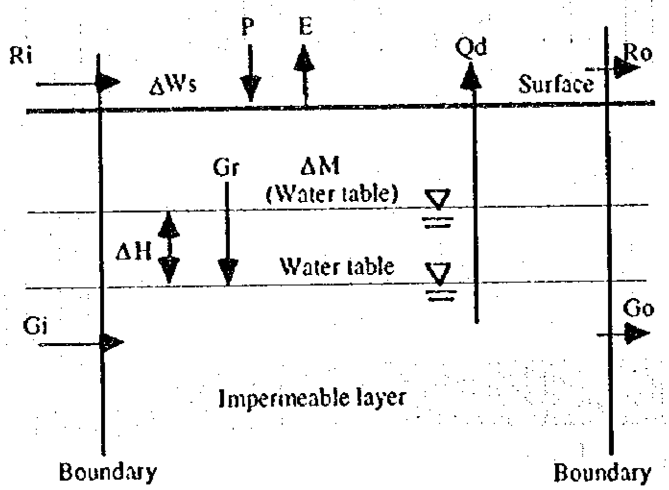
$$S = \Delta Ws + \Delta M + m\Delta H$$

$$Gr = Go - Gi + m\Delta H + Qd$$
$$= P + Ri - Ro - E - \Delta Ws - \Delta M$$

where:

P	: Precipitation
Ri	: Lateral surface flow from adjacent areas
Ro	: Lateral surface outflow into adjacent areas
Gi	: Lateral groundwater flow from adjacent areas
Go	: Lateral groundwater outflow into adjacent areas
E	: Evapotranspiration from shallow water table areas
ΔWs	: Change in surface storage
ΔM	: Change in soil moisture in unsaturated zone
$m\Delta H$	: Change in groundwater storage
m	: Effective porosity
ΔH	: Change in groundwater level
Qd	: Groundwater extraction
S	: Total storage
Gr	: Recharge amounts of groundwater

A schematic section of water balance and flow components are shown below.



Flow Components of Water Balance

Among the terms of the equations, precipitation (P), groundwater extraction (Qd) and evapotranspiration (E) can be regarded as constant when a time period for water balance is long enough. In this case, change in surface water storage (ΔWs) can be approximately neglected. When groundwater level is almost constant, change in groundwater storage (mΔH) and soil moisture (ΔM) can be neglected. Then, change in total storage becomes zero. Consequently, the following simplified equation is obtained.

$$P + Ri + Gi = E + Ro + Go$$
$$Gr = Go - Gi + Qd$$
$$= P + Ri + Ro - E$$

(3) Water Balance Model

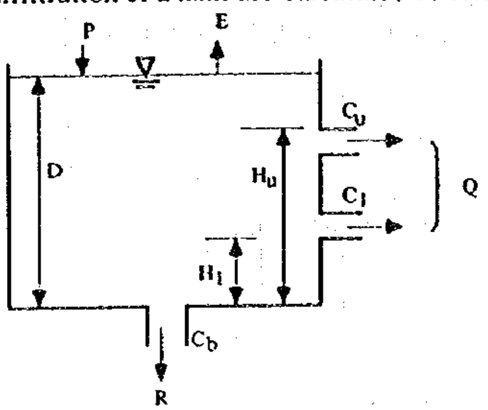
A tank model method which is a serial storage type model was applied for the water balance analysis. The tank model is composed of a number of containers which indicate the catchment basin (hereinafter the container is called a 'tank').

The tanks have several holes on their sides and bottoms. Rain enters the top tank first then passes into the lower tank through holes on the bottom of the upper tank. Water also passes through holes on the sides of the respective tanks. Water moving through the bottom holes indicates infiltration, while runoff moving through the side holes of all the tanks indicates river discharge.

When a model with serial three tanks is provided, each tank represents the runoff mechanism on the ground surface or layer, and is a component of the runoff hydrograph, which are generally considered as follows:

Top tank	Surface Runoff
2nd tank	Sub-surface / Groundwater Runoff
3rd tank	Groundwater Runoff (Baseflow)

At some time step, runoff and infiltration of a tank are calculated as follows.



$Q = (D - H_u) \times C_u + (D - H_l) \times C_l \qquad (D > H_u)$

$Q = (D - H_l) \times C_l \qquad (H_l < D < H_u)$

$Q = 0 \qquad (D < H_l)$

$R = D \times C_b$

Where,

P	:	Precipitation or infiltration from the upper tank
Q	:	Runoff
R	:	Infiltration to the lower tank
E	:	Evapotranspiration
C_u	:	Coefficient of the upper hole on the side
C_l	:	Coefficient of the lower hole on the side
C_b	:	Coefficient of the bottom hole
H_u	:	Height of the upper hole from the bottom
H_l	:	Height of the lower hole from the bottom
D	:	Depth of water (storage of tank)

Note: All variables are in mm.

Conceptual Diagram of Tank Model

Calculations are made for all tanks from the upper to the lower tanks. The sum of runoff from the side holes of all the tanks indicates river runoff. The remaining depth of each tank constitutes the initial depth for the next step, and the calculations are repeated using the same process.

To establish a tank model, precipitation and potential evapotranspiration are given as input for calculating runoff. Actual evapotranspiration is obtained as a result of calculation. The coefficients, such as H_u, C_u, H_l, C_l and C_b, are analyzed by comparing the computed runoff with the observed runoff. Model calibration is carried out by trial and error for adjusting the coefficients until the computed hydrograph fits in with that of the observed.

3.3.2 Objective Area

The objective areas for water balance analysis and groundwater simulation cover the areas of the groundwater potential structures at Ain Defali, Teroual and J. Berda, respectively.

(1) Ain Defali

The Ain Defali synclinal structure is similar to a close basin, stretching 4 km from east to west and 3 km from north to south. The area of the structure is some 12 km^2 with the ground surface elevation ranging from 250 m in the north to 90 m in the south/east along Rdat river. The base formation of the structure is the Miocene series dipping towards the center axis. The basin is filled up by the Quaternary ancient (Villafranchian) conglomerates with light brown marl matrix.

(2) Teroual

The Teroual structure is roughly a close synclinal basin oriented north-east to south-west. The ground surface elevation ranges from 500 m in the north to 400 m in the south. The area of the structure is around 6 km^2. According to the hydrogeological investigation, presence of two aquifer is confirmed. The surface aquifer is presented around the eastern part of structure. It composes of the Miocene conglomerates with marl intercalation, overlaying the silt stone of upper Oligocene formation. The lower aquifer, which was recognized by the exploratory drilling, belongs to the Oligocene epoch. It composes of silt stone with marl matrix. The average thickness of this aquifer is estimated around 60/m existing at the depth between 40 m to 150 m below ground surface.

(3) J. Berda

The monoclinal structure of J. Berda is an oval form stretching over 5 km from east to west and about 2 km from north to south. It belongs to the Jurassic system having a limestone deposition on its summit and cracked cavernous boulders of limestone underneath. The area of the structure is around 6 km^2. There are two steep mountains with the elevations of 900 m and 1,000 m at their summits, and the elevations are around 500 m to 600 m in the south east to west along the foot of the mountains. The hydrogeological investigations confirmed the presence of groundwater in the conglomerates, the consolidated marl stone and schist formation with fissure and crack. Such formations exist in the base of the monoclinal structure and in areas close to the southern faulted line in the upper Cretaceous formation. These formations present around 40 m below ground surface with the estimated average thickness of 60 m.

3.3.3 Water Balance Analysis for Objective Area

Applying the tank model as discussed previously, water balance analysis was carried out for estimating groundwater recharge of each objective area. The tank model was established for the gauged river basin which is closely located to the objective area. The objective gauged basins are the Rdat river basin for Ain Defali and the Amzaz river basin for J. Berda, respectively. For Teroual, since no runoff record is available on the neighboring tributary, the tank model established for the Rdat river basin was applied. The meteo-hydrological records used for water balance analysis are summarized in Table 3.3.1 and described below.

(1) Rainfall

The locations of rainfall gauging stations managed by the AH are shown in Figure 3.1.1. Of them, the gauging stations such as Had Kourt, M'Jaara and Rhafsai are located closely to the respective potential groundwater structures. The data are available for the period from the hydrological year 1957/58 to 1994/95. The monthly rainfall for each station is given in Tables 3.3.4 to 3.3.6.

(2) Runoff

The location of AH's hydrological gauging stations are illustrated in Figure 3.1.2. Of them, the runoff records are available at Had Kourt and Rhafsai for the respective river basins. The monthly runoff records for both gauging stations are tabulated on Tables 3.3.7 and 3.3.8.

(3) Potential Evapotranspiration

Since a loss of rainfall is mostly depending on a rate of evapotranspiration, it is an important factor for groundwater recharge analysis. Generally, it is known as the potential evapotranspiration estimated from the several meteorological records. In the Study Area, the potential evapotranspiration was obtained in the previous study using the Penman Method based on the meteorological record at Ourtzagh.

Using the basic data above, the tank models were constructed as shown in Figure 3.3.1 for the respective river basins. The serial three tanks were provided for the model. Comparison of the observed and computed runoff are shown in Figure 3.3.2 on annual basis and in Figure 3.3.3 on flow duration curve, respectively. In general, the computed runoff almost corresponds with the observed runoff, the results are therefore regarded as acceptable.

The groundwater recharge for each objective area was obtained through water balance analysis using the tank model. The application of the tank model and rainfall input were shown in Table 3.3.1.

The groundwater recharge for the objective area was estimated through the water balance resulted from tank model simulation on the following assumptions.

1) In the water balance equation, groundwater extraction (Qd) is negligible because the amount of extraction is small compared with the water balance in the present condition. In addition, surface and groundwater inflow (Ri and Gi) can be negligible in consideration of topography of the modeling area. As a result, the water balance equation is simplified as follows:

$$Gr = Go = P - Ro - E$$

Rainfall (P), surface outflow (Ro) and evapotranspiration (E) are components of surface runoff system expressed by the top tank. Value of (P - Ro - E) gives runoff from bottom hole of the top tank.

2) In the water balance equation, Go is groundwater outflow in a hydrological year, while Go is equivalent to the sum of outflow and losses of the 2nd and 3rd tanks of the tank model in the water balance shown in Figure 3.3.4. As the tank model was created based on the basin rainfall and the river runoff at the hydrological gauging station, the sum of runoff from side holes gives that at the gauging station. On the other hand, actual runoff phenomena may contain a loss of sub-surface and groundwater runoff before flowing into rivers or during flowing through rivers. Such losses may be explained as those of 2nd and 3rd tanks of the model.

Water Balance of Objective Area

Unit: mm

Objective Area	Rainfall (P)	Surface Runoff (Ro)	Evapo-transpiration (E)	Recharge (Gr = Go)
Ain Defali	587	65	468	54
Teroual	775	154	544	77
J. Berda	953	336	533	84

The value of recharge indicates the average of the gauged river basin. On the other hand, the objective area with the relatively high groundwater potential is quite small in the river basin which is mostly covered with the area of low recharging rate. With consideration to this, the values of groundwater recharge estimated by the tank model are necessary to be reviewed in the groundwater simulation discussed in Section 4.5.

Table 3.3.1 List of Data Used for Tank Model

River Basin	Rdat	Amzaz
Rainfall		
Reference Station	4404 Had Kourt	6400 Rhafsai
Period	1957/58 - 1993/94	1957/58 - 1993/94
Multiplier for Converting into Basin Rainfall	1.40	1.29
Runoff		
Reference Station	1436/8 Had Kourt	607/9 Rhafsai
Period	1957/58 - 1993/94	1957/58 - 1993/94
Catchment Area	673 km2	777 km2
Evapotranspiration		
Reference Station	6200 Ourtzagh	6200 Ourtzagh

Table 3.3.2 Application of Tank Model for Objective Area

Objective Area	Ain Defali	Teroual	J. Berda
Catchment Area	12.0 km2	6.1 km2	6.3 km2
Applied Tank Model	Rdat	Rdat	Amzaz
Rainfall			
Reference Station	4404 Had Kourt	5128 M'Jaara	6400 Rhafsai
Period	1957/58 - 1994/95	1957/58 - 1994/95	1957/58 - 1994/95
Multiplier for Converting into Basin Rainfall	1.15	1.29	1.11
Evapotranspiration			
Reference Station	6200 Ourtzagh	6200 Ourtzagh	6200 Ourtzagh

Table 3.3.3 Potential Evapotranspiration at Ourtzagh

Unit: mm

SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	ANNUAL
175	115	65	52	49	59	105	116	162	193	234	216	1541

Table 3.3.4 Monthly Rainfall at Had Kourt

MONTHLY RAINFALL

4104 HAD KOURT — Unit : mm

YEAR	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	ANNUAL
1957/58	10.2	65.3	148.7	164.7	77.0	20.9	62.7	107.8	18.5	13.8	4.3	16.5	710.6
1958/59	8.8	22.9	31.5	263.5	31.1	42.2	63.8	29.3	90.9	4.0	4.0	6.9	598.8
1959/60	10.6	22.4	74.4	58.9	160.0	80.8	147.1	11.0	51.8	6.9	6.8	7.2	637.9
1960/61	4.0	103.5	75.5	104.5	46.9	13.5	16.0	30.0	26.1	31.0	4.0	4.0	458.8
1961/62	23.8	21.5	164.0	72.2	14.2	18.1	149.4	18.8	21.9	9.4	4.0	4.0	521.3
1962/63	12.7	40.4	163.1	90.2	193.0	185.5	19.4	49.8	77.6	8.6	6.0	4.0	850.2
1963/64	8.9	14.4	60.7	255.5	22.9	82.8	90.4	78.6	4.0	5.9	4.0	4.0	632.1
1964/65	4.0	4.0	98.9	96.9	54.8	74.9	35.4	31.2	4.0	12.9	5.5	4.3	426.8
1965/66	35.3	102.4	57.9	43.0	54.8	92.7	11.2	4.0	0.0	0.0	0.0	0.0	401.3
1966/67	0.0	79.5	32.8	9.9	18.5	42.7	12.5	37.8	0.0	0.0	0.0	0.0	233.6
1967/68	3.0	38.5	76.5	80.5	7.6	138.4	70.9	8.5	0.0	0.0	0.0	0.0	423.9
1968/69	0.0	0.0	194.6	93.6	89.8	216.8	132.6	58.1	27.2	15.2	4.2	0.0	832.1
1969/70	32.9	39.5	101.2	128.2	213.5	2.5	78.1	64.1	22.9	4.7	4.0	0.0	691.6
1970/71	0.0	27.4	21.2	141.0	127.1	5.3	147.9	190.4	73.3	8.1	0.0	0.8	742.5
1971/72	0.0	0.0	105.0	75.6	89.6	94.4	71.8	21.2	40.6	3.8	0.0	1.1	503.1
1972/73	11.4	122.0	14.7	57.9	50.8	48.6	45.0	4.7	24.7	11.3	0.0	8.6	399.7
1973/74	1.0	7.9	40.9	144.2	21.6	64.1	72.4	154.9	4.5	20.3	2.5	0.0	534.3
1974/75	0.6	10.4	10.2	0.0	60.9	56.6	120.3	80.5	25.8	56.9	0.0	0.0	422.2
1975/76	0.3	3.9	45.7	173.3	43.6	50.0	43.3	94.7	66.6	5.1	0.0	0.0	526.5
1976/77	13.0	100.6	5.4	157.7	221.3	82.0	8.0	1.4	29.6	16.0	0.0	4.0	639.0
1977/78	0.0	100.3	58.7	54.5	84.4	131.4	57.5	124.0	44.0	27.9	0.0	0.0	682.7
1978/79	0.0	8.6	16.4	138.5	82.3	147.1	51.6	29.7	0.0	0.5	24.0	0.0	498.7
1979/80	2.4	156.5	13.7	17.0	62.1	12.9	78.4	30.5	37.5	3.5	0.0	0.0	414.5
1980/81	6.1	51.5	81.8	16.5	10.8	14.2	39.7	49.9	32.5	0.0	0.0	0.0	303.0
1981/82	4.5	4.7	0.0	125.3	67.5	87.6	32.1	89.2	15.7	0.0	0.0	0.0	426.6
1982/83	0.0	98.1	91.9	44.8	0.0	118.9	33.0	15.7	10.6	0.0	0.0	0.5	413.5
1983/84	0.0	2.4	153.9	125.1	22.9	26.6	89.1	30.5	132.0	8.3	8.2	0.0	599.0
1984/85	5.6	124.9	93.4	10.9	64.6	36.7	9.3	14.7	23.2	2.0	0.0	0.0	385.3
1985/86	6.4	10.0	125.0	105.3	100.1	152.4	51.9	81.5	0.0	17.0	0.0	0.0	649.6
1986/87	1.1	11.5	46.0	30.5	125.3	110.1	14.0	15.3	0.0	0.0	10.7	5.0	369.5
1987/88	0.0	27.5	133.6	101.0	99.4	38.4	34.0	37.1	18.5	12.2	0.0	0.0	501.7
1988/89	0.0	56.4	138.1	13.5	49.4	100.1	51.4	85.5	15.5	2.0	0.0	2.0	513.9
1989/90	6.6	73.7	129.0	156.0	62.5	3.5	40.2	81.1	46.0	15.0	0.0	0.0	613.6
1990/91	0.0	32.6	64.3	152.5	7.0	100.7	117.5	27.0	8.0	0.0	0.0	1.0	510.6
1991/92	49.0	56.0	16.5	16.5	0.0	49.5	58.0	69.0	7.5	56.0	0.0	2.0	380.0
1992/93	6.5	60.0	17.0	21.0	14.5	12.0	62.0	59.3	41.5	0.0	0.0	0.0	293.8
1993/94	8.0	54.0	150.0	15.5	58.0	117.0	0.0	35.0	14.0	0.0	0.0	0.0	451.5
1994/95	2.0	32.5	60.5	0.0	9.0	20.5	14.0	23.5	0.0	39.0	7.5	0.0	208.5
Ave.	7.3	47.0	76.7	88.3	66.3	70.9	58.7	52.0	27.8	11.0	2.6	2.0	510.6

Table 3.3.5 Monthly Rainfall at Rhafsai

MONTHLY RAINFALL

6400 RHAFSAI

Unit : mm

YEAR	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	ANNUAL
1957/58	3.5	98.1	193.3	351.3	152.1	17.3	105.3	144.7	18.3	4.1	0.0	16.5	1104.5
1958/59	3.2	31.9	49.2	519.6	48.4	61.7	139.5	29.9	119.0	0.0	0.7	1.8	1004.9
1959/60	62.3	15.7	169.7	173.5	290.6	202.1	386.7	19.2	41.2	10.5	1.0	0.0	1372.5
1960/61	1.5	191.2	121.3	218.9	72.7	8.6	64.9	35.0	79.5	35.1	0.0	0.0	828.7
1961/62	17.3	45.9	301.4	148.1	41.2	32.8	251.7	49.7	22.1	5.3	5.2	2.1	922.8
1962/63	17.7	97.9	388.6	197.3	434.8	363.7	16.0	86.9	65.5	6.0	12.5	5.0	1691.9
1963/64	11.0	20.8	100.2	595.6	22.4	200.3	196.0	122.7	20.8	0.0	0.0	0.0	1289.8
1964/65	6.5	5.1	174.4	188.7	114.0	142.1	48.7	41.5	3.7	39.2	0.0	0.0	763.9
1965/66	67.4	172.1	100.8	80.1	157.2	179.9	22.1	43.1	7.7	1.7	1.3	0.0	833.4
1966/67	4.0	130.9	44.8	18.9	47.2	157.4	28.8	71.6	37.8	22.6	0.0	0.0	564.0
1967/68	6.4	72.3	167.8	53.9	6.6	272.7	147.5	67.3	27.3	45.9	0.0	0.0	867.7
1968/69	3.6	0.0	271.3	207.5	220.6	330.2	183.7	109.9	35.2	15.5	2.6	0.0	1380.1
1969/70	33.8	75.9	208.4	234.6	554.6	1.9	161.6	68.7	39.3	11.2	0.0	0.0	1390.0
1970/71	0.0	23.3	27.6	202.3	227.2	8.7	226.5	379.1	81.6	14.0	4.0	0.0	1194.3
1971/72	17.3	0.0	147.0	92.7	164.9	108.3	115.0	45.5	79.3	11.7	0.0	0.0	781.7
1972/73	17.6	200.9	23.0	42.7	107.3	80.8	63.1	19.8	29.8	15.5	0.0	5.2	605.7
1973/74	0.0	23.5	34.5	306.5	36.0	117.4	87.6	274.8	1.9	35.1	0.0	0.0	917.3
1974/75	0.0	27.3	14.0	0.0	69.7	124.6	217.4	56.6	45.4	13.8	0.0	2.5	571.3
1975/76	0.9	0.4	35.7	195.8	71.7	92.8	108.5	131.7	83.1	11.4	3.8	1.8	737.6
1976/77	15.9	185.1	6.5	311.7	369.7	115.2	15.0	0.2	15.9	8.9	0.0	0.0	1044.1
1977/78	1.7	67.6	99.5	118.8	130.9	195.7	78.8	183.4	74.1	58.6	0.0	0.0	1009.1
1978/79	0.0	3.3	14.3	180.7	191.4	359.2	85.6	46.8	9.5	1.0	13.9	0.0	905.7
1979/80	13.1	283.9	39.8	25.4	69.5	30.7	82.3	46.6	69.7	10.5	0.0	0.0	671.5
1980/81	49.7	83.2	165.4	29.6	14.4	22.2	67.1	120.8	40.1	1.9	0.0	0.0	594.4
1981/82	3.3	8.2	0.0	260.2	123.7	106.6	61.6	133.5	30.0	0.0	2.9	4.4	734.4
1982/83	0.4	87.8	120.9	47.9	0.0	196.9	49.8	24.2	22.8	0.0	0.0	0.0	550.7
1983/84	0.0	1.8	231.8	281.5	24.8	38.6	113.6	101.7	132.7	2.0	5.4	0.0	933.9
1984/85	3.7	1.6	181.2	17.7	137.2	96.9	28.7	55.1	44.4	3.4	4.3	0.0	574.2
1985/86	0.6	1.2	214.2	68.0	233.6	298.5	79.4	110.8	0.1	4.5	0.0	0.0	1010.9
1986/87	8.8	72.0	58.6	30.3	269.0	171.3	1.5	23.2	2.7	0.0	4.1	0.0	641.5
1987/88	21.1	27.2	136.9	155.4	159.4	53.2	27.6	65.5	56.7	8.5	0.0	0.0	711.5
1988/89	1.7	66.9	151.9	22.1	41.6	154.4	74.9	161.2	54.4	1.9	0.6	8.3	739.9
1989/90	0.1	71.1	257.5	211.7	92.9	6.4	21.0	138.2	18.0	0.2	2.5	0.0	819.6
1990/91	6.5	58.6	116.7	195.1	3.3	134.1	311.6	15.1	0.1	0.0	0.9	1.7	843.7
1991/92	43.7	87.9	21.8	42.2	0.1	62.5	80.6	157.1	17.0	45.6	0.0	2.2	560.7
1992/93	8.5	91.4	11.1	45.4	9.5	12.6	73.0	89.8	53.1	0.0	0.0	1.1	395.5
1993/94	13.5	61.0	222.3	50.3	86.6	146.3	41.3	41.4	22.6	0.1	0.0	0.0	685.4
1994/95	15.0	43.6	105.1	1.7	22.9	14.9	83.9	32.5	3.0	38.4	1.5	0.0	362.5
Ave.	12.7	66.8	124.4	155.9	126.8	124.2	103.9	88.0	39.6	12.7	1.8	1.4	858.2

Table 3.3.6 Monthly Rainfall at M'Jaara

MONTHLY RAINFALL

5128 M'JAARA

Unit : mm

YEAR	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	ANNUAL
1957/58	8.1	79.3	187.2	208.0	94.5	21.9	76.0	134.4	18.8	12.7	0.4	16.1	857.4
1958/59	6.2	24.5	35.6	335.7	35.1	49.4	77.4	32.7	112.4	0.0	0.0	3.8	712.8
1959/60	8.5	23.8	91.1	71.1	201.8	99.4	185.1	9.1	61.9	3.8	3.6	4.2	763.4
1960/61	0.0	128.7	92.5	130.0	55.5	12.3	15.6	33.6	28.6	34.9	0.0	0.0	531.7
1961/62	25.7	22.7	207.0	88.2	13.2	18.3	188.1	19.2	23.2	7.0	0.0	0.0	612.6
1962/63	11.3	47.1	205.9	111.5	244.5	234.8	19.9	59.3	95.2	6.0	2.6	0.0	1038.1
1963/64	6.4	13.5	73.4	325.4	24.5	102.0	111.8	96.5	0.0	2.5	0.0	0.0	756.0
1964/65	0.0	0.0	122.8	120.2	65.8	91.7	40.7	35.2	0.0	11.5	2.0	0.4	490.3
1965/66	40.5	173.0	90.4	61.9	65.7	109.3	1.3	30.8	2.0	0.8	0.0	0.0	575.7
1966/67	7.5	83.1	37.3	7.6	29.9	100.5	21.3	43.7	38.5	43.3	0.0	0.6	413.3
1967/68	0.0	55.7	72.6	41.5	4.7	173.9	86.6	50.1	24.8	38.1	0.0	6.8	554.8
1968/69	3.7	13.9	193.7	108.7	134.5	308.0	101.1	65.6	10.9	24.9	0.0	2.0	967.0
1969/70	24.3	70.2	141.0	145.9	372.5	0.0	101.5	34.4	24.5	4.7	0.0	0.0	919.0
1970/71	0.6	15.4	13.1	180.5	167.7	2.0	137.0	256.9	77.4	15.8	0.0	0.3	866.7
1971/72	5.0	0.0	91.5	90.3	95.3	108.2	90.6	32.8	62.2	5.0	0.0	0.2	581.1
1972/73	27.4	151.7	8.6	36.6	74.4	53.3	57.6	15.8	15.4	0.0	0.0	0.8	441.6
1973/74	0.0	14.0	26.8	180.2	25.2	82.7	65.5	204.1	4.3	27.2	0.0	0.0	630.0
1974/75	0.0	26.1	12.3	0.0	53.2	85.8	168.8	51.1	46.2	27.1	0.0	0.6	471.2
1975/76	1.1	2.2	33.1	147.3	46.1	53.0	94.7	106.5	76.4	1.0	5.7	0.0	567.1
1976/77	29.6	142.7	4.0	194.0	290.1	101.9	6.9	0.5	18.9	15.6	0.0	0.0	804.2
1977/78	2.2	56.0	72.6	105.9	88.3	117.0	67.5	141.1	61.8	43.6	0.0	0.5	756.5
1978/79	0.6	1.9	28.3	142.3	136.2	204.0	60.9	38.2	1.6	5.1	14.3	0.0	633.4
1979/80	8.0	197.3	17.5	30.8	65.1	25.5	67.4	27.2	42.6	9.5	0.0	0.0	490.9
1980/81	8.0	53.1	100.7	19.5	9.8	13.6	36.0	79.3	22.9	10.1	0.0	0.0	353.0
1981/82	3.0	10.8	0.0	140.4	94.1	115.7	52.1	113.5	19.4	0.8	0.3	0.0	550.1
1982/83	1.3	85.9	84.3	38.8	0.0	121.1	28.7	22.9	15.8	0.0	0.0	0.0	398.8
1983/84	0.0	5.2	160.3	144.3	20.0	20.7	80.4	54.2	128.3	5.6	5.5	0.0	624.5
1984/85	0.3	1.5	115.7	20.3	98.3	44.7	20.0	34.1	27.9	1.3	0.0	0.0	364.1
1985/86	20.7	0.0	130.8	76.0	88.8	181.7	49.8	85.6	0.0	0.2	0.0	0.0	633.6
1986/87	7.2	15.5	72.5	31.5	155.7	118.1	9.1	17.9	2.4	0.0	8.7	0.0	438.6
1987/88	12.9	13.3	130.1	126.6	105.5	38.5	19.6	46.3	63.6	49.5	0.0	0.0	605.9
1988/89	0.1	72.9	146.1	10.5	33.6	109.7	44.9	120.1	42.2	0.0	0.5	3.3	583.9
1989/90	6.0	57.1	174.3	167.3	66.1	0.4	34.1	108.3	25.2	6.2	1.0	0.0	646.0
1990/91	6.7	34.9	71.2	209.5	2.7	116.0	165.8	9.2	0.2	29.7	0.2	2.1	648.2
1991/92	36.8	47.4	19.2	20.2	0.0	38.4	47.2	96.5	6.1	30.4	1.0	1.2	344.4
1992/93	5.3	97.7	13.9	23.3	10.1	29.7	61.4	70.3	49.2	0.5	0.0	0.0	361.4
1993/94	8.8	61.6	190.0	21.3	53.1	134.9	15.3	43.0	18.7	0.2	0.4	0.0	547.3
1994/95	17.2	36.3	65.6	0.2	22.6	9.2	36.9	43.3	5.6	43.9	7.1	0.3	288.2
Ave.	9.2	50.9	87.7	103.0	82.7	85.5	67.0	64.8	33.6	13.6	1.4	1.1	600.6

Table 3.3.7 Monthly Mean Discharge at Had Kourt

1436/8 HAD KOURT

Unit : m3/sec

YEAR	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	ANNUAL
1957 / 58	0.02	0.20	1.58	9.43	3.97	1.87	1.55	3.45	0.93	0.32	0.09	0.04	1.96
1958 / 59	0.04	0.07	0.26	19.72	4.50	3.89	4.47	2.21	2.30	0.71	0.14	0.06	3.22
1959 / 60	0.19	0.11	0.77	7.05	11.14	13.22	21.55	5.25	1.22	0.64	0.19	0.09	5.09
1960 / 61	0.07	1.09	2.35	5.68	4.09	1.52	0.74	0.60	0.31	0.61	0.06	0.02	1.43
1961 / 62	0.02	0.08	5.77	8.35	4.00	1.44	14.70	3.13	1.13	0.39	0.13	0.06	3.29
1962 / 63	0.06	0.36	8.00	6.06	32.48	26.83	3.92	2.53	2.40	0.91	0.31	0.15	6.88
1963 / 64	0.12	0.10	0.97	25.81	2.53	5.54	7.54	8.38	1.17	0.49	0.20	0.10	4.42
1964 / 65	0.09	0.09	1.85	3.74	5.95	5.66	9.05	1.67	0.53	0.35	0.11	0.11	2.42
1965 / 66	0.24	1.15	2.74	2.24	6.67	8.64	2.85	1.31	0.44	0.17	0.06	0.04	2.17
1966 / 67	0.05	0.13	0.26	0.32	0.57	5.55	0.25	2.22	0.19	0.13	0.09	0.04	0.78
1967 / 68	0.04	0.09	0.20	0.18	0.19	8.60	5.57	1.21	0.58	0.08	0.01	0.00	1.35
1968 / 69	0.00	0.00	0.39	12.10	21.00	39.90	24.20	8.21	1.79	1.04	0.48	0.14	8.92
1969 / 70	0.14	0.27	1.48	10.10	69.50	3.25	2.83	3.56	1.14	0.67	0.23	0.05	7.87
1970 / 71	0.05	0.05	0.06	0.39	7.67	2.48	7.40	30.20	6.94	1.27	0.52	0.22	4.76
1971 / 72	0.02	0.00	0.04	0.33	5.25	8.59	13.90	1.48	1.54	0.45	0.07	0.00	2.61
1972 / 73	0.00	0.34	0.03	0.09	1.58	1.51	0.59	0.42	0.04	0.00	0.00	0.00	0.38
1973 / 74	0.00	0.00	0.00	4.87	0.30	2.41	1.34	13.00	2.45	0.64	0.10	0.00	2.08
1974 / 75	0.00	0.00	0.00	0.00	0.02	0.25	2.55	1.18	0.84	0.27	0.00	0.00	0.43
1975 / 76	0.00	0.00	0.00	1.21	0.09	5.90	1.35	2.79	4.61	0.59	0.02	0.00	1.35
1976 / 77	0.00	0.20	0.20	18.90	46.20	29.70	2.49	0.81	0.46	0.25	0.13	0.05	8.19
1977 / 78	0.05	0.10	0.11	2.09	4.89	9.26	7.55	10.90	8.02	2.01	0.93	0.16	3.60
1978 / 79	0.00	0.00	0.00	0.86	5.76	38.00	8.96	2.34	0.84	0.13	0.05	0.01	4.52
1979 / 80	0.00	1.08	0.25	0.11	0.78	0.38	0.90	0.45	0.48	0.01	0.00	0.00	0.37
1980 / 81	0.00	0.00	0.51	0.04	0.01	0.00	0.00	0.14	0.70	0.00	0.00	0.00	0.12
1981 / 82	0.00	0.00	0.08	1.84	4.16	3.33	0.77	5.32	0.35	0.01	0.00	0.00	1.30
1982 / 83	0.00	0.00	0.06	0.09	0.01	6.65	0.17	0.03	0.00	0.00	0.00	0.01	0.54
1983 / 84	0.00	0.00	4.04	20.50	0.57	0.08	1.72	0.21	3.28	0.50	0.01	0.00	2.61
1984 / 85	0.00	0.00	0.00	0.24	1.94	1.73	0.14	0.02	0.03	0.00	0.00	0.00	0.33
1985 / 86	0.00	0.00	1.70	0.12	4.49	33.70	6.95	2.88	0.10	0.01	0.12	0.04	3.97
1986 / 87	0.00	0.00	0.00	0.00	2.58	11.50	1.31	0.31	0.03	0.00	0.00	0.00	1.24
1987 / 88	0.00	0.00	0.00	1.20	7.94	1.15	0.44	0.45	0.13	0.01	0.05	0.00	0.95
1988 / 89	0.01	0.00	0.04	0.19	0.13	5.00	3.84	7.22	2.84	1.77	0.57	0.33	1.80
1989 / 90	0.44	0.67	3.67	20.00	9.54	5.10	4.37	4.65	4.15	3.48	2.41	0.50	4.93
1990 / 91	0.04	0.09	0.19	6.93	0.06	7.80	19.50	5.01	4.11	0.24	0.05	0.03	3.66
1991 / 92	0.00	0.00	0.21	0.50	0.21	0.00	0.27	2.27	0.32	0.00	0.00	0.00	0.31
1992 / 93	0.00	0.00	0.01	0.28	0.05	0.13	0.00	0.79	0.53	0.10	0.00	0.00	0.16
1993 / 94	0.00	0.00	2.52	0.49	2.51	3.64	3.70	1.77	0.39	0.00	0.00	0.00	1.23
Ave.	0.05	0.17	1.09	5.19	7.39	8.22	5.12	3.74	1.55	0.49	0.19	0.06	2.74

Table 3.3.8 Monthly Mean Discharge at Rhafsai

607/9 RHAFSAI Unit : m3/sec

YEAR	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	ANNUAL
1957 / 58	0.08	1.36	9.39	38.36	23.30	8.98	7.32	21.90	4.50	1.07	0.29	0.05	9.74
1958 / 59	0.20	0.11	0.50	59.10	26.70	24.80	28.30	7.04	13.30	3.54	0.51	0.14	13.71
1959 / 60	0.97	0.22	4.65	29.70	67.80	77.50	130.00	19.80	3.57	1.47	0.30	0.08	27.83
1960 / 61	0.34	5.38	14.90	32.50	23.30	6.70	3.19	2.20	2.04	3.21	0.18	0.02	7.87
1961 / 62	0.02	0.10	38.90	54.60	22.00	5.78	97.40	12.70	3.29	1.07	0.23	0.06	19.86
1962 / 63	0.08	2.03	51.70	43.70	324.00	151.00	15.80	13.10	8.86	3.55	0.71	0.21	50.78
1963 / 64	0.20	0.17	4.42	159.00	3.24	25.70	39.00	45.60	1.74	0.83	0.52	0.40	23.50
1964 / 65	0.42	0.42	8.50	19.56	32.25	30.41	50.12	7.63	1.08	0.02	0.55	0.53	12.57
1965 / 66	0.27	4.64	13.91	10.97	36.09	46.61	14.26	5.51	0.57	0.85	0.29	0.20	10.96
1966 / 67	0.21	0.93	1.95	0.04	0.67	20.72	6.61	3.22	0.77	0.11	0.23	0.06	2.83
1967 / 68	0.10	1.10	8.25	1.92	1.69	44.10	38.93	13.14	4.78	0.35	0.47	0.28	9.35
1968 / 69	0.20	0.20	10.37	49.78	75.50	103.39	71.49	33.58	13.21	2.99	0.18	0.63	29.73
1969 / 70	0.69	0.97	13.81	35.75	257.36	15.71	18.05	17.72	4.96	1.08	0.89	0.49	30.99
1970 / 71	0.15	0.26	0.30	7.41	36.30	11.70	30.40	98.60	25.40	9.91	1.76	0.74	18.54
1971 / 72	0.59	0.52	1.99	3.17	33.30	32.20	44.80	7.09	19.60	2.30	0.83	0.53	12.18
1972 / 73	0.28	6.61	1.38	2.04	10.20	8.82	5.03	2.97	1.42	0.49	0.12	0.04	3.26
1973 / 74	0.03	0.05	0.13	27.80	7.48	15.10	16.70	50.10	16.20	2.56	0.52	0.20	11.36
1974 / 75	0.15	0.20	0.32	0.28	2.03	3.52	25.90	10.30	6.40	2.68	0.34	0.07	4.37
1975 / 76	0.04	0.04	0.09	11.60	3.73	25.80	9.34	29.80	22.70	2.68	0.98	0.25	8.79
1976 / 77	0.19	5.96	3.50	61.90	87.80	60.70	11.90	3.74	2.07	0.84	0.28	0.18	19.78
1977 / 78	0.11	0.55	0.81	11.20	17.40	38.90	24.60	20.20	29.80	4.08	1.50	0.26	12.30
1978 / 79	0.13	0.10	0.11	14.90	42.20	81.70	32.70	11.20	2.81	0.85	0.34	0.08	15.19
1979 / 80	0.43	15.60	4.07	1.74	7.61	3.20	11.00	4.75	16.20	1.40	0.27	0.18	5.59
1980 / 81	0.19	0.61	10.70	1.72	0.92	0.55	1.18	10.30	15.40	1.01	0.23	0.06	3.58
1981 / 82	0.05	0.10	0.07	17.80	33.90	11.90	11.00	28.50	4.74	0.85	0.30	0.12	9.11
1982 / 83	0.04	0.50	5.27	4.26	1.68	25.00	4.86	3.78	3.52	1.32	0.74	0.52	4.14
1983 / 84	0.07	0.08	12.49	66.24	6.05	1.89	16.45	7.08	31.56	5.09	1.16	0.45	12.54
1984 / 85	0.33	0.34	3.59	3.76	13.53	29.10	3.71	1.52	1.62	0.67	0.24	0.14	4.72
1985 / 86	0.29	0.27	7.47	1.89	28.11	97.98	24.92	17.93	3.42	0.53	0.55	0.30	14.72
1986 / 87	0.22	0.33	0.43	0.34	17.10	57.40	8.03	3.68	1.82	1.36	1.71	1.42	7.48
1987 / 88	1.17	1.35	3.44	19.70	23.30	4.49	2.87	5.93	3.31	1.77	1.24	0.99	5.84
1988 / 89	0.85	1.14	4.40	3.67	2.21	15.00	7.79	20.30	7.23	2.37	1.02	0.84	5.48
1989 / 90	0.84	0.97	40.10	58.10	27.60	7.05	2.47	8.66	3.32	0.61	0.24	0.10	12.55
1990 / 91	0.14	0.34	1.96	17.70	2.47	14.80	56.30	7.83	2.84	1.04	0.48	0.36	8.87
1991 / 92	0.48	2.87	0.73	0.67	0.83	1.09	0.78	20.20	0.87	0.96	0.25	0.03	2.46
1992 / 93	0.00	1.64	0.63	2.05	0.88	0.61	2.69	3.07	8.53	1.37	0.14	0.09	1.82
1993 / 94	0.31	1.25	22.40	2.30	19.00	16.50	16.20	2.27	0.77	0.35	0.06	0.00	6.71
Ave.	0.29	1.60	8.31	23.71	35.66	30.44	24.11	15.76	7.95	1.82	0.56	0.30	12.46

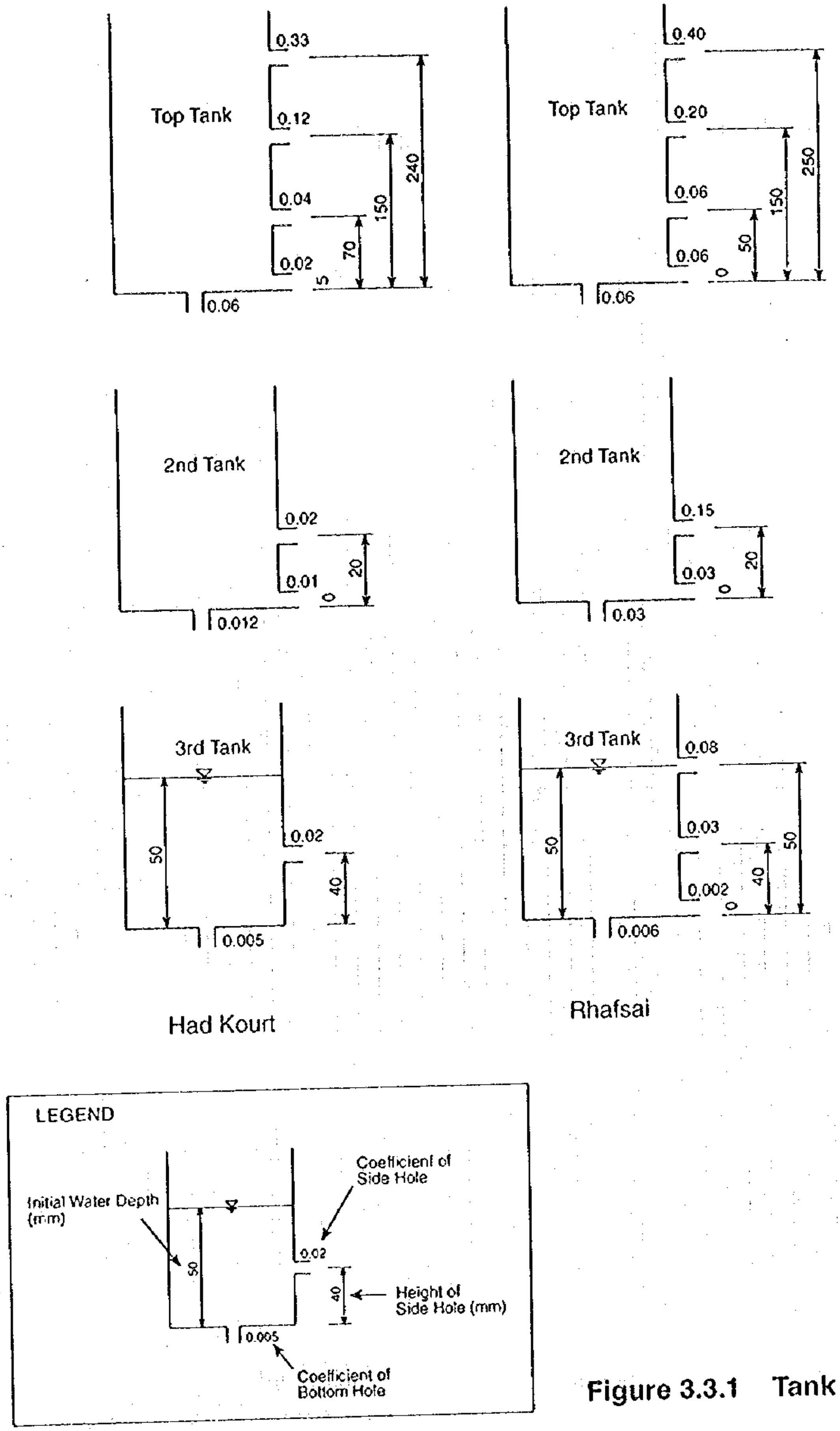
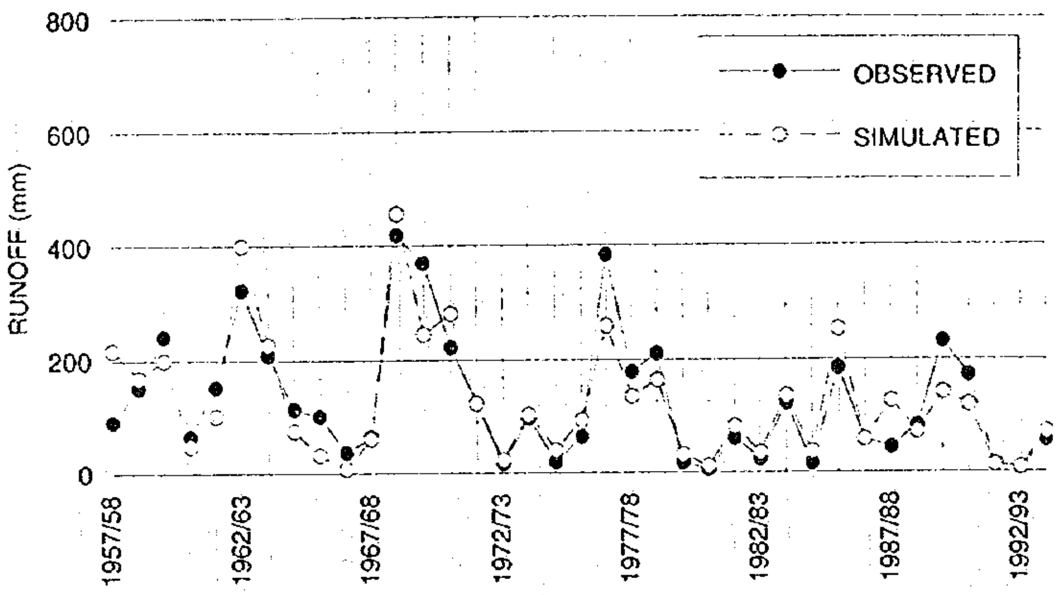


Figure 3.3.1 Tank Model

HAD KOURT



RHAFSAI

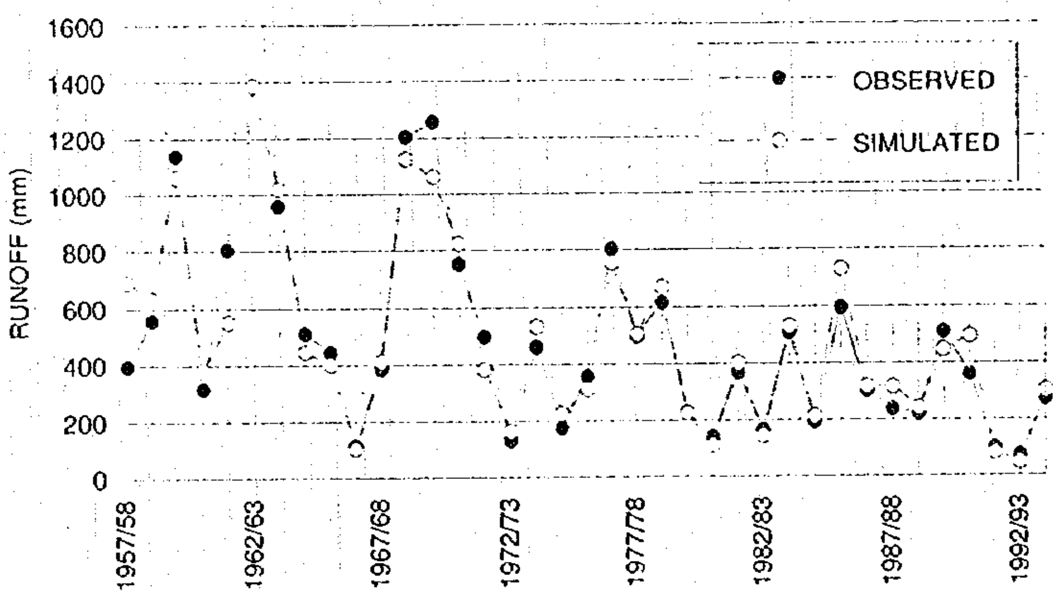
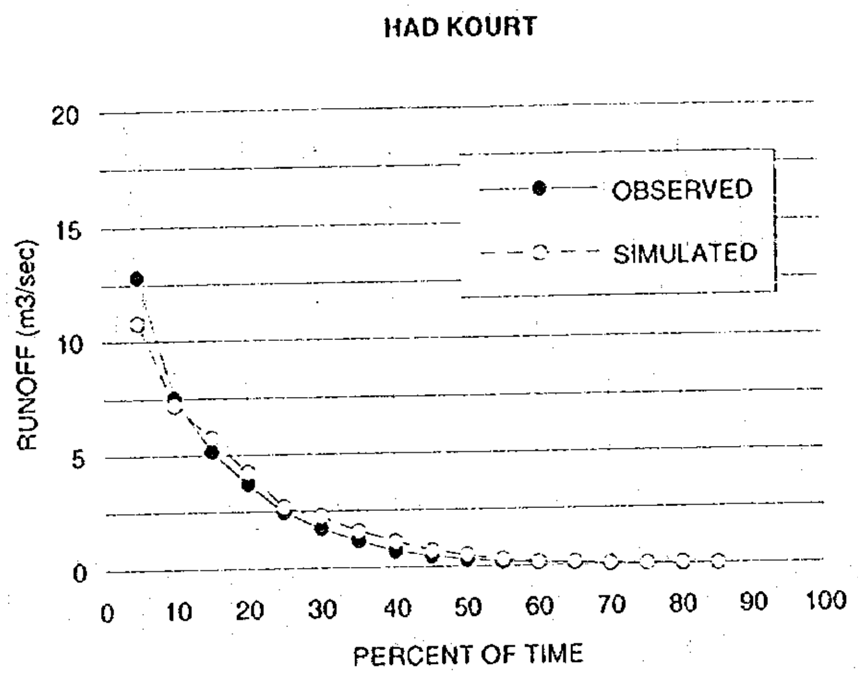


Figure 3.3.2 Comparison of Hydrograph



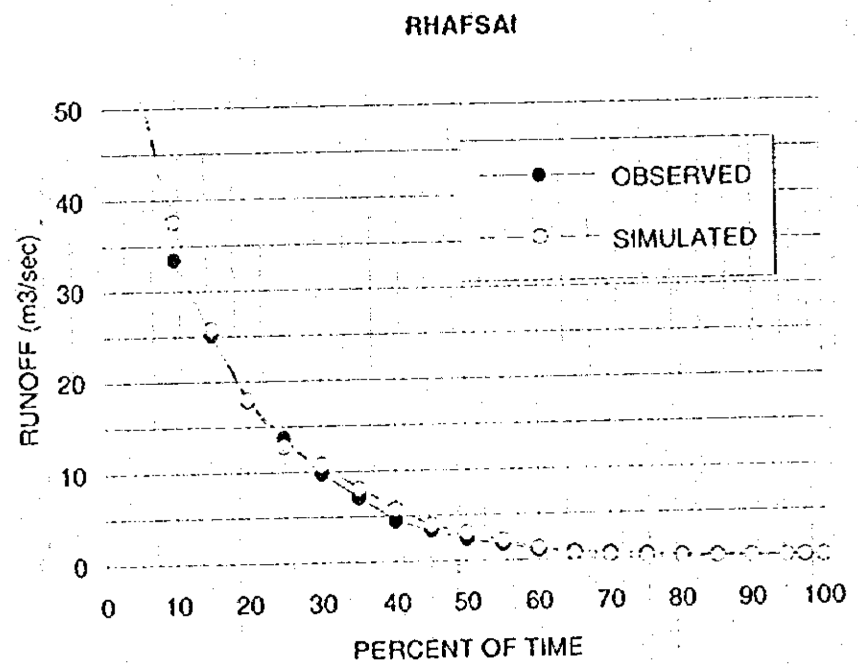


Figure 3.3.3 Comparison of Flow Duration Curve

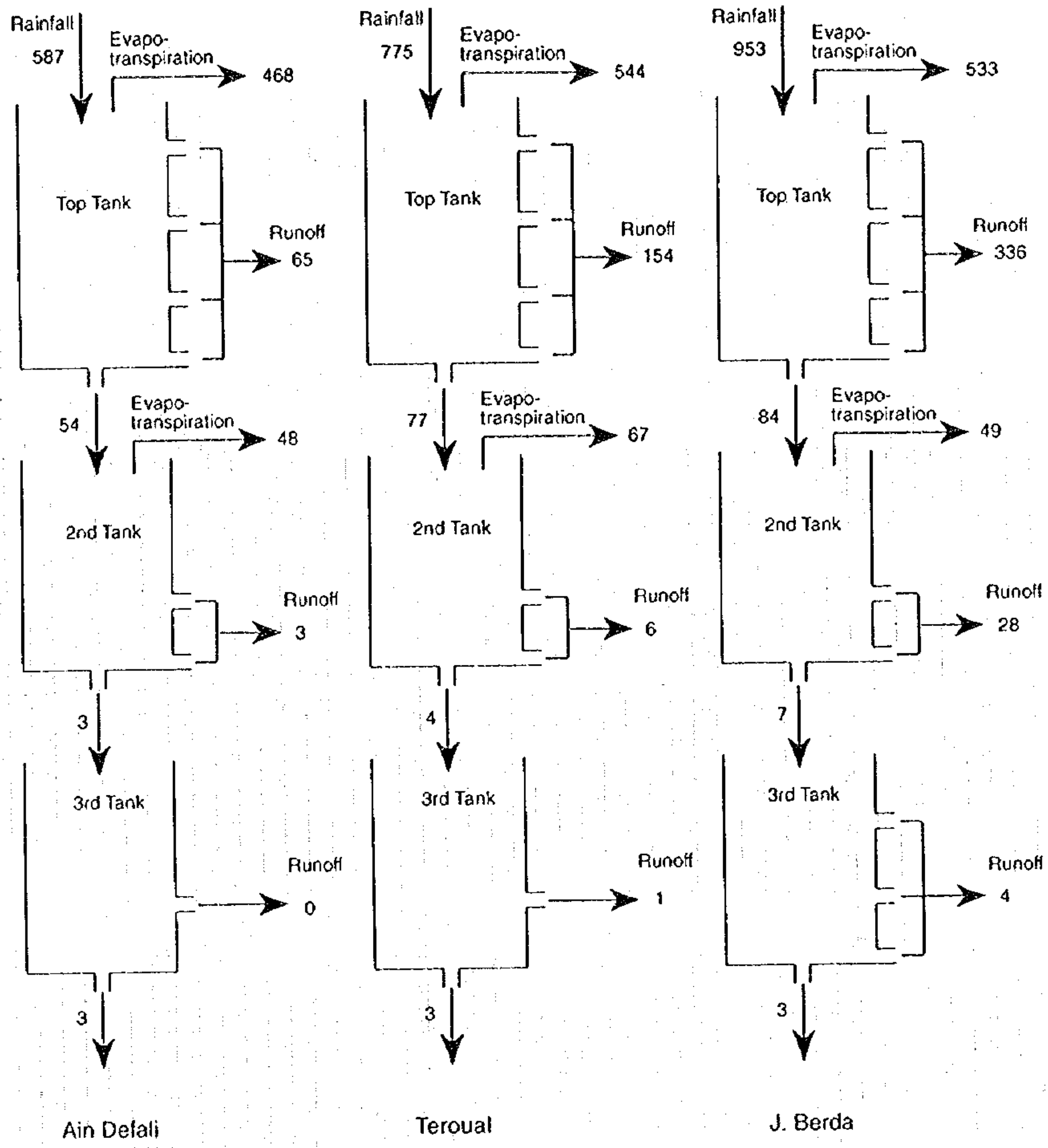


Figure 3.3.4 Water Balance Estimated by Tank Model

3.4 Inventory of Medium,Small and Hill Dams

3.4 Inventory of Medium, Small and Hill Dams

Construction of medium, small and hill dams is the one of the important policy of the Government of Morocco. This project purposes improvement of socio-economic conditions in line with water resource development and conservation of watershed.

Concerning to the Study Area the dam inventory was originally prepared by "The Integrated Management and Development of the Ouergha River Basin" in 1988. This inventory gave the 301 dam sites.

Subsequently, "The Agricultural Development of the Ouergha River Basin" was carried out in 1992. The objective of this project was the regional development in the upper Ouergha basin, which is to be achieved by improvement of agriculture and rural infrastructures in line with water resource development by construction of dams.

The original inventory was reviewed, and the additional investigations and studies were carried out . Consequent to those works, the "base inventory " was prepared for 358 sites including 20 sites of medium scale dams with storage capacity of 2 to 300 million m^3, 42 sites of small scale dams with 0.2 to 2 million m^3, and 316 sites of hill dams with 0.01 to 0.2 million m^3.

The master plan of the rural development was also elaborated with the implementation program for construction of dams. Screening of dams in the base inventory was carried out for preparation of the implementation program. The 215 dams were screened including 8 medium scale dams, 36 small scale dams and 171 hill dams.

Table 3.4.1 to 3.4.3 show the inventory of the proposed dams and the current information for the dam construction program. As of 1995, 1 medium scale dam, 2 small scale dams and 14 hill dams have been completed.

Table 3.4.1 Inventory of Medium Scale Dams

Name of Dam	Province	River	Location (Coordinates, km)		Catchment	Storage	Remarks
			X	Y	Area (km2)	(Mil. m3)	
Tizemlal	Al Hoceima	Mengon	592.65	471.45	174	20.0	AH
Bourendance	Al Hoceima	Bou Chabet	594.95	464.00	46	9.5	
Lemdaouara	Al Hoceima	El Guezzar	588.20	455.50	89	13.2	
Akajar	Al Hoceima	Amzaz	564.50	476.15	67	40.0	
K. Imougra	Al Houceima	Ketama	569.10	473.30	95	20.0	JICA
Azilal	Chefchaouen	Zitoun	507.85	466.10	22	27.0	AH
Tazarane	Chefchaouen	Bou Ich	540.30	484.20	34	12.0	AH
Tourarine	Chefchaouen	Zebre	518.00	475.00	177	4.1	
Ratba	Taounate	Aoulai	542.15	467.85	490	40.0	AH
Mkabrine	Taounate	Sahela	566.80	441.40	122	62.0	AH, JICA (Existing)
Zrizer	Taounate	Islane	571.25	444.20	26	7.0	AH, JICA
Bouhouda	Taounate	Sra	574.90	444.56	478	50.0	AH (Under Construction)
Lhaouder	Taounate	El Guezzar	584.20	445.85	137	12.0	AH, JICA
Abdoun	Taounate	Thamda	590.55	442.50	58	19.0	AH, JICA
Arsat Beri	Taounate	Asfalou	615.85	454.15	302	90.0	
Beni Berberes	Taounate	Aousra	577.90	449.35	42	5.4	
Sidi Mokfi	Taounate	Amzaz	558.45	448.30	378	25.7	
Jemaa Adlem	Taounate	Bou Mlal	598.20	452.24	14	2.3	
Thar Souk	Taounate	Ras Ouergha	602.95	452.65	468	20.0	JICA
Oued Sra	Taounate	Sra	571.70	436.40	540	40.0	AH, JICA
Asfalou	Taounate	Asfalou	610.75	448.80	560	320.0	SBO, AH, JICA
Boured	Taza	Asfalou	617.60	458.35	252	40.0	

Note :
- SBO: Proposed by Integrated Master Plan of Water Management in Sebou, Bou Regreg and Oum Er Rbia Basins, Water Superior Council of Morocco, 1992
- JICA: Proposed by Agricultural Development Project of Ouergha River Basin, JICA, 1992 (Short Term and Mid/Long Term Program)
- AH: Studied/Designed by AH, as of 1995

Table 3.4.2 Inventory of Small Scale Dams (1/3)

(1) Short Term Program (12 Sites)*

No.	Site	River	Province	Coordinates X	Coordinates Y	Catchment Area (km2)	Storage Capacity (1000 m3)	Remarks
PA-3	Bouassame	S. Bouchetta	Al Hoceima	575.500	476.200	4.43	1,000	
PC-1	Bouzembou	Assououl	Chefchaouene	505.250	482.500	4.10	1,300	Design Completed
PT-2	Addad	Aoulai	Taounate	539.800	440.800	19.39	887	Design Completed
PT-5	Bab Fouhla	Khouabi	Taounate	562.100	437.000	20.50	432	
PT-13	Kalaat El Assassa	Amzaz	Taounate	556.500	438.850	27.49	570	Design Completed
PT-14	Kelaat Nfes	Amzaz	Taounate	551.150	440.050	4.68	432	
PT-15	Kraker	Kraker	Taounate	543.700	429.200	2.10	470	
PT-19	Msalia	Gzaier	Taounate	560.300	435.400	4.71	600	
PT-22	Rharbia	Rharbia	Taounate	552.750	429.130	5.20	750	
PT-23	Saf	Melah	Taounate	546.900	429.550	5.57	1,000	Completed (Essaf)
PT-24	Sidi Krim	Roumane	Taounate	569.200	435.000	19.02	378	
PT-25	Souahel	Souahel	Taounate	569.200	435.000	3.16	1,560	

Note : * Proposed by Agricultural Development Project of Ouergha River Basin, JICA, 1992

Table 3.4.2 Inventory of Small Scale Dams (2/3)

(2) Mid-Long Term Program (24 Sites)*

No.	Site	River	Province	Coordinates X	Coordinates Y	Catchment Area (km2)	Storage Capacity (1000 m3)	Remarks
PA-1	Arekdi	Merj	Al Hoceima	608.500	462.200	3.00	230	
PA-2	Azila	Sgara	Al Hoceima	580.000	473.950	7.66	60	Design Completed
PA-4	Bouhout	S. Bouchetta	Al Hoceima	608.200	470.200	3.28	440	Design Completed
PA-5	Izghar	Amzaz	Al Hoceima	567.150	474.400	3.86	1,100	
PA-6	Mrint	Mrint	Al Hoceima	588.000	478.000	40.84	1,618	Design Completed
PC-3	El Koucha	Chahbia	Chefchaouene	506.000	465.450	6.05	1,348	Design Completed
PC-4	Sidi Abdessalem	Zebzar	Chefchaouene	516.900	417.650	7.60	1,357	Design Completed
PC-6	Tiliouane	Tarhumart	Chefchaouene	512.050	481.450	2.50	608	Design Completed
PT-1	A. Daroua	Aoulai	Taounate	542.750	444.450	2.77	500	
PT-3	Afounas	Afounas	Taounate	530.700	448.150	41.57	1,280	
PT-7	Boudouma	Sidi Tifssa	Taounate	561.800	444.700	8.51	290	
PT-8	Bousfoul	Aoulai	Taounate	544.000	450.000	5.08	990	Design Completed
PT-9	Douar El Hajra	Ouergha	Taounate	555.000	427.500	8.66	378	Degign Completed
PT-10	Gaaidine	Ouergha	Taounate	568.000	429.100	2.30	267	Design Completed
PT-11	Gada Sayah	Khnenndek	Taounate	566.000	436.500	1.63	920	
PT-12	Harraka	Rhadouss	Taounate	556.500	438.850	14.24	630	
PT-16	Maalouma	Afounas	Taounate	566.375	420.750	4.25	240	
PT-17	Mechkour	Sra	Taounate	572.600	447.400	2.30	500	Design Completed
PT-18	Merjdouar	Ouergha	Taounate	580.000	443.400	0.86	192	
PT-20	O. D. Merziane		Taounate	568.300	447.775	2.85	209	Design Completed
PT-21	Rhafsai	Aoudour	Taounate	552.750	429.130	4.71	288	
PT-26	Tazzart	Tazerene	Taounate	537.350	445.450	5.61	216	
PTZ-1	Afarzaz 2	Aferzar	Taza	619.650	457.650	9.45	1,549	
PTZ-2	Tamjout Haut	Tamjount	Taza	625.300	464.500	23.10	917	

Note : * Proposed by Agricultural Development Project of Ouergha River Basin, JICA, 1992

Table 3.4.2 Inventory of Small Scale Dams (3/3)

(3) Others Proposed/Completed

No.	Site	River	Province	Coordinates X	Coordinates Y	Catchment Area (km2)	Storage Capacity (1000 m3)	Remarks
	Kchahada		Chefchaouene	507.800	468.600	19.50	5,210	Design Completed
	Jorf El Ghorab		Taounate	534.800	423.950		900	Completed
	Amlilis		Taza	624.700	465.500	8.30	1,600	Design Completed

Table 3.4.3 Inventory of Hill Dams (1/4)

(1) Short Term Program (53 Sites)*

No.	Site	River	Province	Coordinates X	Coordinates Y	Catchment Area (km2)	Storage Capacity (1000 m3)	Remarks
LA-2	Achouch	Ketama	Al Hoceima	573.350	477.000	1.64	60	
LA-15	Cooperatif Asila	Sgara	Al Hoceima	578.700	475.200	2.58	158	
LA-17	Griha	Amzaz	Al Hoceima	568.800	478.900	1.18	48	
LA-22	Ikaouen	Sra	Al Hoceima	566.850	462.500	0.91	50	
LA-23	Imaziouen	Mengou	Al Hoceima	588.600	482.800	2.55	180	
LA-34	Koudia Chaib 3	Ketama	Al Hoceima	576.200	477.250	5.10	220	
LA-37	Ladai	Mengou	Al Hoceima	588.000	473.000	3.25	53	
LA-47	Oulad Mkhlad 1	S. Bouchetta	Al Hoceima	611.700	468.450	2.54	45	
LA-48	Oulad Mkhlad 2	S. Bouchetta	Al Hoceima	611.700	467.650	0.31	60	
LA-63	Tbijbijiene	S. Bouchetta	Al Hoceima	614.550	467.100	5.90	95	
LA-65	Timilizene	El Kebir	Al Hoceima	617.550	469.600	1.03	80	
LA-66	Timizine 1	El Kebir	Al Hoceima	617.150	469.400	1.29	40	
LA-67	Timizine 2	El Kebir	Al Hoceima	618.500	469.500	2.69	72	
LA-71	Ziya Hajjami	Amzaz	Al Hoceima	564.350	457.600	1.60	27	
LC-38	El Anassar	Chentou	Chefchaouen	537.200	490.600	1.90	160	
LC-52	Laalaech	Tallet	Chefchaouen	505.000	481.600	0.43	63	
LC-57	Moukhrissat 1	Tallet	Chefchaouen	504.850	482.350	3.05	45	
LT-13	Arekdi	S. Bouchetta	Taounate	608.400	462.600	0.85	72	
LT-17	Aznzar	Manchouk	Taounate	549.450	468.350	0.80	32	
LT-21	Bab El Friyen	Afounas	Taounate	534.750	448.550	1.01	68	
LT-24	Bab Laouinat	Rharbia	Taounate	552.150	429.670	7.10	96	
LT-28	Ben Mohamed	Krorchef	Taounate	532.400	431.700	0.61	72	
LT-35	Boubiad	Melah	Taounate	548.200	428.500	0.51	27	
LT-39	Dchar El Amar	M. Bouchta	Taounate	522.300	441.300	0.79	32	
LT-44	Dhar Khachab	Amzaz	Taounate	556.250	443.900	0.45	72	
LT-45	Douar Dachra	Ouergha	Taounate	560.000	428.050	0.75	64	
LT-49	Dr Erazna	El Brared	Taounate	562.450	422.050	3.86	85	
LT-51	El Ghaba Lekbira	Aouidiyar	Taounate	516.500	448.800	2.00	90	
LT-57	El Haouati	Ouergha	Taounate	565.150	426.400	1.00	72	
LT-61	Emal	Krorchef	Taounate	534.800	430.300	1.36	90	
LT-62	Esnoun	Charrouf	Taounate	549.550	429.550	0.43	24	
LT-66	Gharbaoui	El Homma	Taounate	564.650	433.050	0.76	64	
LT-68	Hadjar Mimoun	Ouergha	Taounate	528.500	432.600	0.11	64	
LT-70	Hallab	Aoulai	Taounate	542.450	463.200	0.61	60	
LT-72	Hazdour	Ouergha	Taounate	530.500	441.850	1.29	20	
LT-73	Houet	Asfalou	Taounate	610.950	450.900	0.50	48	
LT-74	Ifrour	Amzaz	Taounate	557.250	462.700	0.81	40	
LT-75	Imatan	Amzaz	Taounate	555.950	466.200	1.34	19	
LT-83	Kentra	Sra	Taounate	573.150	435.350	0.51	80	
LT-87	Khanchouf	Aouidiya	Taounate	518.700	447.000	1.00	156	
LT-88	Khandak	Ouergha	Taounate	526.300	445.000	0.50	128	
LT-95	Koudiat Alia	Barared	Taounate	562.500	424.750	1.69	96	
LT-97	Koudiat Detban	Aoudour	Taounate	527.750	447.200	0.70	96	
LT-103	Koudiat Tahinat	Sra	Taounate	575.800	442.500	0.65	36	
LT-107	Lamkabin	Tleta	Taounate	567.350	443.250	1.32	36	
LT-109	Larbaa Tazougart	Amzaz	Taounate	556.100	463.850	1.31	80	
LT-111	Marjat Laarab	Ouergha	Taounate	550.300	430.000	0.76	48	
LT-114	Mrablionnie	Darif	Taounate	571.800	453.750	2.13	90	
LT-122	Oulad Kaddour	Krorchef	Taounate	532.700	431.750	7.56	60	
LT-130	Rhadoussa	Rhadoussa	Taounate	557.900	439.800	7.55	56	
LT-131	Rhiaba	Souita	Taounate	559.250	426.125	1.36	24	
LT-132	Rhirhane	Aoudiyar	Taounate	520.100	459.450	1.11	24	
LT-150	Tanza							

Note : * Proposed by Agricultural Development Project of Ouergha River Basin, JICA, 1992

Table 3.4.3 Inventory of Hill Dams (2/4)

(2) Mid-Long Term Program (118 Sites)*, page 1of 2

No.	Site	River	Province	Coordinates X	Coordinates Y	Catchment Area (km2)	Storage Capacity (1000 m3)	Remarks
LA-1	Achenak	Mengou	Al Hoceima	592.700	466.500	1.04	24	
LA-4	Aguerchf	Amzaz	Al Hoceima	562.950	474.200	3.61	90	
LA-5	Amarstas	Amzaz	Al Hoceima	561.000	470.000	2.70	22	
LA-7	Arhil Ahmed	S. Bouchetta	Al Hoceima	610.600	466.200	7.05	108	
LA-8	Asanson	Mengou	Al Hoceima	589.700	466.200	2.93	36	
LA-11	Azerhar	Amzaz	Al Hoceima	566.000	474.600	1.54	36	
LA-14	Chekkara	Amzaz	Al Hoceima	561.850	466.000	1.20	54	
LA-18	Griha 2	Ketama	Al Hoceima	568.150	478.400	1.08	45	
LA-21	Ijouaouence 2	S. Bouchetta	Al Hoceima	607.550	468.200	1.50	60	
LA-24	Izihel	S. Bouchetta	Al Hoceima	607.600	466.200	2.40	36	
LA-26	Izouger 2	Sra	Al Hoceima	565.500	466.250	1.11	19	
LA-29	Jbel Sidi Ali	Amzaz	Al Hoceima	563.850	466.700	1.38	65	
LA-32	Koudia Chaib 1	Ketama	Al Hoceima	577.650	477.300	1.19	60	
LA-35	Koudiat Dahra	Amzaz	Al Hoceima	555.350	473.550	0.82	35	
LA-39	Oued Ghazoum	Amzaz	Al Hoceima	565.950	479.200	7.26	72	
LA-41	Oued Mrinet	Mengou	Al Hoceima	585.700	466.000	2.60	43	
LA-44	Oued Rhiamane	Sra	Al Hoceima	585.400	466.000	5.53	72	
LA-45	Oued Sgara	Sra	Al Hoceima	576.550	470.400	1.13	26	
LA-49	Ouled Mahkem	Ahmidou	Al Hoceima	603.400	468.400	1.21	30	
LA-50	Sahil	Machouk	Al Hoceima	553.800	470.650	1.25	29	
LA-51	Sfa	Mengou	Al Hoceima	583.250	479.900	2.07	54	
LA-52	Sidi Boucheta	S. Bouchetta	Al Hoceima	612.450	463.500	2.75	81	
LA-53	Sidi Mokhfi	Guezzar	Al Hoceima	588.150	459.900	3.53	18	
LA-54	T. Ali Oujetou	El Kebir	Al Hoceima	623.650	472.100	2.59	36	
LA-58	Taizn Tigrout	Ketama	Al Hoceima	572.800	476.250	4.28	60	
LA-59	Tamellourit	Amzaz	Al Hoceima	567.900	476.200	1.83	40	
LA-60	Tassakette 1	S. Bouchetta	Al Hoceima	616.650	465.750	1.04	60	
LA-62	Tazougart	Amzaz	Al Hoceima	555.850	468.350	0.71	36	
LA-64	Tiguita	S. Bouchetta	Al Hoceima	614.550	467.100	5.90	95	
LC-1	Adraouiyine 1	Aoudour	Chefchaouen	524.450	472.400	1.11	27	
LC-2	Adraouiyine 2	Aoudour	Chefchaouen	525.800	472.600	1.33	48	
LC-14	Asrih	Berranda	Chefchaouen	523.950	494.600	0.59	96	
LC-17	Azemmour	Aoulai	Chefchaouen	550.700	484.000	1.46	80	
LC-19	Bab Taza 2	Berranda	Chefchaouen	517.800	494.850	1.42	63	
LC-20	Beni Ahmed	Aoudour	Chefchaouen	529.700	470.950	0.53	30	
LC-23	Beni Mouauia	Zebzar	Chefchaouen	515.900	474.000	0.40	45	
LC-27	Blat	Aoulai	Chefchaouen	538.200	479.250	5.08	72	
LC-33	Chaaliyene	Aoudour	Chefchaouen	517.250	464.500	1.91	108	
LC-36	Cherbahat	Tasrafete	Chefchaouen	525.500	467.000	1.30	60	
LC-37	Dar Elghaba	Tasrafete	Chefchaouen	527.900	469.450	1.26	36	
LC-50	Kourt	Zebzar	Chefchaouen	518.900	481.700	2.52	24	
LC-54	Maasra	Berranda	Chefchaouen	519.300	493.400	0.50	120	
LC-66	Talazioul	Aoulai	Chefchaouen	541.950	480.700	1.08	45	
LC-69	Takasbout	Machouk	Chefchaouen	550.400	472.800	0.58	24	
LC-70	Talla Moksa	Amzaz	Chefchaouen	554.950	474.600	1.34	40	
LC-71	Tarkalou	Tasrafete	Chefchaouen	528.100	468.800	0.56	30	
LC-76	Tlam Daoud	Anourhra	Chefchaouen	555.800	483.500	1.60	77	
LT-1	Abdellah	Abdellah	Taounate	609.000	453.450	0.71	48	
LT-6	Ain Sahil	Amassina	Taounate	606.950	449.100	1.84	40	
LT-7	Ain Salah	Ouergha	Taounate	577.150	434.000	0.89	12	
LT-10	Amran	Daichrif	Taounate	614.550	455.550	2.05	24	
LT-11	Amtout	Aoulai	Taounate	542.800	446.700	0.56	23	
LT-14	Arhil Ahmed	S. Bouchetta	Taounate	609.100	466.300	6.98	72	
LT-20	Bab El Aloua	Tleta	Taounate	567.900	456.200	0.61	14	
LT-22	Bab El Kalaa	Amzaz	Taounate	554.400	445.900	1.33	19	
LT-25	Bed El Kia	Chouatoa	Taounate	598.100	454.100	0.48	16	
LT-26	Ben Hayen	Ain Kouub	Taounate	552.450	439.900	1.24	20	
LT-27	Ben Lwalid	Amzaz	Taounate	557.300	447.100	0.98	72	
LT-29	Bemass	Amzaz	Taounate	557.950	473.100	1.03	32	
LT-32	Bir Merja	El Brared	Taounate	562.700	425.050	0.58	45	
LT-34	Bou Chein	Tarhzout	Taounate	603.650	448.800	0.41	13	
LT-36	Boukherfal	Aslalou	Taounate	616.300	452.700	1.12	18	
LT-40	Deflin	Deflin	Taounate	607.600	451.900	1.04	24	

Table 3.4.3 Inventory of Hill Dams (3/4)

(2) Mid-Long Term Program (118 Sites)*, page 2 of 2

No.	Site	River	Province	Coordinates X	Coordinates Y	Catchment Area (km2)	Storage Capacity (1000 m3)	Remarks
LT-41	Demerdene	Demerdene	Taounate	579.320	442.650	1.29	32	
LT-42	Dhar Almazou	Ouergha	Taounate	524.400	435.150	0.71	12	
LT-43	Dhar Amimar	Ouergha	Taounate	524.000	437.700	0.30	40	
LT-50	El Araba	Sehhaja	Taounate	612.400	446.900	1.08	48	
LT-54	El Haddara	Ouergha	Taounate	601.150	454.050	0.48	24	
LT-55	El Hamda	Hamda	Taounate	550.050	429.200	0.40	18	
LT-56	El Hamra	Ouergha	Taounate	564.650	430.400	0.22	16	
LT-59	El Matlous	El Matlos	Taounate	611.800	458.600	4.51	48	
LT-60	El Ouidan	Ouergha	Taounate	524.950	445.100	0.46	48	
LT-65	Geiza	S. Bouchetta	Taounate	607.750	462.750	3.71	45	
LT-76	Jbal Sfoula 1	Amzaz	Taounate	556.200	469.200	1.38	60	
LT-77	Jbal Sfoula 2	Amzaz	Taounate	555.350	469.550	0.47	24	
LT-81	Kdioua Chrif	Aoudiyar	Taounate	523.200	453.800	0.34	48	
LT-84	Khallad 1	Machouk	Taounate	553.250	465.200	1.00	85	
LT-86	Khan Dak Mzaoud	Ouergha	Taounate	523.750	438.600	0.88	54	
LT-89	Khandak Selem	Sahala	Taounate	566.250	437.750	0.50	30	
LT-91	Khendark Sbaa	Khenndek	Taounate	527.100	445.825	0.43	15	
LT-96	Koudiat Baida	Ouergha	Taounate	561.200	426.800	1.85	144	
LT-100	Koudiat Sanhaja	Bou Koufene	Taounate	558.650	437.650	0.36	30	
LT-102	Koudiat Sir Maazouza	Teheriss	Taounate	579.900	430.550	0.45	14	
LT-104	Koudiat Taourant	Ouergha	Taounate	526.950	443.600	0.70	30	
LT-105	Lalla Boumzia	Aoudour	Taounate	531.300	458.450	2.48	72	
LT-108	Lamraj	Machouk	Taounate	548.150	462.800	1.06	21	
LT-115	Mrira	Aoulai	Taounate	537.600	446.000	0.48	24	
LT-116	My Bouchta	Aoudiyar	Taounate	521.250	448.750	0.74	43	
LT-117	Nader	Sahala	Taounate	567.000	437.150	0.46	24	
LT-121	Oulad Kacem	Ouergha	Taounate	564.600	424.600	0.56	30	
LT-125	Ouled Bentaher	Aicha	Taounate	516.400	456.250	0.73	24	
LT-127	Ouled Jaber	Selloum	Taounate	556.950	427.320	3.21	36	
LT-128	Ouled Tahar	Ouergha	Taounate	555.760	434.850	1.05	24	
LT-129	Rabanir	Ouergha	Taounate	526.000	435.850	0.55	24	
LT-135	Selfah	Tleta	Taounate	569.350	455.150	0.74	34	
LT-136	Sfssef	Machouk	Taounate	543.800	465.100	0.75	48	
LT-137	Sghoula	Ouergha	Taounate	531.000	432.850	0.71	36	
LT-138	Si Bouamar	Tleta	Taounate	570.400	454.250	0.75	24	
LT-139	Si El Haja Lamdaber	Aoudour	Taounate	533.550	456.400	1.35	60	
LT-141	Si Med Chrif	Ouergha	Taounate	569.300	428.550	0.58	19	
LT-143	Sidi Ahmed	Ouergha	Taounate	531.600	432.800	0.30	36	
LT-149	Tafraout	Amassine	Taounate	607.000	455.550	1.74	45	
LT-151	Tazrout	Amassine	Taounate	608.100	454.500	3.20	19	
LT-152	Tenza	Aoudour	Taounate	526.900	456.800	0.74	22	
LT-153	Timhid	Machouk	Taounate	550.900	465.250	0.59	29	
LT-154	Touam	Ouergha	Taounate	561.000	429.550	0.25	36	
LT-156	Zaouyat Amejout	Aoudiyar	Taounate	524.000	455.300	0.86	36	
LTZ-2	Ain Aotoun	Tamjount	Taza	622.800	464.300	0.79	30	
LTZ-3	Bouzineb	Tamjount	Taza	625.050	468.600	2.10	38	
LTZ-4	Dhar El Louz	Sarhour	Taza	619.600	450.700	1.46	27	
LTZ-5	Guer Sekka	Boured	Taza	616.000	458.100	1.60	100	
LTZ-6	Irhzar	Ed Daflou	Taza	625.550	459.900	2.80	38	
LTZ-7	Jbel Amlils	Tamjount	Taza	624.750	466.200	7.91	84	
LTZ-8	Jbel Taoura	Tamjount	Taza	622.500	460.750	1.33	30	
LTZ-9	Jbel Timchat	Tamjount	Taza	626.200	465.750	1.85	60	
LTZ-11	Sahil	Imechouene	Taza	613.600	460.000	1.30	18	
LTZ-12	Sidi Abdelmoumen	Ed Defla	Taza	624.100	460.000	2.50	40	
LTZ-14	Sidi Massaoud	Tamda	Taza	598.350	440.300	0.95	24	

Note : * Proposed by Agricultural Development Project of Ouergha River Basin, JICA, 1992

Table 3.4.3 Inventory of Hill Dams (4/4)

(3) Others Proposed/Completed

No.	Site	River	Province	Coordinates X	Coordinates Y	Catchment Area (km2)	Storage Capacity (1000 m3)	Remarks
LA-40	Oued Mobrouk	S. Bouchetta	Al Hoceima	609.546	470.334	1.40	170	Completed
LT-5	Ain Guettra	Ouergha	Taounate	557.150	431.400	0.25	20	Completed
LT-12	Ank Jmal	Merakat	Taounate	541.900	430.350	1.70	32	Completed
LT-18	Bab Boughazi	Ouergha	Taounate	554.650	430.630	0.29	20	Completed
LT-38	Chtioui	Ouergha	Taounate	551.000	430.000	0.62	58	Completed
LT-47	Douar Lakhazayne	Ouergha	Taounate	554.500	430.250	0.28	25	Completed
LT-48	Douar Trifa	Ouergha	Taounate	549.950	430.100	0.95	80	Completed
LT-58	El Khmiss Zrayzar	Islane	Taounate	572.100	443.600	0.90	43	Completed
LT-110	Mahadama	Ouergha	Taounate	524.850	436.250	3.34	75	Completed
LT-123	Ouldiat El Hafa 1	Ouergha	Taounate	527.100	432.450	0.45	40	Completed
LT-126	Ouled Boumaiza	Merkat	Taounate	538.770	429.200	1.65	200	Completed
LT-134	Sahelomar	Kartaba	Taounate	574.750	428.805	0.87	125	Completed
LT-140	Si El Makhfi	Amzaz	Taounate	556.250	445.300	1.10	80	Completed
LT-147	Sidi Moussa	El Brared	Taounate	562.650	425.750	0.35	35	Completed

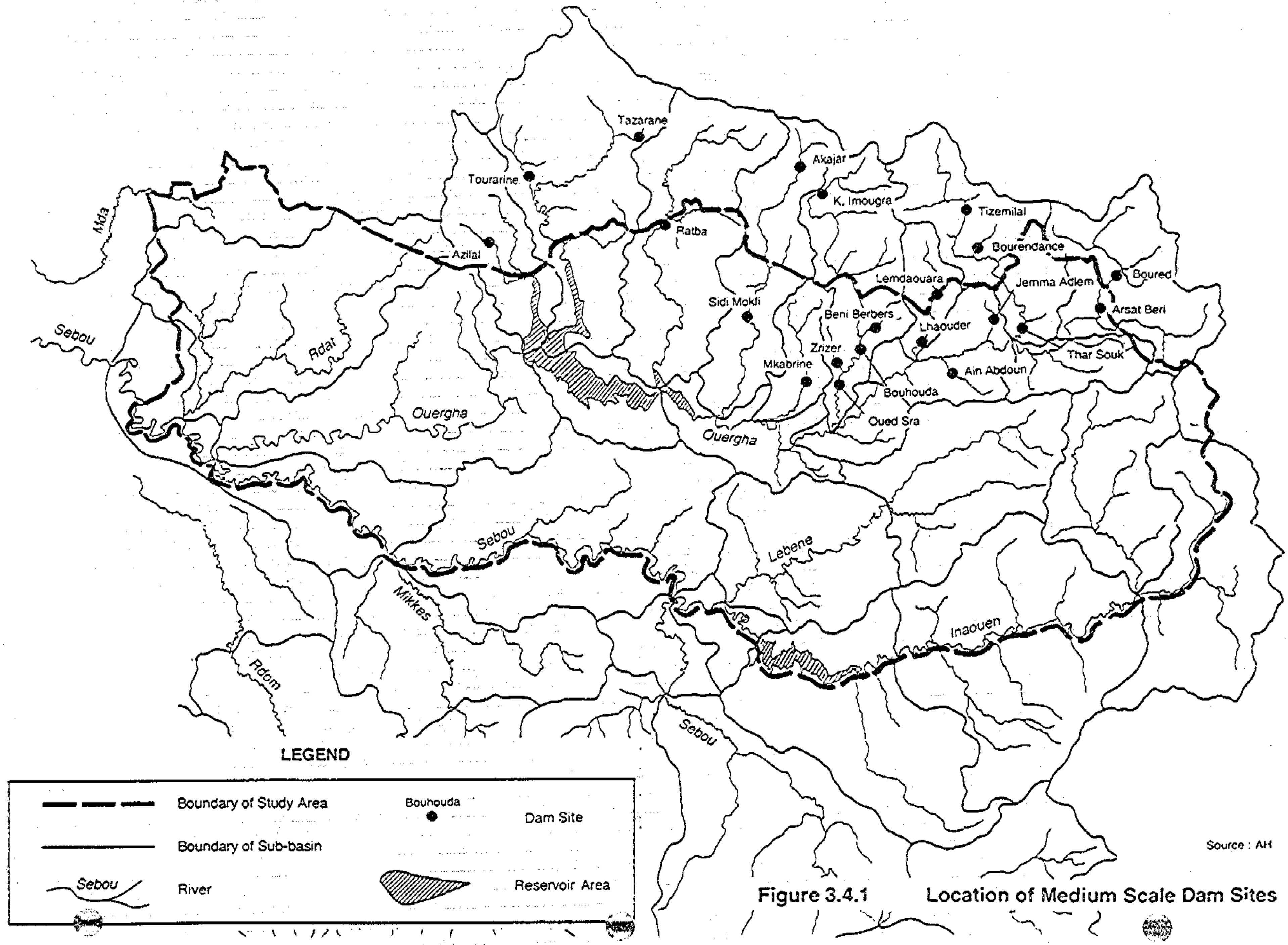


Figure 3.4.1 Location of Medium Scale Dam Sites

3.5 Prelinminary Water Balance Study

3.5 Preliminary Water Balance Study

3.5.1 General

In the upper Ouergha basin, surface water development is being implemented by constructing medium and small scale dams. construction these dams generally aims at enhancing development of rural area by use of water for agriculture. Meanwhile, the medium scale dam with a sufficient storage capacity for regulating the river discharge is expected to be utilized for a source of potable water supply. In this study, the city of Taounate and the neighboring communes were selected and water use in this area was assessed in consideration of the agricultural development and the future potable water demand.

3.5.2 Water Balance Study

(1) Dams

According to the Ouergha River Master Plan, the area along the Ouergha river near the city of Taounate has the highest potential for agricultural development. The Ouergha River Master Plan proposed the agricultural development in this areas as the priority project using water to be developed by construction of the Zrizer dam and the Sra headwork on the Sra river, and the El Mekabline dam on the Sahela river. Construction of the El Mekabline dam was completed in 1994. Other than these dam plans, construction of the Bouhouda dam located on the Sra river was commenced in 1995. Purposes of this project are the said agriculture and potable water supply.

(2) Water Demand

"The Agricultural Development in the Ouergha River Basin" gave the irrigation demand for the agricultural development. The proposed agricultural development schemes are presented below.

Location	Area (ha)	Irrigation Water Demand (Million m^3/year)
Downstream Sra River	2,500	27.7
Downstream Sahela River	4,230	45.7
Total	6,730	73.4

Potable water demand is obtained from the water demand projection of this study. The potable water demand of the objective area including the six communes is shown below.

Commune	Potable Water Demand in Year 2010	
	(m^3/day)	(m^3/year)
Taounate	1,832	668,680
Rghoua	155	56,575
Bouadel	41	14,965
Ain Mediouna	469	171,185
Mezraoua	272	99,280
Zrizer	217	79,205
Bouhouda	648	236,520
Total	3,634	1,326,410

(3) Water Balance

This monthly runoff Data from the hydrological year 1957/58 to 1993/94 were used for the water balance calculation. Water balance of each dam is calculated as follows.

$$\Delta S = I - O - E$$

where

S : Storage of Reservoir

I : Inflow

D : Outflow

E : Reservoir Surface Evaporation

Outflow from dam is determined depending on storage, inflow and water requirement. For example, when river discharge is not enough for water demand, a required volume of water is supplied from dam in case that a sufficient reservoir storage is available.

The water balance is evaluated for the case of an average hydrological year and a 1/10 drought year as shown in Table 3.5.1 and 3.5.2, The water balance calculations at the respective storage dams are illustrated in Figures 3.5.1 to 3.5.6 for both cases.

The results shows that the surface water resource to be developed by the above-mentioned dam construction will meet with both potable water demand of 1.33 million m^3/year for the seven communes and irrigation requirement of 73.4 million m^3/year. A schematic diagram of water balance in the objective area is shown in Figure 3.5.7.

Table 3.5.1 Water Balance in Taounate Area (Average Year)

Bouhouda + Zrizer + Oued Sra (Headwork)

Potable Water	1.3 MCM/Year	(6 communes)
Irrigation	27.7 MCM/Year	(2500 Ha)

Year : 1978/79

Month	(1) Bouhouda Outflow	(2) Zrizer Outflow	(3) Residual Catchement	(4) Oued Sra Site (1)+(2)+(3)	(5) Potable Water Demand	(6) Irrigation Demand	(7) Balance (4)-(5)-(6)
Sept	0.94	0.02	0.03	0.99	0.11	0.88	0.00
Oct	0.61	0.00	0.03	0.64	0.11	0.52	0.00
Nov	0.31	0.00	0.03	0.33	0.11	0.23	0.00
Dec	9.32	0.00	0.62	9.94	0.11	0.49	9.34
Jan	77.76	0.00	3.35	81.10	0.11	0.58	80.41
Feb	137.32	0.00	5.91	143.24	0.11	0.89	142.24
Mar	52.46	0.00	2.25	54.71	0.11	2.41	52.20
Apr	23.56	0.00	1.04	24.60	0.11	3.37	21.12
May	6.20	0.00	0.27	6.47	0.11	5.08	1.27
June	1.46	4.75	0.08	6.28	0.11	6.18	0.00
July	3.93	1.18	0.05	5.16	0.11	5.05	0.00
Aug	2.11	0.00	0.03	2.13	0.11	2.02	0.00
	315.97	5.95	13.67	335.59	1.33	27.69	306.57

Sahela

Irrigation Water Demand : 45.7 MCM/Year (4230 Ha)

Year : 1978/79

	(1) Sahela Site	(2) Residual Catchement	(3) Release from Sra River	(4) Irrigation Demand	(5) Balance (1)+(2)+(3)-(4)
Sept	0.78	0.04	0.00	0.82	0.00
Oct	0.52	0.05	0.00	0.58	0.00
Nov	0.23	0.06	0.00	0.29	0.00
Dec	0.00	0.90	9.34	0.75	9.49
Jan	0.00	4.95	80.41	0.94	84.42
Feb	18.50	8.74	142.24	1.49	167.99
Mar	9.57	3.35	52.20	4.24	60.88
Apr	4.35	1.52	21.12	5.87	21.12
May	8.47	0.42	1.27	8.89	1.27
June	10.65	0.09	0.00	10.74	0.00
July	8.32	0.04	0.00	8.36	0.00
Aug	2.73	0.01	0.00	2.74	0.00
	64.12	20.18	306.57	45.70	345.17

Table 3.5.2 Water Balance In Taounate Area (10-Year Drought)

Bouhouda + Zrizer + Oued Sra (Headwork)
Potable Water 1.3 MCM/Year (6 Communes)
Irrigation 27.7 MCM/Year (2500 Ha)

Year : 1991/92

Month	(1) Bouhouda Outflow	(2) Zrizer Outflow	(3) Residual Catchement	(4) Oued Sra Site (1)+(2)+(3)	(5) Potable Water Demand	(6) Irrigation Demand	(7) Balance (4)-(5)-(6)
Sept	1.80	0.00	0.00	1.80	0.11	0.88	0.82
Oct	0.76	0.00	0.19	0.95	0.11	0.52	0.31
Nov	0.40	0.00	0.08	0.48	0.11	0.23	0.15
Dec	0.84	0.00	0.21	1.06	0.11	0.49	0.46
Jan	1.32	0.00	0.13	1.45	0.11	0.58	0.76
Feb	2.06	0.00	0.18	2.24	0.11	0.89	1.24
Mar	6.34	0.00	0.16	6.50	0.11	2.41	3.98
Apr	9.16	0.00	1.66	10.82	0.11	3.37	7.34
May	12.59	1.09	0.16	13.84	0.11	5.08	8.64
June	16.41	0.16	0.18	16.75	0.11	6.18	10.47
July	13.38	0.01	0.05	13.45	0.11	5.05	8.29
Aug	4.81	0.00	0.03	4.84	0.11	2.02	2.71
	69.89	1.27	3.03	74.19	1.33	27.69	45.17

Sahela
Irrigation 45.7 MCM/Year (4230 Ha)

Year : 1991/92

	(1) Sahela Site	(2) Residual Catchement	(3) Release from Sra River	(4) Irrigation Demand	(5) Balance (1)+(2)+(3)-(4)
Sept	0.00	0.01	0.82	0.82	0.00
Oct	0.00	0.26	0.31	0.58	0.00
Nov	0.16	0.14	0.15	0.29	0.16
Dec	0.46	0.29	0.46	0.75	0.45
Jan	0.75	0.18	0.76	0.94	0.75
Feb	0.85	0.25	1.24	1.49	0.85
Mar	0.64	0.25	3.98	4.24	0.64
Apr	3.42	2.45	7.34	5.87	7.35
May	4.12	0.25	8.64	8.89	4.12
June	0.49	0.26	10.47	10.74	0.49
July	0.00	0.07	8.29	8.36	0.00
Aug	0.00	0.03	2.71	2.74	0.00
	10.89	4.45	45.17	45.70	14.81

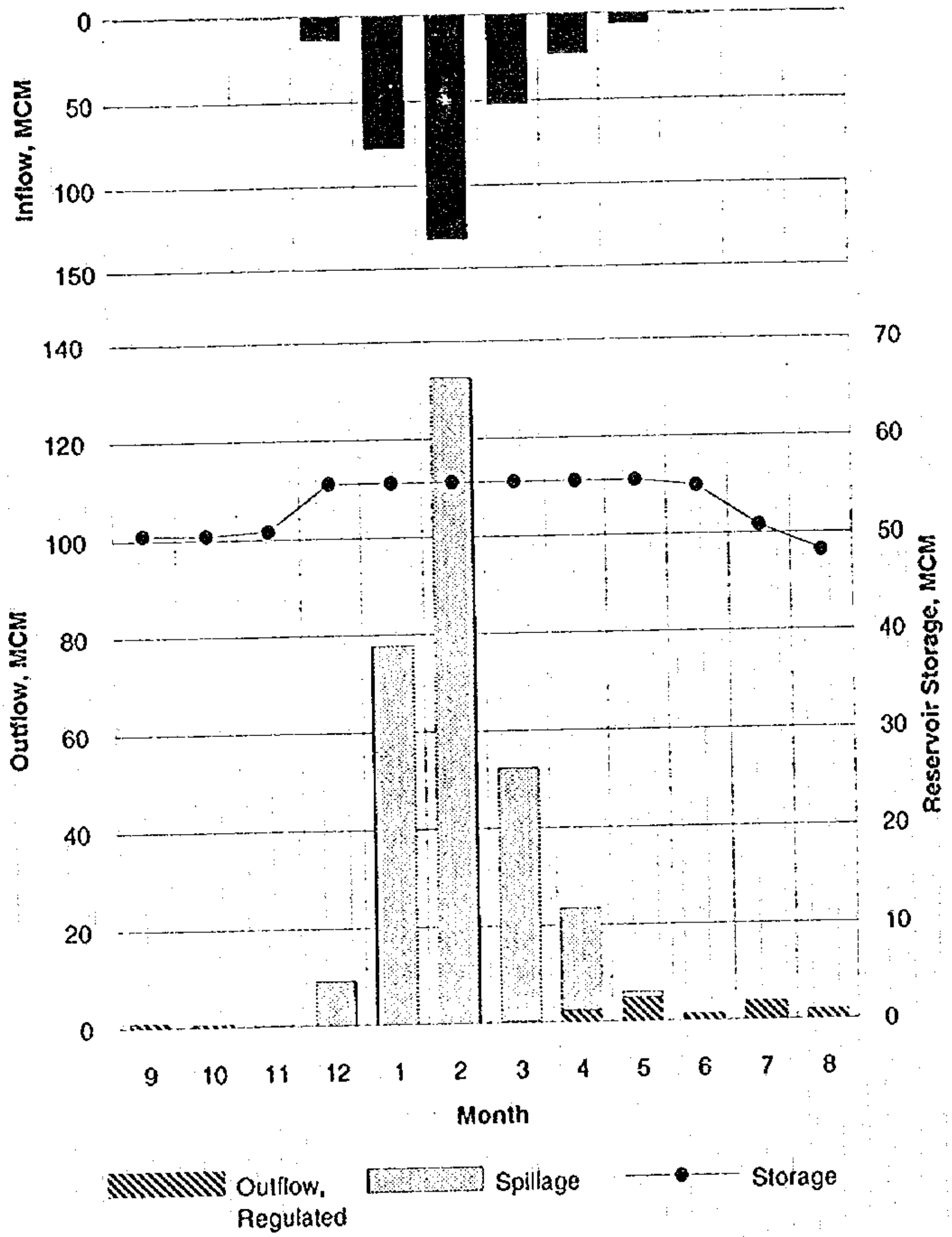


Figure 3.5.1 Water Balance at Bouhouda Dam (Average Year : 1978/79)

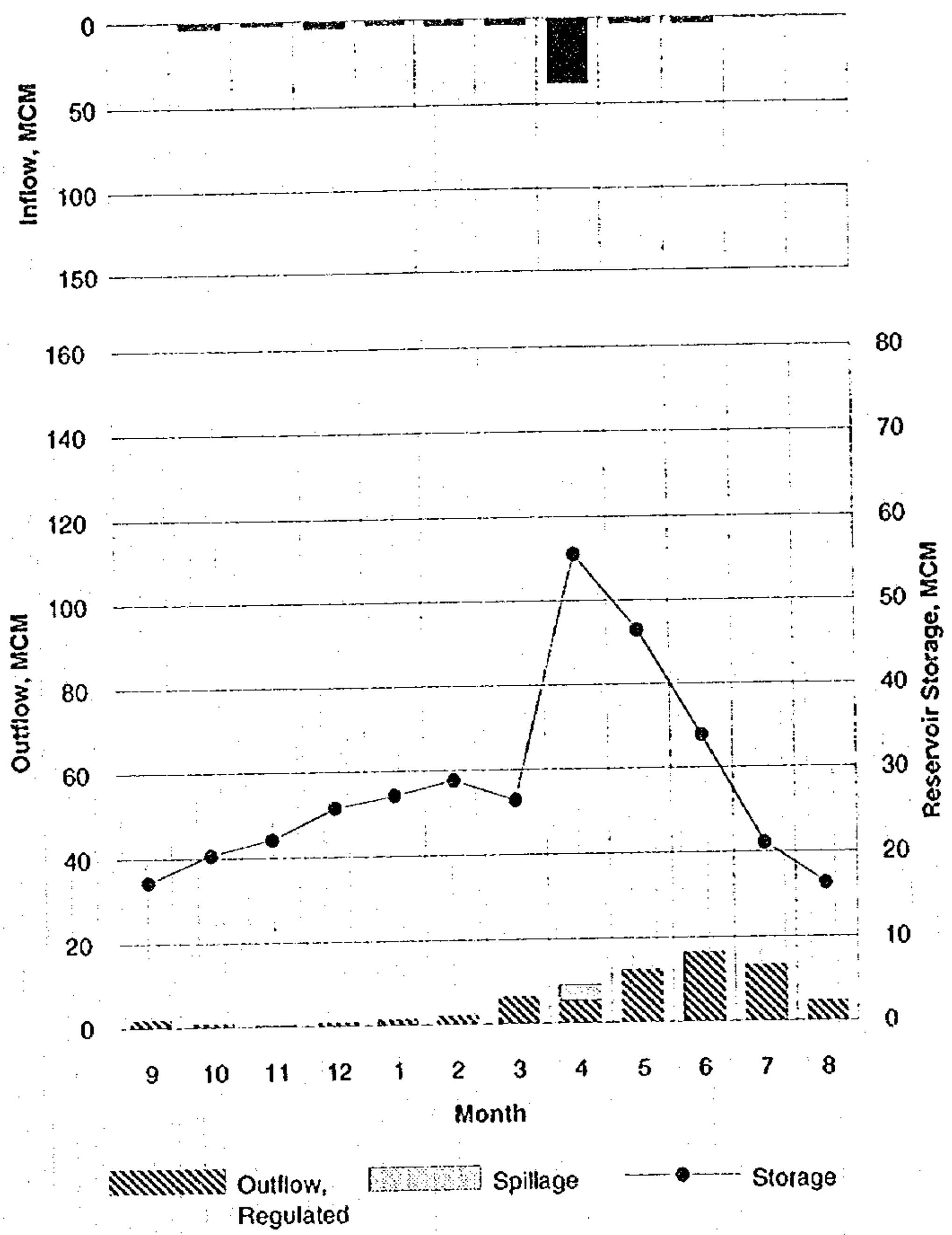


Figure 3.5.2 Water Balance at Bouhouda Dam (10-Year Drought : 1991/92)

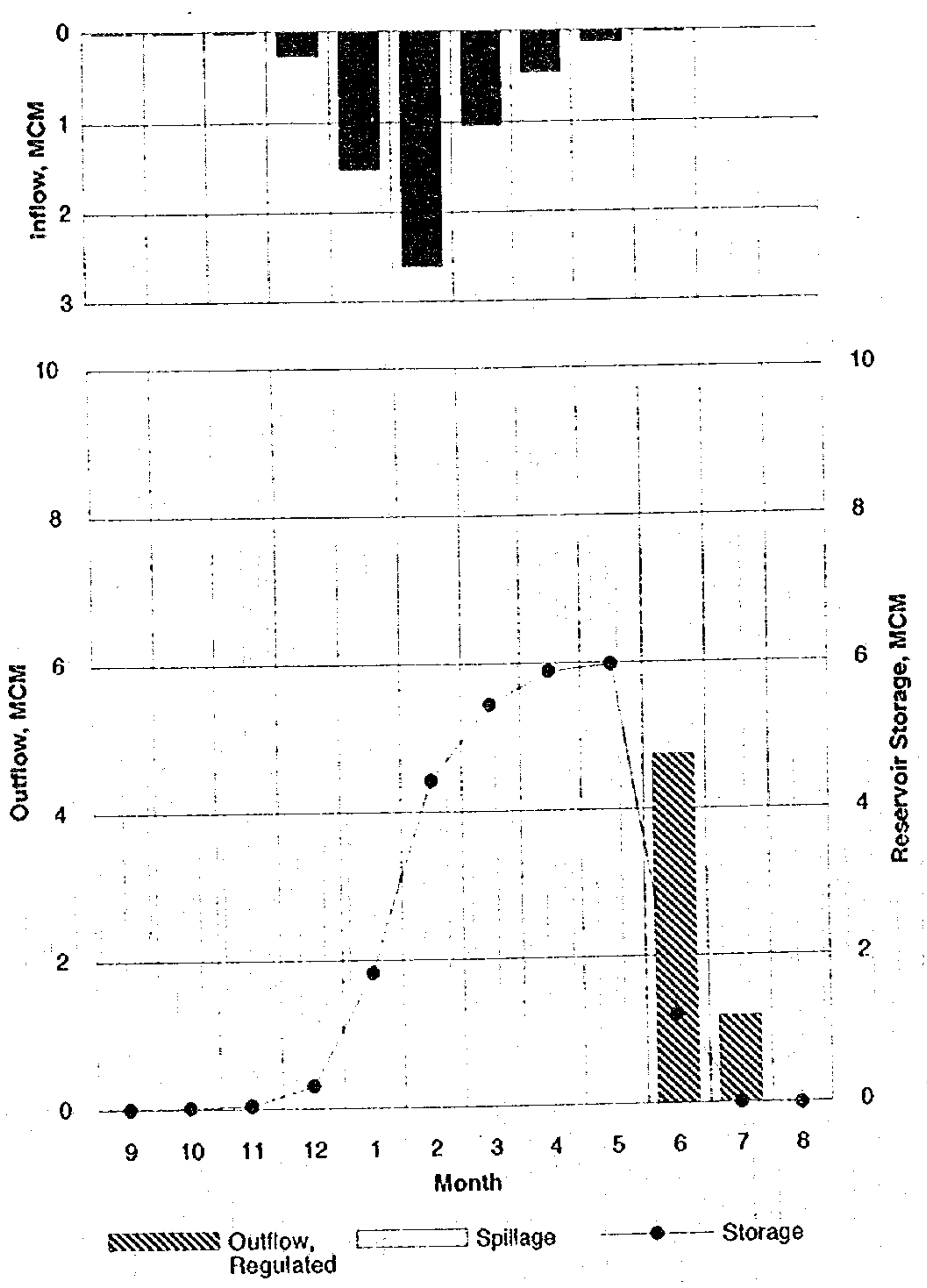


Figure 3.5.3 Water Balance at Zrizer Dam
(Average Year : 1978/79)

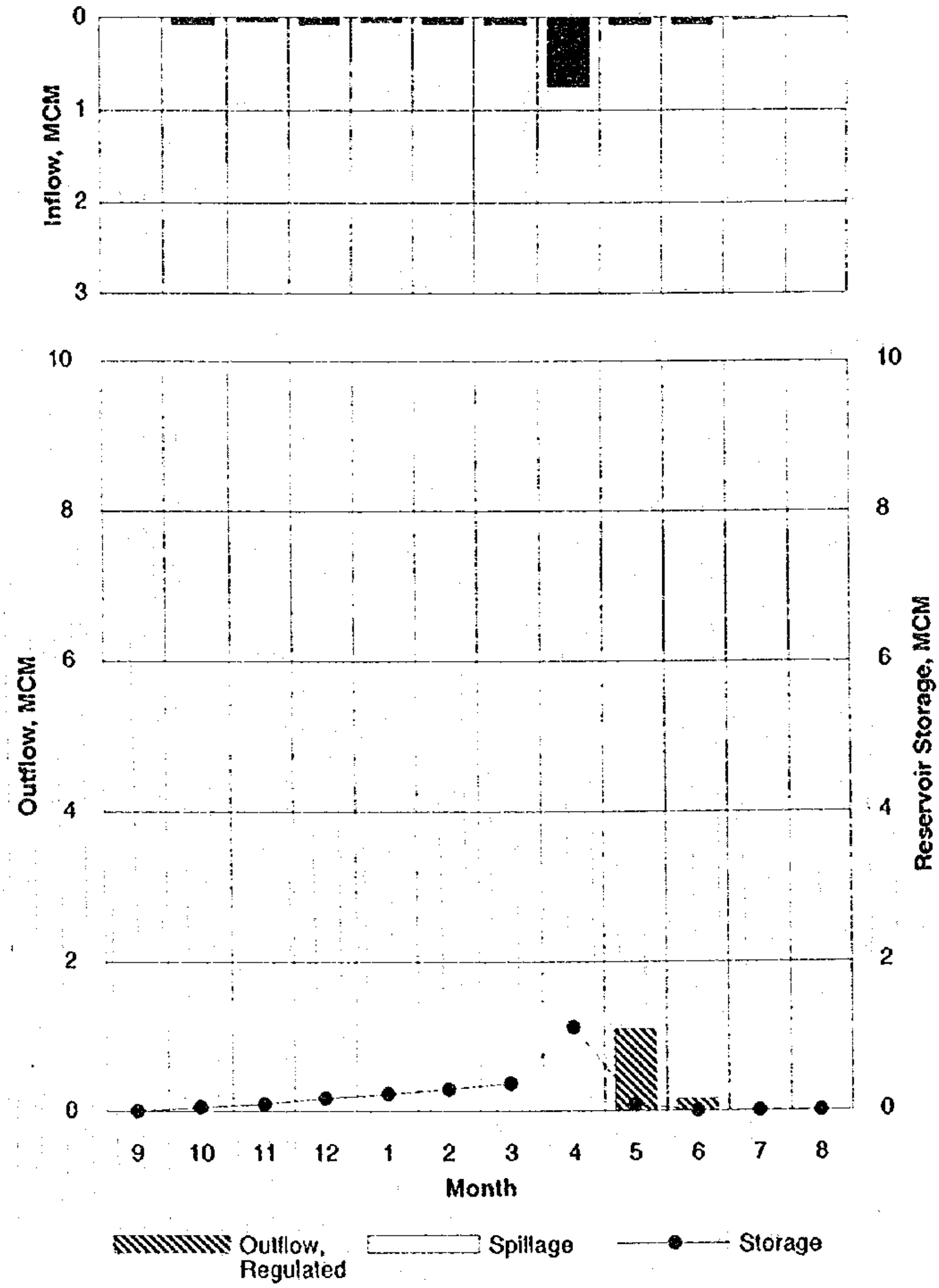


Figure 3.5.4 Water Balance at Zrizer Dam (10-Year Drought : 1991/92)

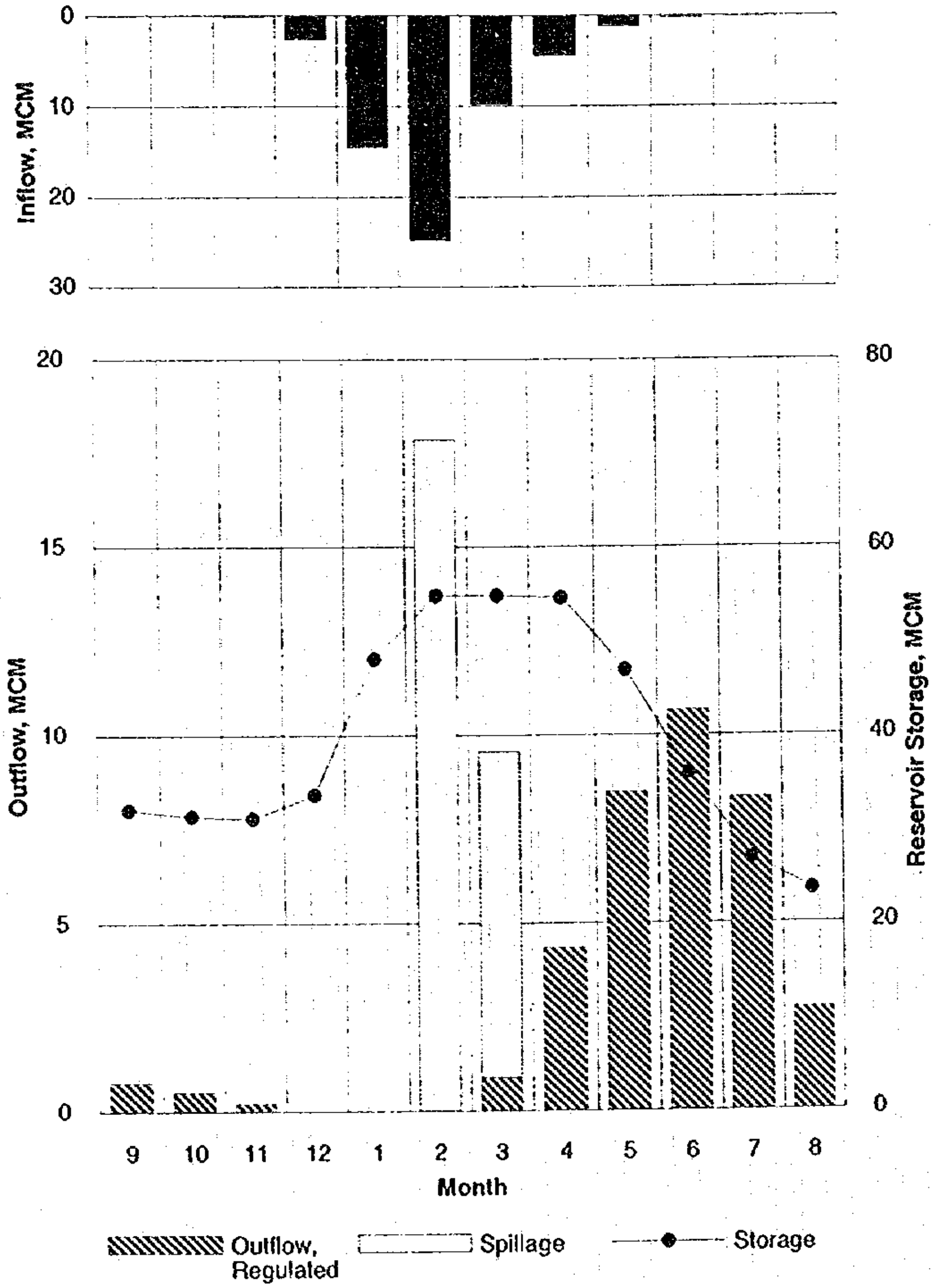


Figure 3.5.5 Water Balance at Sahela Dam (Average Year : 1978/79)

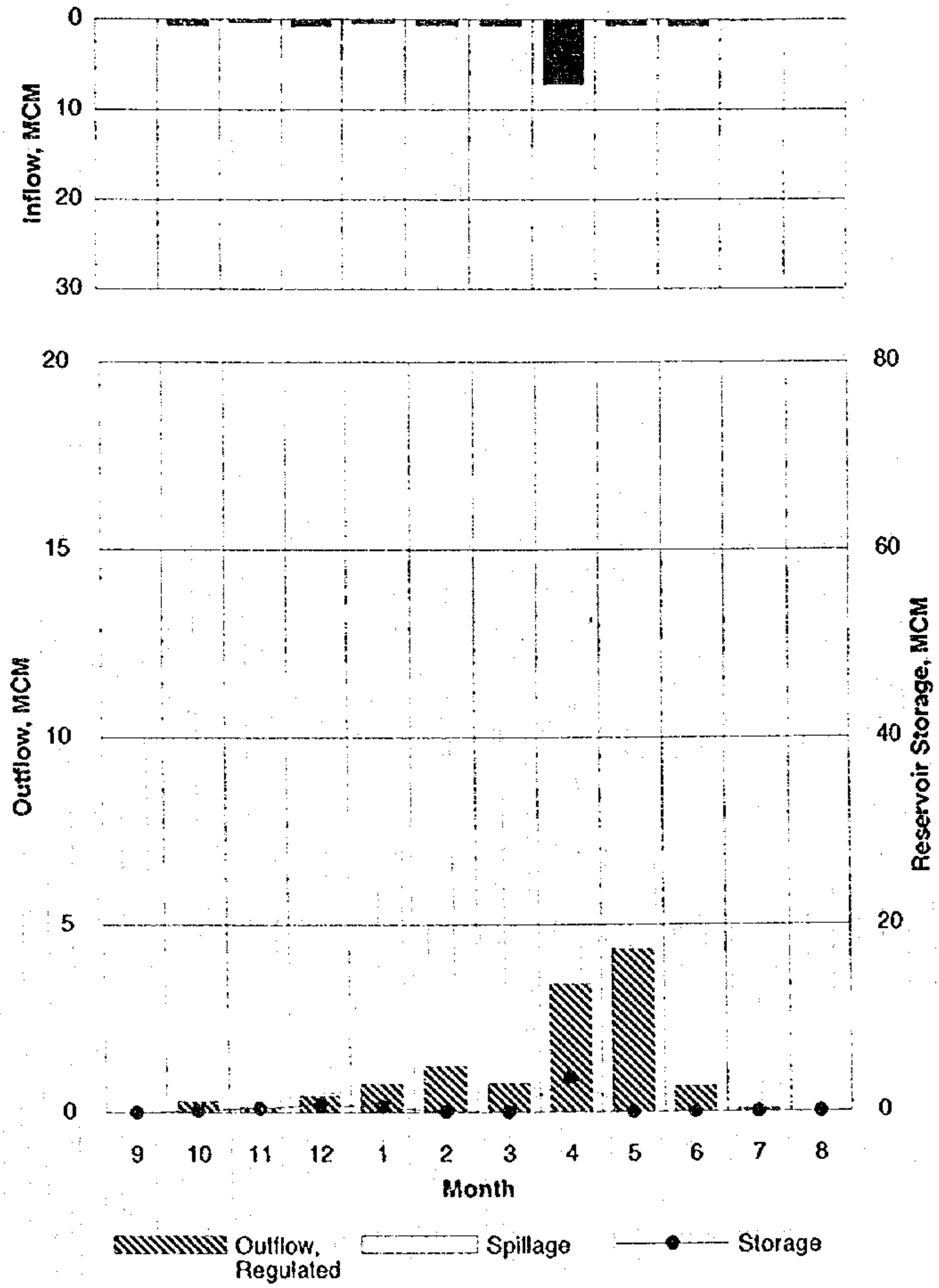
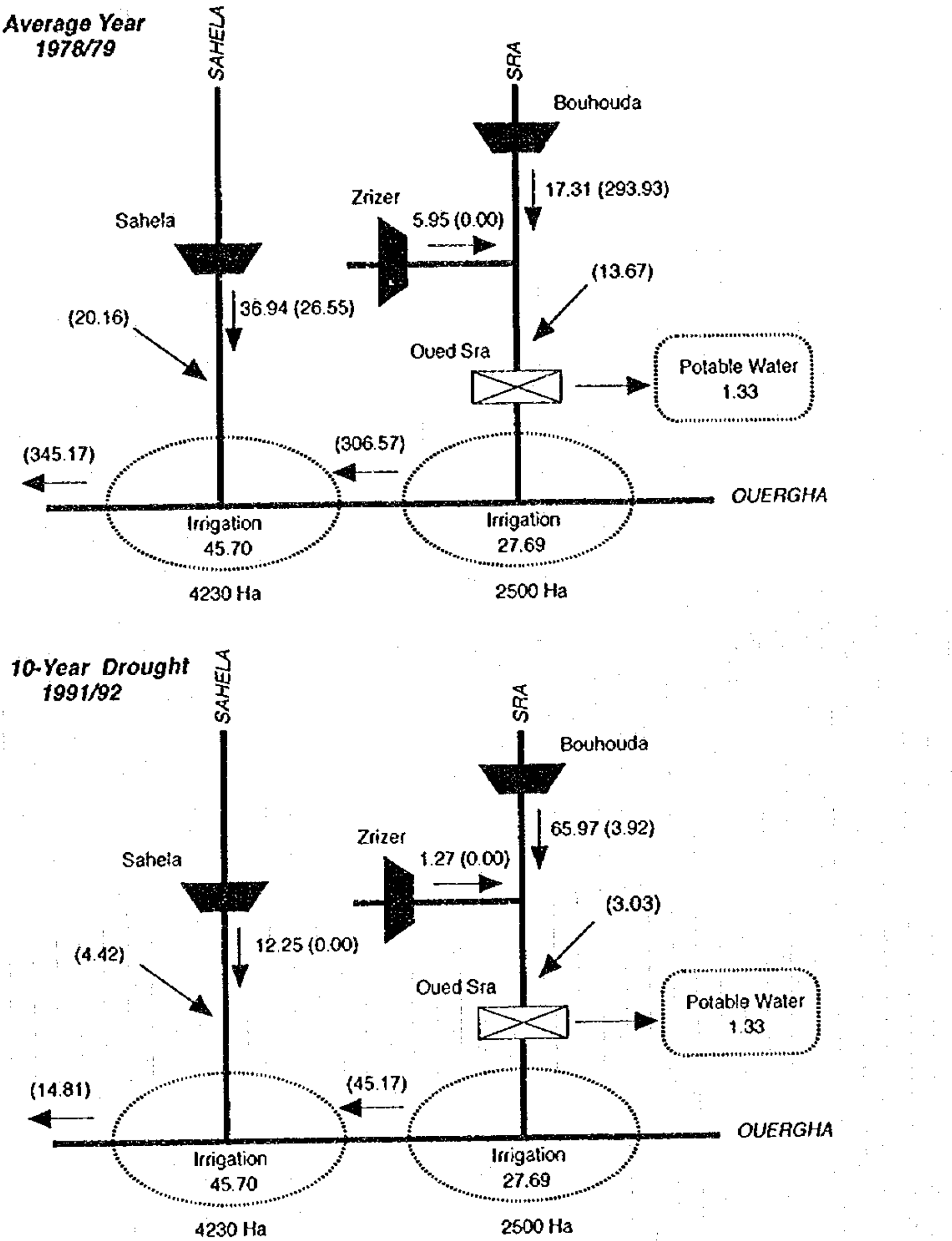
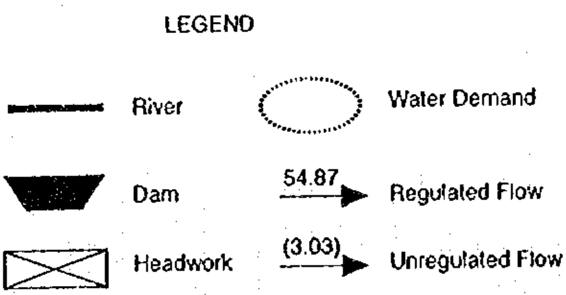


Figure 3.5.6 Water Balance at Sahela Dam (10-Year Drought : 1991/92)



Unit : Million m3/year



Note :
Ouergha river flow is not taken into account.

Figure 3.5.7 Water Balace In Taounate Area

4. Hydrolgeoogy

Supporting Report
4. Hydrogeology

Contents

4.1 Groundwater Potential Structures

Table 4.1.1 Hydrogeological Characteristics of Groundwater Potential Structures (1/2)

Geological Structures			Structure Coordinates			Water Bearing Formations		Water Potential (estimated)				
									Ground Water Exploration			
No.	Location	Type	X	Y	Z (m)	Epoch or Stage	Lithology	Spring	No. of Wells Proposed	Depth (m)	Estimated Productivity (l/s)	Water Quality
	Mountainous Water potential Structures											
1	J. Tainaste	Flexure	616000 to 617000	440000 to 442500	1100 to 1300	Quaternary Jurassic Bajocian-upper Lias Middle Lias	Recent Alluvium Limestone & Marly Limestone Limestone & Dolomite	5- Springs Flow Rate Ranges between 15-85 m3/d	1 1 1	125 100 75	Ranges between 2 - 5 5 - 7 2 - 5	Chemically Acceptable
2	J. Khamise	Monocline	599000 to 600500	427500 to 428700	700-800	Jurassic Bajocian-upper Lias	Limestone & Marly Limestone Limestone and Dolomite	5- Springs Flow Rate Ranges between 15 - 50 m3/d	1 1	150 125	Ranges between 5 - 10 3 - 7	Ditto
3	J. Lakhdar (Keil Mountain)	Monocline	577200 to 581500	435500 to 440750	600-700	Jurassic Bajocian-upper Lias Middle Lias	Limestone & Marly Limestone Limestone & Dolomite	8- Springs Flow Rate Ranges between 15-60m3/d One Spring w/ Large Flowrate-Bou Adel 220 l/s	1 1 1	150 150 100	Ranges between 3 - 10 10 - 20 2 - 3	Ditto
4	J. Berda	Monocline	547000 to 550500	447000 to 448500	750-850	Jurassic Bajocian-upper Lias Middle Lias	Limestone & Marly Limestone Limestone & Dolomite	3- Springs Flow Rate Ranges between 20-700 m3/d	1 1 1 1	100 125 125 150	Ranges between 1 - 3 2 - 5 3 - 5 5 - 10	Ditto
5	Dhar Souk	Syncline	597500 to 602500	449500 to 452000	480-550	Quaternary Miocene (Sahelian)	Recent alluvium Conglomerates	—	2 3	150(each) 30 (each)	Ranges between 3 - 7 1 - 3	Ditto
	Hilly Water Potential Structures											
6	Teroual	Syncline	511000 to 512500	451500 to 453000	400-430	Upper Miocene Oligocene	Conglomerates + Marl Marly Sandy Limestone	2- Springs Flow Rate Ranges between 20-70 m3/d	3 1 1	30 (each) 125 150	Ranges between 1 - 2 5 - 10 8 - 15	Ditto
7	Ourtzarh	Syncline	540000 to 542000	436200 to 438500	150-190	Quaternary Miocene (Tortonian)	Recent Alluvium Karsts & Fissured Conglomerates	5- Springs Flow Rate Ranges Between 1 - 7 m3/d	2	300 (each)	Ranges between 5 - 12	Ditto

Table 4.1.1 Hydrogeological Characteristics of Groundater Potential Structures (2/2)

Geological Structures			Structure Coordinates			Water Bearing Formations		Water Potentiality (Estimated)				
								Structure's	Ground Water Exploration			
No.	Location	Type	X	Y	Z	Epoch or Stage	Lithology	Springs	No. of Wells Proposed	Depth (m)	Estimated Productivity (l/s)	Water Quality
8	Ain Saddine (Rdat Valley)	Syncline	486500 to 489000	449000 to 453000	110-200	Quaternary Pliocene Miocene	Recent Alluvium Conglomerates + Marl Conglomerates + Marl	1- Spring Flow Rate 90m3/d	3 1 1	30(each) 100 150	Ranges between 1 - 2 2 - 5 3 - 7	Chemically Acceptable
9	Taounate Sra Valley	Syncline	571000 to 573000	440000 to 443000	300-330	Quaternary Miocene-Tortonian	Recent Alluvium Karsts & fissured conglomerates	——	3 1	30(each) 250	Ranges between 5 - 15 15 - 20	Ditto
10	Tissa Lebene Valley	Syncline	569000 to 547000	410000 to 412000	190-200	Quaternary Oligocene	Conglomerates Marly Sandy Limestone	——	3 1 1	30(each) 75 100	Ranges between 3 - 5 4 - 7 5 - 10	Ditto
	Flat Plain water Potenial Structure											
11	Jorf El Malha	Syncline	488500 to 491000	429500 to 431500	40-70	Quaternary Miocene-Tortonian	Recent Alluvium Conglomerates	——	3 1	30(each) 125	Ranges between 5 - 10 7 - 12	Ditto
12	Ain Defali	Syncline	484500 to 487500	443200 to 446500	90-130	Quaternary Miocene	Recent Alluvium Conglomerates	——	3 1	30(each) 125	Ranges between 3 - 5 5-10	Ditto
13	Had Kourt	Depression	468700 to 471300	444000 to 447500	130-150	Quaternary Miocene	Recent Alluvium Conglomerates	——	3 1	30(each) 125	Ranges between 1 - 3 3 - 5	Ditto

Notes : - The numbers and depths of the wells suggested for each structure are based on the geological hydrogeological field reconnaissance, and are subject to modification in accordance with the geophysical prosoection and logging.
- The estimated productivity of each well is estimated based on the lithological composition of the formations to be penetrated.

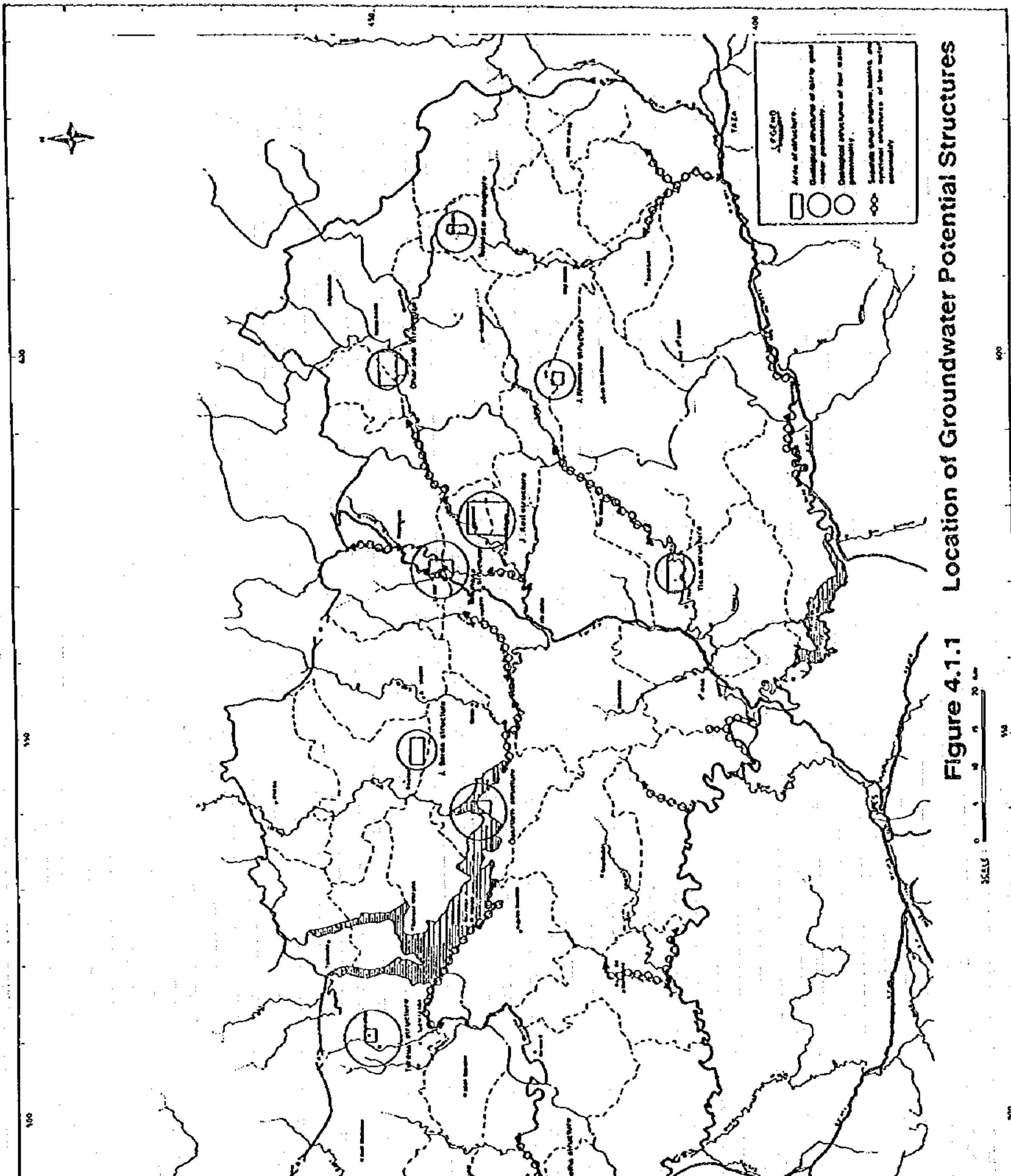
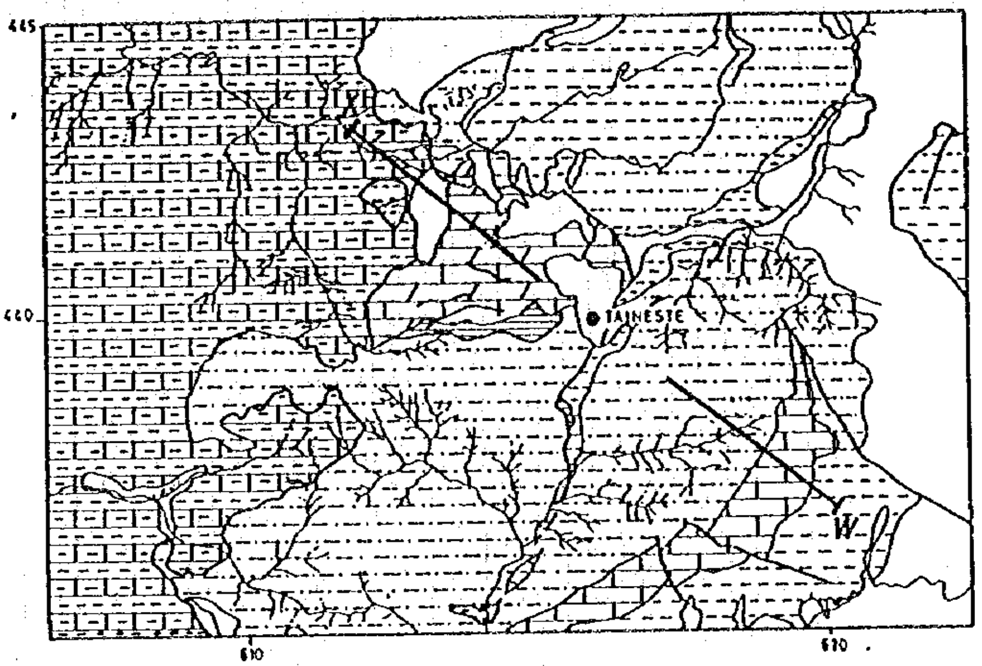


Figure 4.1.1 Location of Groundwater Potential Structures



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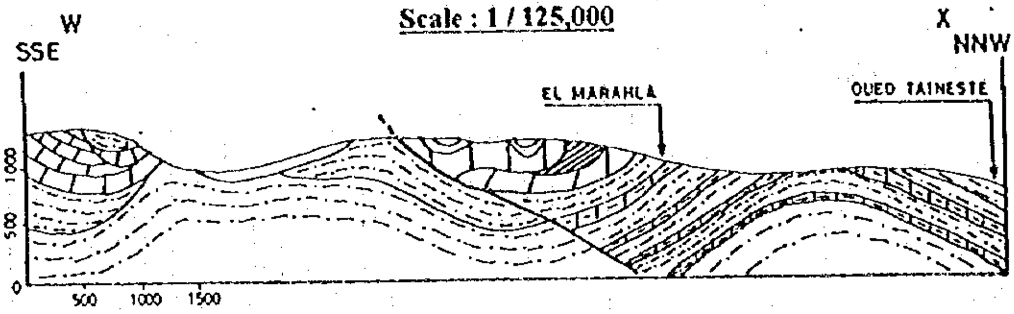

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LEGEND

QUATERNARY ALLUVIUM DEPOSITS

m4 MIOCENE_MIDDLE_MARL, AND MARLY LIMSTONE.

n4.6 CRETACEOUS_INF. SILTY MARL.

j6.7 JURASSIC_SUP. TITHONIAN LIMESTONE.

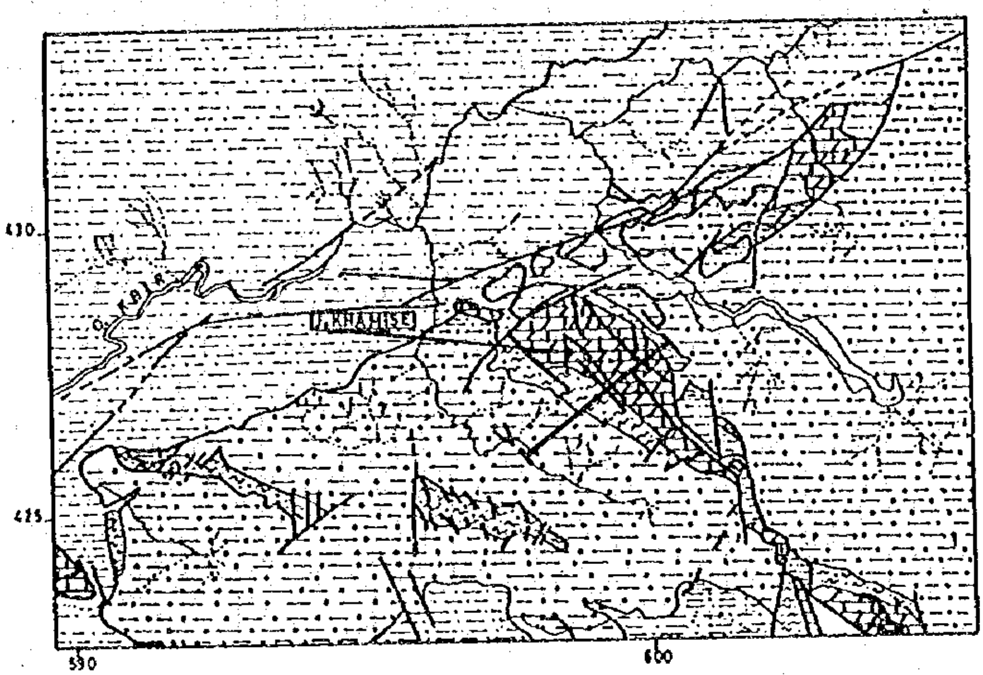
j3.5 JURASSIC_SUP. SCHISTS AND MARL SERIES.

l6 JURASSIC_LIAS_MIDDLE: LIMESTONE AND DOLOMITE.

TRIAS OPHITES

FAULT. DIP VERTICALE. STEEP. NORMAL.

Figure 4.1.2 Geological Structure of Taineste



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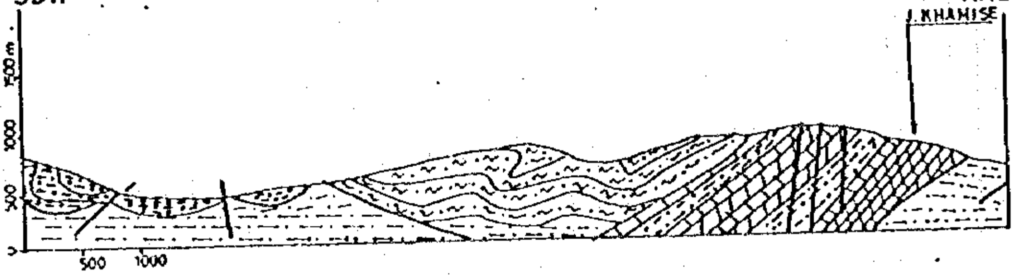
V SSW

U NNE



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LEGEND

mm5 MIOCENE SUP. TORTONIAN (Flysch) SCHISTS AND SILTY MARL.

CRETACEOUS INF. SILTY CLAYSTONE (Flysch)

JURASSIC SUP. TITHONIAN (Flysch) SANDY MARL.

cll JURASSIC . LOWER LIAS . LIMESTONE AND DOLOMITE .

FAULT DIP VERTICAL ⊥ STEEP ⊥ NORMAL

Figure 4.1.3 Geological Structure of Jbel Khamise

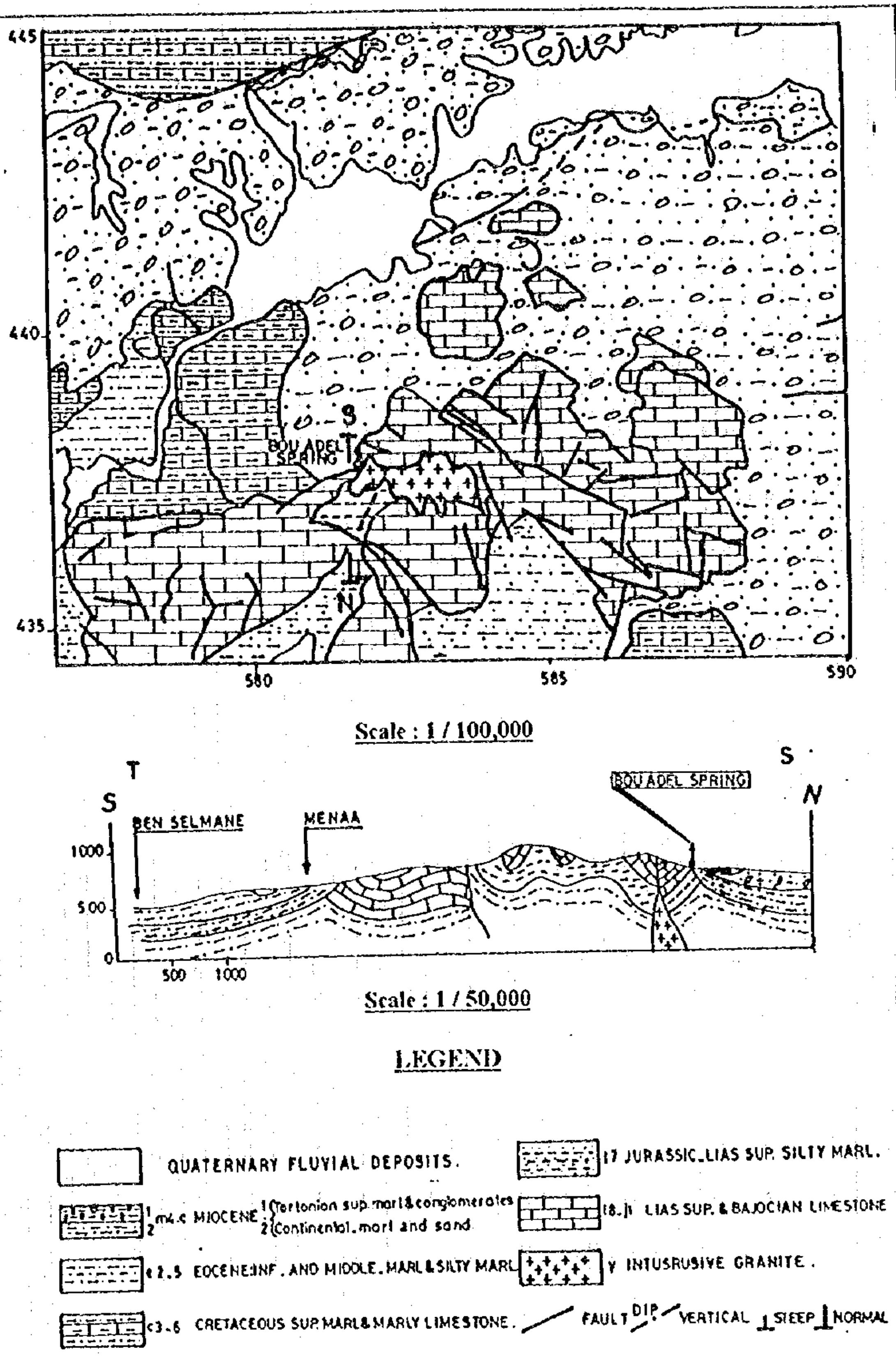


Figure 4.1.4 Geological Structure of Jbel Keil

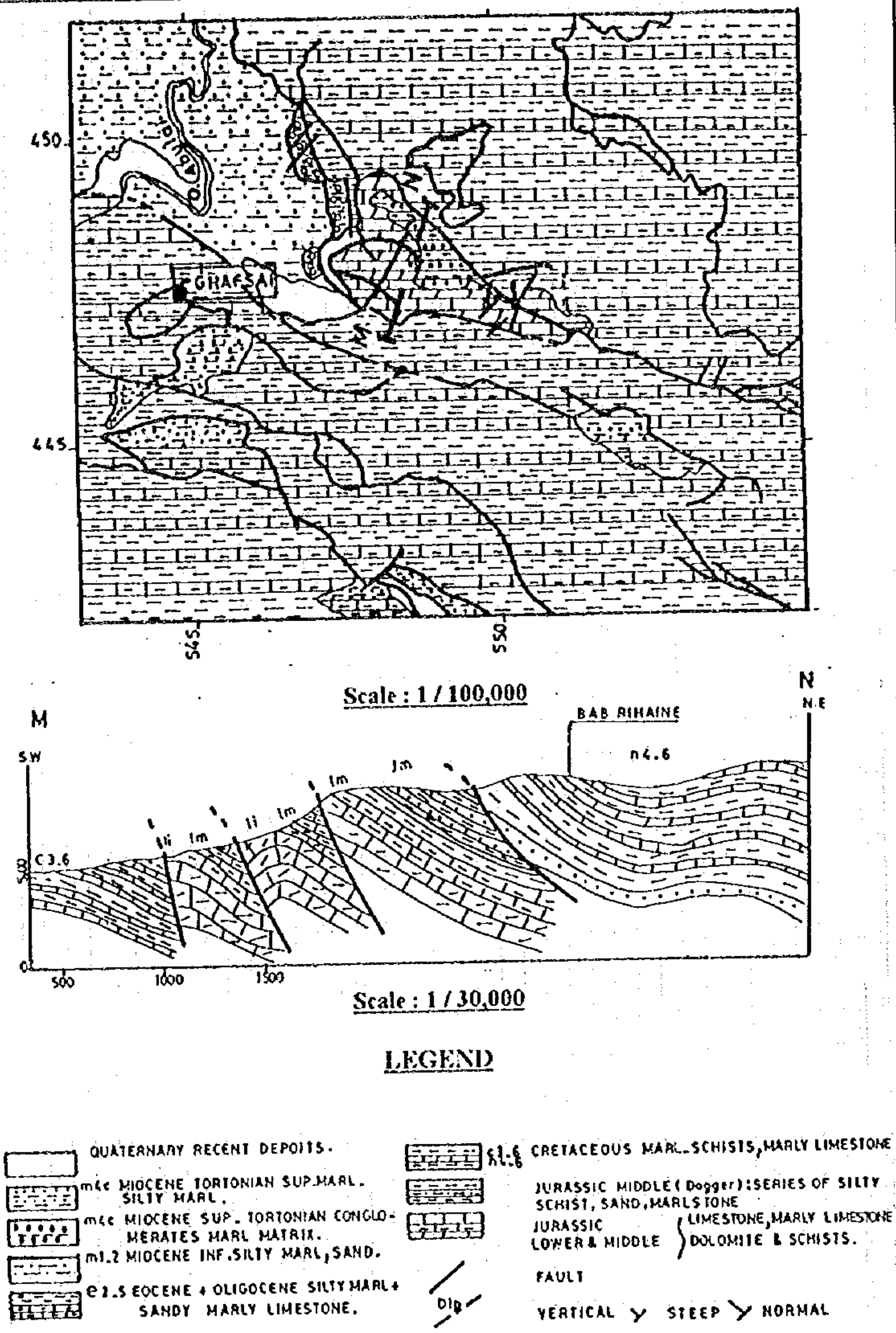
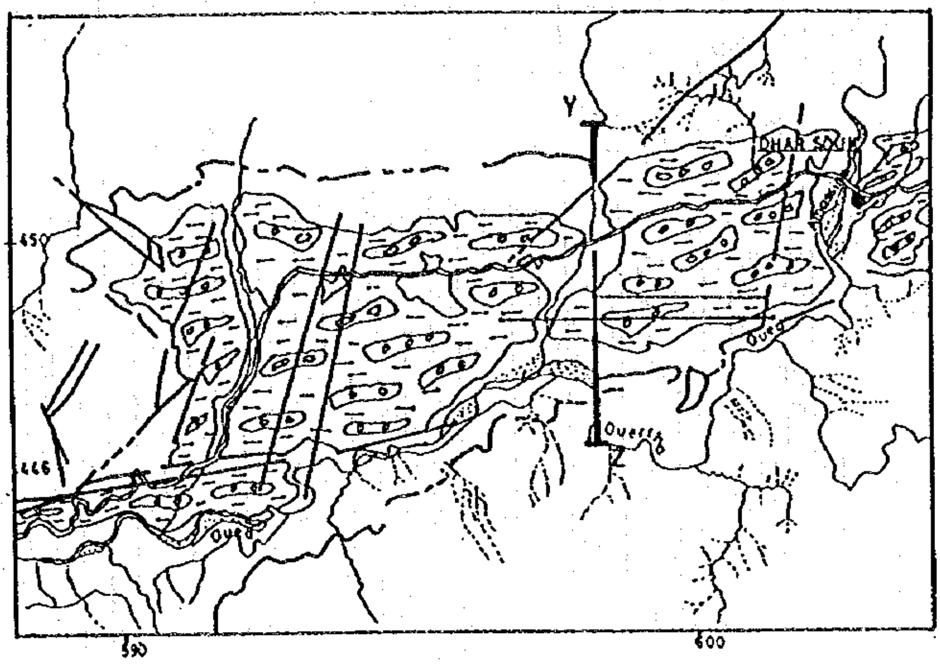


Figure 4.1.5 Geological Structure of Jbel Berda



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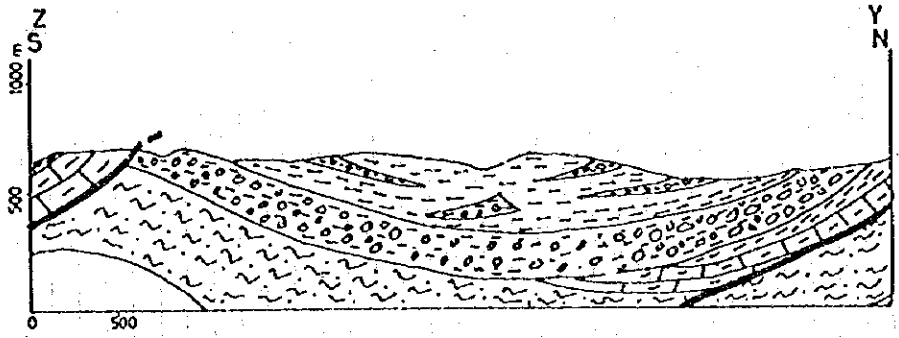

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LEGEND

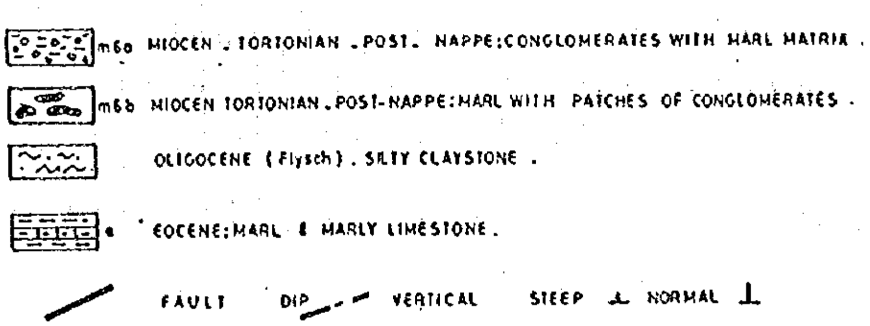
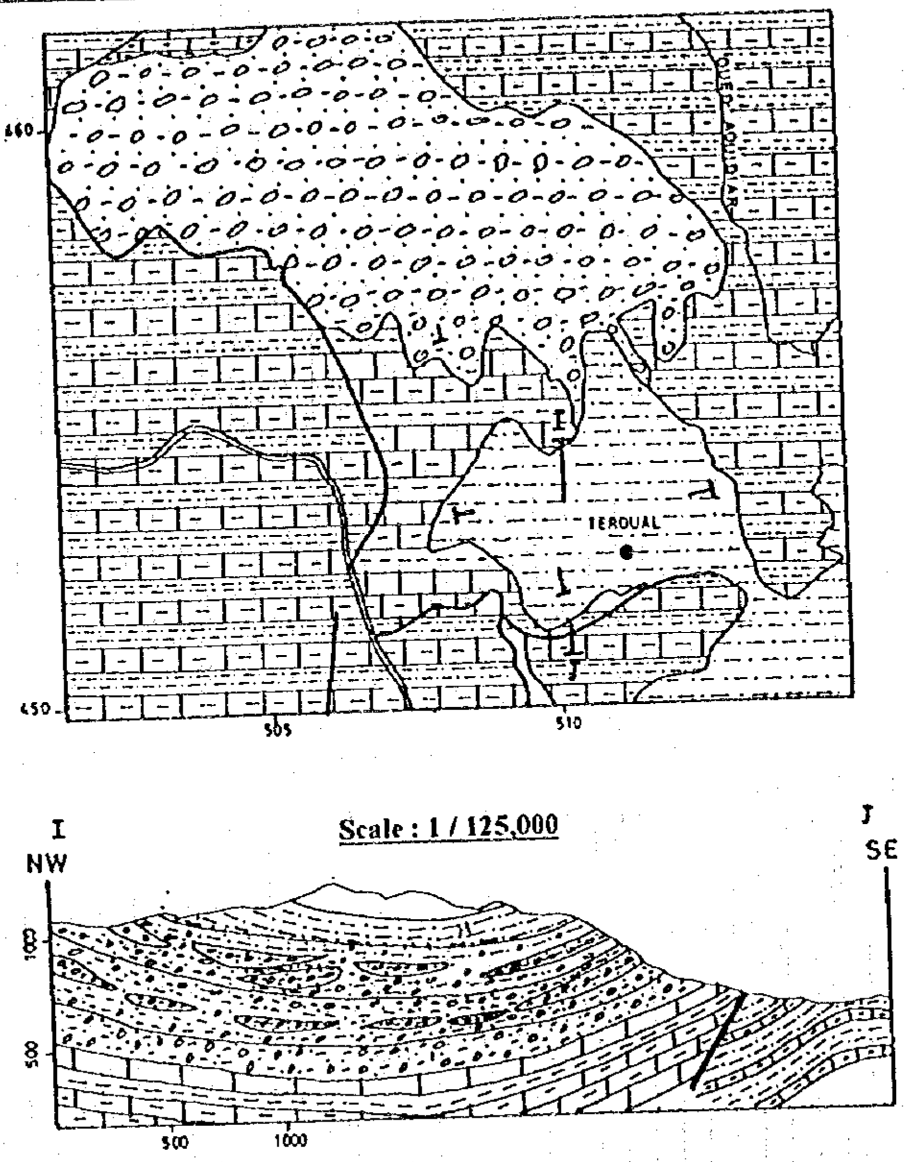


Figure 4.1.6 Geological Structure of Dhar Souk



Scale : 1 / 125,000

Scale : 1 / 62,500

LEGEND

- QUATERNARY. RECENT ALLUVIUM DEPOSITS.
- MIOCENE SUP. MARL AND SILTY MARL.
- OLIGOCENE. SANDY CONGLOMERATES WITH MARL MATRIX.
- EOCENE. LIMESTONE, MARLY LIMESTONE AND MARL.
- CRETEOUS. SUP. SILTY MARL, MARLY LIMESTONE AND SCHISTS.
- FAULT. DIP VERTICALE. ⊥ STEEP. ⊥ NORMALE.

Figure 4.1.7 Geological Structure of Teroual

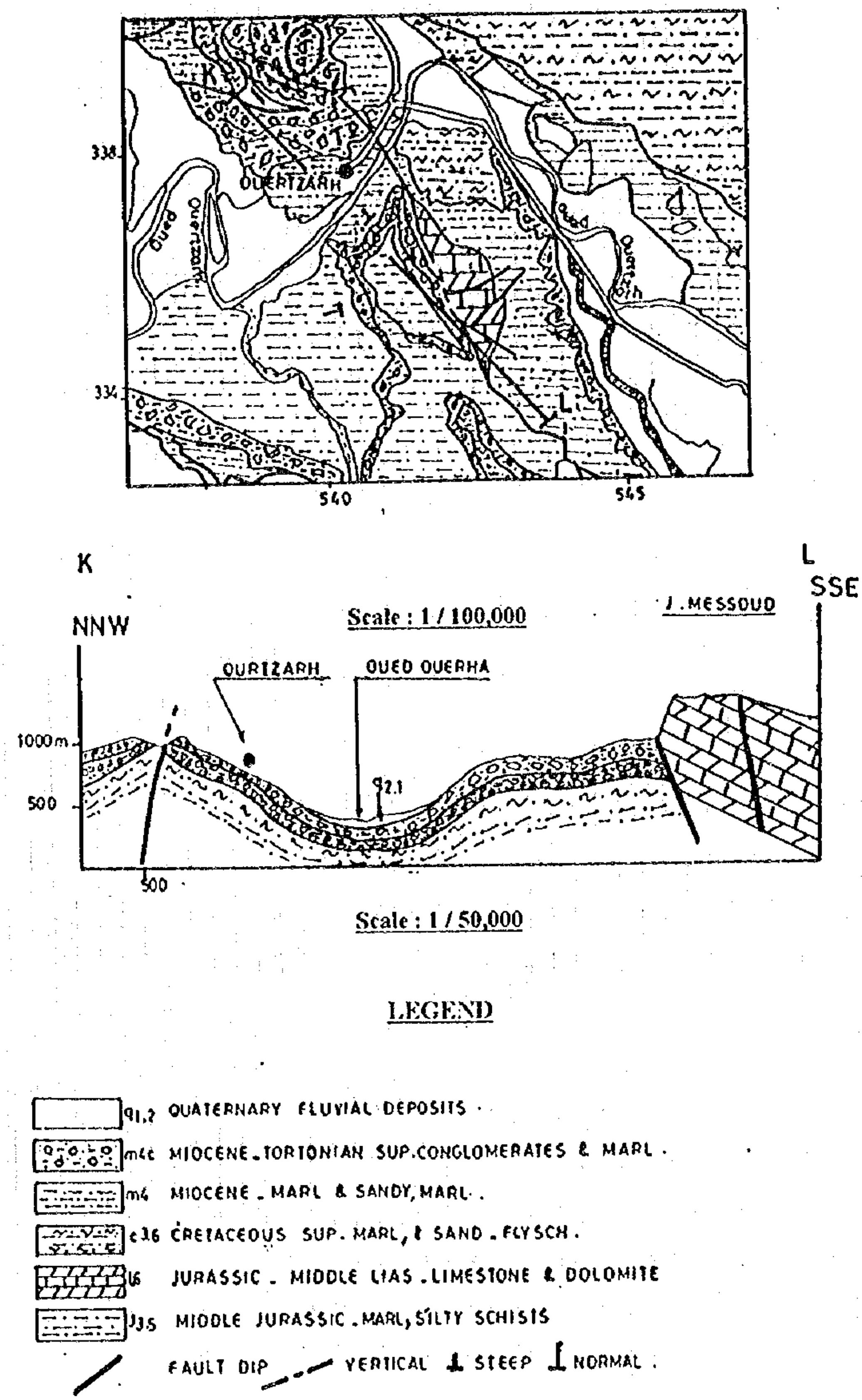
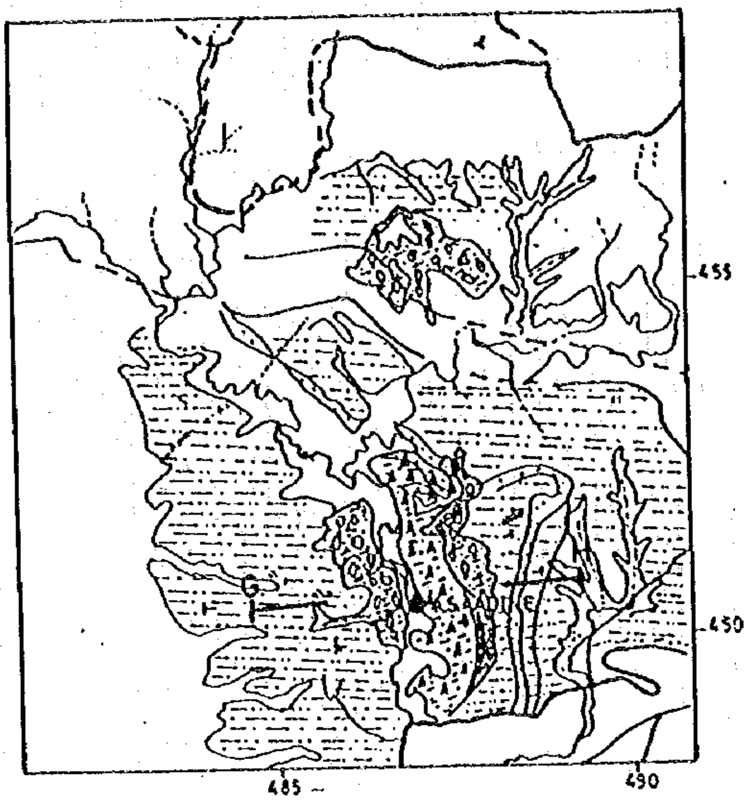


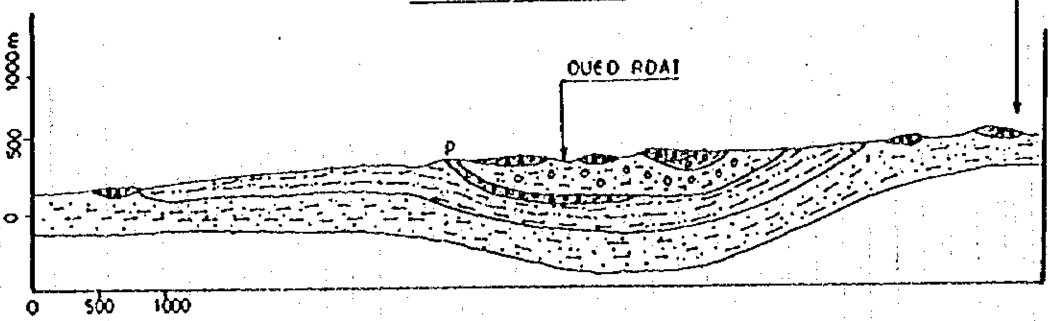
Figure 4.1.8 Geological Structure of Ourtzagh



SSE G

H NNW

Scale : 1 / 100,000



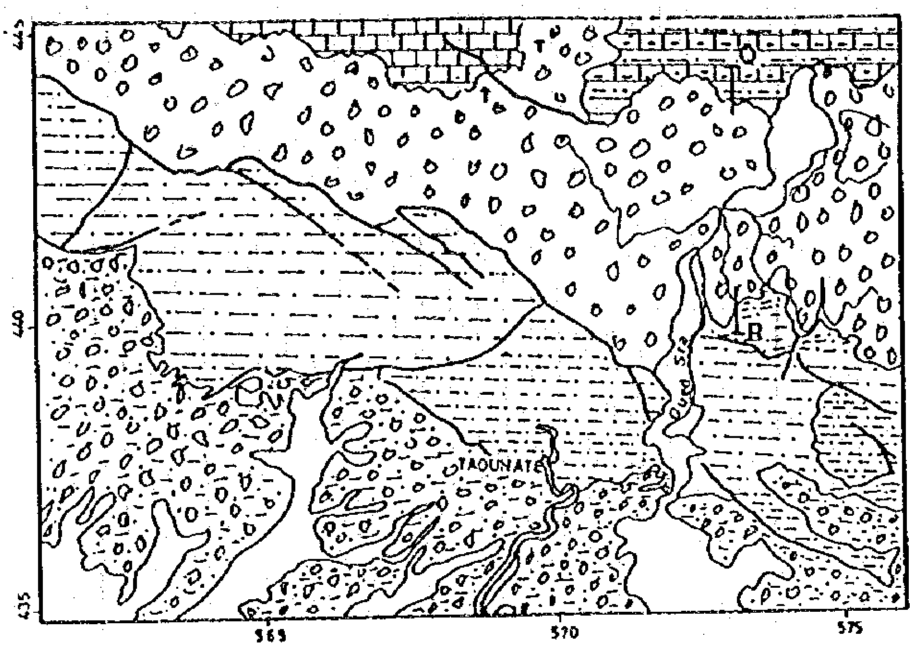
Scale : 1 / 51,000

LEGEND

- QUATERNARY FLUVIAL DEPOSITS.
- q1.5 QUATERNARY RECENT ALLUVIUN DEPOSITS.CLAY, MARL, SAND.
- q6 QUATERNARY ANCIENT DEPOSITS:CONGLOMERATES & MARL.
- P PLIOCENE;CONGLOMERATES & MARLY SAND.
- m6 m5 MIOCENE:TORTONIAN & TERMINAL.

FAULT DIP VERTICAL STEEP NORMALE.

Figure 4.1.9 Geological Structure of Ain Saddine



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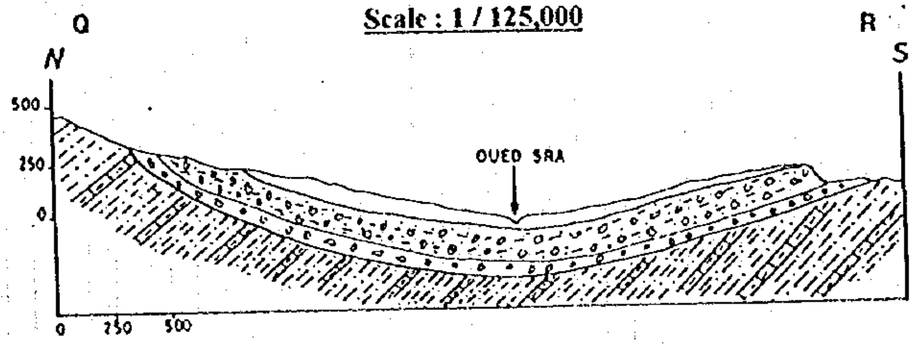
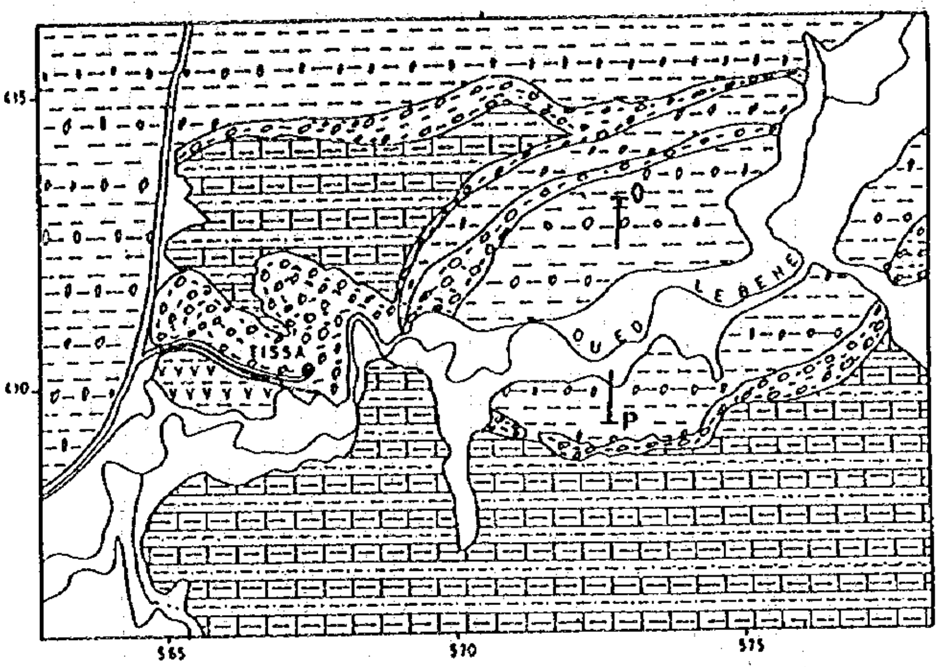


Scale : 1 / 31,250

LEGEND

- QUATERNARY FLUVIAL DEPOSITS
- m4c — MIOCENE - TORTONIAN SUP. POST-NAPPE: MARL AND CONGLOMERATES MIOCENE-SUP-CONGLOMERATES
- e25 — EOCENE-INF. AND MIDDLE - MARL & SILTY MARL.
- c3.6 — CRETACEOUS-SUP., MARL AND MARLY LIMESTONE.
- n5.6 — CRETACEOUS - APTIAN, ALBIAN: SILTY SCHIST SERIES.
- j3.5 — JURASSIC: MIDDLE, MALM: SILTY SCHISTS.
- l6-l1 — JURASSIC: LIAS INF. & MIDDLE: LIMESTONE.
- FAULT DIP VERTICAL
- STEEP NORMAL

Figure 4.1.10 Geological Structure of Taounate



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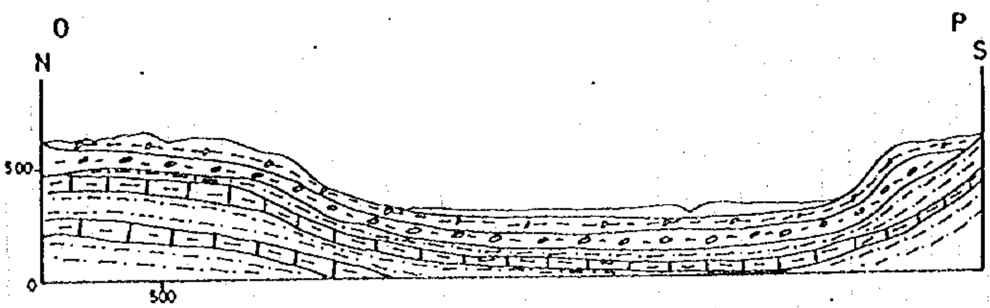


Scale : 1 / 31,250

LEGEND

- QUATERNARY FLUVIAL DEPOSITS.
- MIOCENE – SILTY MARL, WITH LITTLE CONGLOMERATES.
- OLIGOCENE – CONGLOMERATES, WITH MARL MATRIX.
- CRÉTACEOUS – SUP. SILTY MARL AND MARLY LIMESTONE.
- TRIASSIC – BROWN ARGILITE AND SALT.
- FAULT. DIP: VERTICAL. STEEP. NORMAL.

Figure 4.1.11 Geological Structure of Tissa

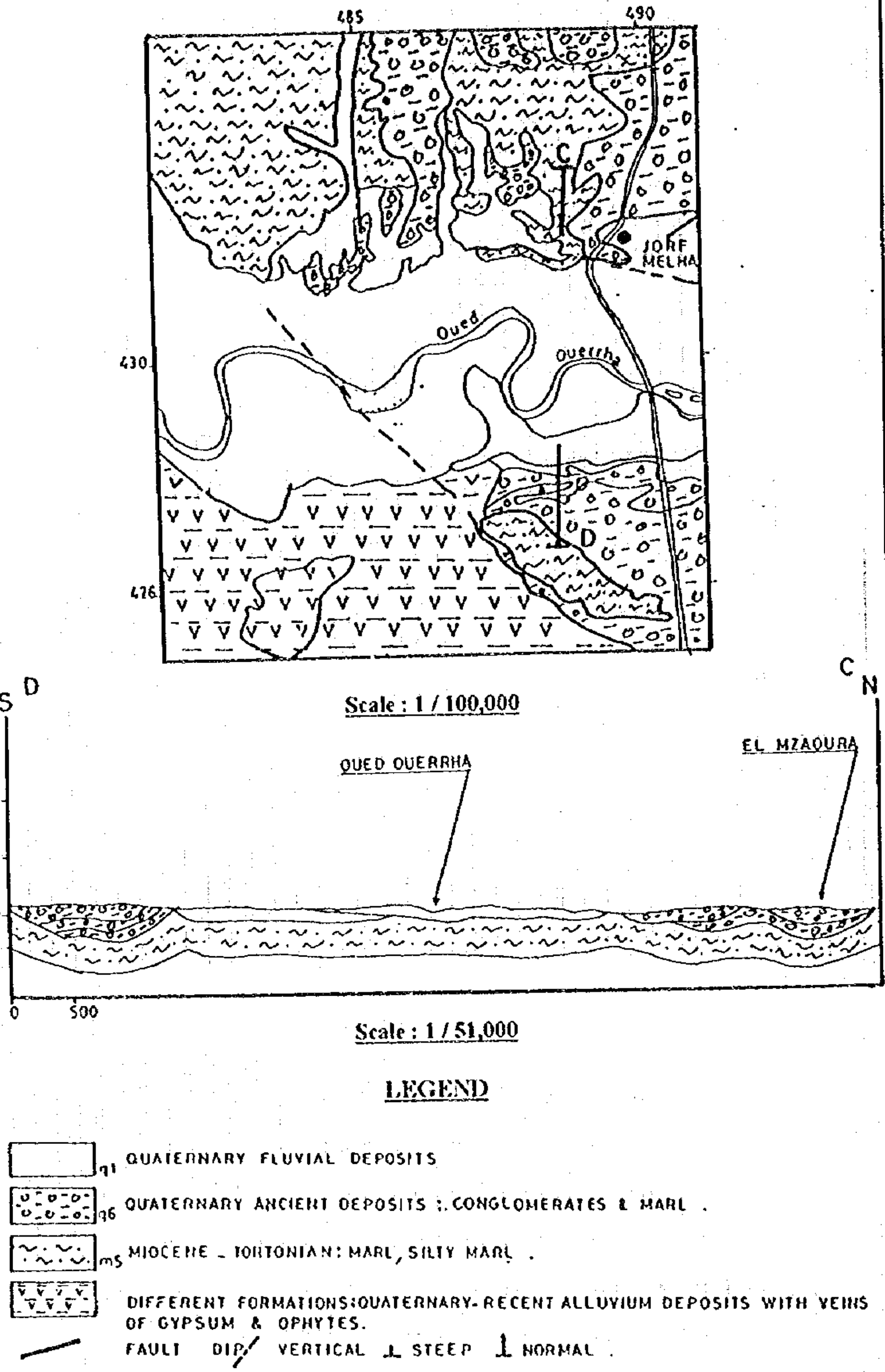
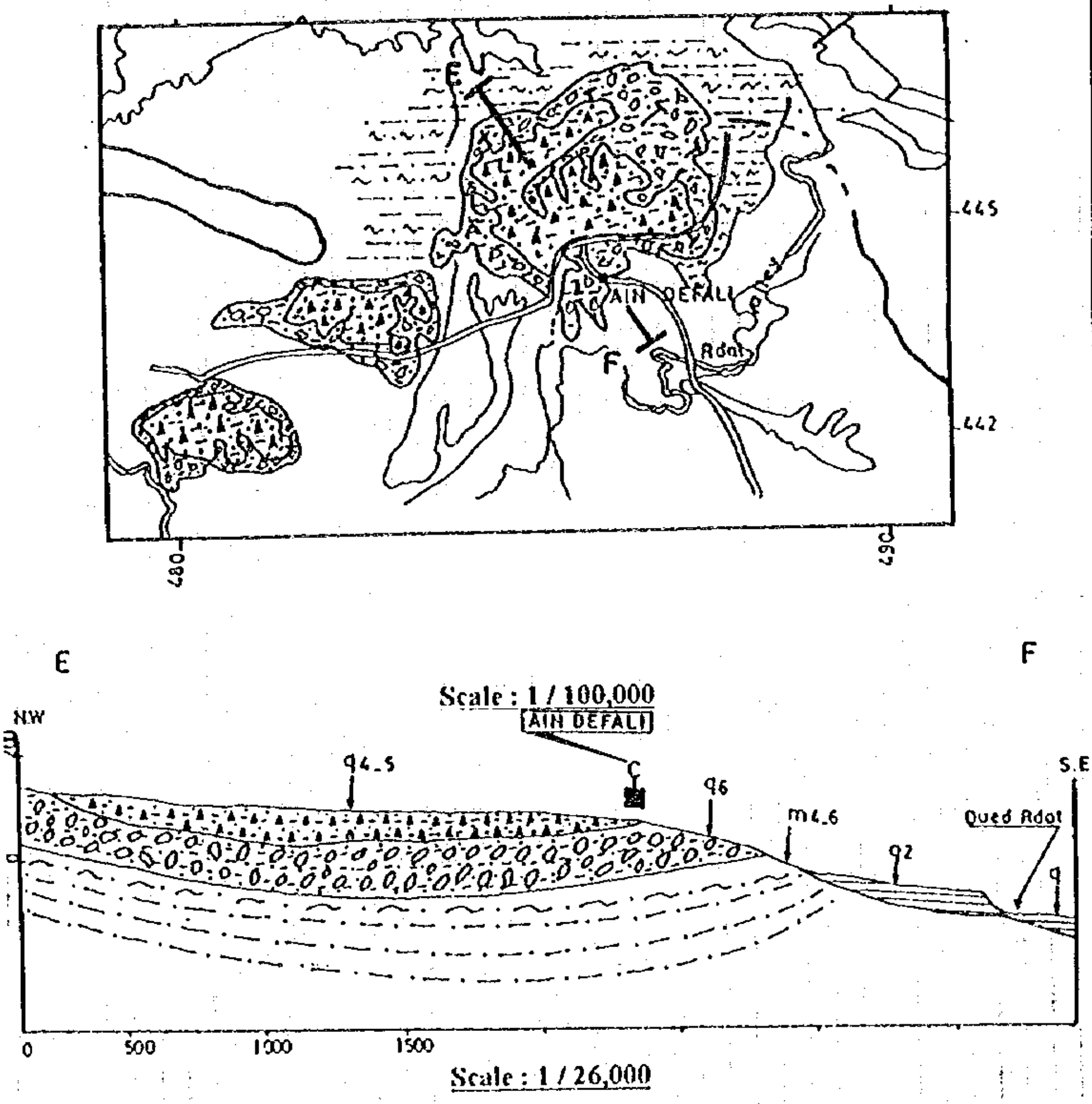


Figure 4.1.12 Geological Structure of Jorf El Melha



LEGEND

QUATERNARY FLUVIAL DEPOSITS.

q4.5 QUATERNARY RECENT ALLUVIUM DEPOSITS, SILTY MARL AND GRAVELS.

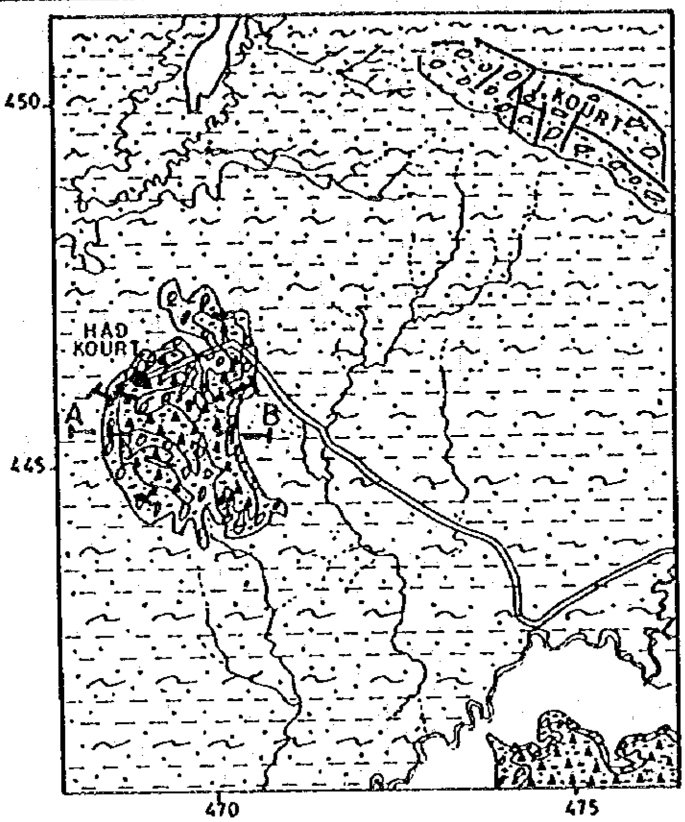
q6 QUATERNARY ANCIENT DEPOSITS: CONGLOMERATES AND MARL.

m4.5.6 MIDDLE MIOCENE-TORTONIAN AND TERMINAL: MARL AND SILTY MARL

FAULT

Dip VERTICAL ⊥ STEEP ⊥ NORMAL

Figure 4.1.13 Geological Structure of Ain Defali



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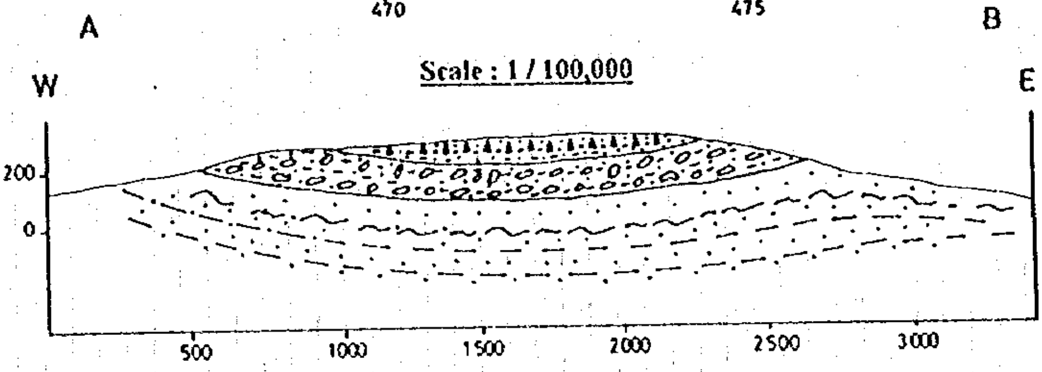


Scale : 1 / 25,000

LEGEND

QUATERNARY FLUVIAL DEPOSITS.

q3.5 QUATERNARY RECENT ALLUVIUM DEPOSITS.

q6 QUATERNARY ANCIENT CONGLOMERATES.

m5b POST_NAPPE_MIOCENE MARL AND SILTY MARL.

Fault   Vertical   Steep   Normal

Figure 4.1.14 Geological Structure of Had Kourt

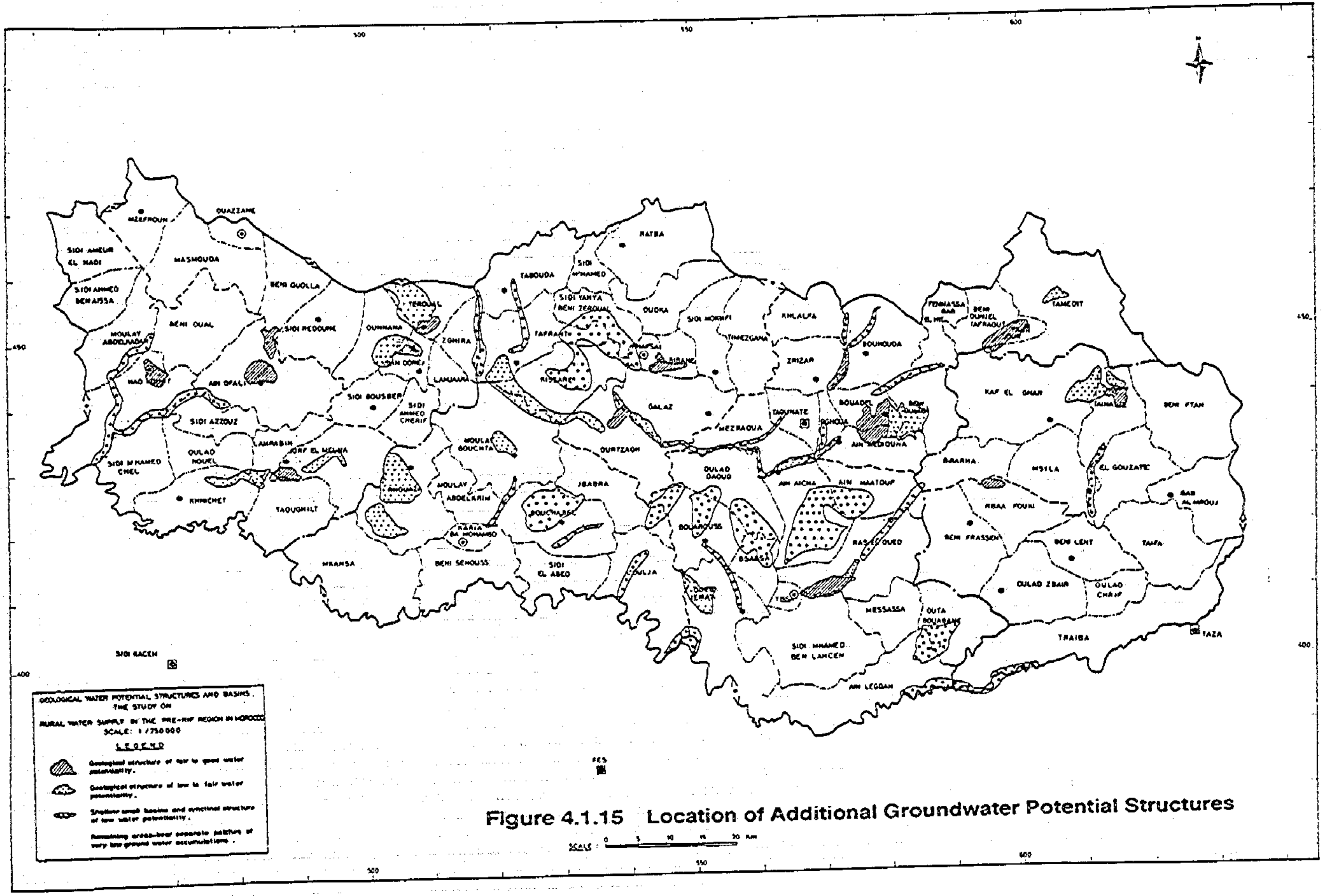
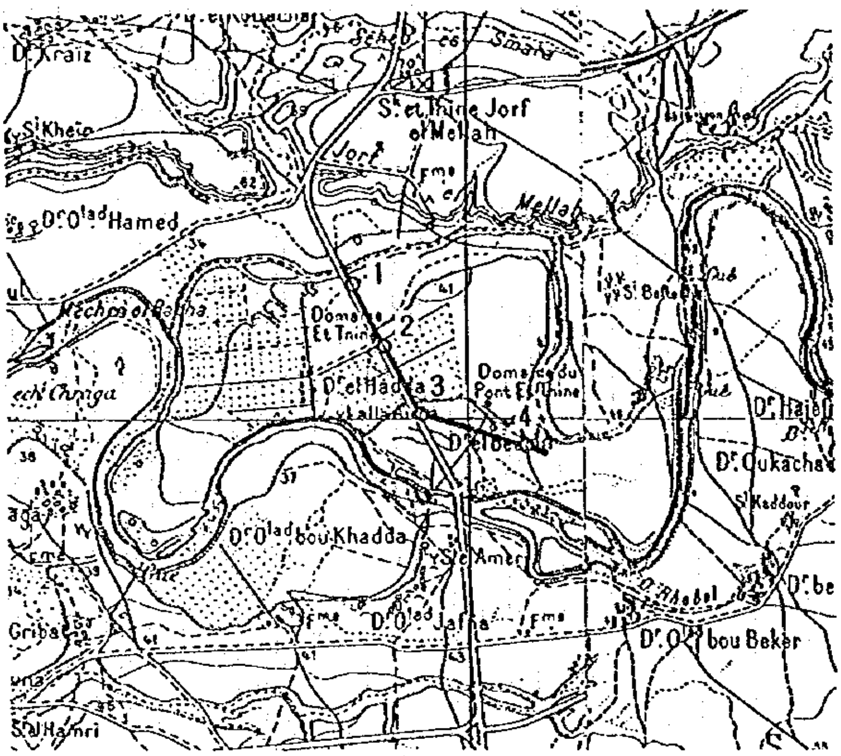
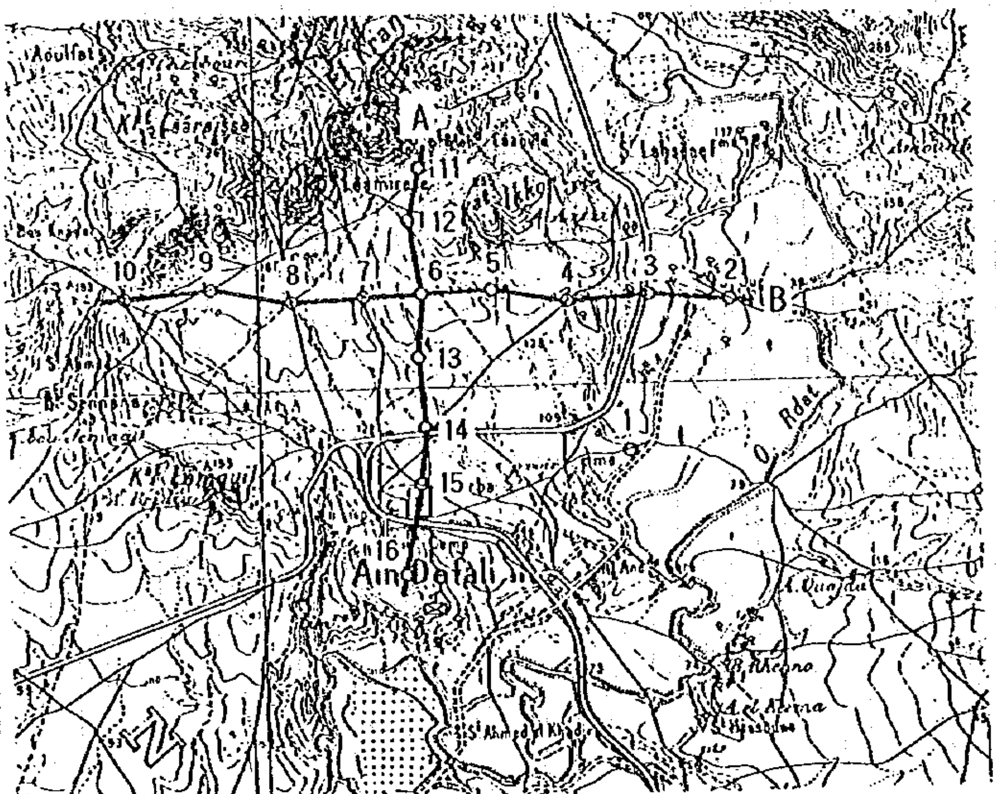


Figure 4.1.15 Location of Additional Groundwater Potential Structures

4.2 Geophysical Prospecting

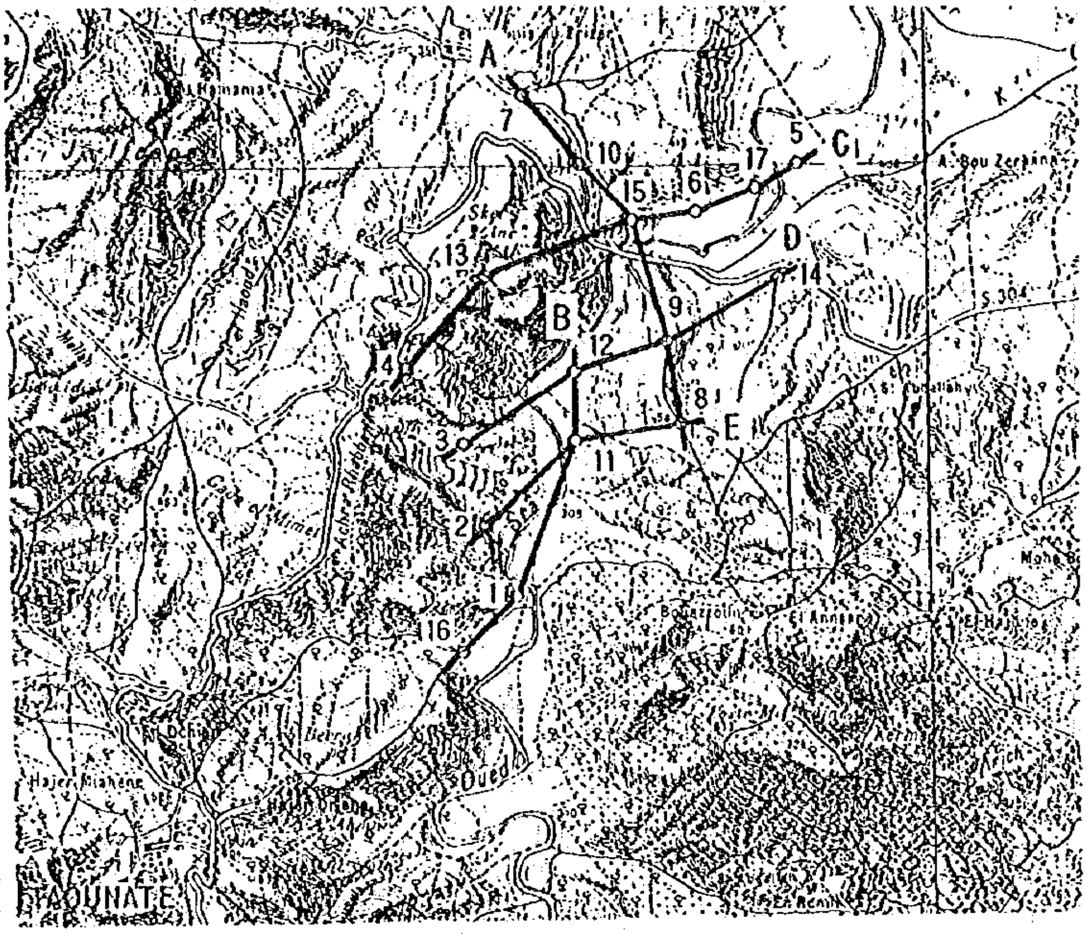


Jorf El Melha

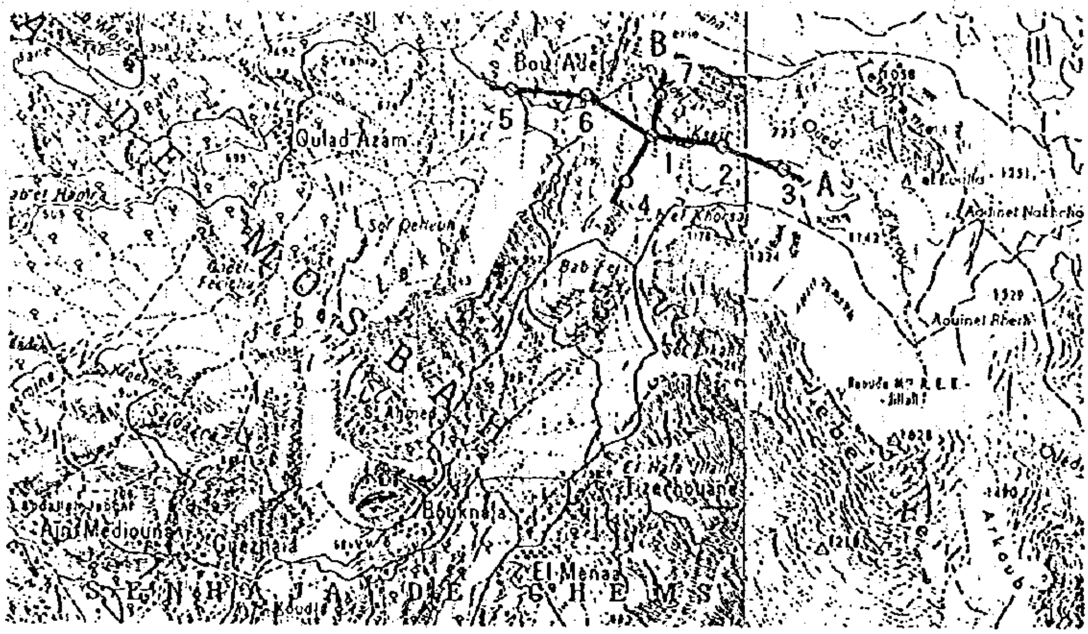


Ain Defali

Figure 4.2.1 Location of Vertical Electric Sounding (1/4)

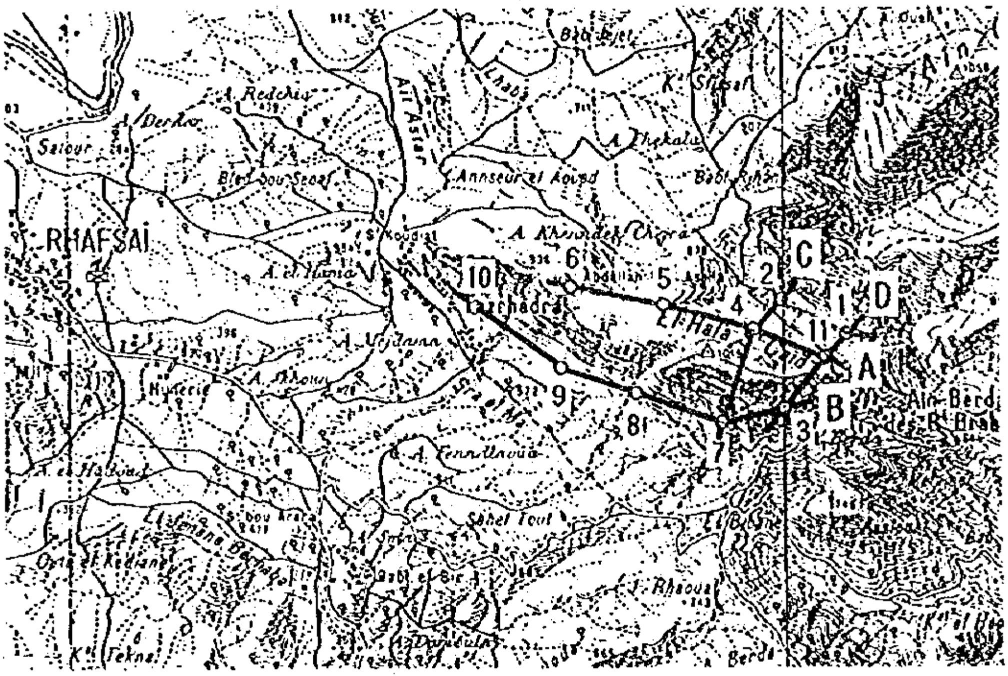


Taounate

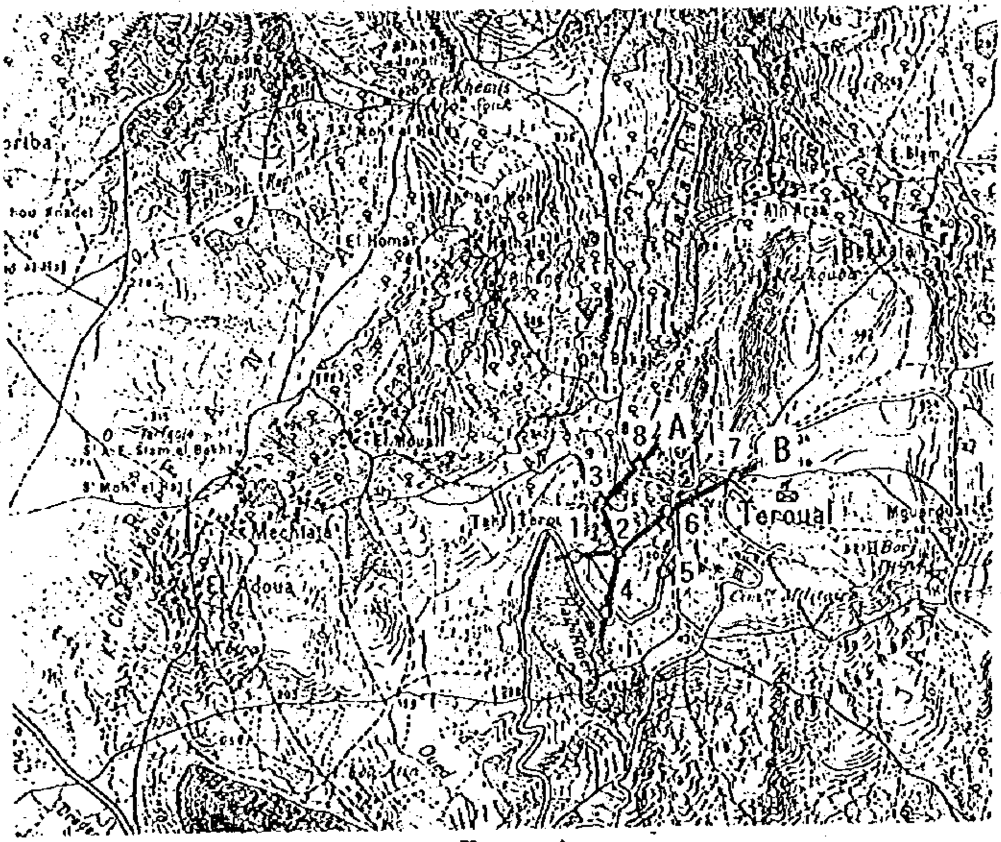


J. Keil

Figure 4.2.1 Location of Vertical Electric Sounding (2/4)

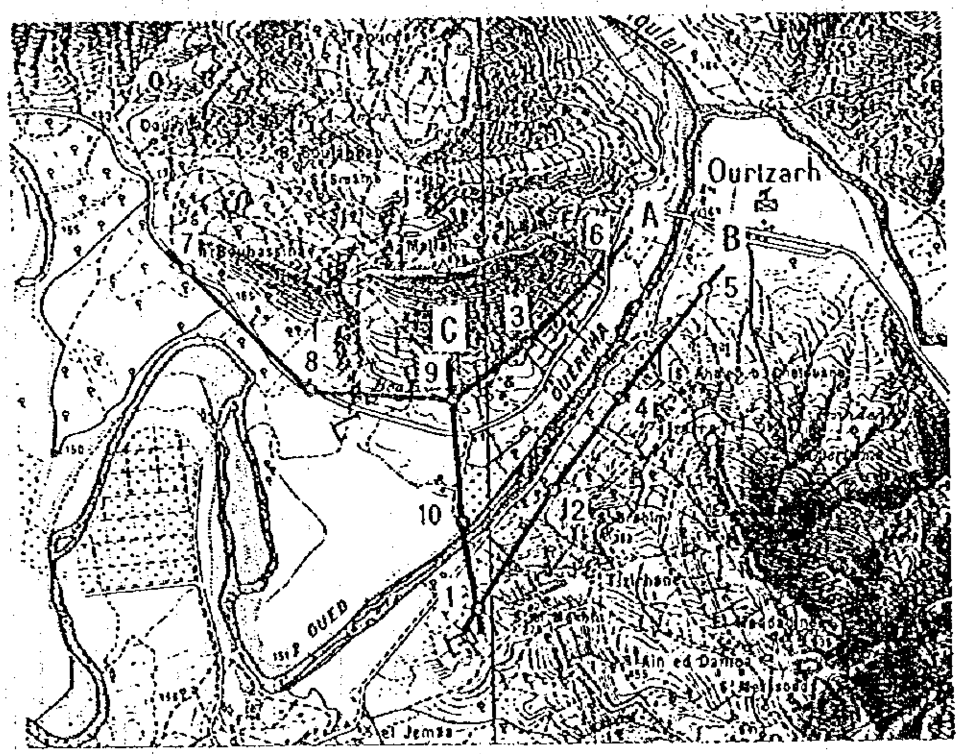


Ain Berda



Teroual

Figure 4.2.1 Location of Vertical Electric Sounding (3/4)



Ourtzarh

Figure 4.2.1 Location of Vertical Electric Sounding (4/4)

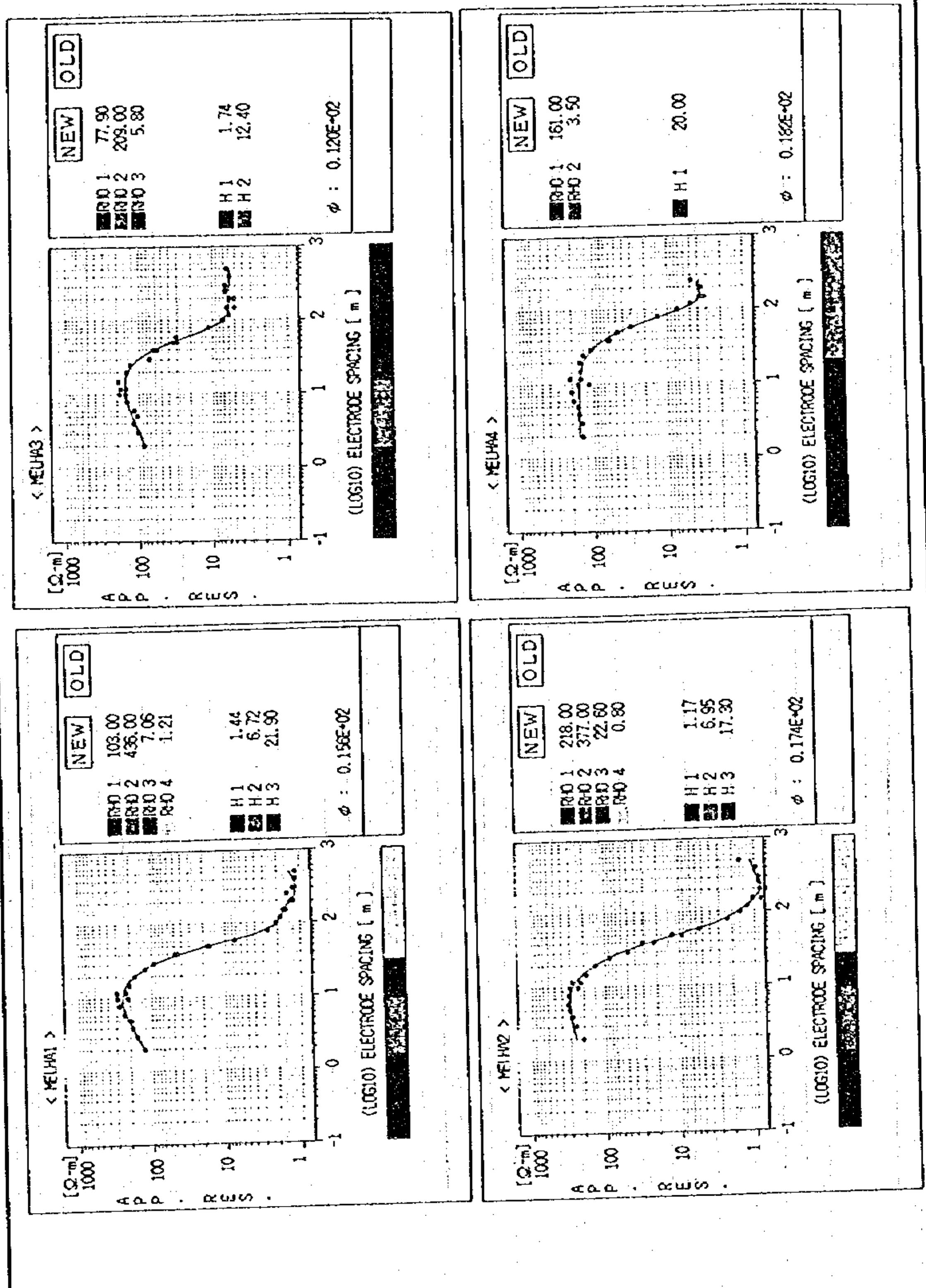


Figure 4.2.2 Vertical Electric Sounding Curves (1/19)

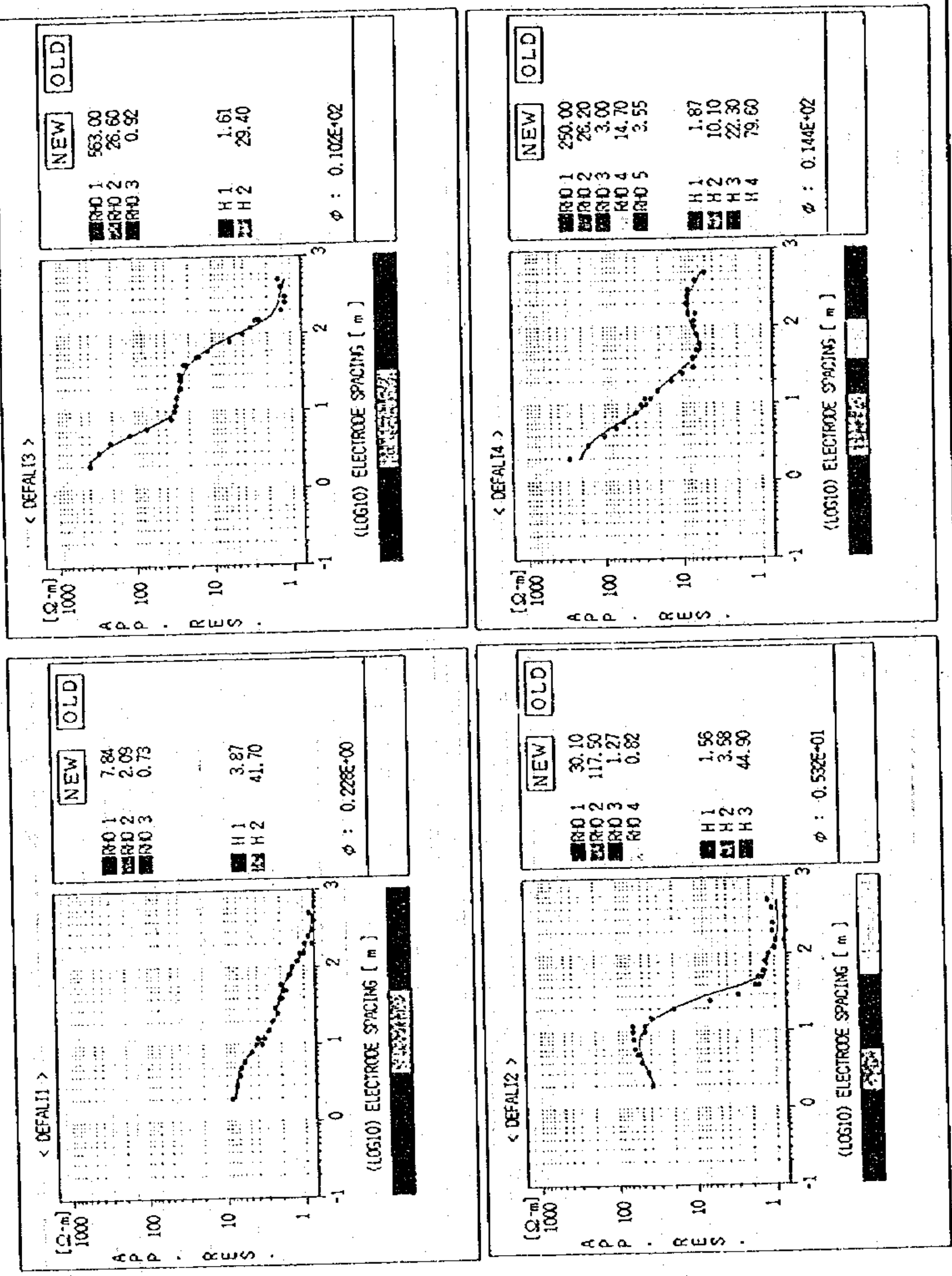


Figure 4.2.2 Vertical Electric Sounding Curves (2/19)

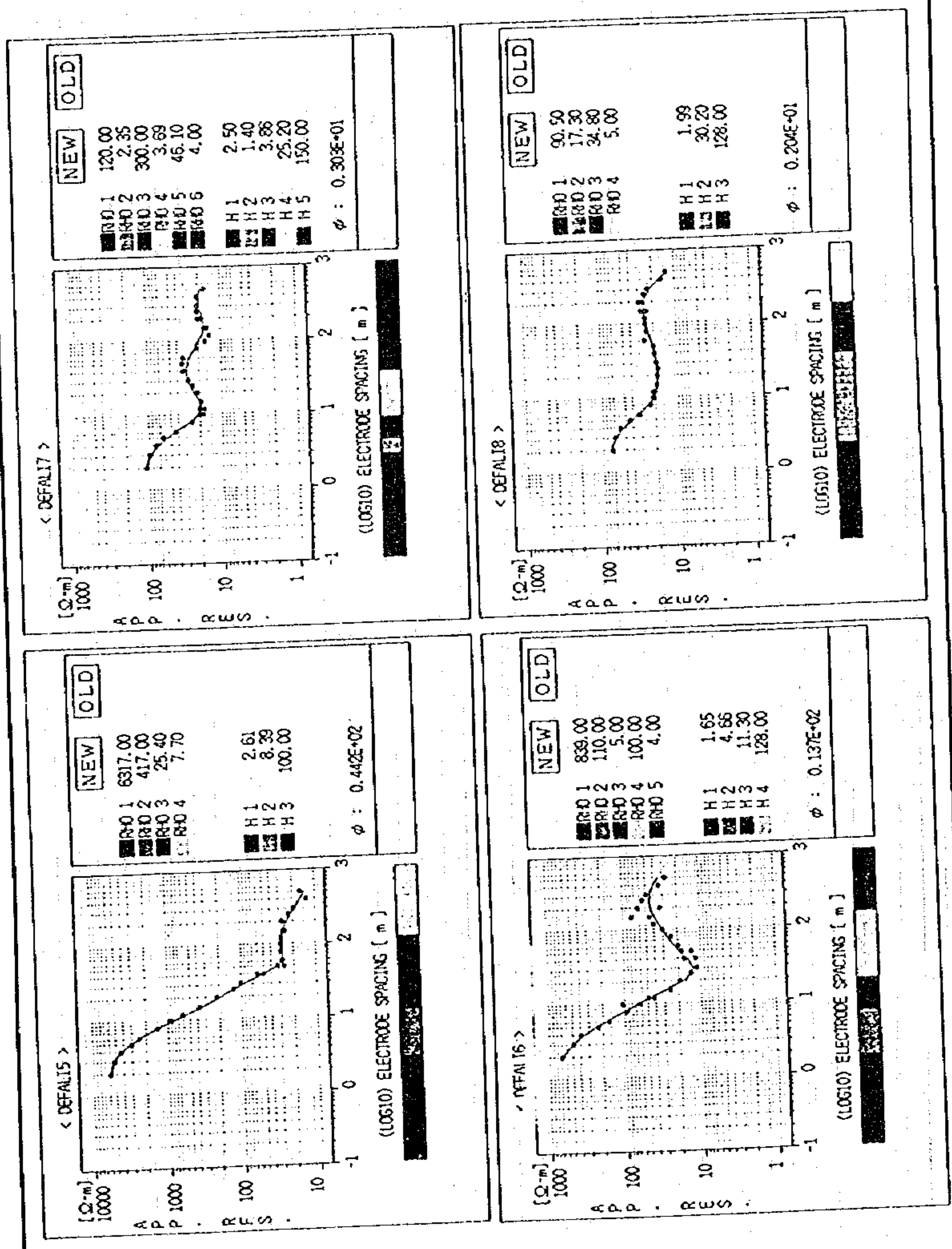


Figure 4.2.2 Vertical Electric Sounding Curves (3/19)

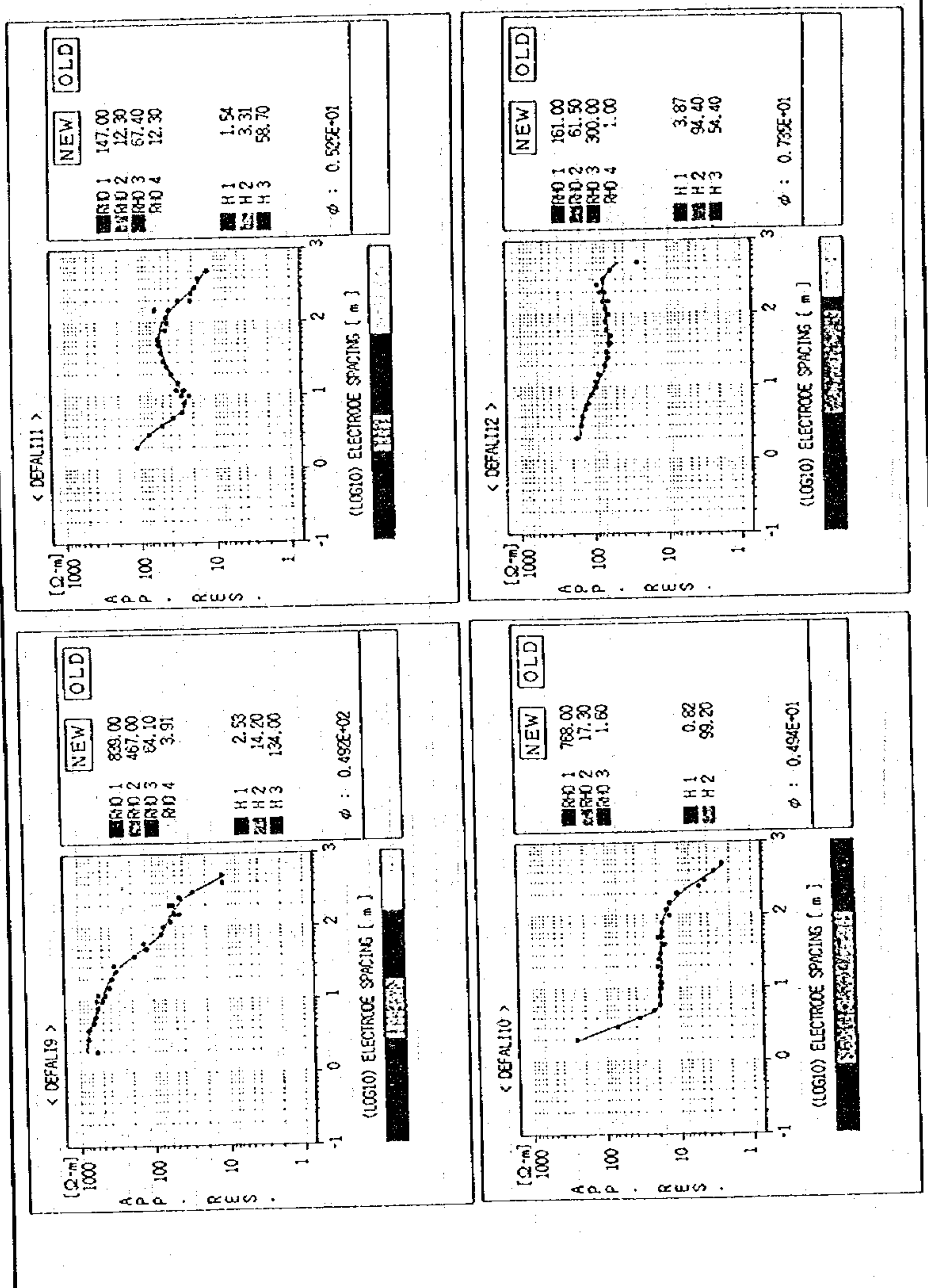


Figure 4.2.2 Vertical Electric Sounding Curves (4/19)

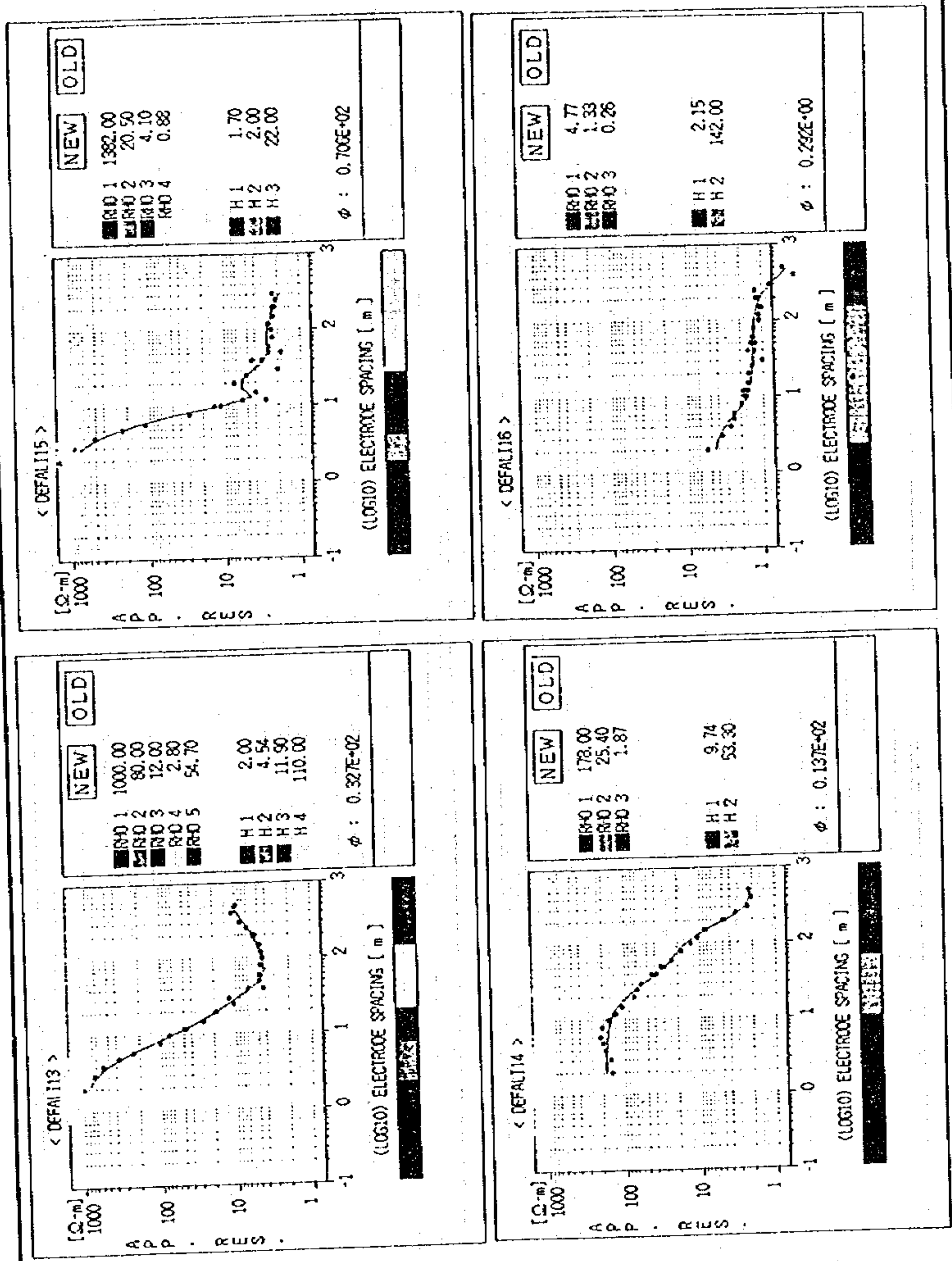


Figure 4.2.2 Vertical Electric Sounding Curves (5/19)

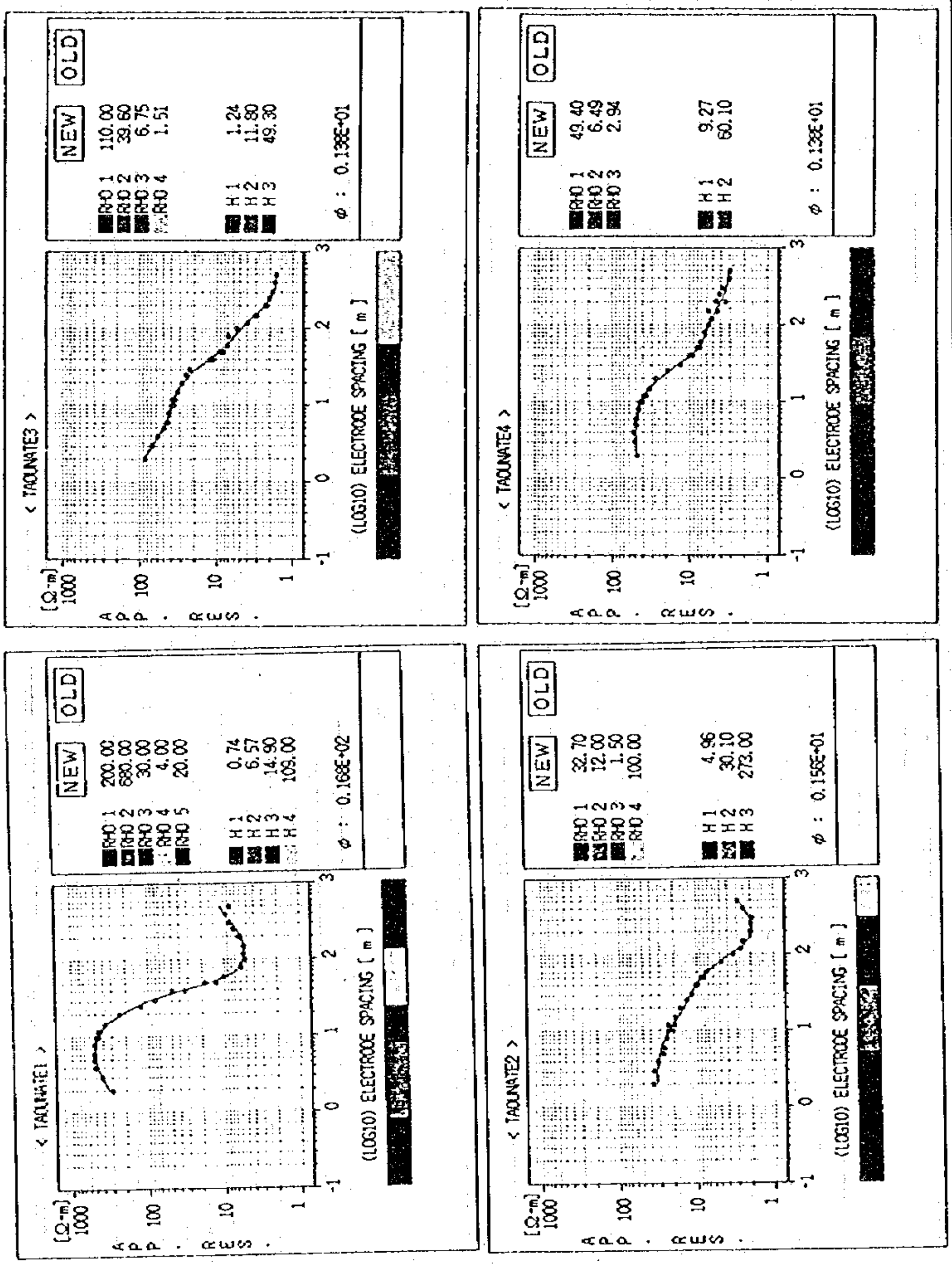


Figure 4.2.2 Vertical Electric Sounding Curves (6/19)

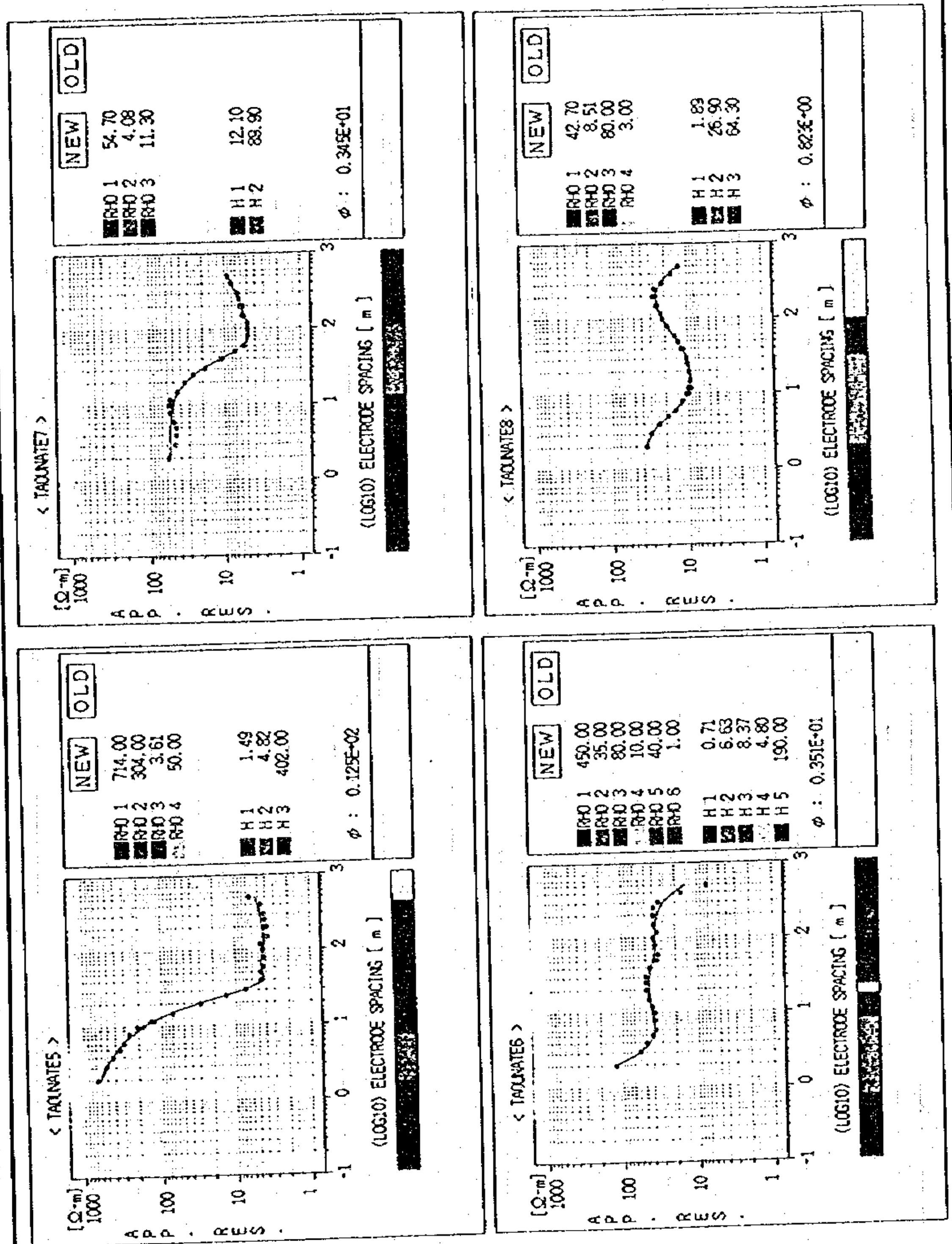


Figure 4.2.2 Vertical Electric Sounding Curves (7/19)

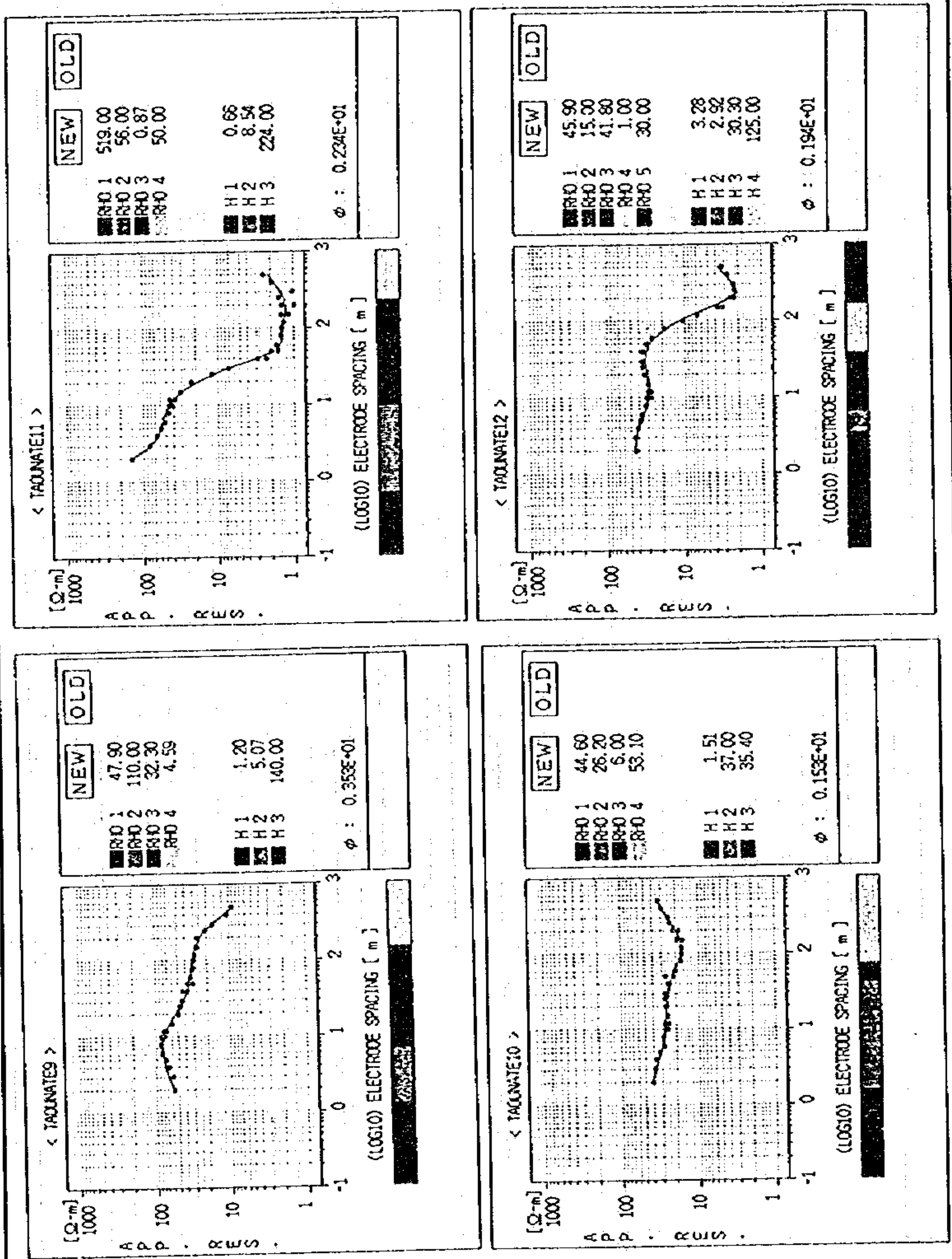


Figure 4.2.2 Vertical Electric Sounding Curves (8/19)

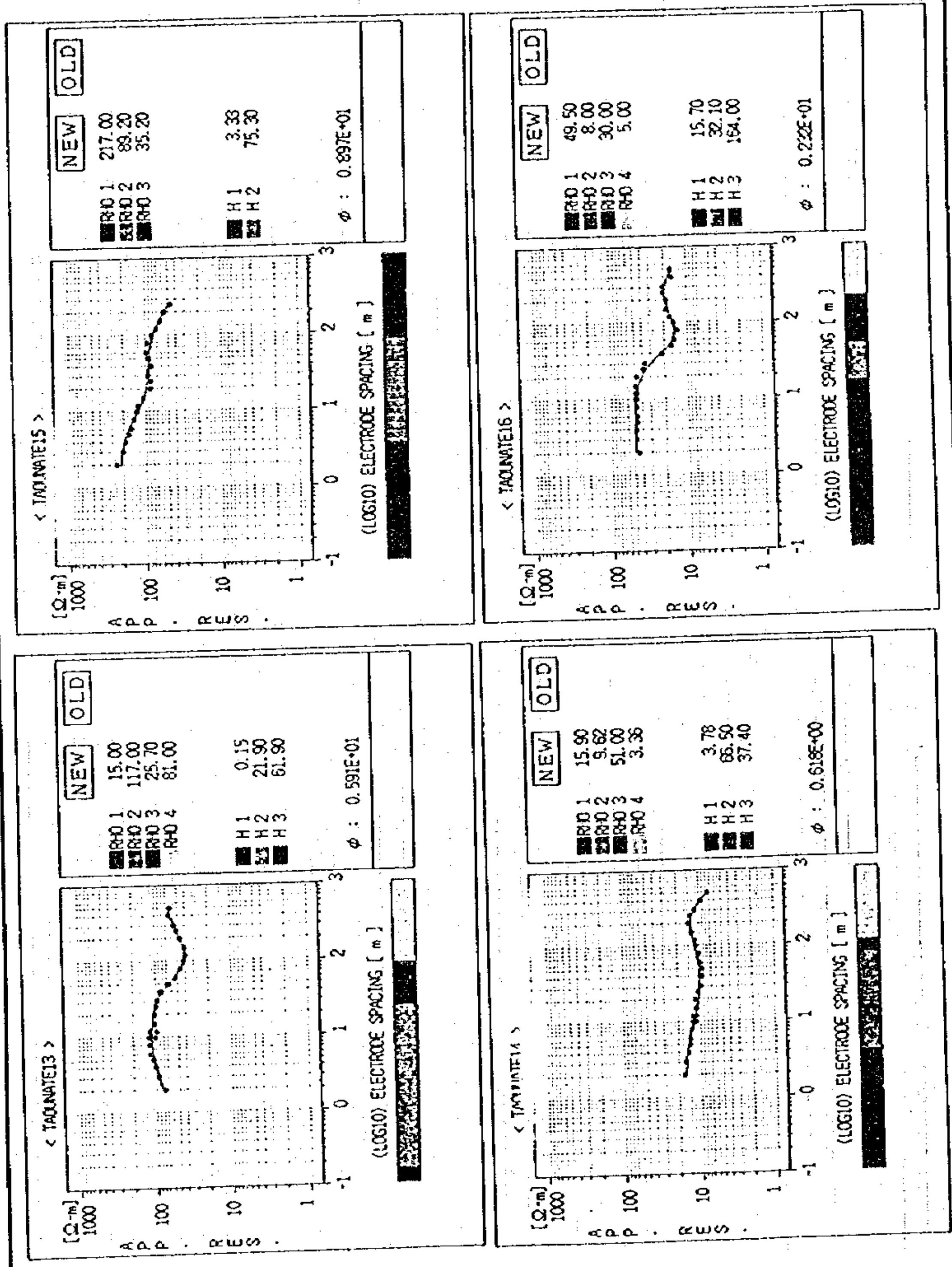


Figure 4.2.2 Vertical Electric Sounding Curves (9/19)

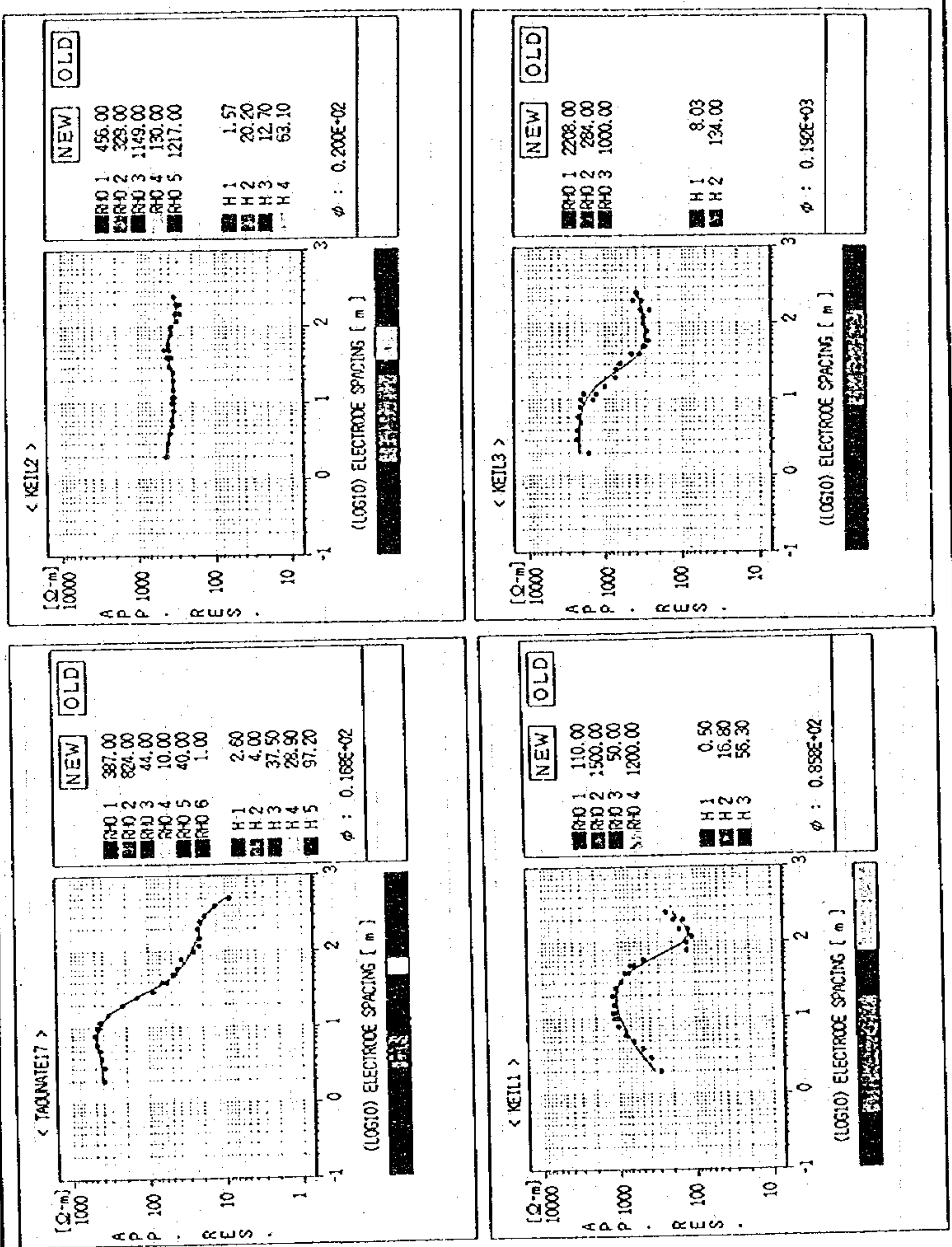


Figure 4.2.2 Vertical Electric Sounding Curves (10/19)

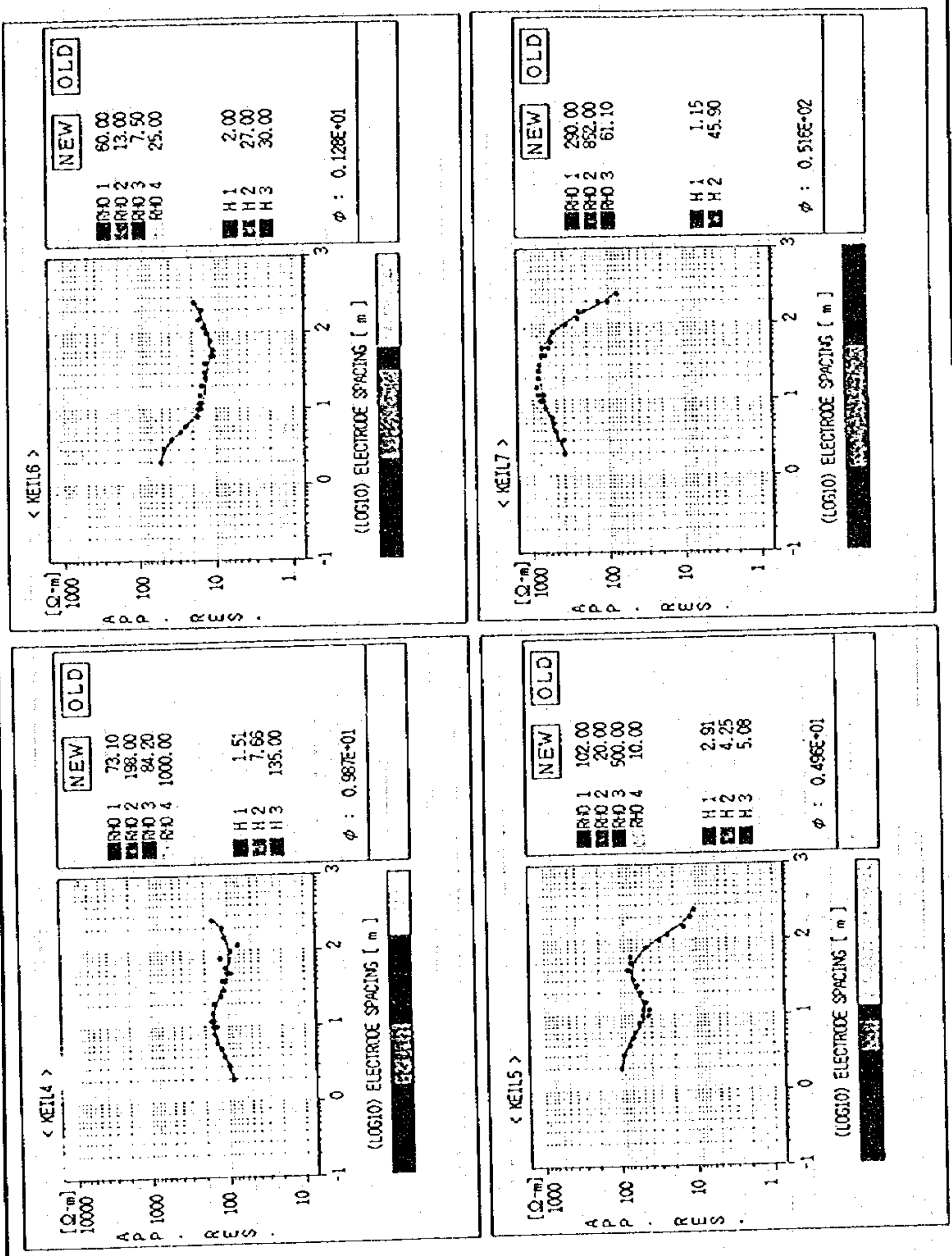


Figure 4.2.2 Vertical Electric Sounding Curves (11/19)

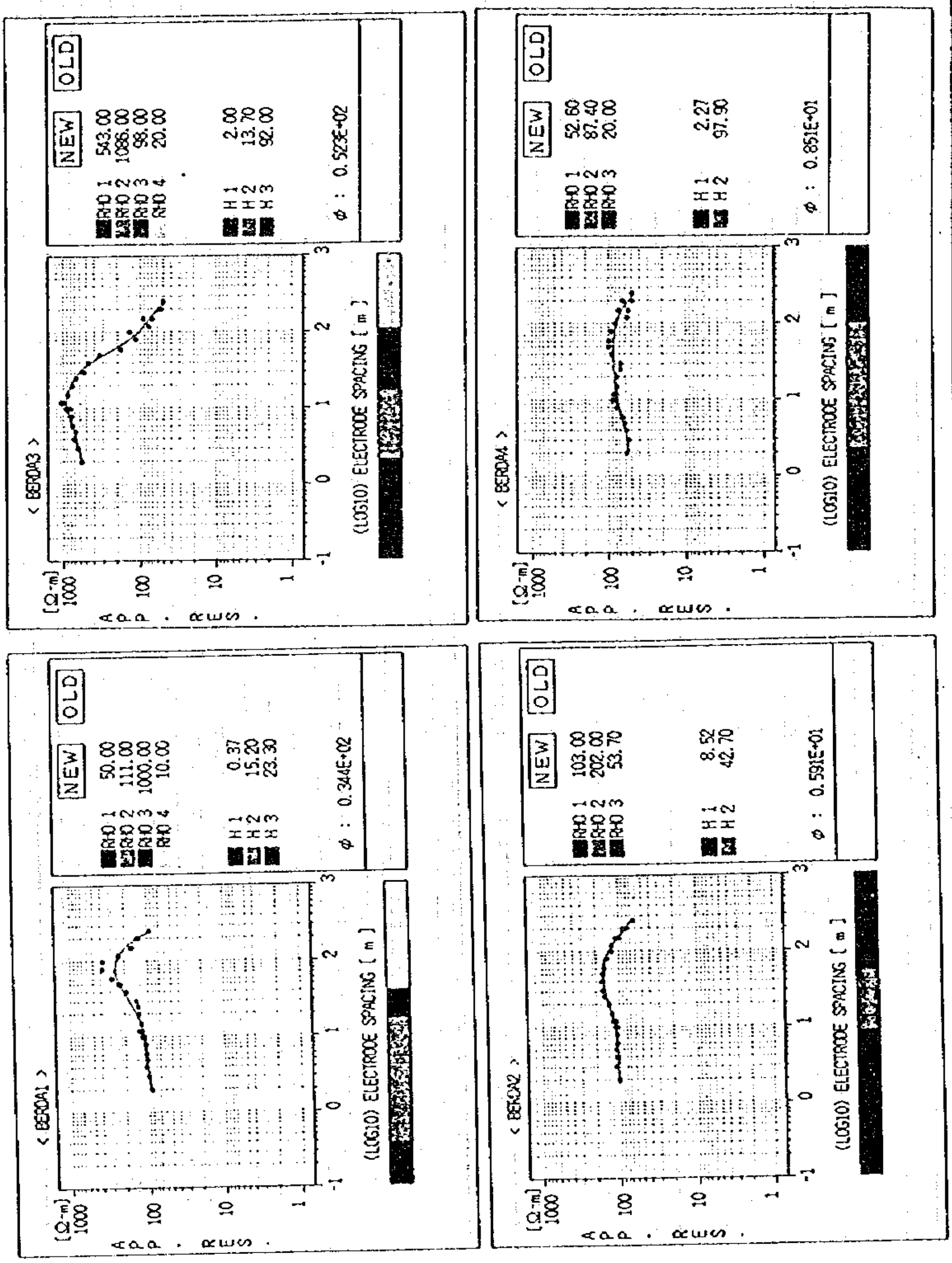


Figure 4.2.2 Vertical Electric Sounding Curves (12/19)

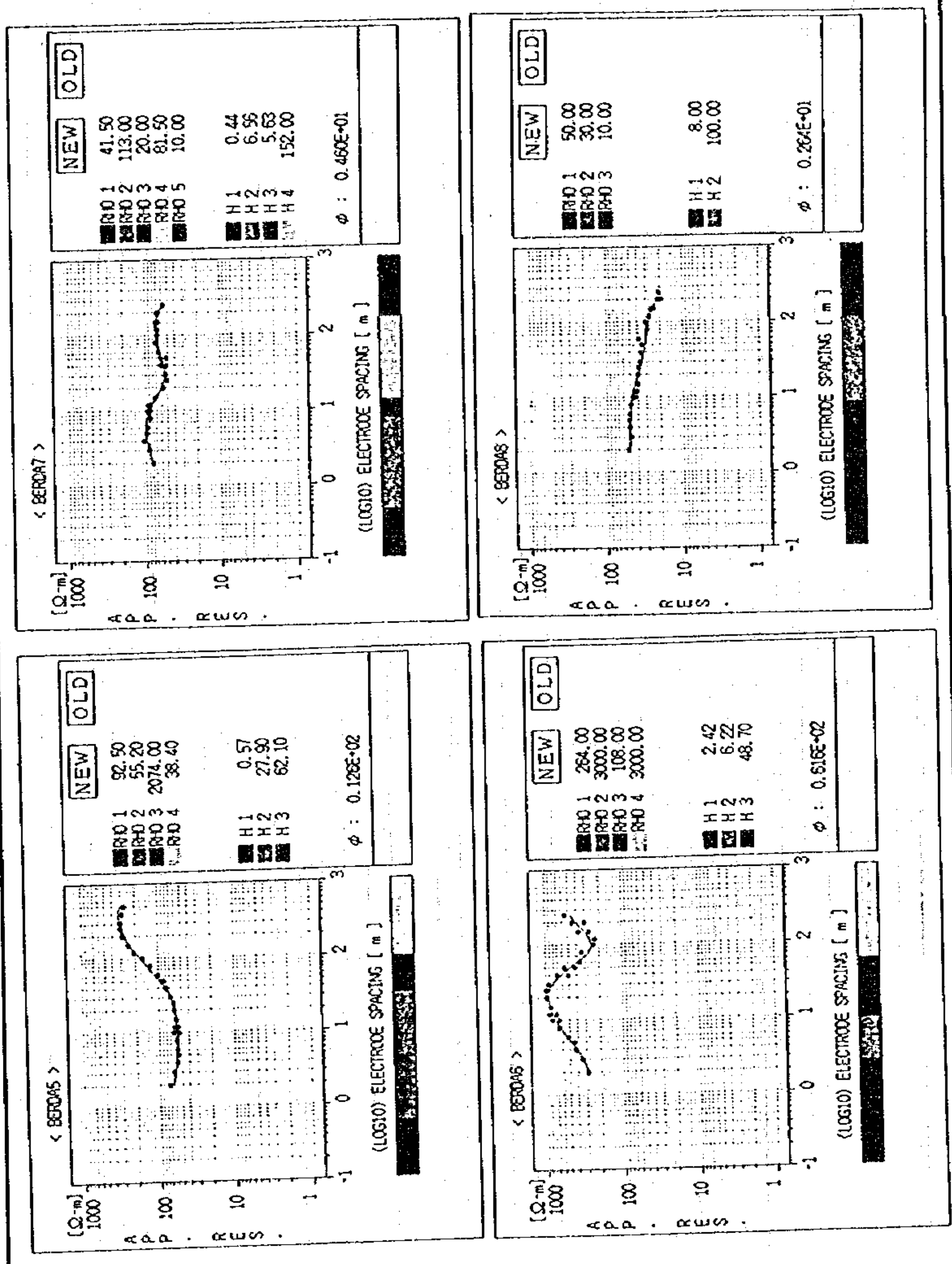


Figure 4.2.2 Vertical Electric Sounding Curves (13/19)

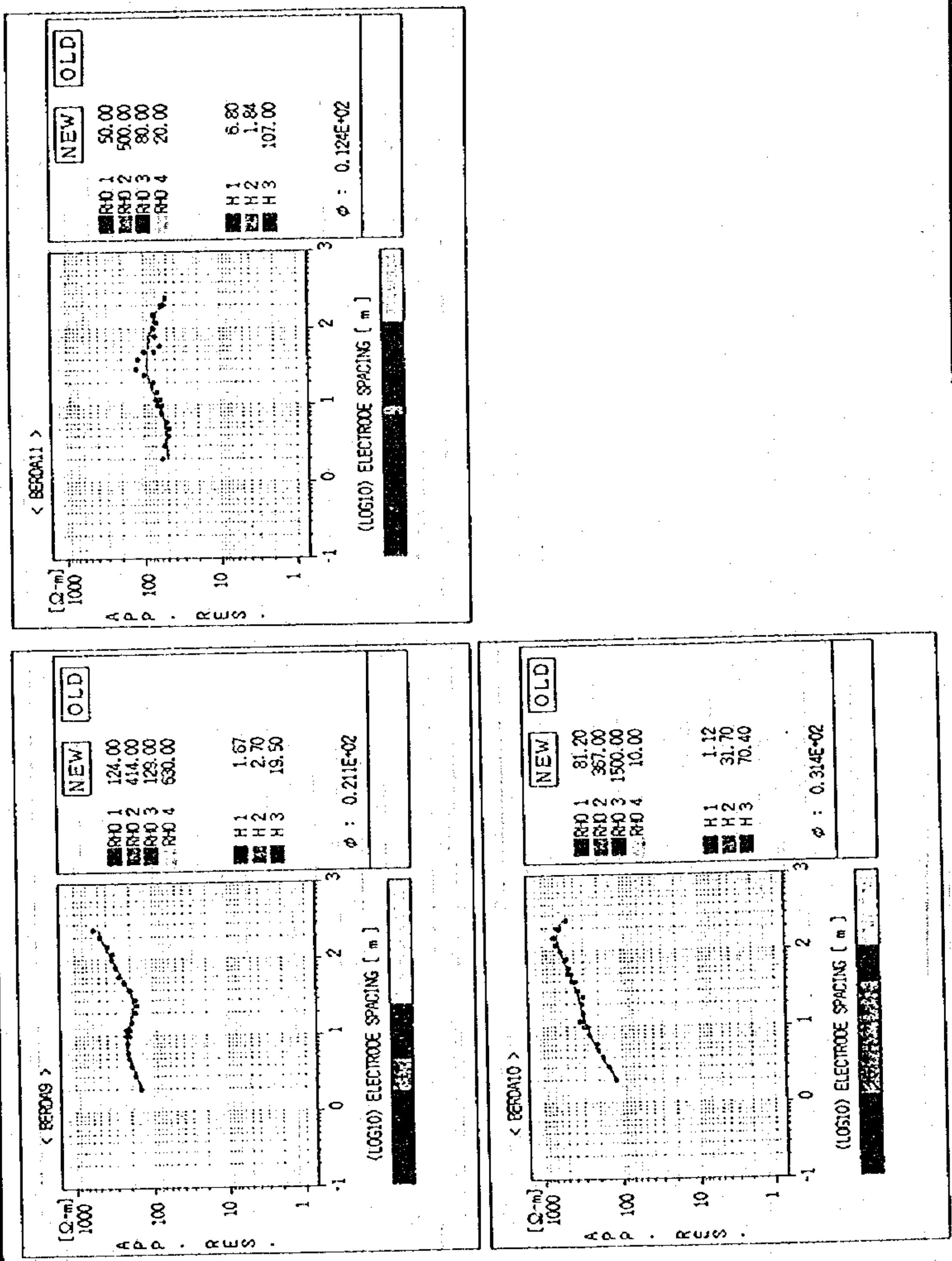


Figure 4.2.2 Vertical Electric Sounding Curves (14/19)

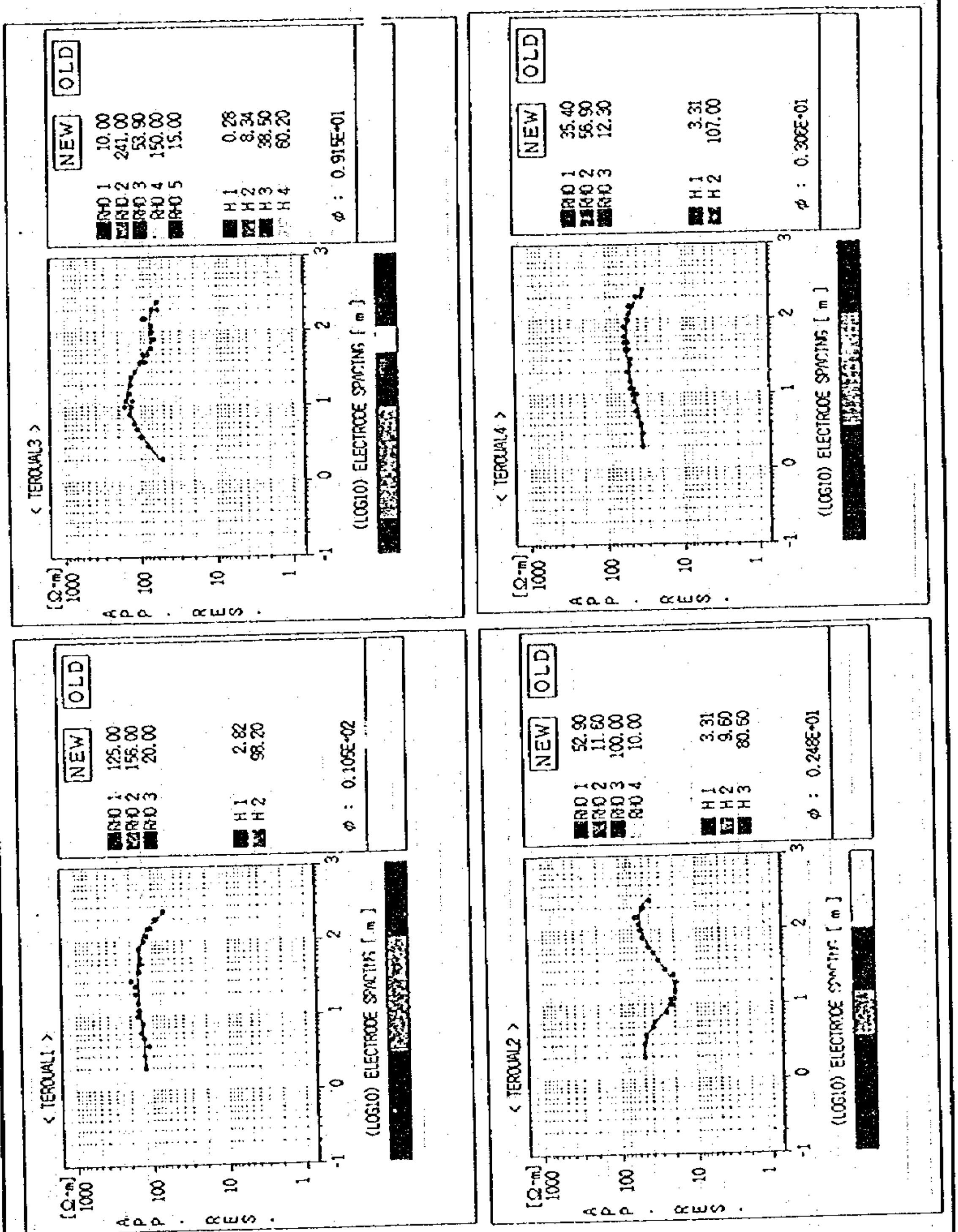


Figure 4.2.2 Vertical Electric Sounding Curves (15/19)

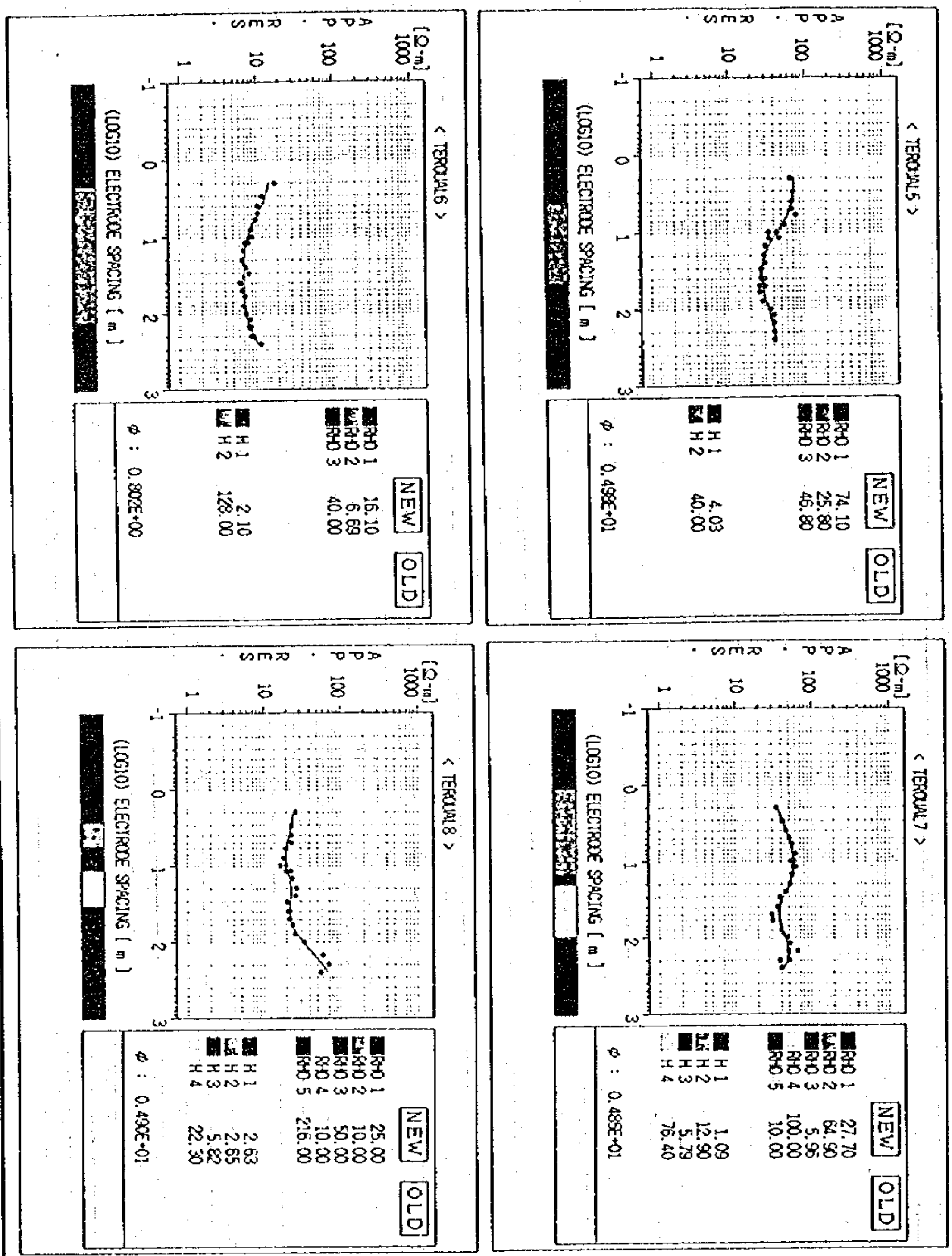


Figure 4.2.2 Vertical Electric Sounding Curves (16/19)

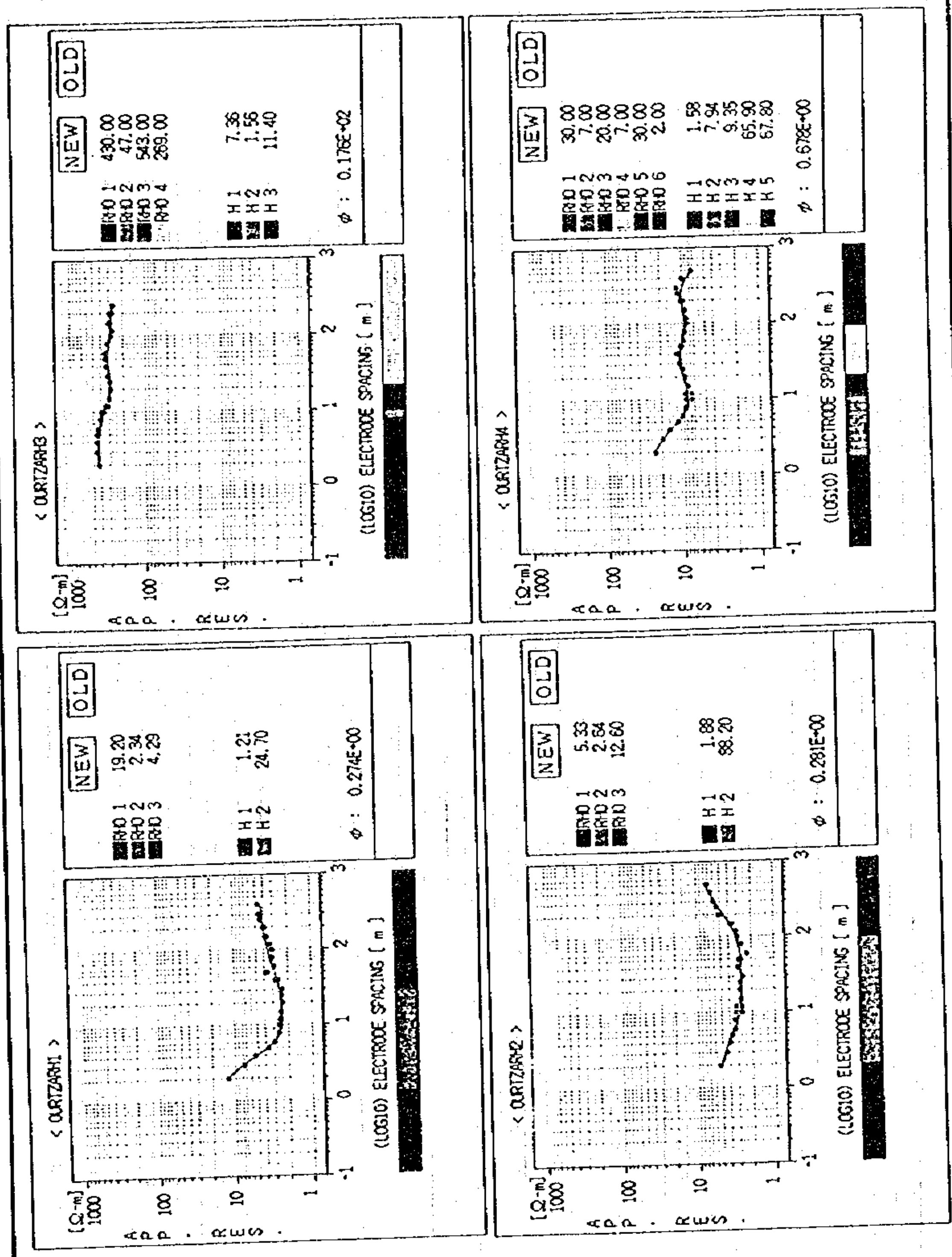


Figure 4.2.2 Vertical Electric Sounding Curves (17/19)

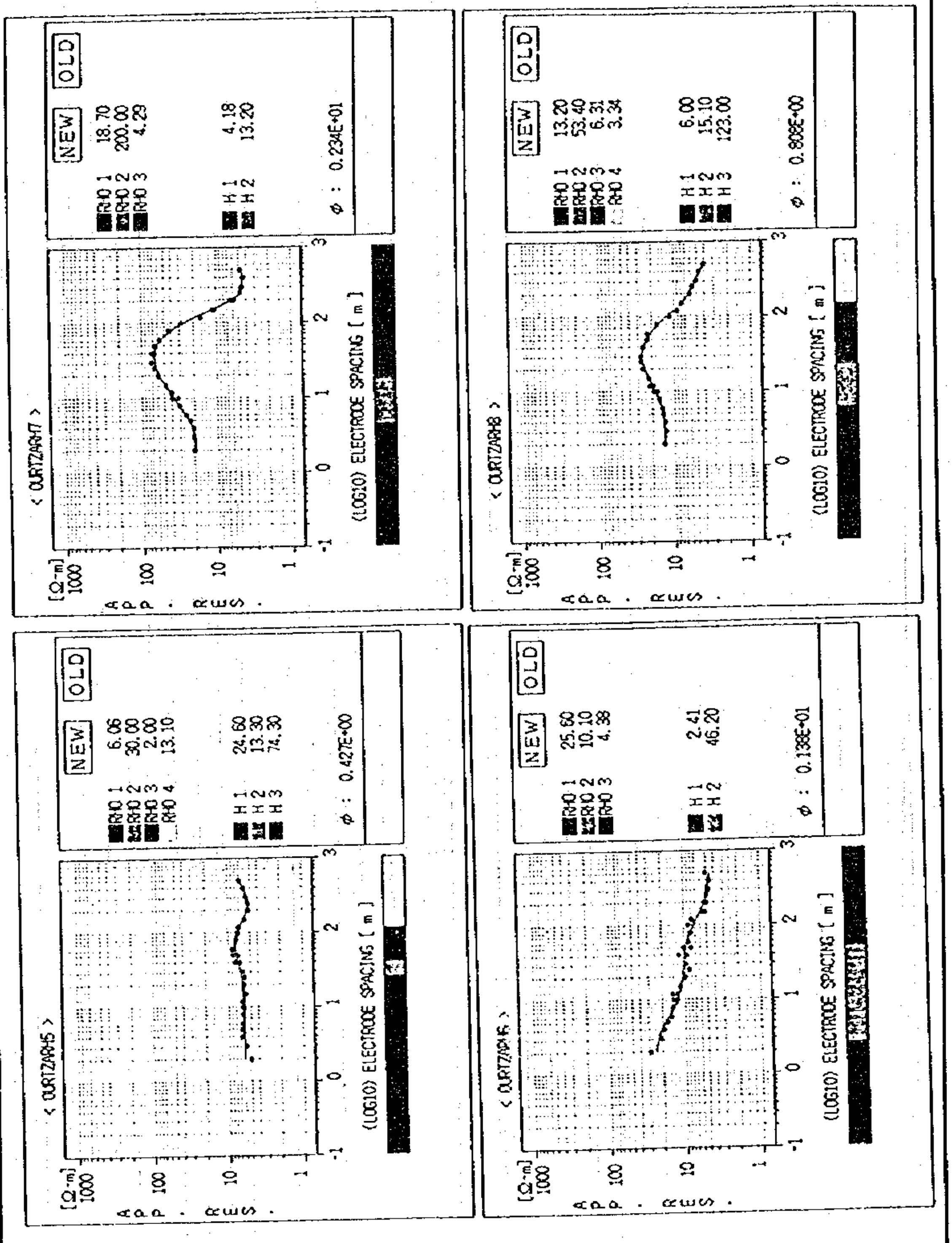
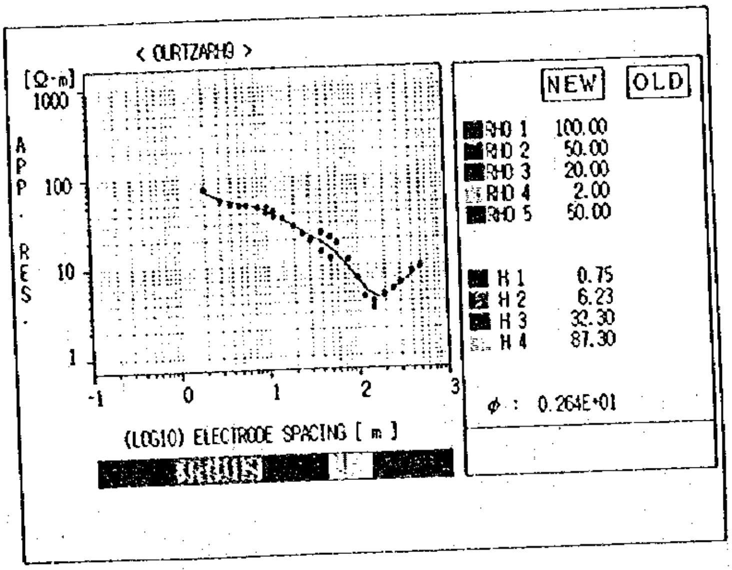


Figure 4.2.2 Vertical Electric Sounding Curves (18/19)



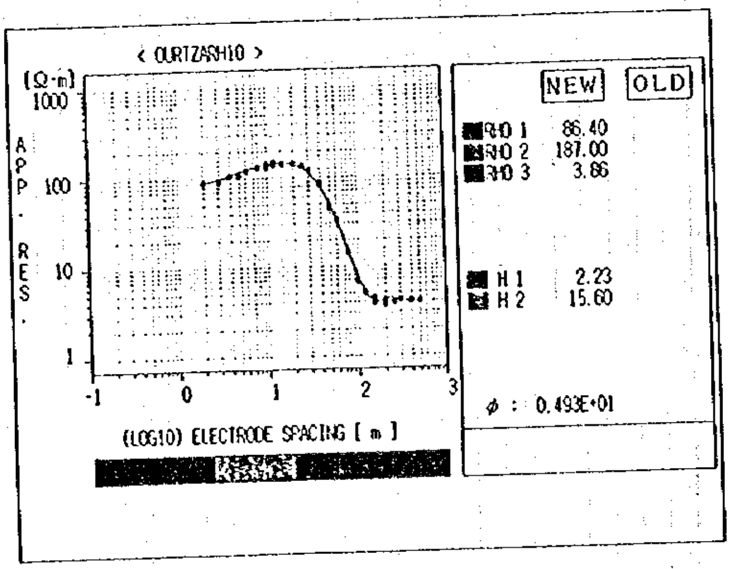
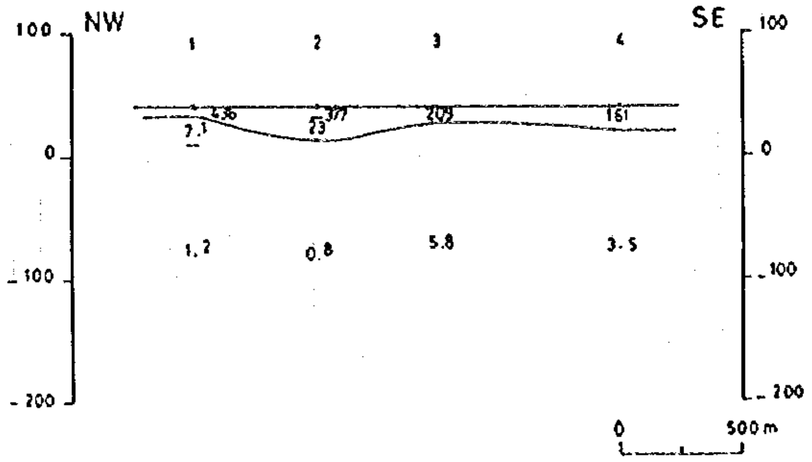
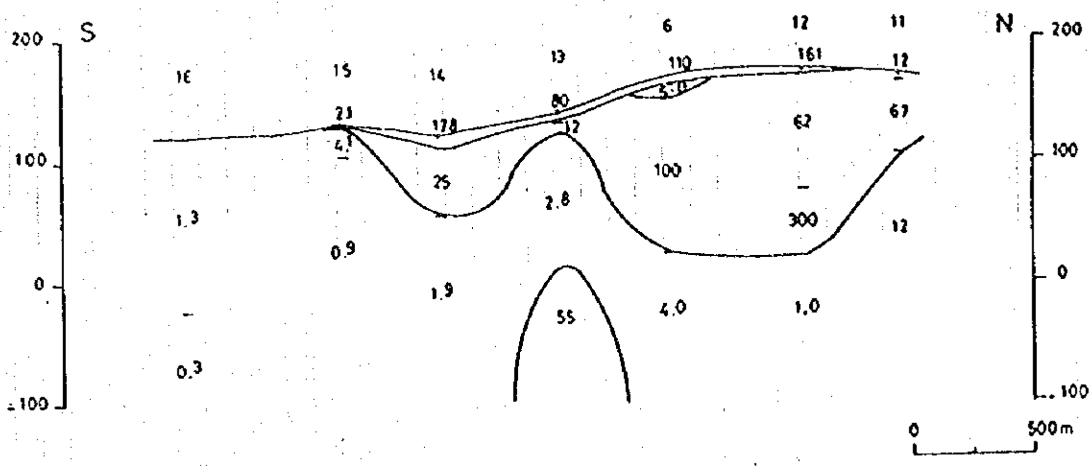


Figure 4.2.2 Vertical Electric Sounding Curves (19/19)

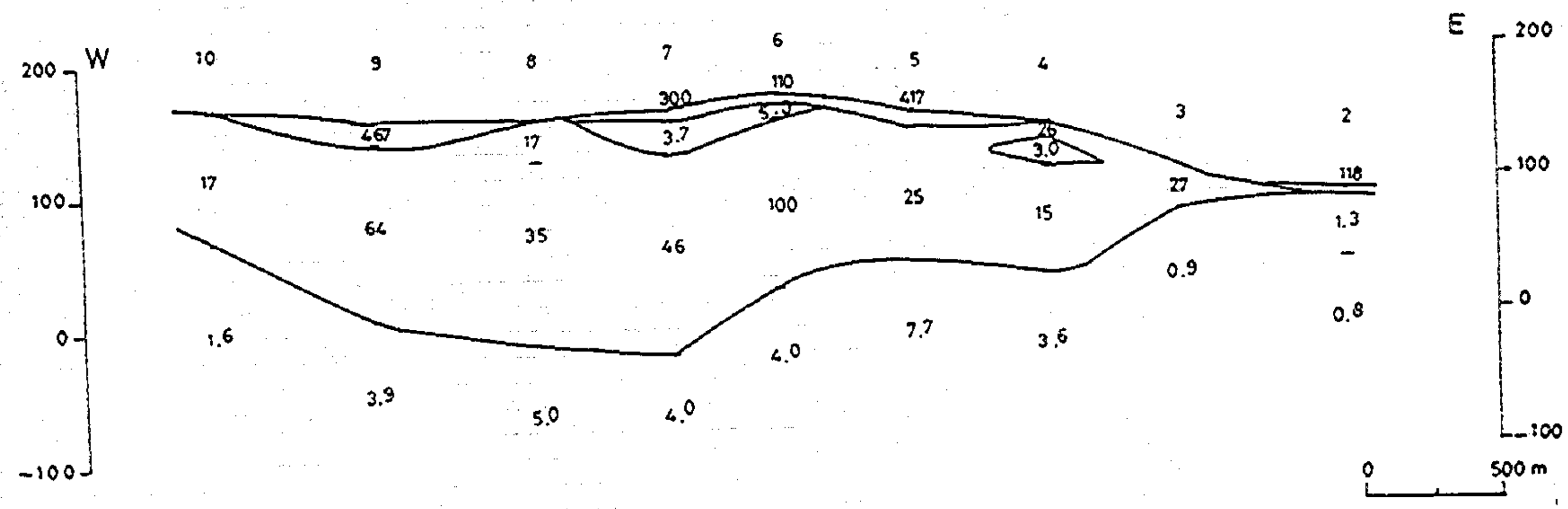


(1) JORF EL MELHA



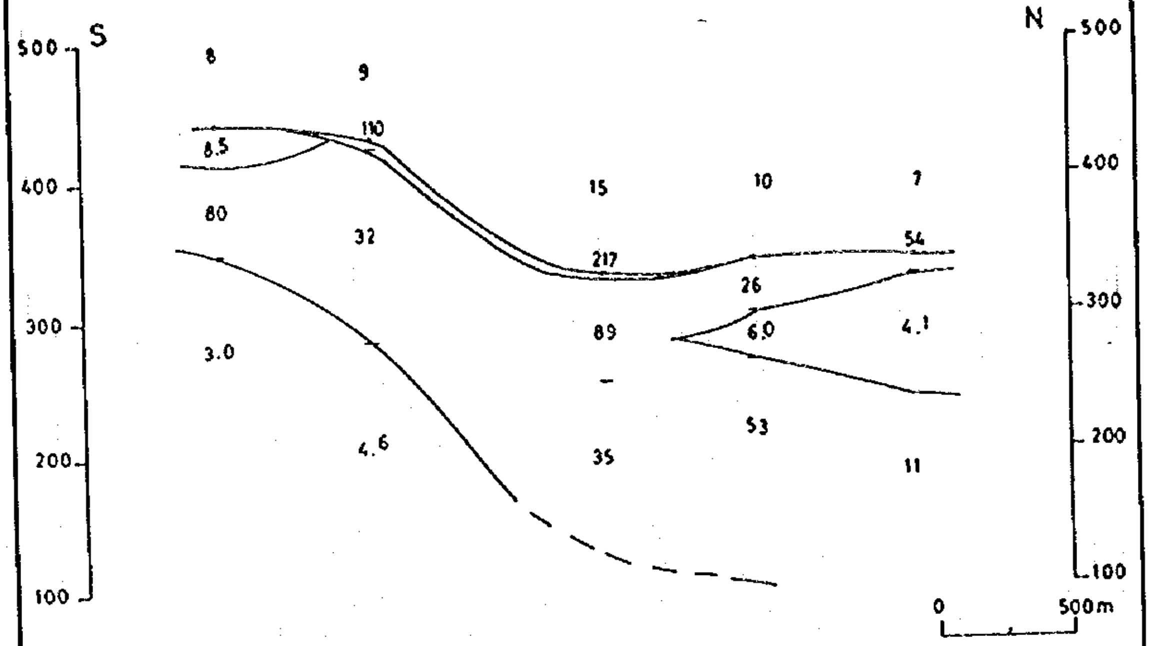
(2) AIN DEFALI (Line A)

Figure 4.2.3 Resistivity Profiles (1/11)

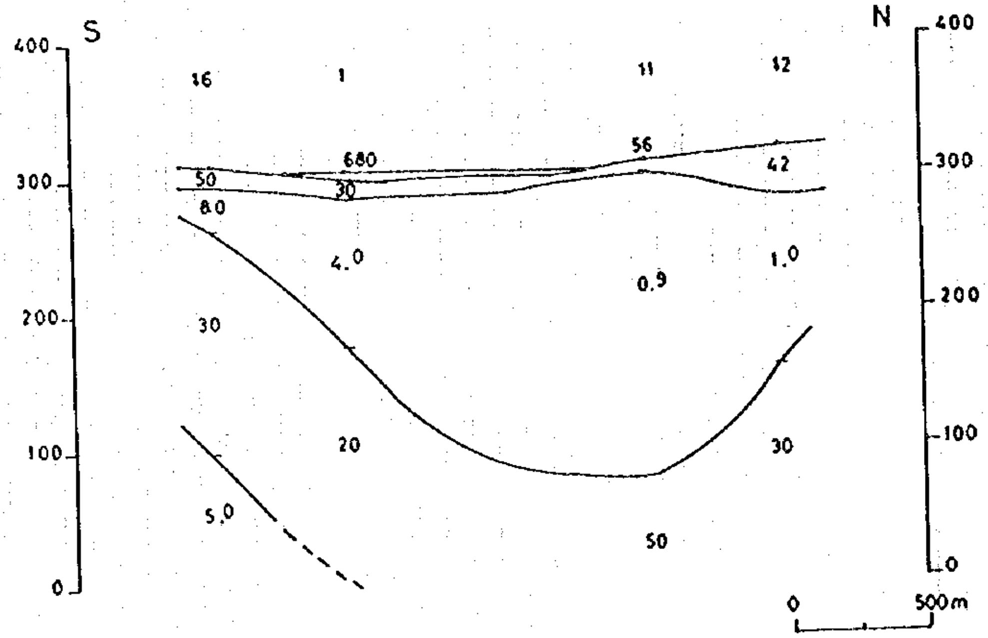


(3) AIN DEFALI (Line-B)

Figure 4.2.3 Resistivity Profiles (2/11)

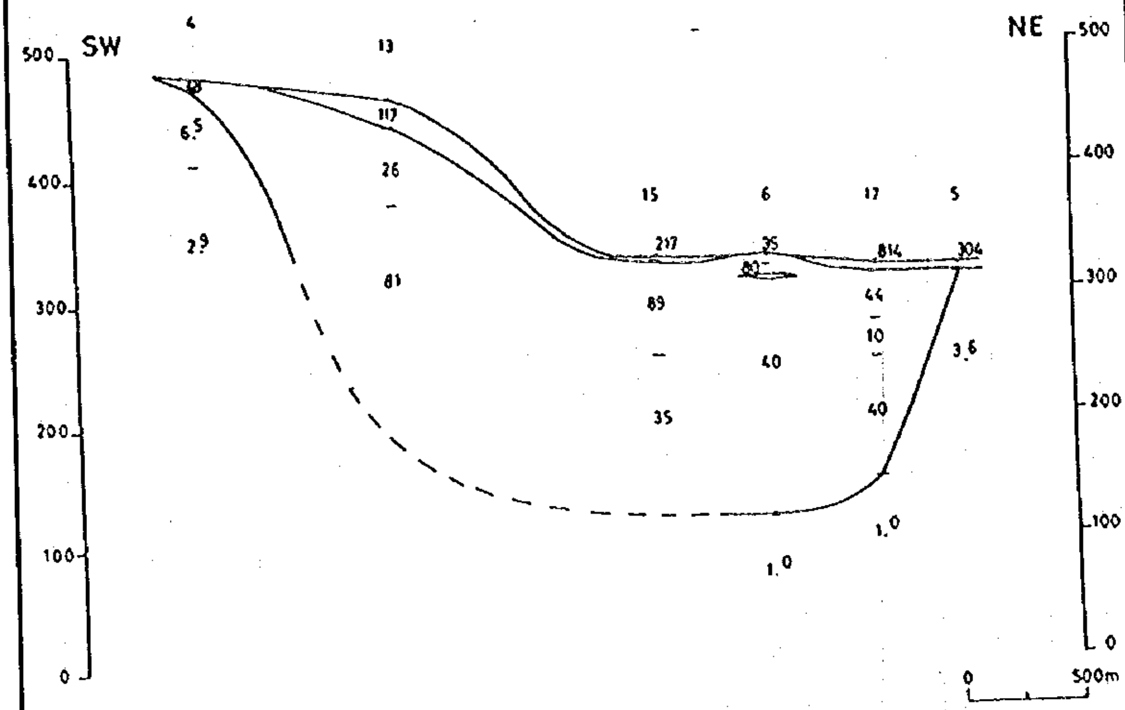


(4) TAOUNATE (Line - A)

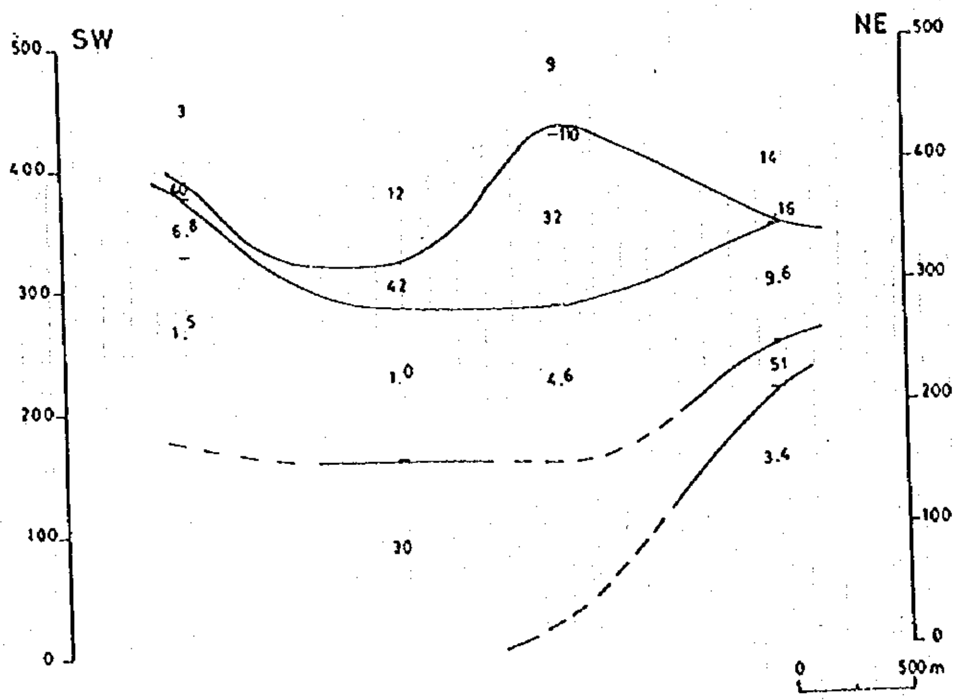


(5) TAOUNATE (Line - B)

Figure 4.2.3 Resistivity Profiles (3/11)

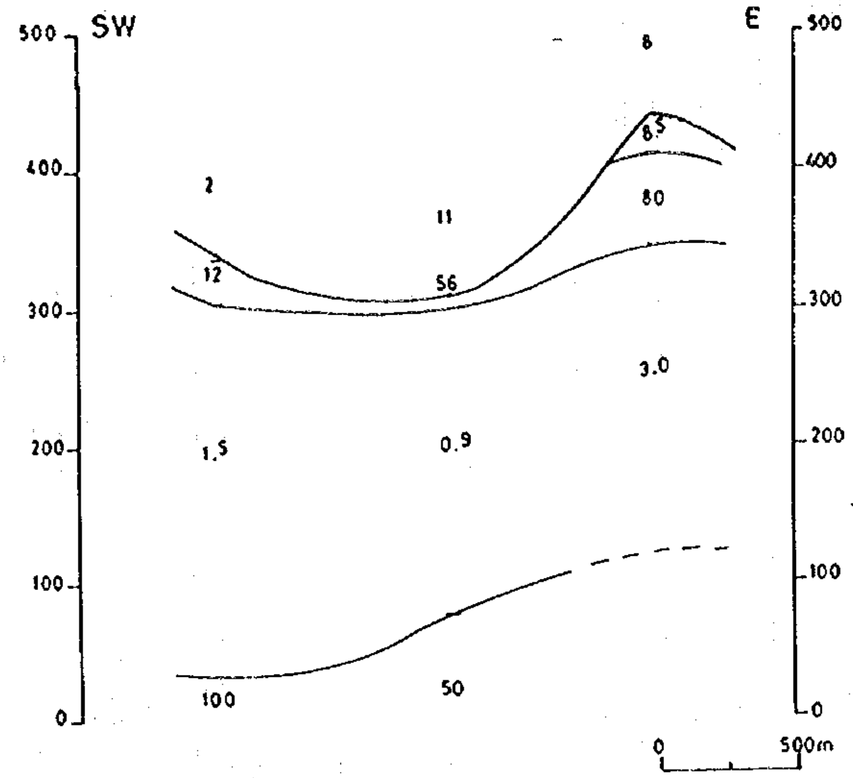


(6) TAOUNATE (Line - C)

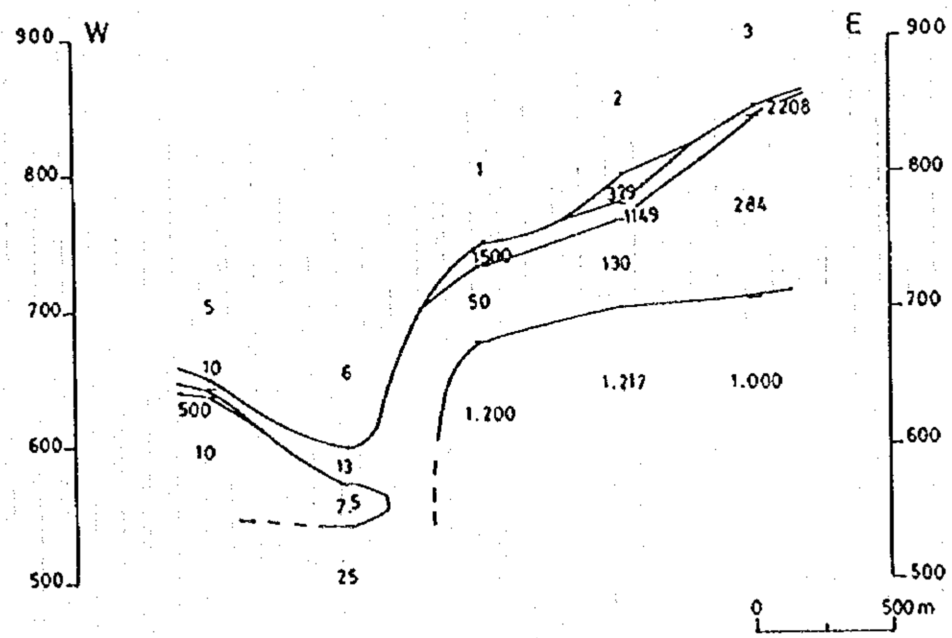


(7) TAOUNATE (Line - D)

Figure 4.2.3 Resistivity Profiles (4/11)

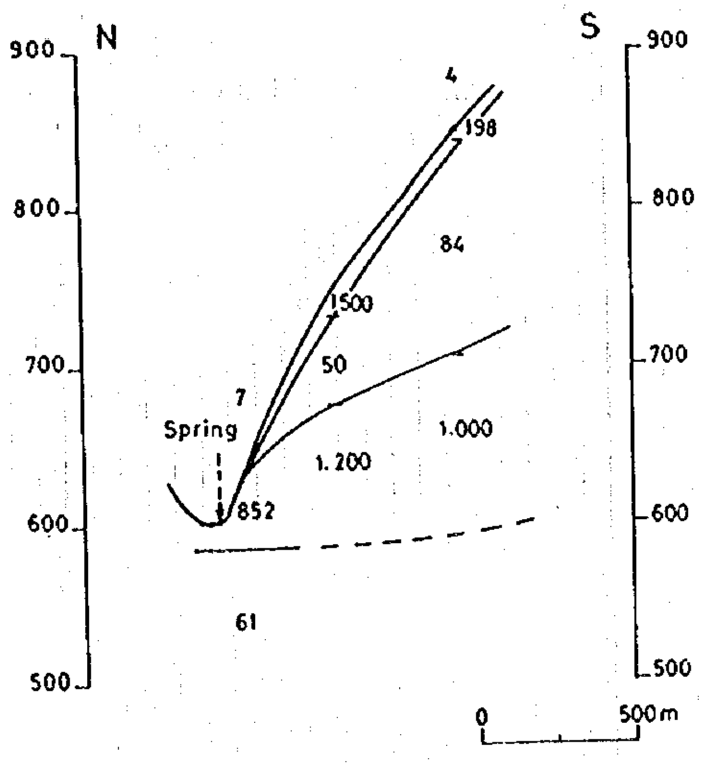


(8) TAOUNATE (Line - E)



(9) J. KEIL (Line - A)

Figure 4.2.3 Resistivity Profiles (5/11)



(10) J. KEIL (Line - B)

Figure 4.2.3 Resistivity Profiles (6/11)

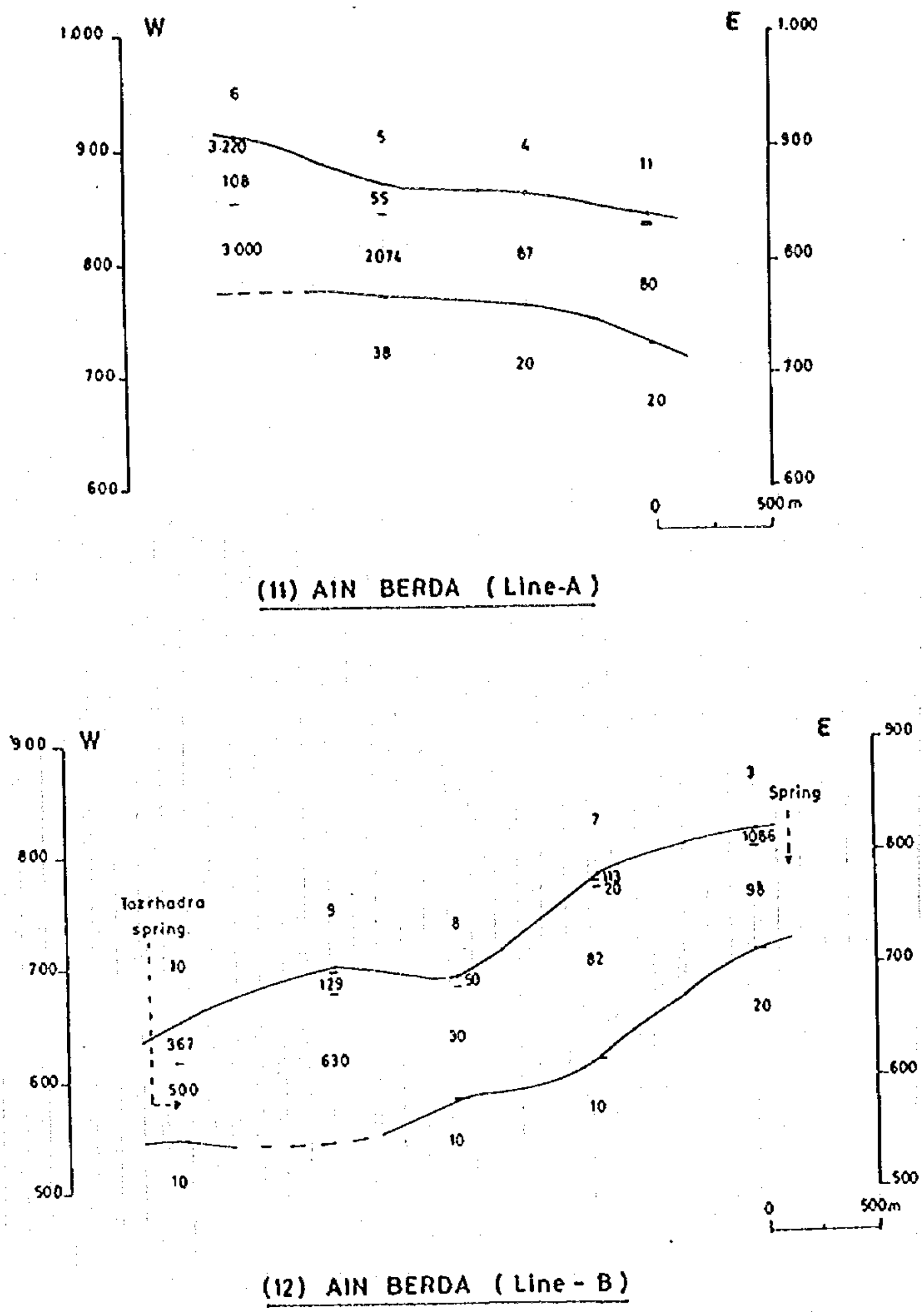
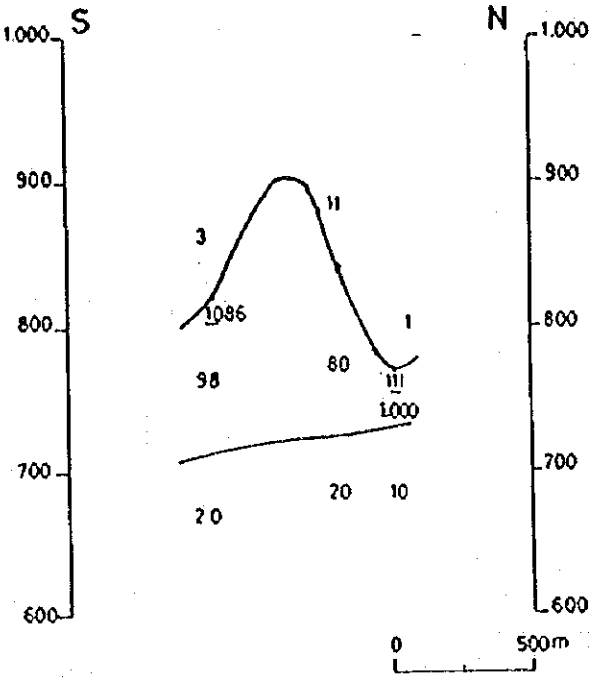
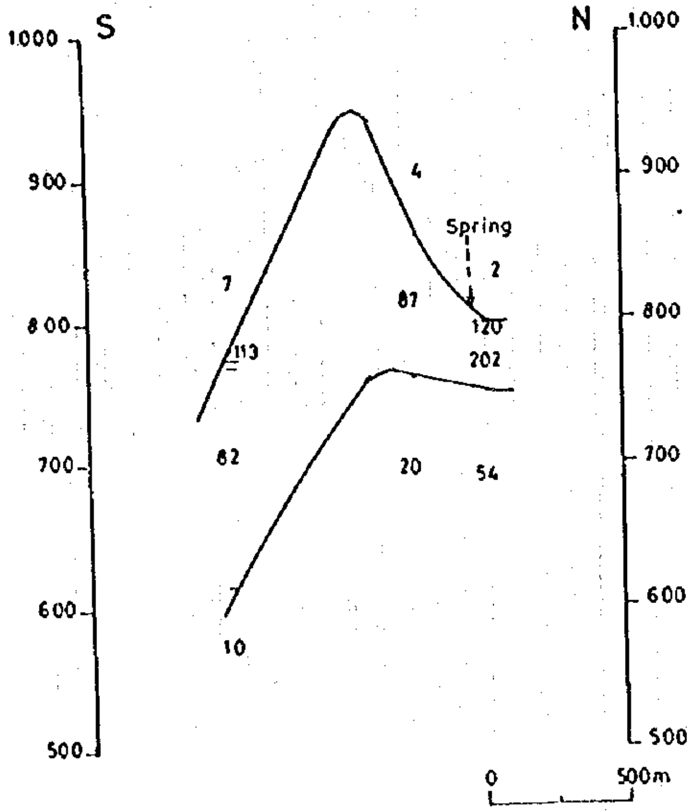


Figure 4.2.3 Resistivity Profiles (7/11)

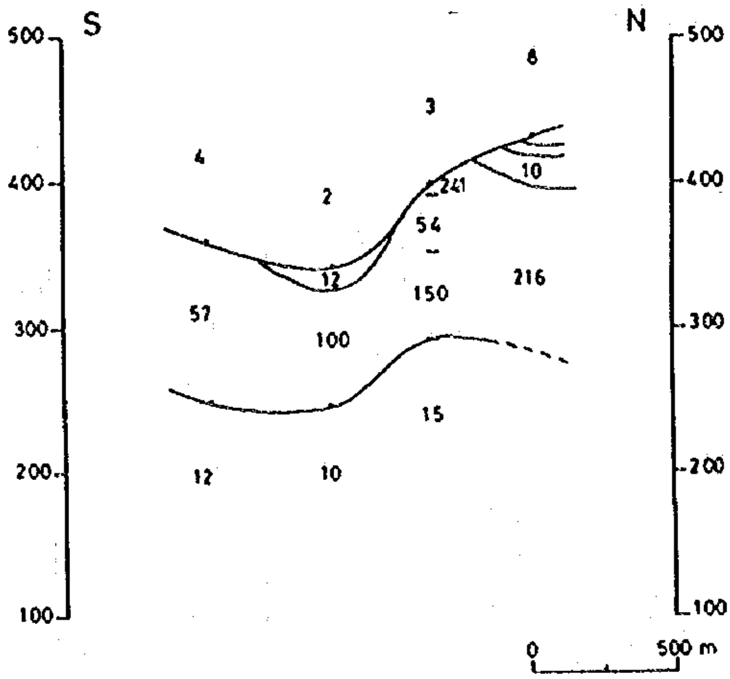


(14) AIN BERDA (Line-D)

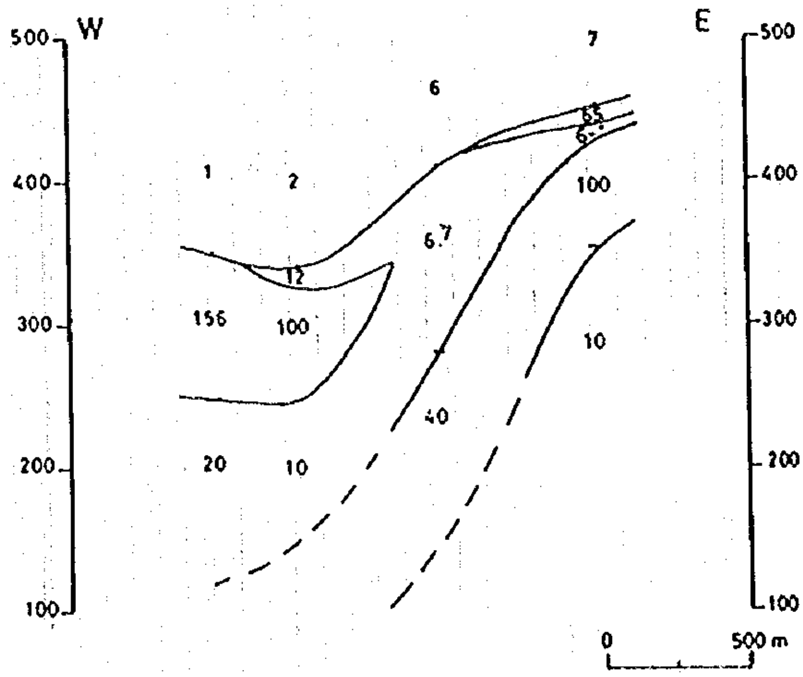


(13) AIN BERDA (Line-C)

Figure 4.2.3 Resistivity Profiles (8/11)

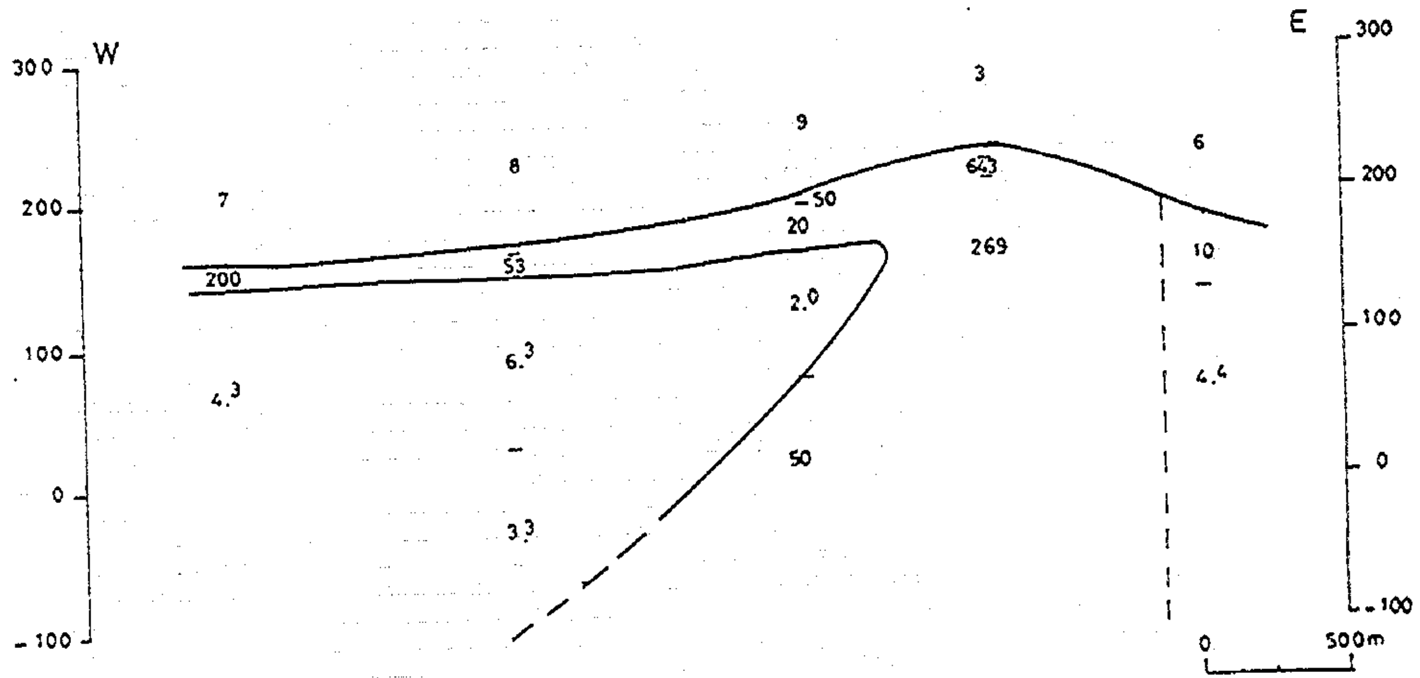


(15) TEROUAL (Line_A)



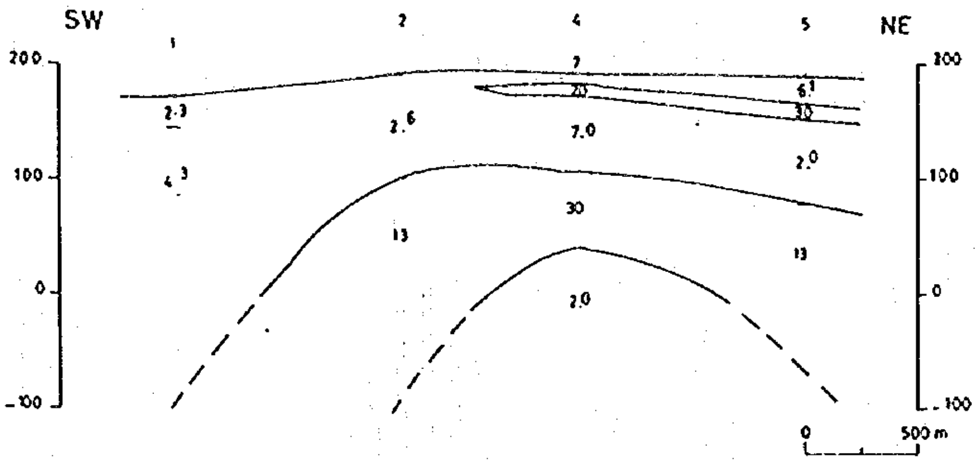
(16) TEROUAL (Line_B)

Figure 4.2.3 Resistivity Profiles (9/11)

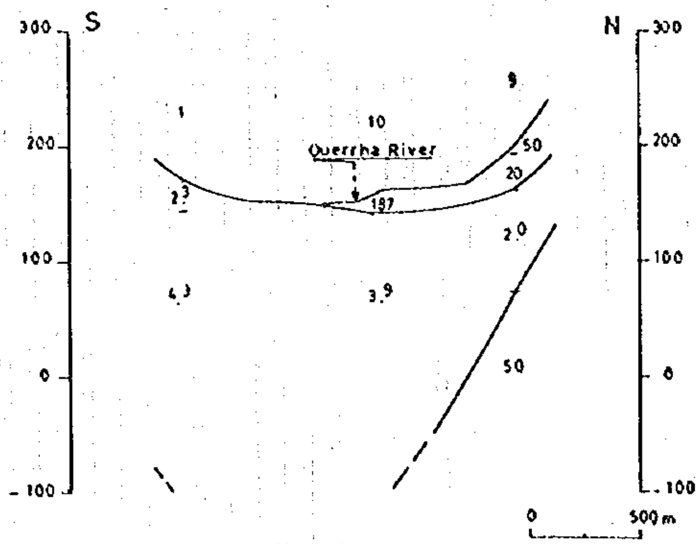


(17) OURTZARH (Line A)

Figure 4.2.3 Resistivity Profiles (10/11)



(18) OURTZARH (Line - B)



(19) OURTZARH (Line - C)

Figure 4.2.3 Resistivity Profiles (11/11)