ANNEX–D

HYDROGEOLOGY AND GROUNDWATER

ANNEX - D

HYDROGEOLOGY AND GROUNDWATER

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ANNEX-D HYDROGEOLOGY AND GROUNDWATER

D.1 INTRODUCTION

The Malir river basin has played an important role to Karachi city in supplying agricultural products and potable water. In the 1960s, demand for fruit and vegetables and potable water supply were increased mainly due to rapid population growth of Karachi city, the largest city of Pakistan. In the 1960s and thereafter, intensive tube/dug well development was continued, and results in overdraft of groundwater and drop of groundwater table. Critical situations have been developed in shortage of both irrigation and potable water supply as well as salt water intrusion into the aquifer.

In order to cope with these situations, groundwater investigations were carried out by WAPDA in 1979, and the results of these investigations were presented in the previous feasibility study report (Ref. 01).

To analyze recharge and groundwater movement mechanisms, further hydrogeological investigations and studies were performed. This ANNEX presents all the results including review of the previous reports.

D.2 HYDROGEOLOGY

D.2.1 Field Investigations

Hydrogeological investigations included measurements of groundwater table, electric conductivity (EC) of groundwater and its pH, electric resistivity survey of the ground and other hydrogeological surveys. Investigations carried out for this study were as follows:

- Electric resistivity sounding	75 points
- Pumping test of shallow wells	6 points
- Infiltration test	5 points
- Soil test (Grain size analysis)	5 samples
- Water quality analysis (chemical analysis)	15 samples
- Tritium contents analysis	2 samples
- Automatic groundwater leveling gauge	2 sets

On the basis of these investigations, maps showing the groundwater contours, the distribution of electric resistivity of ground, and electric conductivity as well as pH of groundwater were prepared for clarification of hydrogeological setting.

The scope of works for major investigation items are presented in the following paragraphs:

(1) Electric Resistivity Survey

Electric resistivity survey was carried out by the study team in order to obtain more precise and intensified hydrogeological information which is required for more detailed study of groundwater movement and recharge mechanism.

The electric resistivity survey was performed in the vertical electric sounding method (100 m depth) with Wenner's electrode arrangement at 75 points to make clear the hydrogeologic structure in the Malir basin area. These points were selected along the hydrogeological cross sections, A to F, covering from the vicinity of the national highway bridge in the lower reaches to the confluence of the Mol and the Khadeji tributaries. The sections are of northwest-to-southeast trend, and are nearly at right angle to the flow of the Malir River (see Fig. D.2-3). In addition, along with groundwater surveys, geological logging of dug wells and site interviews with local residents were performed to collect supplementary hydrogeological data.

(2) Pumping Test

Pumping tests were performed at the selected six (6) dugwells to obtain characteristics of aquifers (see Table D.2.3). Most of the dugwells in the study area have supplementary boreholes and/or galleries at the bottom to squeeze the groundwater from the surroundings. For the pumping test, wells with less supplementary measures were selected in order to minimize the effects of structural complexity of well upon the analysis of the pumping test record.

(3) Infiltration and Soil Tests

Infiltration tests were performed to know the infiltration rates in different spots and layers in the Malir river bed. The location of test sites is shown in Fig. D.2-1 and the test result is shown in Fig. D.2-11. Grain size analysis of five soil samples which were collected near the infiltration test sites was made to clarify the characteristics of soil layers. The test result is shown in Table D.2.4.

(4) Water Quality Analysis

Electric conductivity (EC) and pH of both surface and subsurface water were checked at the selected sites through the course of groundwater survey. Results are shown in Figs. D.2-10 and D.2-12. In addition, chemical analysis of water samples was made by the Pakistan Council of Scientific and Industrial Research. The results of the analysis are shown in Table D.2.5 and Fig. D.2-17. Tritium content analysis sampled at two sites was also made to study saline water intrusion. Study on the groundwater quality was made on the basis of the results of these surveys and analysis, as presented in Section D.2.8.

D.2.2 Geology

The study area is located from 30 km to 60 km northeast of Karachi, lying along the northeasterly trending the Malir river and its upstream tributaries of Khadeji and Mol rivers. Topographically, the area is relatively flat with general land slope of 1/300 to southwest and it forms 20 m to 100 m in elevation. The upstream area from the confluence of Khadeji and Mol rivers showing over 100 m in elevation has steeper gradient of slopes in comparison with the downstream area. The location of the study area in Pakistan is shown in Fig. D.2-2.

The Malir river flows down southwest collecting water from the tributaries and drains into the Arabian Sea. The main tributaries are Mol, Khadeji, Thaddo and Sukkan rivers (see Fig. D.2-3).

Bedrock of the study area consists of Gaj formation of Miocene age and Manchar formation of Pliocene age. Gaj formation distributes in the north including exposures in two damsites and underlies the Manchar formation, which exposes in the southern hills as well as mound rocks of the study area.

The Gaj formation is generally composed of limestone, sandstone and shale. The Manchar formation consists of sandstone, shale and conglomerate in general. Gaj and Manchar formations are underlain by Nari and Laki formations of Tertiary age, but they are not outcropped in the study area. The strike and dip of Manchar formation are N60-80W/5-10°S and those of the Gaj formation show a wide variation.

The various rock units described above are folded to form gentle structural undulations, such as anticlinal hills and synclinal valleys, with moderate to gentle dips of less than 10 degrees. The fold axes run approximately north-to-south and are inclined southward.

Quaternary deposits are distributed overlying the said two formations in most of the study area. The recent unconsolidated loessic sediments cover the above layers scattering along the Malir river and its tributaries.

Quaternary deposits which are composed mainly of sand and gravels with boulders (some of them are cemented compact) are distributed along the present river bed. Thickness of this formation is assessed to be about 50 meters in the lower reaches and 1-30 m in the upper reaches judging from the observation of geology of the wells and the results of electric resistivity survey.

Stratigraphy of the study area is as follows:

Age	Formation	Geological features
Recent to Pleistocene	Quaternary Deposits	Clay and Silt Fine to Coarse Sand with Gravels and Boulders
Pliocene	Manchar Formation	Sandstone, Shale, and Conglomerate
Miocene	Gaj Formation	Limestone, Sandstone, and Shale
Oligocene Eocene (Early to Mid.)	Nari Formation* Laki Formation*	Sandstone Limestone

Remarks: * No Nari and Laki formations are outcropped in the study area.

The distribution of unconsolidated layers is examined mainly through electric resistivity survey. On the basis of resistivity value, the geological profile of the area is classified mainly into three zones, namely, permeable, slightly permeable and impermeable zone.

The strata of resistivity values more than 100 ohm.m are interpreted to indicate probable existence of gravel or coarse sand. The strata of resistivity values from 20 to 100 ohm.m indicate presence of arenaceous materials, namely sandy silt or fine to medium sand. The strata of resistivity values less than 20 ohm.m indicate presence of clay or shale, sandstone and conglomerates of the bedrock. They are summarized as follows:

Classification	Electric Resistivity (ohm.m)	Geological Features
Permeable	more than 100	Gravel, Coarse sand
Slightly Permeable	20 - 100	Sandy silt, Fine to medium sand
Impermeable	less than 20	Shale, Sandstone, Conglomerate

Intercalation of some thin clay layers with thickness ranging between 0.6 m and 1.5 m was observed during the survey. Consolidated sand and cemented boulder beds are recognized at various depths. The hydrogeological profiles are shown in Fig. D.2-4 and the electric resistivity profiles are also shown in Fig. D.2-5.

D.2.3 Geomorphology

Geomorphology of the study area is classified into six (6) categories, such as alluvial plain, alluvial terraces of two different levels, hilly terrains, piedmont slope and hills. Their hydrogeological settings are as follows:

(1) Alluvial Plain

In this area, the stream bed deposits consist of fine to coarse sands with gravels, which form a shallow good aquifer. It is extensively exploited through a large number of shallow wells.

(2) Alluvial Terraces (Low and High)

Alluvial terrace deposits largely comprise sand and silt with some gravels and form a narrow zone between the hilly terrains and alluvial terraces. It forms a good shallow aquifer zone and a number of wells have been dug in this zone. The groundwater is slightly saline in general.

(3) Hilly Terrains, Piedmont Slopes and Hills

These areas comprise Quaternary fan gravel deposits and/or some talus deposits and partly of Tertiary sedimentary bedrocks, all occurring in higher levels than the alluvial terraces. In this area these deposits are not likely to retain groundwater.

The geomorphological map of the study area is shown in Fig. D.2-4. The groundwater development potential of the study area can be classified into the following three categories on the basis of the geomorphology of the area:

Classification	Development Potential	Topography	Geology
Recent deposits (Unconsolidated)	Good	Alluvial Flood Plain	Quaternary Deposits
Old Terrace deposits (Unconsolidated)	Moderately good	Alluvial Terrace (Low & High)	Quaternary Deposits
Rocks with Quaternary deposits (Consolidated)	Poor	Hilly Terrains, Piedmont Slopes, Hills	Quaternary Deposits Manchar, Gaj Formation

In the study area, 511 tube/dugwells are confirmed as the production wells through the course of well inventory survey. The dugwells are mainly located in the plains and terraces of Quaternary deposits and tubewells are distributed in the hilly terrains and piedmont slopes of Tertiary sedimentary rocks.

The aquifer which is recharged mainly by the river run-off is confined to the area of Recent deposits and Old terrace deposits. Therefore, the project area is confined to the above basin aquifer due to limitation of groundwater development potential.

D.2.4 Recharge and Flow System

The recharge to the aquifer and discharge from the aquifer are balanced in natural state, where the volume of the groundwater is unchanged in the aquifer. However, the annual and seasonal fluctuations of the groundwater volume are normal. The water table declines, when the discharge exceeds the recharge in the aquifer.

According to the groundwater level contour map made in the course of this study, the water table in the phreatic aquifer along the Malir river is generally higher than that in both banks as seen in Figs. D.2-7 and D.2-8. This indicates that the groundwater mound is formed along the Malir river and the groundwater is moving from the river bed area toward both banks where a large number of dug wells are located. The groundwater movement mechanism is discussed in detail in Section D.2.4, and flow vector and groundwater contour under the present condition are shown in Fig. D.2-8.

As seen in the groundwater contour map prepared (see Figs. D.2-7 and D.2-8), the depression of the groundwater table is observed in the downstream area of Thano and Laundhi Union Councils. This depression, which had already existed when the previous survey was carried out in 1977, is formed due to excessive groundwater pumped in the area. There naturally exists a major trend of groundwater movement towards the depression in the study area clearly as seen in the said figures.

A couple of main routes for groundwater flow are conceivable along two valleys as seen in Fig. D.2-8, which run nearly in parallel with the Malir river through its right and left banks. These two routes appear to branch from a single route near the confluence of the Khadeji river and the Mol river, and then, finally converge to one in the vicinity of the National Highway bridge on the downstream Malir river. A groundwater mound is formed between the said two groundwater flows.

The automatic water leveling gages were installed at two (2) wells along the Malir river. The fluctuation of water table has been recorded since the beginning of October 1989. No relatively heavy rainfall has been recorded since the installation of the gages. Therefore, the correlation between river runoff and fluctuation of groundwater table is still unclear judging from the said data.

The groundwater table of twenty-nine (29) wells were recorded from March to August by WAPDA in 1976. The heavy rainfall was recorded during the latter half of July. The fluctuation of the groundwater table was remarkably recorded around that period. Good correlation between the rainfall and fluctuation of groundwater table can be confirmed according to these data.

As discussed in Sections D.3.2 and D.3.3, the main recharge source is river runoff, and annual natural recharge is estimated to be 38.8MCM in 1977-1988 and 46.5MCM in 1929-1988, respectively. Total amount of lateral subsurface inflow and infiltration to the aquifer is estimated to be insignificant in comparison with recharge through river bed.

D.2.5 Well Inventory and Water Use

D.2.5.1 Well Inventory

Inventory survey on existing wells was carried out in 1977 as stated in the WAPDA report. Out of 514 wells, 406 production wells were used for irrigation and potable water supply. However, no detailed information and data were available in the report.

Well inventory survey was carried out in the study area, and the inventory of existing production wells is presented in ANNEX-G and is summarized in Table D.2.1. There are 516 tube and dug production wells in the study area, and about 110 wells were abandoned mainly due to drop of groundwater table, deterioration of water quality and well itself.

Out of 516 production wells, 466 wells exist in the study area which is confined to the basin aquifer as discussed in Section D.2.3, and 2,600 ha were irrigated by 466 wells in 1987/88. Summary of production wells are shown below:

Dia. of Discharge P. mm (inch)	Nos. of Production Wells				
	Project Area	Upper R. Stretch D. Chano U.C.	Middle R. Stretch Konkar U.C.	Lower R. Stretch Laundhi U.C.	Thano U.C.
50 (2.0)	92	-	76	11	5
75 (3.0)	246	44	97	89	16
100 (4.0)	121	52	28	16	25
125 (5.0-)	7	6	-	-	1
Total	466	102	201	116	47

D.2.5.2 Water Consumption

Basin aquifer is only a water supply source for irrigation, potable water to Karachi and domestic water in the project area. Water consumption for respective purposes is estimated as described in the following paragraphs:

(1) Irrigation Water Withdrawal in 1987/88

In the project area, there are 2,600 ha of net irrigation area which are irrigated by 466 production wells. Based on the agricultural electric consumption record in 1987/88 (KESC), pumped water from the production wells is estimated to be about 35.5 MCM in 1987/88 as described in detail in ANNEX-G (see Table D.2.2) and summarized below:

Item	Unit	River Stretch			Whole
		Upper	Middle	Lower	Project Area
1. Nos. of Pumped	Nos.	102	201	163	466
2. Pumped Volume	MCM	11.5	15.2	8.8	35.5
3. Unit Pumping Volume	1,000 m^3	113	76	54	76

The above unit pumping rates are used as an input parameter in groundwater simulation model as described in the following Section D.4.

(2) Potable Water Supply to Karachi

In 1884, a few wells were dug at Dumlotti beside the Malir river bed, since then the entire Dumlotti system which supplies water to Karachi was developed. This source is capable of supplying water up to 9,000 to 22,000 m^3/day (2 to 5 mgd).

According to the KDA's water supply plan, at present, water is supplied to Karachi through the following four systems and their supply capacity is summarize as follows:

System	Supply MCM/Day (mgd)	Source
1. Greater Karachi Bulk Water Supply System (Phase I to IV)	1.082 (238)	Indus River
2. Hub System	0.405 (89)	Hub River
3. Haleji/Gharo System	0.091 (20)	Indus River
4. Dumlotti System	0.009 (2)	Wells in Malir
Total	1.587 (349)	

Source: the KDA's water supply plan.

Function of the Dumlotti water supply system is replaced by other three systems. According to the previous WAPDA feasibility report, average water supply from 1974 to 1976 was 4.72 MCM/yr. Actual average water supply in 1986-88 was 0.7 MCM, and operation months were limited to 11 months in 1986 and only

5 months in 1987 and 1988, mainly due to shortage of groundwater and deterioration of the system. The following table shows operation hours and water supply amount to Karachi:

Item	Unit	WAPDA*	JICA Study			
		(1974-76)	1986	1987	1988	Average (1986-88)
1. Water Supply to Karachi	MCM	4.72	1.10	0.57	0.53	0.73
2. Operation Months	Month		10	5	5	6.6

Source: *Ref. 01

(3) Domestic Water Use

As projected in ANNEX-E, the present population in the project area is estimated at 71,000 and total household at 12,790. According to standard consumption rate applied by the Public Health Engineering Office being responsible for rural water supply, per capita consumption rate of domestic water supply is 90 l/day (20 gd). Applying this rate, domestic water consumption is estimated at about 2.3 MCM per annum.

D.2.6 Phreatic Aquifer and Characteristic

The phreatic aquifer of the Quaternary deposits is the main aquifer in the study area. The phreatic aquifers mainly comprise alluvial deposits distributing along the Malir river, which consist of layers of sand and gravels with silty sand layers. The dimensions of alluvial deposits in respective stretches are as follows:

River Stretch	Width (km)	Thickness (m)
Upper reaches	3 (2.5)	20 (10)
Middle reaches	7 (5.5)	30 (10)
Lower reaches	6 (2.5)	40 (40)

Remarks: Parenthesis indicate figures for sand and gravel layer.

A large number of dugwells in the southern area have supplementary boreholes and/or galleries at the bottom to increase the groundwater yield from the surroundings. For the pumping test, wells with less supplementary measures were selected in order to minimize effects of structural complexity of well upon the analysis of the pumping test. Taking the above into account, pumping tests were performed at six (6) representative dugwells (see Fig. D.2-1) to obtain characteristics of aquifers. Results of pumping tests are presented in Table D.2.3 and Fig. D.2-9, and their geological profiles are presented in Fig. D.2-10.

As seen in Table D.2.3, measured transmissivities of the wells vary ranging from 4,100 m^2/day (4.7 cm^2/sec) to 166,000 m^2/day (193 cm^2/sec). Low transmissivities of 4,100-5,900 m^2/day (4.7-6.8 cm^3/sec) are observed in the southern (lower) part of the phreatic aquifer, and high values of 45,000-60,000 m^2/day (53-70 cm^2/sec) in the northern (upper) part.

The phreatic aquifer of the area consists mainly of unconsolidated Quaternary formation and partly the superficial portion of the bedrock. Since the phreatic aquifer in the study area being unconfined, the storativity (S) is equivalent to the effective porosity. Considering the hydrogeological condition of the aquifer, which is reflected in the electric resistivity, it is probable that the average storativity is in the range from 0.03 to 0.20. The aquifer parameters estimated in this study are summarized below:

Item	Unit	Lower	Upper
1. Transmissivity	m^2/day	4,100 to 5,900	45,000 to 60,000
2. Storativity	-	0.03 to 0.20	0.03 to 0.20

Remarks: Transmissivity is estimated on the basis of pumping test and storativity on the basis of electric resistivity results.

These parameters are used for input data in a groundwater simulation model as described in the following Chapter D.4, and for assessment of groundwater potential in Section D.2.7.

D.2.7 Groundwater Table and Potential

There is no long-term groundwater table observation record in the study area. In the course of the previous feasibility study, WAPDA carried out regular observation at 29 representative wells from March 1976 to August 1976 as illustrated in Fig. D.2-12. Groundwater table measurements were performed in the study area in 1977. Since then, no systematic groundwater monitoring was carried out. Groundwater table contour map in 1977 is illustrated in Fig. D.2-7.

The water table of the wells in the study area was measured in October 1989 and February 1990 in the course of this study. The results are presented in Fig. D.2-8 together with groundwater contour observed in 1977. As seen in Fig. D.2-7, for last 13 years from 1977 to 1989, groundwater table was lowered due to overdraft of groundwater. Groundwater depression being below mean sea level (El. 0 m) was observed in 1977 in the southern (lower) part of the project area, and its area in 1989 was expanded. As discussed in the latter paragraph, the drawdown of the average groundwater table in the phreatic aquifer is estimated at about 8.0 m for last 13 years and accordingly the average annual drawdown is 0.43 m.

The aquifer in the study area is unconfined and consists of the Quaternary deposits. The total volume of the Quaternary deposits below the river-bed level is estimated to be 3,300 MCM based on the hydrogeological profiles as studied in Section D.2.6.

According to the previous report prepared by WAPDA in 1979, the porosity and specific yield of the aquifer are 38.25% and 25.11%, respectively. As shown in Fig. D.2-4, these values show the porosity and specific yield of the upper zone of the Quaternary deposits which is composed of sand and gravels. The lower zone of the Quaternary deposits is composed of silty sand and its values seem to be smaller than the value mentioned in the WAPDA report of 1979.

As mentioned in Section D.2.2, the geological profiles of the study area are classified into three zones, such as permeable, slightly permeable and impermeable zones in the descending order from the surface. The aquifer is composed of upper two zones of permeable and slightly permeable zones. The slightly permeable zone is divided into two parts, the lower part of the Quaternary deposits and the superficial part of the bedrock.

The effective porosity of the permeable zone is estimated to be 20%, that of the Quaternary deposits of the slightly permeable zone to be 7%, and Tertiary bedrocks of the slightly permeable zone to be 4%. Total groundwater volume in the phreatic aquifer in 1977 and 1989 is estimated on the basis of these values, and summarized below:

Stretch	Aquifer Area (km^2)	Groundwater Potential 1977 (MCM)	Groundwater Potential 1989 (MCM)	Net Withdrawal 1977-1989 (MCM)
Upper	54	57.9	24.7	33.2
Middle	55	96.3	56.8	39.5
Lower	76	62.8	39.4	23.4
Total	185	217.0	120.9	96.1
Average annual net withdrawal				8.0
Average annual drawdown of groundwater table				0.43 m

Net withdrawal from the basin phreatic aquifer is estimated at 96 MCM for last 13 years from 1977 to 1989. The remaining groundwater potential is limited only about 120 MCM in the project area. If withdrawal and recharge in the basin would be similar to the conditions for the last 13 years, groundwater would dry up within 20 years.

D.2.8 Water Quality

D.2.8.1 General

In the course of groundwater table measurement in the study area, electric conductivity (EC) and pH value were recorded at more than 200 representative wells as shown in Table D.2.1 and illustrated in Figs. D.2-13 and D.2-14. Moreover, 15 samples were collected for chemical analysis in the project area, and 7 samples among them are collected in the low land for the analysis of saline water intrusion, and the results are presented in Table D.2.5.

In 1977, WAPDA carried out chemical analysis for 7 representative wells as summarized in Table D.2.6 (Ref. 01). In addition, chemical analysis of river water were carried out by WAPDA from 1976 to 1986, and the results of analyses are illustrated in Fig. D.2-15.

Studies on water quality for surface water and groundwater are described in the following subsections.

D.2.8.2 Surface Water

Water quality of surface runoff in the Malir river is excellent and categorized into C_1S_2 according to the USDA standard of water classification. As illustrated in Fig. D.2-16, total dissolved salt (T.D.S), electric conductivity (EC) and Sodium Absorption Rate (SAR) in the monsoon season show lower values than these during the winter and spring seasons. Excellent surface runoff water is the main source of recharge to the phreatic aquifer in the project area.

D.2.8.3 Groundwater

Little change of pH distributions is recorded in 1989/1990 in comparison with data collected in 1977. pH values vary from 7.6 to 8.3 in general (see Table D.2.1 and Fig. D.2-14).

According to the distribution of EC in the study area as shown in Fig. D.2-13, EC of around 1,000 μS/cm distributes along the Malir river and its value increases as the distance from the river increases. EC values of groundwater analyzed in 1989 show generally higher values than those recorded in 1977 at wells located in the downstream area (see Table D.2.9).

As presented in Fig. D.2-16 and Table D.2.5, groundwater in the project area is classified generally into C_2S_1 and C_3S_1 according to the USDA standard except two samples taken from the groundwater depression in Thano and Laundhi Union Councils. Groundwater in the project area is moderate to medium high salinity hazard and less sodium (alkalinity) hazard for irrigation purpose. However groundwater in the depression is classified into high salinity hazard and medium alkalinity hazard (C_4S_2). The sodium adsorption ratio (SAR) is low, ranging from 1.1 to 6.18. "Relative Tolerance of Plants to Boron" (Richards, 1954) and "Water Quality Criterion for Various Users" (Davis and Dewiest, 1966) are also shown in Tables D.2.7 and D.2.8. Taking these results into consideration, boron and other chemical contents are almost permissible for irrigation water except the southern part of the depression mentioned above.

As a result of the investigations, the good quality water (EC below 1000 μS/cm) is confined to the Quaternary deposits distributing along the river. As one moves away from the river-bed, the quality of water deteriorates as mentioned before. The electric conductivity of groundwater in the aquifers generally ranges from 1,000 to 3,000 μS/cm and high values were also recorded in the downstream part of the study area. The results appear to show the recharge mechanism in the area, which the phreatic aquifer is recharged by the fresh river flow of Malir river, as mentioned in Section D.2.4.

D.2.9 Saline Water Intrusion

Water quality deterioration in the aquifer near the coastline occurs commonly due to saline water intrusion. The saline water is formed below inland aquifers. The shape and position of the boundary between saline groundwater and fresh groundwater generally depends on the volume of fresh water discharging from the aquifer. The volume of fresh water discharge results in a consequent change in the boundary, so that fluctuations in the boundary between the saline water and fresh water occur with tidal actions and seasonal and annual changes in the amount of freshwater discharge and recharge.

In the WAPDA's previous study, sea water intrusion was indicated in the groundwater depression in Thano and Laundhi Union Councils. In the course of this study, a cone depression of groundwater contour of some 20 meters below the mean sea level was also observed in Thano and Laundhi Union Councils in the downstream of the study area as shown in Fig. D.2-8. This reverses the original seaward hydraulic gradient, so that active saline water intrusion may occur.

In order to assess the saline water intrusion in the southern part of the project area, groundwater surveys including groundwater table measurement and water quality analysis were performed and their results are presented in Table D.2.10 and Fig. D.2-17. The results of chemical analysis of 15 samples (see Table D.2.5) are analyzed by using a simple pattern analysis and trilinear diagrams.

A simple pattern analysis according to Stiff (1951) can be used to trace similar formation water over large areas. Trilinear diagrams proposed by Piper (1944) are widely used for graphic presentation of chemical data. The diagram shows the relative concentrations of the major cation (Ca^{2+}, Mg^{2+}, K^{+}) and anions (CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-}).

The simple pattern diagrams of the water sampled in the southern marginal part of the study area are shown in Fig. D.2-18, and sampling numbers of 9, 13 and 14 show similar pattern to the pattern of the sea water sample (No. 15). The results of these analyses seem to indicate that the sea water intrusion probably affected the quality of the groundwater up to the southern marginal portion of the study area. The following table shows the summary:

Pattern	Sample No.	Remarks
A	2, 6, 7	River water or groundwater sampled near the river flow
B	1, 4, 5, 8, 12	Groundwater sampled at relatively long distant from the river flow
C	3, 9, 10, 11, 13, 14, 15	Sea water or groundwater of similar pattern to that of sea water

Remarks: Refer to Figs. D.2-18 and D.2-19.

As a result of the trilinear (Piper) diagram analysis, groundwater samples (No. 9, 10, 11, 12, 13,14) of the southern area are classified into group III (No. 9, 12) and group IV (No. 10, 11, 13, 14). Classification of group IV is assumed to indicate a possibility of sea water intrusion. The groundwater samples collected in the southern marginal portion of the project area (No. 9, 12) are classified into group III (see Fig. D.2-19) as summarized below:

Group	Type	Sample No.	Remarks
I	$Ca(HCO_2)_2$	2,7	Shallow aquifer and/or river water
II	$NaHCO_3$	-	Confined fresh groundwater
III	$CaSO_4$, $CaCl_2$	1, 4, 5, 6, 8, 9, 12	-
IV	Na_2SO_4, NaCl	3, 10, 11, 14,15	Sea water (including fossil water), spring and/or cave

Remarks: Refer to Table D.2.5.

Moreover, analysis of two groundwater samples for the environmental isotope of tritium was performed. The tritium content of the groundwater in the upstream area (Well No. W-26) is 9.9 ± 0.2 tritium units (TU) and that in the downstream (Well No. NT-15) is 14.8 ± 0.2 TU.

The tritium in waters of the hydrological cycle is originated from both the natural and man-made sources. The tritium is produced naturally in the atmosphere by the interaction of cosmic-ray-produced neutrons and nitrogen. The man-made tritium is produced by the large scale thermonuclear tests since 1953.

Few measurements of natural tritium in precipitation were carried out before 1953, however, the natural tritium content of precipitation before 1953 was assumed in the range of about 5-20 TU. Since the half-life period of tritium is 12.3 years, the tritium content of the groundwater which is recharged before 1953 shows below 2-4 TU. The tritium content in the atmosphere has decreased since around 1963 when the ban on the atmospheric thermonuclear test was agreed by the US and USSR.

Tritium contents at both sites indicate that the groundwaters at the two wells are recharged by precipitation within these forty years since 1953. The tritium content in precipitation is monitored at a large number of places since 1953, and the absolute values vary from place to place. However, the tritium content of the groundwater samples collected for this study might show the groundwater in the downstream area (NT-15) was recharged during the years when the atmospheric tritium content was high and the groundwater in the upstream (W-26) was recharged when the tritium content was low if these groundwaters were recharged at different times.

According to the report titled "Groundwater Potential Study" done by the Ministry of Petroleum and Natural Resources in 1985, the pore waters in the bedrocks of Manchar and Gaj formations are originally saline (the water sample of No. 11 was collected in the Gaj formation). The movement of groundwater from the bedrock to the phreatic aquifer of the study area could also have occurred due to the cone depression formed in the downstream area. Hence, it is probably that some intruded saline water originates not only from the sea water but also the bedrock, of which chemical characteristics are similar.

As the previous studies indicated that there was sea water intrusion in the downstream area, the groundwater sampled from the downstream area of the project area is probably affected by sea water intrusion, judging from the results of the simple pattern analysis (Stiff, 1955), the trilinear diagram analysis (Piper, 1944) and hydrogeological information. As a result of sea water intrusion into the groundwater depression, EC values changed from about 2,000 μS/cm in 1977 to more than 3,000 μS/cm in 1988 as seen in Table D.2.9. The groundwater table and electric conductivity in 1977 and 1989 are shown in Fig. D.2-20. However, further investigations for sea water intrusion is recommended.

D.3 WATER BALANCE

D.3.1 Recharge Study

Groundwater recharge to aquifer system is generally estimated by using a surface runoff model, namely a tank model used in estimate of surface runoff. Water balance is expressed by the following formula as discussed in ANNEX D:

$$P_n = (Ro_n - Ri_n) + (Ep_n + M_n) + Gr_n \quad \text{.................................} \quad (1)$$

where,

P	:	Precipitation
Ro	:	Runoff from the area
Ri	:	Surface inflow to the area
Ep	:	Evaporation or evapotranspiration
M	:	Change in soil moisture
Gr	:	Groundwater recharge
n	:	Given area

In case of one hydrological year or more, change in soil moisture is nil, i.e. $Mn = 0$.

$$P_n = (Ro_n - Ri_n) + Ep_n + Gr_n \quad \text{...} \quad (2)$$

Evaporation (Ep) is usually estimated by the pan evaporation or the modified Penman's Method. Groundwater recharge can be, therefore, estimated by using surface runoff and meteorological data including rainfall data.

In a tank model, respective tank series have outlets on its bottom and side. Water in a tank flows out through each outlet according to the water level above the outlet. Outflows through side outlets correspond to direct runoff or natural groundwater discharge, and outflow from outlet of the last tank corresponds to the groundwater recharge. In this study, the same tank model estimated to surface runoff, which were calibrated by actual discharge measurement at control points, were utilized for the estimate of recharge to groundwater. The results of recharge model is utilized in aquifer simulation as described in Chapter D.4.

D.3.2 Natural Recharge (Without Project Condition)

The basin was divided into six (6) sub-basins, taking into account the topographic conditions, and its control points, such as river runoff gauging stations and proposed structure sites, and referring to the hydrological study in ANNEX-B.

Natural recharge into the basin phreatic aquifer was calculated for 60 years from 1929 to 1988, and is estimated at 46.5 MCM/yr from 1929 to 1988 and 38.8 MCM/yr from 1977 to 1988, respectively as shown below:

Stretch	Average Recharge (MCM)	
	1929-1988	1977-1988
1. Damsites - Super Highway	6.6	3.2
2. Super Highway - National Highway	39.9	35.6
3. Total recharge to phreatic aquifer	46.5	38.8

The natural recharge into the phreatic aquifer and annual recharge amount for last 60 years from 1929 to 1988 are presented in Fig. D.3-1.

Relation between runoff into the basin and recharge ratio (estimated groundwater recharge/runoff) is plotted in Fig. D.3-2. It shows clear trend that recharge ratios against runoff decrease with increase of runoff. In case of less than 9.5 MCM/month, recharge ratio is nearly 100% and in case of 20 MCM/month, its ratio decreases down to about 75%.

D.3.3 Water Balance in Basin Aquifer (1977-1989)

The water balance of the phreatic aquifer is estimated on the basis of the recharge and discharge of the aquifer. Main recharge components are the natural recharge by precipitation and infiltration of surface water. Main discharge components from the aquifer is the artificial discharge like a groundwater pumped and outflow of groundwater to the sea and/or the another aquifer.

There is no continuous records of groundwater monitoring, and water withdrawal for irrigation and potable water supply to Karachi. However, groundwater table records in 1977 and 1989 are available to assess the comprehensive water balance as a whole in the basin phreatic aquifer.

As discussed in Section D.2.7, groundwater potential in the basin aquifer was estimated at 217MCM in 1977 and 121MCM in 1989, respectively, based on results of hydrogeological investigations and studies. Moreover, groundwater use in 1977 and 1989 was calculated as described in Subsection D.2.5.2, as well as the natural recharge for 13 years from 1977 to 1988 was calculated in Subsection D.3.1.(1).

Applying these available study results, a comprehensive water balance in the basin aquifer as a whole is performed as summarized below:

(Unit: MCM/yr.)

Simulation Period : 1977-1988			
A.	Recharge		
	1. Natural recharge	38.8	Refer to Subsection D.3.1(1)
	2. Deep percolation (irrigation)	7.3	15% of Item B.1
	3. Deep percolation (domestic water)	0.3	15% of Item B.3
	4. Total - A	46.4	
B.	Withdrawal		
	1. Irrigation water	48.7	(62.0 + 35.5)/2 (Refer to ANNEX-G)
	2. Potable water supply to Karachi	2.7	(4.7 + 0.7)/2 (Refer to Section D.2.5)
	3. Domestic water	1.9	(1.5 + 2.3)/2 (Refer to Section D.2.5)
	4. Groundwater discharge to sea	1.3*	to be confirmed in Chapter D.4.
	5. Total - B	54.6	
C.	Balance	-8.2	Item A.4 - Item B.5
D.	Measure net withdrawal from the aquifer	-8.0	Refer to Section D.2.7

Remarks : *Natural groundwater discharge from the aquifer is estimated as follows:

$$Q = k \times i \times A = 6{,}200\ (m/yr) \times 0.002 \times 0.106\ (km^2)$$
$$= 1.3\ MCM/yr$$

As seen in the above table, annual net withdrawal from the aquifer from 1977 to 1988 is estimated at 8.2 MCM/yr, which is nearly equal to the measured net withdrawal of 8.0 MCM/yr as calculated in Section D.2.7.

Therefore, all the conditions, and the models described in the previous sections keep a good fit to the conditions between 1977 and 1988. These recharge and discharge can be utilized for the groundwater simulation model studies in the following Chapter 4.

D.3.4 Artificial Recharge by Dam(s)

D.3.4.1 Alternative Cases

Most of the recharge to the phreatic aquifers comes from stream-bed infiltration during the rainy season as mentioned in Section D.3.3. In order to increase the recharge amount, the water exceeding the recharging capacity in the study area, which drains into the sea under the present condition, is subject to be trapped by dams in the upper stream of the recharge area. Small scale existing weirs along the river flows are also useful to trap the river runoff in order to increase the amount of infiltration. In this Section, artificial recharge by dam(s) is estimated by applying the procedure described in Subsection D.3.4.2.

The maximum net reservoir capacities of the proposed dams are fixed at 43.8 MCM for the Mol dam and 35.5 MCM for the Khadeji dam, respectively, according to the topographic limitation at the damsites, as described in ANNEX-H. Recharge to groundwater defers in general depending on runoff pattern, reservoir capacity, combination of dams, and operation of dam.

Recharges of following seven (7) alternative cases are calculated by adopting the proposed dam operation described in ANNEX-H:

Case - 1	Mol	(43.8 MCM) + Khadeji (35.5 MCM)
Case - 2	Mol	(35.0 MCM) + Khadeji (35.5 MCM)
Case - 3	Mol	(43.8 MCM)
Case - 4	Mol	(35.0 MCM)
Case - 5	Mol	(30.0 MCM)
Case - 6	Khadeji	(35.5 MCM)
Case - 7	Khadeji	(30.0 MCM)

D.3.4.2 Dam Operation

The main recharge source in the project area is the Malir river. Runoff at the proposed damsite(s) and water demand in the project area are generally decisive factors in determining the reservoir capacity. However, in the project area, there is huge water demands, so limited water resources, and huge groundwater reservoir in the basin.

In general, water from a reservoir is released depending on water demand in the downstream area. However, since there is a huge groundwater reservoir with a capacity of *more than 300 MCM in the phreatic aquifer, it is not necessary to discharge water from the* reservoir according to the water demand.

Moreover, equal recharge to the phreatic aquifer in the upper and lower stretches should be kept as much as possible. If discharge from the dam is a little, most water will be recharged to groundwater only in the upper river stretch. On the other hand, in case that the discharge is more than recharge capacity, excess water will be wasted into the sea without being utilized. Therefore, allowable discharge from the dam will be only an important factor for the dam operation as described in ANNEX-H.

Allowable discharge from the dam(s) was determined based on three (3) approaches, i.e. (i) hydrological approach, (ii) field infiltration rate, and (iii) lateral groundwater movement, as described in the following:

(1) Based on the Natural Recharge Analysis

Relationship between runoff into the basin and natural recharge to the aquifer is illustrated in Fig. D.3-2 as studied in Subsection D.3.1.2. In case of runoff less than 10 MCM/month, almost all runoffs into the basin are expected to be recharged into the aquifer, i.e. no water will be wasted into the sea. While, recharge ratio is will decrease to 75% in case of about 20 MCM/month. If there is a flood regulation reservoir in the upper stretch, this recharge ratio is expected to be higher due to flood peak cut. Therefore, allowable maximum discharge from the dam is presumed to be within the range between 10 MCM/month and 20 MCM/month (4 m^3/sec to 8 m^3/sec).

(2) Based on Field Infiltration Rate

Infiltration rates in the Malir river bed were measured at five (5) representative sites, and its average basic intake rate is about 60 mm/hr as shown in Fig. D.2-11. Length of the river bed for discharge from the proposed damsite(s) to the National Highway bridge is about 35 km, and its average gradient is 1/350. Applying an average flow width of about 10 m, the above basic intake rate, and flow width, possible deep percolation in the river bed is estimated at 9 m^3/sec (24 MCM/month).

(3) Based on Lateral Groundwater Movement

Lateral groundwater discharge can be calculated by applying lateral hydraulic gradient, depth of phreatic aquifer, and permeability at the respective cross sections, as described in the previous sections. Unit possible recharge (MCM/km/month) is calculated as presented in Table D.3.1, and flow front for respective discharge from the dam is estimated by subtracting recharge from inflow at respective river sections.

As seen in Table D.3.1, all river water will be recharged into the phreatic aquifer near the lower existing flood detention weir located at about 4 km upstream from the National Highway bridge. Allowable discharge from the dam is estimated at 8 m^3/sec (21 MCM/month).

Allowable discharge from the dam was estimated at 8 m^3/sec (21 MCM/month) on the basis of the above three (3) approaches as summarized below:

Item	Allowable Recharge Rate (m^3/sec)
1. Runoff Analysis	4 - 9
2. Field Infiltration Test	9
3. Lateral Groundwater Movement	7 - 9
Adopted	8 m^3/sec (21 MCM per month)

Allowable discharge of 8 m^3/sec from the dam is applied for the dam operation in Subsection D.3.4.3. However, since there are two existing weirs on the Malir river, located at about 4 km and 6.4 km upstream from the National Highway bridge, this allowable discharge should be calibrated after completion of dam(s) construction during the operation and maintenance period.

D.3.4.3 Artificial Recharge by Dam(s)

Applying the procedure and results described in Sections D.3.1 and D.3.2, a modified simulation model with storage dam(s) was prepared for calculation of recharge to corresponds to the balance between the allowable discharge of 8 m^3/sec as fixed in Subsection D.3.4.2, and the runoff from the remaining catchment area from the proposed damsites to the National Highway bridge. In case that runoff from the remaining catchment area exceeds the allowable discharge, no water is released from the dam(s). Only balance of water is released, when runoff is less than the allowable discharge.

Artificial recharge is calculated for respective alternative cases as mentioned in Subsection D.3.4.1. The results are summarized in Tables D.3.2 and D.3.3 and illustrated in Fig. D.3-3. The river runoff patterns and masscurves at the Mol and Khadeji damsites are also presented in Fig. D.3-4. The total volume combining the natural and artificial recharge is summarized as follows:

(Unit: MCM)

	JICA Study							WAPDA
Combination of Dams	Khadeji+Mol	Khadeji+Mol	Mol Only			Khadeji Only		Khadeji + Mol
	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7	
Storage Capacity	35.5 43.8	35.5 35.0	43.8	35.0	30.0	35.5	30.0	54.6 50.9
Natural Recharge from and Dam Spill-out	26.1	26.9	39.6	41.1	41.6	43.1	43.8	26.8
Recharge by Dams	44.5	42.4	25.8	23.6	22.3	19.6	18.3	46.6
Total Recharge	70.6	69.3	65.4	64.7	63.9	62.7	62.1	73.4

As seen in the above table, construction of both Mol and Khadeji dams results in substantial decrease of natural recharge by runoff from the remaining basin, compared to a single dam. The catchment area of Thaddo river is 1,520 km^2 at the confluence of the Malir river with the Thaddo and Sukkan rivers, and 1,205 km^2 at the Super Highway bridge. When two dams are constructed, the runoff from about 80% of the river basin will be regulated, and the recharge ratio sharply drops when the runoff exceeds more than 20 MCM/month. Therefore, the natural recharge by the runoff from the remaining basin and the spillout from the dams are substantially decreased.

In case of a single dam construction, the runoff from about 60% of the total basin and spillout from a single dam can be expected, and which results in an increase of natural recharge to the phreatic aquifer. Fig. D.3-5 shows masscurve of natural and augmented recharge to the aquifer with/without the Mol dam with an active reservoir capacity of 35 MCM,and Fig. D.3-6 presents annual angumented recharge by the Mol dam with a live storage capacity of 35 MCM (case. 4).

D.4 GROUNDWATER MODEL SIMULATION

D.4.1 General

There is no continuous groundwater monitoring records in the project area except two groundwater table measurements in 1977 and 1989 as discussed in Section D.2.7. In addition, there is no continuous record regarding groundwater withdrawals such as irrigated area, electric energy consumption, etc. The non-steady state model simulation is considered to be impractical due to insufficient information and/or data.

However, the average annual natural recharge during the period from 1984 to 1988 is estimated at about 36.4 MCM/yr as shown in Table D.3.2, and the annual irrigation water demand in 1987/88 is estimated at 35.5MCM/yr. These main components of natural recharge and irrigation demand show similar volume. The groundwater table has dropped sharply for last 13 years (1977-1989), however, the groundwater table for last 5 years (1984-1988) is presumed to be constant, i.e. average recharge and discharge is almost balanced.

Taking the above limited records into consideration, the groundwater simulation is performed to assess its movement mechanism in the basin under the steady state condition in spite of the non-steady state as described in the following Sections.

D.4.2 Model Construction

Aquifer modeling is carried out by mathematical water balance modeling method using a digital computer. In this study, a quasi-three dimensional aquifer simulation model is used for groundwater simulation. The model simulates two-dimensional horizontal groundwater flow in the phreatic and confined aquifer, considering aquifer parameters, such as the coefficient of transmissivity and coefficient of storage, as function of piezometric head in vertical director, which result in an approximate simulation of three-dimensional groundwater flow. In this study, the model for only the phreatic aquifer is utilized in consideration of the hydrogeological conditions as described in Section D.2.6.

The model is constructed mainly considering topography, aquifer distribution, hydraulic characteristics and results of groundwater recharge. The finite-element grid mesh of the study area, which is composed of triangular and/or quadrilateral elements, is shown in Fig. D.4-1. The number of nodes and grids are 295 and 267 respectively and covers the area of about 390 km^2. The grid was designed to be finer where more data are available and/or where hydraulic gradients are relatively steep. The distance between adjacent nodes is basically about 1.0 to 2.0 km.

On the basis of the geological and hydrogeological data obtained during the investigations, the aquifer of parameters is determined as described in Section D.2.6. The aquifer is not composed of the homogeneous layer but alternations, such as the layer of sand and gravel, and the layer of silty to medium grained sand with intercalation of clay and cemented gravel layers. The zonal permeabilities of the aquifer are estimated in the order between 5 x 10^{-5} cm/sec for the baserock and 5 x 10^{-3} cm/sec for sand and gravel layer on the basis of the pumping tests carried out during the study period.

D.4.3 *Model Calibration*

In the model formulation, the steady state with some amounts of groundwater withdrawal and annual recovery by natural recharge is adopted in this study, by assuming the two dimensional steady state of partial equation with given boundary conditions and permeabilities.

The model calibration is aimed to demonstrate the constructed simulation model that could account for the features of groundwater flow in the aquifer. Several alternative identifications are postulated and the appropriate parameters are chosen according to the monitored data.

The model calibration was made by comparing the computed piezometric heads with observed heads by using the groundwater level map of 1989, and the result is shown in Fig. D.4-2. The model matches observed conditions relatively well.

D.4.4 Model Prediction

Groundwater recharge to the aquifer is augmented by construction of dam(s) on the Mol and/or Khadeji rivers as discussed in Section D.3.4. Among the several alternatives, only the Mol dam with a net storage capacity of 35 MCM is the most economic and feasible alternative as formulated in ANNEX-H.

Applying the average annual artificial recharge amount of 64.7 MCM/yr, and the same model with the aquifer parameters, further simulation of groundwater was performed to assess the future groundwater condition. The results of the simulation is illustrated in Fig. D.4-3. As seen in Figs.D 4-2 and D.4-3, there is a general tendency to rise the groundwater table along the river stretch in the upper project area and to lower the cone depression of groundwater table in the downstream area. Hence, it is recommended that continuous groundwater monitoring is essential to evaluate the analysis, and groundwater management is also necessary to keep a sustainable use of groundwater.

D.5 GROUNDWATER MANAGEMENT

D.5.1 General

The safe yield of the groundwater basin is the amount of water which can be withdrawn annually without causing an undesirable influence in the basin (Todd, 1959). The undesirable influence usually results in increase of pumping cost due to drop of groundwater level and sea water intrusion, as already experienced in the project area and described in the previous sections. In order to solve such constraints in the basin, the groundwater augmentation project is formulated. However, even after completion of the project, sustainable proper groundwater use is essential.

To achieve the sustainable groundwater development, it is important to establish a groundwater monitoring system, some legal restriction for new groundwater development, and groundwater users' association.

D.5.2 Groundwater Monitoring

The continuous groundwater monitoring including observation of groundwater level, pumping amount, and water quality is essential for the groundwater monitoring.

In the course of this study, two (2) automatic groundwater level recorders were installed. However, it is recommended to add at least three (3) automatic recorders, and ten (10) monthly observation wells, distributed in the project area. Monthly EC and pH observations at the above 15 wells are also recommended for long-term groundwater monitoring.

Extraction amounts by pumping should be monitored in terms of energy consumption or other appropriate means such as installation of water gauging meters, or information of cropped area, etc., through the proposed groundwater users' association as described in Subsection D.5.3.

D.5.3 Groundwater Users' Association

The groundwater is not supplied through artificial pipes nor canals, and it moves in pores of soil particles. Therefore, farmers intend to pump up the groundwater without considering groundwater recharge and flow. As a result, the depth wells is increased year by year due to decline of groundwater level, which results in increase of operation and maintenance costs.

Runoffs exceeding the average runoff usually occur every 3 to 4 years. The dam(s) can augment groundwater recharge, however no function of carry-over water is given to the dam(s), mainly due to its operation rule as discussed in Subsection D.3.4.2. River runoffs directly affect groundwater recharge, and carry-over function is given to the huge groundwater reservoir. Groundwater table will be raised in 3-4 years and this storage should be utilized for 3 to 4 years. If no groundwater management were performed, the similar constraints such as drawdown of groundwater level and acceleration of sea water intrusion will be continuously experienced in the project.

The main objectives of the groundwater users' association in terms of the groundwater management are to keep a sustainable groundwater use, and to control proper groundwater withdrawal by farmers themselves.

According to the field interviews with ten (10) well owners, almost all of owners (90%) recognize the necessity of groundwater users' association to sustain the groundwater use. Since almost all the farmers are facing shortage of water, establishment of the association before the commencement of the project is recommendable.

Demonstration of voluntary groundwater management by the association under the strong support from the Malir project office is recommended in ANNEX-I.

D.5.4 Legal and Institutional Restriction

Less sediment loads will be transported to the river bed in the project area after construction of the dam(s). Therefore, it is so important to stop taking and digging river deposits in the Malir river. However, sediment loads to be deposited in the reservoir(s) can be taken instead of the Malir river bed. Legal restriction excavation of river deposits should be imposed at the earliest possible time.

Moreover, as shown in Fig. D.5.1, existing wells are distributed densely in the project area. In Thano and Laundhi Union Councils, well density is more than 10 wells per km^2, and well interference is observed. In addition, total available water resources are limited to about 60 MCM/yr, and there are 466 existing in the project area. Therefore, necessary legal enforcement on new well development except the replacement of existing wells shall be taken. Special attentions shall be taken on replacement of tubewells to minimize well interference in the high well density area.

LIST OF REFERENCES

01. WATER RESOURCES DEVELOPMENT PROJECT IN THE MALIR BASIN, WATER AND POWER DEVELOPMENT AUTHORITY, 1979

02. GROUNDWATER RESOURCES POTENTIAL OF THANO BULAKAN, KALUKHUHAR, UPPER MALIR AND GADAP BASINS, GEOLOGICAL SURVEY OF PAKISTAN MINISTRY OF PETROLEUM AND NATURAL RESOURCES, 1985

03. KDA MASTER PLAN STUDY (KARACHI BULK WATER SUPPLY), KARACHI DEVELOPMENT AUTHORITY

04. GROUNDWATER MANUAL, U.S. DEPARTMENT OF THE INTERIOR WATER AND POWER RESOURCES SERVICE

05. GROUNDWATER IN CIVIL ENGINEERING (DEVELOPMENTS IN GEOTECHNICAL ENGINEERING), LASZLO RETHATI, D. SC. (TECHN.), INSTITUTE FOR GEODESY AND GEOTECHNICS, BUDAPEST, ELSEVIER SCIENTIFIC PUBLISHING COMPANY

06. APPLIED HYDROGEOLOGY, C.W. FETTER, SR. UNIVERSITY OF WISCONSIN - OSHKOSH CHARLES E. MERVILL PUBLISHING COMPANY, A BELL & HOWELL COMPANY

07. GROUNDWATER, R. ALLAN FREEZE/JOHN A. CHERRY, PRENTICE - HALL, INC.

08. GROUNDWATER AND WELLS, FLETCHER G. DRISCOLL, PH. D. JOHNSON DIVISION, ST. PAUL, MINNESOTA 55112

TABLES

Table D.2.1 WELL INVENTORY (1/5)

No.	Well No.	G.L.*1 (m)	W.L.*2 (m)		W.EL.*3 (m)		E.C.*4 (µS/cm)		pH		Temp (deg. °C)		Dep. (m)	U/C	Dch
			1989	1990	1989	1990	1989	1990	1989	1990	1989	1990			
1	AG01	111.3	5.4	3.6	105.9	107.7	1,647	1,767	-	-	29	18	16.8	DarC	Amil
2	AG29	112.8	-	8.9	-	104.0	1,363	1,320	-	-	27	20	19.8	DarC	Amil
3	ND05	94.8	26.2	26.7	68.6	68.1	4,230	3,264	-	-	30	24	30.5	DarC	Amil
4	ND06	102.7	7.2	11.3	95.5	91.5	1,194	1,400	-	-	28	25	10.7	DarC	Amil
5	ND07	106.7	12.7	10.1	94.0	96.5	1,594	1,836	-	-	27	21	25.0	DarC	Amil
6	ND08	106.1	12.8	11.1	93.3	95.0	1,457	1,456	-	-	28	23	24.4	DarC	Amil
7	ND09	96.3	17.2	16.5	79.1	79.8	1,472	-	-	-	29	-	21.3	DarC	Amil
8	ND10	98.5	-	17.3	-	81.1	1,536	1,632	-	-	27	24	24.4	DarC	Amil
9	W01	90.8	16.2	18.9	74.6	72.0	1,288	2,793	-	-	29	26	24.4	DarC	Amil
10	W02	89.3	-	12.0	-	77.3	884	-	-	-	28	-	-	DarC	Amil
11	W03	89.9	14.1	16.2	75.8	73.8	1,842	2,346	-	-	26	24	24.4	DarC	Amil
12	W07	93.6	-	25.8	-	67.8	-	1,372	-	-	-	26	-	DarC	Amil
13	W08	95.1	24.4	20.3	70.7	74.8	1,895	2,448	-	-	29	24	30.5	DarC	Amil
14	W09	96.9	-	20.2	-	76.7	-	2,940	-	-	-	26	-	DarC	Amil
15	W10	98.8	19.8	20.3	79.0	78.5	3,940	2,968	-	-	25	22	25.9	DarC	Amil
16	W11	103.6	25.4	22.4	78.2	81.3	945	980	-	-	30	26	25.9	DarC	Amil
17	W12	101.2	-	-	-	-	-	-	-	-	-	-	-	DarC	Amil
18	W13	111.9	16.4	16.5	95.5	95.4	7,786	5,035	-	-	27	22	19.8	DarC	Amil
19	AG58	118.3	7.4	7.4	110.9	110.9	720	-	-	-	27	-	10.7	DarC	Bayl
20	ND04	108.2	4.3	7.7	103.9	100.5	1,674	1,870	-	-	29	20	8.5	DarC	Bayl
21	AG02	122.5	27.4	25.7	95.1	96.8	8,004	-	-	-	29	28	27.4	DarC	Kath
22	AG04	123.1	23.8	25.7	99.3	97.4	736	-	7.8	-	29	28	28.0	DarC	Kath
23	AG06	124.1	25.0	22.9	99.1	101.1	902	-	-	-	29	-	25.9	DarC	Kath
24	AG08	118.9	-	20.2	-	98.7	-	-	-	-	-	-	-	DarC	Kath
25	AG10	108.8	29.2	31.9	79.6	76.9	2,547	-	7.2	-	28	-	38.1	DarC	Kath
26	AG11	108.8	30.9	-	77.9	-	2,244	-	7.6	-	26	28	33.5	DarC	Kath
27	AG14	112.2	30.4	30.8	81.8	81.4	2,124	-	7.8	-	30	25	32.0	DarC	Kath
28	AG25	118.3	31.1	26.9	87.2	91.4	2,337	-	7.4	-	29	-	33.5	DarC	Kath
29	AG28	119.2	29.5	26.8	89.7	92.4	-	-	-	-	-	-	25.9	DarC	Kath
30	AG30	108.5	-	30.0	-	78.5	-	-	-	-	-	-	-	DarC	Kath
31	AG31	107.6	-	31.1	-	76.5	-	-	-	-	-	28	-	DarC	Kath
32	AG36	100.9	26.7	26.5	74.2	74.4	2,817	-	-	-	30	28	30.5	DarC	Kath
33	AG39	103.6	-	25.5	-	78.1	-	-	-	-	-	28	-	DarC	Kath
34	AG40	103.7	26.2	-	77.5	-	2,871	-	-	-	30	-	35.1	DarC	Kath
35	AG41	104.9	-	30.5	-	74.4	-	-	-	-	-	28	-	DarC	Kath
36	AG50	106.7	24.1	23.9	82.6	82.8	1,705	-	-	-	26	-	32.0	DarC	Kath
37	AG51	119.5	18.3	22.1	101.2	97.4	429	-	-	-	17	-	24.4	DarC	Kath
38	AG52	125.0	16.1	15.9	108.9	109.0	1,380	-	-	-	29	-	24.4	DarC	Kath
39	AG62	116.7	30.0	22.6	86.7	94.1	2,430	-	7.6	-	25	-	30.5	DarC	Kath
40	ND01	125.3	25.5	22.2	99.8	103.0	2,079	-	-	-	30	-	26.8	DarC	Kath
41	ND02	118.9	19.6	20.4	99.3	98.5	-	-	-	-	-	-	23.8	DarC	Kath
42	ND03	108.5	30.6	30.8	77.9	77.7	920	-	-	-	29	28	32.0	DarC	Kath
43	L01	93.0	16.8	17.4	76.2	75.5	774	-	8.1	-	26	-	-	DarC	Chur
44	L04	98.5	19.8	18.6	78.7	79.8	1,225	-	8.1	-	26	-	-	DarC	Chur
45	L17	96.6	13.6	15.8	83.0	80.8	774	-	8.1	-	26	-	-	DarC	Chur
46	LA3	80.2	-	5.0	-	75.2	-	-	-	-	-	-	-	Konk	Bazr
47	ND11	86.9	19.8	19.7	67.1	67.1	-	-	-	-	-	-	27.4	Konk	Bazr
48	V02	86.0	-	21.9	-	64.0	-	980	-	-	-	26	-	Konk	Bazr
49	V06	85.1	19.2	18.2	65.9	66.9	470	-	8.5	-	26	25	-	Konk	Bazr
50	V08	82.4	15.3	-	67.1	-	-	-	-	-	-	-	-	Konk	Bazr
51	V13	79.0	15.2	16.4	63.8	62.6	637	490	8.1	-	26	26	-	Konk	Bazr
52	V16	78.4	16.8	18.5	61.6	59.9	784	-	7.4	-	26	24	-	Konk	Bazr
53	V17	78.7	16.9	17.8	61.8	60.9	608	500	7.7	-	26	25	-	Konk	Bazr

Remarks:
*1 G.L.: Ground level
*2 W.L.: Water level from ground surface
*3 W.EL.: Water level above mean sea level
*4 E.C.: EC value at 25°C

Table D.2.1 WELL INVENTORY (2/5)

No.	Well No.	G.L.*1 (m)	W.L.*2 (m) 1989	W.L.*2 (m) 1990	W.EL.*3 (m) 1989	W.EL.*3 (m) 1990	E.C.*4 (μS/cm) 1989	E.C.*4 (μS/cm) 1990	pH 1989	pH 1990	Temp (deg. °C) 1989	Temp (deg. °C) 1990	Dep. (m)	U/C	Deh
54	W15	77.2	17.4	-	59.8	-	4,116	-	7.2	-	26		-	Konk	Bazr
55	W15/1	77.4	17.5	20.1	59.9	57.3	1,519	1,450	7.4	-	26	25	-	Konk	Bazr
56	W17	75.6	-	19.8	-	55.9	3,136	3,060	7.1	-	26	24	-	Konk	Bazr
57	W18	75.6	19.2	20.0	56.4	55.6	3,744	3,528	7.3	-	27	26	-	Konk	Bazr
58	W19	75.6	17.7	-	57.9	-	2,592	3,600	7.5	-	27	25	-	Konk	Bazr
59	W19/1	75.9	18.5	19.8	57.4	56.1	4,116	2,600	7.6	-	26	25	-	Konk	Bazr
60	W25	75.6	10.1	-	65.5	-	-	-	-	-	-	-	-	Konk	Bazr
61	W28	73.5	15.5	17.5	58.0	56.0	8,330	-	-	-	26	25	20.1	Konk	Bazr
62	W29	71.4	12.9	-	58.5	-	-	-	-	-	-	-	-	Konk	Bazr
63	W30	71.4	11.9	-	59.5	-	-	-	-	-	-	-	-	Konk	Bazr
64	W32	69.0	17.1	10.6	51.9	58.5	2,646	2,268	-	-	26	21	19.5	Konk	Bazr
65	W33	68.3	16.1	10.7	52.2	57.6	3,332	3,520	-	-	26	20	19.2	Konk	Bazr
66	W35	64.6	11.4	9.5	53.2	55.1	1,372	660	-	-	26	20	22.5	Konk	Bazr
67	W37	64.6	7.6	9.4	57.0	55.3	1,568	1,296	-	-	26	21	18.0	Konk	Bazr
68	W40	62.8	12.5	-	50.3	-	3,332	-	-	-	26	-	15.5	Konk	Bazr
69	W45	59.1	15.8	22.3	43.3	36.8	1,274	-	-	-	26	25	25.6	Konk	Bazr
70	W47	63.7	19.3	23.6	44.4	40.1	2,058	-	-	-	26	25	25.6	Konk	Bazr
71	W48	61.6	29.4	30.3	32.2	31.3	4,032	-	-	-	27	23	31.1	Konk	Bazr
72	W49	60.7	23.1	27.3	37.6	33.4	4,128	-	-	-	27	25	32.7	Konk	Bazr
73	W49/1	60.4	17.4	-	43.0	-	3,840	-	-	-	27	-	25.3	Konk	Bazr
74	NK11	66.5	-	8.6	-	57.8	-	-	-	-	-	-	-	Konk	DarC
75	NK12	64.0	-	5.8	-	58.2	-	-	-	-	-	-	-	Konk	DarC
76	NK13	55.8	-	15.0	-	40.8	-	-	-	-	-	-	-	Konk	DarC
77	NK14	48.8	-	17.9	-	30.9	-	-	-	-	-	-	-	Konk	DarC
78	T02	68.9	12.3	-	56.6	-	6,528	-	8.3	-	27	-	-	Konk	DarC
79	T06	67.1	12.7	16.0	54.4	51.1	437	-	8	-	29	-	-	Konk	DarC
80	T07	66.8	12.7	15.2	54.1	51.6	313	-	7.5	-	29	-	-	Konk	DarC
81	T09	66.4	12.3	15.5	54.1	50.9	377	-	8	-	29	-	-	Konk	DarC
82	T15	64.9	-	-	-	-	500	-	8.5	-	26	-	-	Konk	DarC
83	T15/1	64.9	-	-	-	-	872	-	8.5	-	26	-	24.4	Konk	DarC
84	T19	64.9	15.1	-	49.8	-	634	-	7.9	-	27	-	-	Konk	DarC
85	T20	62.8	-	-	-	-	370	-	8.4	-	27	-	22.9	Konk	DarC
86	T59	58.8	24.3	19.8	34.5	39.1	1,008	-	7.7	-	27	-	-	Konk	DarC
87	T63	57.9	23.8	18.5	34.1	39.4	-	-	-	-	-	-	-	Konk	DarC
88	T68	53.3	21.5	20.0	31.8	33.3	1,421	-	8.2	-	26	-	22.9	Konk	DarC
89	W67	59.1	7.0	8.6	52.1	50.5	936	884	-	-	27	23	11.0	Konk	DarC
90	W68	59.1	8.1	7.9	51.0	51.3	882	648	-	-	26	21	24.1	Konk	DarC
91	W69	55.0	-	-	-	-	440	-	8	-	31	-	-	Konk	DarC
92	W70	56.4	11.9	10.9	44.5	45.5	396	-	7.7	-	29	-	-	Konk	DarC
93	W111	55.2	-	9.4	-	45.8	-	-	-	-	-	-	-	Kank	DarC
94	W112	53.6	22.8	21.5	30.8	32.2	2,064	-	-	7.2	27	-	-	Konk	DarC
95	W113	50.6	22.9	-	27.7	-	1,978	-	7.5	-	29	-	-	Konk	DarC
96	LA11	57.6	2.7	-	54.9	-	2,688	-	-	-	27	-	6.4	Konk	Khar
97	LA13	57.9	-	2.1	-	55.8	6,912	4,896	-	-	27	24	137.2	Konk	Khar
98	T52	53.6	19.5	23.7	34.1	29.9	700	-	-	-	25	-	29.9	Konk	Khar
99	T52/1	53.3	-	19.5	-	33.8	-	-	-	-	-	24	-	Konk	Khar
100	T53	54.2	13.4	17.0	40.8	37.2	4,512	-	-	-	27	20	23.2	Konk	Khar
101	W51	58.5	19.9	21.6	38.6	36.9	2,112	-	-	-	27	24	24.7	Konk	Khar
102	W52	57.3	8.2	-	49.1	-	-	-	-	-	-	-	13.4	Konk	Khar
103	W53	56.4	13.1	13.0	43.3	43.4	872	125	-	-	26	17	23.2	Konk	Khar
104	W54	54.5	21.5	18.8	33.0	35.7	902	-	-	-	26	20	25.3	Konk	Khar
105	LA04	88.4	-	21.6	-	66.8	-	-	-	-	-	26	-	Konk	Konk
106	LA07	60.4	7.1	6.3	53.3	54.1	5,978	-	-	-	26	-	9.4	Konk	Konk

Remarks: *1 G.L.: Ground level; *2 W.L.: Water level from ground surface; *3 W.EL.: Water level above mean sea level; *4 E.C.: EC value at 25°C

Table D.2.1 WELL INVENTORY (3/5)

No.	Well No.	G.L.*1 (m)	W.L.*2 (m) 1989	W.L.*2 (m) 1990	W.EL.*3 (m) 1989	W.EL.*3 (m) 1990	E.C.*4 (μS/cm) 1989	E.C.*4 (μS/cm) 1990	pH 1989	pH 1990	Temp (deg. °C) 1989	Temp (deg. °C) 1990	Dep. (m)	U/C	Deh
107	LA08	64.0	-	4.6	-	59.4	-	-	-	-	-	-	-	Konk	Konk
108	LA15	65.2	10.4	-	54.8	-	3,800	2,940	-	-	25	26	11.6	Konk	Konk
109	LA17	81.7	-	12.9	-	68.8	3,200	-	-	-	25	22	121.9	Konk	Konk
110	LA18	83.2	-	12.0	-	71.2	-	-	-	-	-	-	-	Konk	Konk
111	LA18A	83.2	-	13.5	-	69.7	-	-	-	-	-	-	-	Konk	Konk
112	LA19	82.0	12.6	10.0	69.4	72.0	2,852	-	-	-	29	-	18.3	Konk	Konk
113	LA21	85.7	-	-	-	-	-	-	-	-	-	-	137.2	Konk	Konk
114	LA22	88.4	-	-	-	-	-	-	-	-	-	-	106.7	Konk	Konk
115	LA23	79.3	7.9	-	71.4	-	9,504	-	-	-	27	-	15.5	Konk	Konk
116	LA24	82.9	-	-	-	-	8,928	-	-	-	27	-	137.2	Konk	Konk
117	LA25	82.9	-	-	-	-	2,688	-	-	-	27	-	140.2	Konk	Konk
118	LA26	84.1	-	-	-	-	2,820	-	-	-	28	-	140.2	Konk	Konk
119	LA27	84.1	-	-	-	-	-	-	-	-	-	-	106.7	Konk	Konk
120	LA28	84.1	-	-	-	-	-	-	-	-	-	-	121.9	Konk	Konk
121	LA29	83.8	-	40.5	-	43.3	-	1,728	-	-	-	27	121.4	Konk	Konk
122	LA30	35.5	-	-	-	-	-	-	-	-	-	-	121.9	Konk	Konk
123	LA32	82.6	-	-	-	-	-	-	-	-	-	-	121.9	Konk	Konk
124	LA33	82.6	-	-	-	-	-	-	-	-	-	-	121.9	Konk	Konk
125	LA34	88.1	-	17.7	-	70.4	-	-	-	-	-	-	15.8	Konk	Konk
126	LA35	85.6	-	13.1	-	72.5	-	-	-	-	-	-	13.4	Konk	Konk
127	LA36	85.0	-	-	-	-	-	-	-	-	-	-	131.1	Konk	Konk
128	LA37/1	87.8	-	8.0	-	79.8	-	-	-	-	-	-	15.8	Konk	Konk
129	LA37/2	87.5	-	10.9	-	76.6	-	-	-	-	-	-	16.5	Konk	Konk
130	NK07	65.5	-	14.7	-	50.8	-	-	-	-	-	-	-	Konk	Konk
131	NK08	73.2	-	10.5	-	62.7	-	-	-	-	-	-	-	Konk	Konk
132	NK09	74.7	7.0	7.5	67.7	67.2	-	-	-	-	-	-	-	Konk	Konk
133	NK10	80.8	-	8.7	-	72.1	-	-	-	-	-	-	-	Konk	Konk
134	2	42.4	32.7	32.3	9.7	10.0	7,208	-	-	-	22	-	34.7	Konk	Malh
135	9	41.1	-	37.6	-	3.5	2,184	-	-	-	23	-	-	Konk	Malh
136	10	41.1	-	37.9	-	3.2	2,940	-	-	8.1	26	25	39.0	Konk	Malh
137	12	41.8	-	36.7	-	5.1	2,688	-	-	7.7	27	24	37.5	Konk	Malh
138	19	41.8	-	42.0	-	-0.3	6,336	-	-	7.9	27	26	44.8	Konk	Malh
139	26	41.8	20.3	21.0	21.5	20.8	392	-	-	8	26	22	21.9	Konk	Malh
140	30	38.4	27.5	35.4	10.9	3.0	499	-	-	-	27	25	36.6	Konk	Malh
141	31	37.7	30.5	33.2	7.2	4.5	470	-	-	-	26	23	37.5	Konk	Malh
142	32	38.4	27.3	25.3	11.1	13.1	-	-	-	-	-	-	29.3	Konk	Malh
143	33	38.1	-	39.0	-	-0.9	768	-	-	-	27	25	40.8	Konk	Malh
144	41	40.2	-	45.3	-	-5.1	1,034	-	-	-	28	26	-	Konk	Malh
145	42	40.5	44.0	44.3	-3.5	-3.8	-	-	-	-	-	25	44.8	Konk	Malh
146	43	40.2	42.3	47.9	-2.1	-7.6	2,016	-	-	-	27	25	45.4	Konk	Malh
147	47	36.6	-	38.1	-	-1.5	-	2,537	-	-	-	16	-	Konk	Malh
148	49	36.9	35.4	-	1.5	-	-	-	-	-	-	24	36.6	Konk	Malh
149	56	35.1	35.0	-	0.1	-	768	-	-	-	27	-	54.9	Konk	Malh
150	63	39.3	28.6	28.4	10.7	10.9	-	3,600	-	-	-	25	32.0	Konk	Malh
151	74	36.7	38.7	38.5	-2.0	-1.8	2,068	2,596	-	-	28	16	39.6	Konk	Malh
152	75	38.7	38.3	39.0	0.4	-0.3	1,728	-	-	-	27	20	39.8	Konk	Malh
153	79	40.0	15.6	15.3	24.4	24.7	4,644	-	7.6	-	21	27	20.1	Konk	Malh
154	81	41.1	14.0	13.9	27.1	27.2	-	-	-	-	23	-	15.2	Konk	Malh
155	85	41.5	-	17.8	-	23.7	3,300	-	-	-	20	-	26.5	Konk	Malh
156	85A	42.4	19.7	18.2	22.7	24.2	2,016	-	-	-	27	18	21.6	Konk	Malh
157	NK01	37.8	25.9	-	11.9	-	1,728	-	-	-	27	-	27.1	Konk	Malh
158	NK03	36.9	24.6	25.2	12.3	11.7	-	-	-	-	-	-	27.7	Konk	Malh
159	NK06	37.8	23.7	-	14.1	-	-	-	-	-	-	-	38.1	Konk	Malh

Remarks: *1 G.L.: Ground level; *2 W.L.: Water level from ground surface; *3 W.EL.: Water level above mean sea level; *4 E.C.: EC value at 25°C

Table D.2.1 WELL INVENTORY (4/5)

No.	Well No.	G.L.*1 (m)	W.L.*2 (m) 1989	W.L.*2 (m) 1990	W.EL.*3 (m) 1989	W.EL.*3 (m) 1990	E.C.*4 (µS/cm) 1989	E.C.*4 (µS/cm) 1990	pH 1989	pH 1990	Temp (deg. °C) 1989	Temp (deg. °C) 1990	Dep. (m)	U/C	Deh
160	T23	43.9	19.6	-	24.3	-	3,920	-	8.3	-	26	-	29.0	Konk	Malh
161	T24	45.1	27.9	28.7	17.2	16.5	4,324	-	8.3	-	28	25	29.3	Konk	Malh
162	T26	43.6	19.5	-	24.1	-	4,116	-	8	-	26	-	-	Konk	Malh
163	T33	45.1	17.7	15.0	27.4	30.1	4,100	-	8	-	25	23	20.4	Konk	Malh
164	T38	46.9	26.1	26.0	20.8	21.0	1,400	-	8	-	25	19	27.1	Konk	Malh
165	T40	46.6	-	30.6	-	16.1	1,152	-	8.3	-	27	20	-	Konk	Malh
166	T41	47.9	18.7	25.3	29.2	22.6	549	-	8.3	-	26	24	28.3	Konk	Malh
167	T42	46.6	22.7	22.5	23.9	24.1	2,352	-	-	-	26	24	27.7	Konk	Malh
168	T47	48.9	-	19.3	-	29.7	1,078	-	-	-	26	19	19.2	Konk	Malh
169	T49	51.9	14.5	-	37.4	-	-	-	-	-	-	-	31.1	Konk	Malh
170	W59	50.7	14.6	16.3	36.1	34.4	490	-	-	-	26	-	16.2	Konk	Malh
171	W63	45.1	17.3	17.4	27.8	27.7	-	-	-	-	-	-	19.8	Konk	Malh
172	W86A	41.9	17.2	16.3	24.7	25.6	3,000	-	-	-	25	22	20.1	Konk	Thad
173	W87A	49.5	12.2	11.9	37.3	37.7	951	-	-	-	26	-	14.9	Konk	Thad
174	NL07	41.8	-	-	-	-	1,920	-	-	-	27	-	44.2	Land	Khar
175	NL10	44.5	29.3	25.7	15.2	18.8	853	-	-	-	26	16	-	Land	Khar
176	NL09	45.7	23.9	24.6	21.8	21.1	-	-	-	-	-	-	-	Land	Sanh
177	NL11	44.2	36.1	29.4	8.1	14.8	-	-	-	-	-	17	-	Land	Sanh
178	NL12	44.8	-	30.7	-	14.2	-	-	-	-	-	19	-	Land	Sanh
179	NL13	47.2	20.6	23.6	26.7	23.6	-	-	-	-	-	-	-	Land	Sanh
180	NL14	49.1	23.6	15.9	25.5	33.2	-	-	-	7.1	-	-	-	Land	Khar
181	NL15	49.1	24.6	19.9	24.5	29.2	-	-	-	7.1	-	-	-	Land	Khar
182	NL16	44.8	15.1	19.9	29.7	24.9	-	721	-	7.9	-	22	27.0	Land	Khar
183	NL17	45.7	14.4	15.0	31.3	30.7	-	668	-	7.6	-	22	27.0	Land	Khar
184	NL18	44.2	20.1	21.5	24.1	22.7	-	447	-	8.2	-	23	27.0	Land	Khar
185	W65	54.0	21.3	-	32.7	-	383	-	8.3	-	31	23	-	Land	Khar
186	D24	37.5	35.6	35.2	1.9	2.3	-	808	-	-	28	28	42.7	Land	Land
187	D29	36.7	36.0	34.4	0.7	2.3	1,914	-	7.5	-	29	-	42.7	Land	Land
188	D30	37.2	-	28.3	-	8.9	-	1,710	-	-	-	18	-	Land	Land
189	LA29	35.7	36.0	-	-0.3	-	1,861	-	-	-	28	-	44.2	Land	Land
190	LA41	31.1	36.7	36.9	-5.6	-5.8	1,677	1,617	7.3	-	32	26	-	Land	Land
191	LA43	29.9	37.7	39.0	-7.8	-9.1	2,346	1,880	-	-	29	28	-	Land	Land
192	LA45	30.8	35.7	-	-4.9	-	2,365	-	-	-	32	-	-	Land	Land
193	NL01	29.3	-	31.8	-	-2.5	2,068	-	-	-	28	-	-	Land	Land
194	NL02	31.5	34.3	35.3	-2.8	-3.8	-	-	7.5	-	-	-	33.5	Land	Land
195	NL03	31.4	31.2	31.8	0.2	-0.4	2,068	1,666	-	-	28	26	-	Land	Land
196	NL04	29.0	29.5	29.0	-0.6	-0.1	2,538	1,920	-	-	28	27	33.5	Land	Land
197	NL06	35.1	33.9	-	1.2	-	1,080	-	7.7	-	30	-	36.6	Land	Land
198	D10	43.3	35.1	29.8	8.2	13.5	-	-	-	-	-	16	39.6	Land	Khar
199	D11	43.4	32.3	29.4	11.1	14.0	1,008	-	7.6	-	30	22	39.6	Land	Sanh
200	D14	39.7	30.1	-	9.6	-	1,260	-	7.9	-	29	-	-	Land	Sanh
201	D32	36.6	35.7	36.3	0.9	0.3	1,035	1,081	7.4	-	30	28	36.6	Land	Sanh
202	D33	37.5	36.4	36.3	1.1	1.2	1,080	1,104	7.7	-	30	27	-	Land	Sanh
203	D36	37.2	29.1	-	8.1	-	2,009	-	7.3	-	26	-	-	Land	Sanh
204	NL05	38.7	36.0	-	2.7	-	2,300	-	-	-	29	-	-	Land	Sanh
205	D40	41.2	30.2	-	11.0	-	470	-	-	-	28	-	57.3	Land	Khar
206	W79	48.8	-	25.0	-	23.8	-	-	-	6.8	-	-	-	Land	Khar
207	W80	46.9	-	24.6	-	22.3	-	-	-	-	-	-	-	Land	Khar
208	W82	48.8	-	-	-	-	4,018	-	7.7	-	26	-	29.0	Land	Khar
209	W83	47.3	22.6	-	24.7	-	500	-	7.2	-	26	-	27.4	Land	Khar
210	DR05	28.4	18.8	18.4	9.6	10.0	-	-	7	-	26	25	-	Than	Than
211	NT06	26.2	-	41.3	-	-15.1	-	1,200	-	-	-	25	19.0	Than	Than
212	NT07	24.4	42.5	39.7	-18.1	-15.3	1,467	1,500	-	-	30	25	50.3	Than	Than

Remarks: *1 G.L.: Ground level *2 W.L.: Water level from ground surface
*3 W.EL.: Water level above mean sea level *4 E.C.: EC value at 25°C

Table D.2.1 WELL INVENTORY (5/5)

No.	Well No.	G.L.*1 (m)	W.L.*2 (m)		W.EL.*3 (m)		E.C.*4 (µS/cm)		pH		Temp (deg. °C)		Dep. (m)	U/C	Deh
			1989	1990	1989	1990	1989	1990	1989	1990	1989	1990			
213	NT08	27.6	44.8	45.2	-17.2	-17.6	589	-	-	-	29	25	45.7	Than	Than
214	NT11	29.1	38.4	-	-9.3	-	2,178	-	-	-	30	-	26.7	Than	Than
215	NT12	27.0	39.5	38.2	-12.5	-11.2	4,050	-	-	-	30	-	50.3	Than	Than
216	NT13	27.1	37.0	32.6	-9.9	-5.5	3,825	3,796	-	6.5	30	23	48.8	Than	Than
217	NT14	26.5	31.2	27.4	-4.7	-0.9	5,607	4,759	-	6.3	30	23.5	51.8	Than	Than
218	NT15	25.3	26.0	23.1	-0.7	2.2	6,273	4,437	-	6.3	30	24	48.8	Than	Than
219	NT16	25.0	30.0	29.0	-5.0	-4.0	4,338	3,966	-	6.6	30	23.5	51.2	Than	Than
220	NT17	19.8	18.5	-	1.3	-	4,560	3,800	7.15	-	27	25	-	Than	Than
221	NT18	19.2	12.1	-	7.1	-	1,200	1,000	7.85	-	27	25	-	Than	Than
222	NT19	26.5	33.7	-	-7.2	-	4,026	3,400	7.3	-	26.5	25	-	Than	Than
223	NT20	31.1	-	-	-	-	4,099	3,136	6.7	-	27	26	-	Than	Than
224	W88	32.1	37.1	-	-5.0	-	1,134	-	-	-	30	-	44.2	Than	Than
225	W90	32.5	40.7		-8.2	-	-	-	-	-	-	-	39.6	Than	Than
226	W91	31.2	32.1	-	-0.9	-	873	-	-	-	30	-	39.6	Than	Than
227	W95	28.5	-	41.2	-	-12.7	860	2,150	-	-	29	25	57.9	Than	Than
228	W96	26.1	-	37.1	-	-11.0	1,224	2,100	-	-	29	25	45.1	Than	Than
229	W99	26.7	43.5	51.0	-16.8	-24.3	2,686	1,908	7	-	29	22	52.4	Than	Than
230	W100	26.4	36.1	-	-9.7	-	3,128	-	8.2	-	29	-	48.8	Than	Than
231	W101	26.1	34.0	28.4	-7.9	-2.3	3,542	3,744	6.8	-	29	23	53.3	Than	Than
232	W102	26.7	36.9	36.9	-10.2	-10.2	1,575	-	7.3	-	30	-	39.6	Than	Than
233	W104	26.8	34.7	26.6	-7.9	0.2	3,266	3,296	6.6	6.9	29	23.5	52.4	Than	Than
234	W106	24.4	-	27.7	-	-3.3	-	2,496	-	-	-	23	-	Than	Than
235	WR03	30.5	42.0	41.4	-11.5	-10.9	810	-	-	-	30	24	52.4	Than	Than
236	WR05	31.3	35.5	-	-4.2	-	-	-	-	-	-	-	35.7	Than	Than
237	WR06	30.5	35.7	-	-5.2	-	-	-	-	-	-	-	35.7	Than	Than

Remarks:
*1 G.L.: Ground level
*2 W.L.: Water level from ground surface
*3 W.EL.: Water level above mean sea level
*4 E.C.: EC value at 25°C

Table D.2.2 ELECTRIC ENERGY CONSUMPTION AND ESTIMATE OF PUMPED WATER

	Union Council	Recorded by KESC			Project Area			Average	Estimated
		Sample W. Number No.	Sanction Load kWh	Energy Consump. x1000kWh	Estimated Number No.	Sanction Load kWh	Energy Consump. x1000kWh	Depth of Well m	Pumped Volume x1000m3
A.	Average in 1987/88								
1	Darsano Chano	30	387	602	102	1,316	2,047	24.6	11,508
2	Konkar	162	1,668	2,675	201	2,070	3,319	29.1	15,177
3	Laundhi	70	857	1,130	116	1,419	1,873	36.4	6,572
4	Thano	32	355	585	47	521	859	47.6	2,223
5	Total	294	3,267	4,992	466	5,326	8,098	31.3	35,480
	Average					11kW	17,377 kWh		
B.	1987								
1	Darsano Chano	30	393	627	102	1,336	2,132	24.6	11,986
2	Konkar	162	1,650	2,888	201	2,047	3,583	29.1	16,385
3	Laundhi	70	892	1,204	116	1,478	1,995	36.4	7,003
4	Thano	32	364	629	47	535	924	47.6	2,390
5	Total	294	3,299	5,348	466	5,396	8,634	31.3	37,764
	Average						18,528 kWh		
C.	1988								
1	Darsano Chano	30	381	577	102	1,295	1,962	24.6	11,031
2	Konkar	162	1,686	2,462	201	2,092	3,055	29.1	13,968
3	Laundhi	70	821	1,055	116	1,361	1,748	36.4	6,136
4	Thano	32	346	541	47	508	795	47.6	2,056
5	Total	294	3,234	4,635	466	5,256	7,559	31.3	33,191
	Average						16,222 kWh		

Remarks: Refer to ANNEX-G

Table D.2.3 RESULTS OF PUMPING TEST

1. DRAWDOWN

Well No.	*1 Dia (m)	*2 Depth (m)	*3 W.L. (m)	*4 W.D. (m)	*5 DD (m)	*6 dS (m)	*7 Q (m3/s)	*8 T (cm2/s)	*9 M (cm)	*10 K (cm/s)
AG-6	5.6	26.0	23.08	3.0	2.32	1.80	0.0517	52.6	6492	0.0081
W-3	6	24.0	15.60	8.4	0.70	0.48	0.0183	69.8	1440	0.0485
W15-1	4	30.0	18.05	12.0	1.43	0.38	0.0400	192.7	895	0.2153
T-63	6	30.0	23.80	6.2	4.30	3.08	0.0115	6.8	3620	0.0019
NL-10	4.5	32.0	28.80	3.2	2.21	2.66	0.0069	4.7	520	0.0091
NT-13	6	42.0	33.30	8.7	2.50	2.74	0.0072	4.8	670	0.0072

2. RECOVERY

Well No.	*1 Dia (m)	*2 Depth (m)	*3 W.L. (m)	*4 W.D. (m)	*5 DD (m)	*6 dS (m)	*7 Q (m3/s)	*8 T (cm2/s)	*9 M (cm)	*10 K (cm/s)
AG-6	5.6	26.0	23.08	3.0	2.32	1.96	0.0517	48.3	6492	0.0074
W-3	6.0	24.0	15.60	8.4	0.70	0.53	0.0183	63.2	1440	0.0439
W15-1	4.0	30.0	18.05	12.0	1.43	0.43	0.0400	170.3	895	0.1902
T-63	6.0	30.0	23.80	6.2	4.30	4.16	0.0115	5.1	3620	0.0014
NL-10	4.5	32.0	28.80	3.2	2.21	3.55	0.0069	3.6	520	0.0068
NT-13	6.0	42.0	33.30	8.7	2.50	3.02	0.0072	4.4	670	0.0065

Remarks: Permeability was analysed by Jacob formula.

*1 Dia. : Diameter of Well
*2 Depth : Depth of Well
*3 W.L. : Water Level from Ground Surface
*4 W.D. : Water Depth
*5 DD : Drawdown
*6 ds : Drawdown over one log cycle in the graph for analysis by Jacob formula
*7 Q : Yield
*8 T : Transmissivity
*9 M : Thickness of Aquifer estimated based on electric resistivity profiles.
*10 K : Hydraulic Conductivity (Permeability)

Table D.2.4 PERMEABILITY BASED ON GRAIN SIZE ANALYSIS

(Unit: cm/sec)

Formula	Sample No. 1	2	3	4	5
Hazen	0.08625	21.344	71.08886	0.3335	0.21344
Crager	0.00028	0.045	0.1765	0.00028	0.000224
D60/D10	0.24	0.31	0.38	0.029	0.36

Results of grain size analysis

Sample No.	1	2	3	4	5
d10	0.05	0.40	0.73	0.05	0.04
d20	0.03	0.60	0.93	0.12	0.06
d50	0.20	1.10	1.60	1.00	0.07
d60	0.21	1.30	1.90	1.70	0.11

Remarks: Location of sampling is shown in Fig. D.2-1.

Table D.2.5 RESULTS OF WATER QUALITY ANALYSIS IN 1989 & 1990

Sample No.*1			1	2	3	4	5	6	7
		(Well No.)			(W-3)	(KDA-8)	(KDA-6)	(D-32)	(T-63)
1	PH		7.57	8.12	7.60	7.77	7.70	7.65	7.74
2	EC	µS (x1,000)	0.79	0.48	1.20	0.62	0.76	0.66	0.68
3	Cl	ppm	165	70	370	154	161	182	126
4	CO3	ppm	N.D	N.D	N.D	N.D	N.D	N.D	N.D
5	HCO3	ppm	427	268	293	159	207	220	305
6	CaF2	ppm	1.0	0.7	0.9	0.5	0.6	1.0	0.8
7	NO4	ppm	44	17	22	14	20	19	7
8	SO4	ppm	87	41	241	62	81	44	65
9	Ca	ppm	79	50	100	64	67	67	60
10	Mg	ppm	42	26	55	26	31	40	42
11	Na	ppm	115	40	292	62	90	62	71
12	K	ppm	3	4	5	4	4	4	4
13	B	ppm	0.30	0.04	0.38	0.16	0.12	0.16	0.16
14	Fe	ppm	0.31	0.28	0.26	0.37	0.56	0.42	0.38
15	SiO2	ppm	19.2	9.4	21.4	13.0	13.2	15.6	10.2
16	TDS	ppm	768	475	1187	515	610	620	630
	SAR		2.60	1.14	6.18	1.65	2.28	1.48	1.72

Sample No.*1			8	9	10	11	12	13	14	15
		(Well No.)	(L-10)		(NT-15)	(GADAP)	(M06)	(M09)	(M11)	
1	PH		7.75	7.73	7.05	7.3	7.1	7	7	8.1
2	EC	µS (x1,000)	0.48	2.30	4.30	2.62	0.48	1.41	1.32	22.00
3	Cl	ppm	105	587	2096	2213	305	1709	993	20815
4	CO3	ppm	N.D	N.D	N.D	N.D.	N.D.	N.D.	N.D.	N.D.
5	HCO3	ppm	232	439	342	425	341	561	451	159
6	CaF2	ppm	0.6	1.3	0.5	-	-	-	-	1.1
7	NO4	ppm	16	62	52	47	84	40	60	18
8	SO4	ppm	31	328	329	644	141	528	368	2906
9	Ca	ppm	55	104	429	215	97	184	149	392
10	Mg	ppm	28	109	404	182	83	256	167	1410
11	Na	ppm	40	330	400	1250	168	840	510	9500
12	K	ppm	3	9	9	7	10	30	19	350
13	B	ppm	0.08	0.50	0.32	0.66	0.28	0.59	0.62	1.38
14	Fe	ppm	0.38	0.78	1.01	N.D.	N.D.	N.D.	N.D.	0.2
15	SiO2	ppm	18.5	9.4	8.3	54	23	35	32	17.5
16	TDS	ppm	477	1635	3810	5230	1214	4474	2820	41604
	SAR		1.10	5.40	3.33	15.17	Ç	9.40	6.82	50.20

Remarks:
- N.D : Not detectable in ppm.
- SAR : Sodium Adsorption Ratio
- *1 : Location of sampling is presented in Fig. D.2-18.

SAMPLING POINTS

1	The well upstream of Khadeji damsite
2	Mol River at proposed Mol damsite
9	The well near National Highway
11	Borehole well in Gadap district
12,13,14	National Hwy to Sea
15	Sea at Port Qasim

Table D.2.6 RESULTS OF WATER QUALITY ANALYSIS IN 1977 (BY WAPDA)

SAMPLE NO.			1	2	3	4	5	6	7
		(WELL NO)	LA-45	D-37	W-75	W-6	L-13	AG-12	W-13
1	PH		8.5	8.7	8.2	8.0	8.0	8.2	8.8
2	EC	μS/cm	3,000	3,100	3,500	2,600	850	1,120	4,100
3	Cl	ppm	823	766	901	681	142	199	993
4	CO3	ppm	N.D	N.D	N.D	N.D	N.D	N.D	N.D
5	HCO3	ppm	171	195	220	244	146	183	244
6	CaF2	ppm	-	-	-	-	-	-	-
7	NO4	ppm	-	-	-	-	-	-	-
8	SO4	ppm	192	298	288	134	101	125	432
9	Ca	ppm	192	200	253	240	68	96	337
10	Mg	ppm	156	146	187	78	36	63	185
11	Na	ppm	175	207	161	175	48	28	207
12	K	ppm	-	-	-	-	-	-	-
13	B	ppm	-	-	-	-	-	-	-
14	Fe	ppm	-	-	-	-	-	-	-
15	SiO2	ppm	-	-	-	-	-	-	-
16	D.S.	ppm	1,920	1,984	2,240	1,840	304	716	2,624

Remarks: D.S.: Dissolved Solids
N.D : Not detectable in ppm.

Table D.2.7 RELATIVE TOLERANCE OF PLANTS TO BORON

	Sensitive	Semi-tolerant	Tolerant
Excellent water	Less than 0.3 mg/l	Less than 0.7 mg/l	Less than 1.0 mg/l
Unsuitable water	More than 1.3 mg/l	More than 2.5 mg/l	More than 3.8 mg/l
	Lemon	Bean(Lima)	Carrot
	Avocado	Pepper	Cabbage
	Orange	Pumpkin	Onion
	Apricot	Oat	Alfalfa
	Peach	Maise	Date palm
	Apple	Wheat	
	Walnut	Barley	
		Tomato	
		Cotton	
		Sunflower	

(after Richard, 1954)

Table D.2.8 WATER QUALITY CRITERION FOR VARIOUS USE

Unit:mg/l

		Drinking	General Household Use		Irrigation	
			Good	Poor	Good	Poor
Bicarbonate	HCO3	500	150	500	200	500
Fluoride	CaF2	1.5	-	-	-	-
Nitrate	NO4	20	-	-	-	-
Sulphate	SO4	250	100	300	200	500
Calcium	Ca	200	40	100	-	-
Magnesium	Mg	125	20	100	-	-
Sodium	Na	200	100	300	50	300
Boron	B	20	-	-	0.3	3
Iron	Fe	1	0.2	0.5	-	-
Silica	SiO4	-	10	50	-	-
TDS		1500	300	2000	500	3000

(after Davis and DeWiest,1966)

Table D.2.9 ELECTRIC CONDUCTIVITY IN 1977 AND 1989

	Well No.	EC in 1977 EC (μS/cm)	Temp. (°C)	EC (μS/cm at 25 °C)	EC in 1989 EC μS/cm	Temp. (°C)	EC (μS/cm at 25 °C)	Union Council
1	W03	1,150	(30)	1,035	1,880	(26)	1,842	Darsano Chano
2	W11	1,550	(31)	1,364	1,050	(30)	945	Darsano Chano
3	AG11	1,350	(30)	1,215	2,290	(28)	2,153	Darsano Chano
4	AG04	750	(29)	690	800	(28)	752	Darsano Chano
5	AG06	1,200	(28)	1,128	980	(29)	902	Darsano Chano
6	L17	950	(30)	855	790	(26)	774	Darsano Chano
7	W15	1,000	(30)	900	4,200	(26)	4,116	Konkar
8	V06	550	(33)	462	480	(26)	470	Konkar
9	V13	550	(31)	484	650	(26)	637	Konkar
10	W19	1,400	(30)	1,260	2,700	(27)	2,592	Konkar
11	W37	1,700	(35)	1,360	1,600	(26)	1,568	Konkar
12	T07	450	(33)	378	2,150	(29)	1,978	Konkar
13	63	1,800	(32)	1,548	3,600	(25)	3,600	Konkar
14	12	1,550	(29)	1,426	2,800	(27)	2,688	Konkar
15	T41	1,600	(28)	1,504	560	(26)	549	Konkar
16	LA45	3,000	(30)	2,700	2,750	(32)	2,365	Landhi
17	W100	1,900	(30)	1,710	3,400	(29)	3,128	Thano
18	W102	2,200	(30)	1,980	1,750	(30)	1,575	Thano
19	WR03	900	(30)	810	2,200	(24)	2,244	Thano
20	W88	1,000	(32)	860	1,260	(30)	1,134	Thano
21	W91	1,000	(32)	860	970	(30)	873	Thano
22	W104	2,400	(30)	2,160	3,550	(29)	3,266	Thano
23	DR05	2,500	(30)	2,250	5,950	(26)	5,831	Thano
	AVERAG	1,411	31	1,258	2,103	28	1,999	

Remarks: Parenthesis shows measured water temperature (°C).
* Source Ref.01.

Table D.2.10 INVESTIGATION FOR SALINE WATER INTRUSION

WELL NO.*	Ground Level (m)	Depth to Water Level (m)	Water Level (m)	Wtaer Temperature (°C)	E.C. (μS/cm at 25 °C)	Well Depth (m)
NO.1	22.9	14.2	8.6	24.0	2,652	42.0
NO.2	20.1	12.0	8.2	24.0	1,428	38.0
NO.3	22.3	10.6	11.7	23.0	1,664	-
NO.4	20.4	8.4	12.1	24.0	1,122	21.0
NO.5	19.5	7.0	12.5	23.0	1,144	19.0
NO.6	20.1	-	-	25.0	1,600	12.0
NO.7	20.1	8.5	11.7	24.5	3,485	24.0
NO.8	14.6	2.0	12.6	-	-	-
NO.9	21.0	8.2	12.8	24.0	4,080	-
NO.10	14.3	11.0	3.3	26.0	3,773	24.0
NO.11	18.3	10.9	7.4	25.0	2,950	-
NO.12	17.1	4.8	12.3	23.0	3,536	-
NO.13	16.8	7.2	9.6	-	-	-
NO.14	18.3	5.0	13.3	22.0	1,802	-
NO.15	12.2	7.0	5.2	20.0	440	-
NO.16	13.7	8.5	5.2	22.0	3,392	-
NO.17	13.4	-	-	26.0	3,430	-

Remarks: Location of wells is shown in Fig. D.2-17.

Table D.3.1 RECHARGE TO AQUIFER

	Section of Elec. R. Survey	Stretch	Depth of Aquifer m	Permability m/sec	Gradient (Cross S.)	Water Movement 1000m3/km/month
Upper	F	0 - 5	20	0.0003	0.005	156
	E	5 - 10	30	0.0003	0.005	234
	D	10 - 15	35	0.0005	0.005	455
	C	15 - 20	50	0.0005	0.014	1820
	B	20 - 25	40	0.0004	0.010	832
Lower	A	25 - 30	40	0.0003	0.020	1248

	Section of Elec. R. Survey	St.No. km	Recharge to Aquifer 1000m3/km	Release at Super Highway (1000 m3/month) 4 m3/sec	6 m3/sec	8 m3/sec	10 m3/sec
Upper S.		0	156	10,400	15,600	20,800	26,000
		1	156	10,244	15,444	20,644	25,844
Super		2	156	10,088	15,288	20,488	25,688
Highway		3	156	9,932	15,132	20,332	25,532
	F	4	156	9,776	14,976	20,176	25,376
		5	234	9,542	14,742	19,942	25,142
		6	234	9,308	14,508	19,708	24,908
		7	234	9,074	14,274	19,474	24,674
		8	234	8,840	14,040	19,240	24,440
	E	9	234	8,606	13,806	19,006	24,206
		10	455	8,151	13,351	18,551	23,751
		11	455	7,696	12,896	18,096	23,296
		12	455	7,241	12,441	17,641	22,841
	D	13	455	6,786	11,986	17,186	22,386
		14	1,820	4,966	10,166	15,366	20,566
		15	1,820	3,146	8,346	13,546	18,746
		16	1,820	1,326	6,526	11,726	16,926
		17	1,820	-494	4,706	9,906	15,106
	C	18	1,820	-2,314	2,886	8,086	13,286
		19	832	-3,146	2,054	7,254	12,454
		20	832	-3,978	1,222	6,422	11,622
		21	832	-4,810	390	5,590	10,790
	B	22	832	-5,642	-442	4,758	9,958
		23	1,248	-6,890	-1,690	3,510	8,710
		24	1,248	-8,138	-2,938	2,262	7,462
		25	1,248	-9,386	-4,186	1,014	6,214
		26	1,248	-10,634	-5,434	-234	4,966
		27	1,248	-11,882	-6,682	-1,482	3,718
		28	1,248	-13,130	-7,930	-2,730	2,470
	A	29	1,248	-14,378	-9,178	-3,978	1,222
National		30	1,248	-15,626	-10,426	-5,226	-26
Highway		31					

Table D.3.2 SUMMARY OF ARTIFICIAL RECHARGE BY DAMS (1/2)

(Unit:MCM)

Year	Natural Recharge	Case-1			Case-2			Case-3			Case-4		
		Active Storage	Mol : 43.8 MCM Khadeji : 35.5 MCM		Active Storage	Mol : 35.0 MCM Khadeji : 35.5 MCM		Active Storage	Mol : 43.8 MCM Khadeji : -		Active Storage	Mol : 35.0 MCM Khadeji : -	
		Rec. from Rem. Basin	Recharge from Dam	Total Recharge	Rec. from Rem. Basin	Recharge from Dam	Total Recharge	Rec. from Rem. Basin	Recharge from Dam	Total Recharge	Rec. from Rem. Basin	Recharge from Dam	Total Recharge
1929	12.9	0.8	12.1	12.9	0.8	12.1	12.9	6.4	6.5	12.9	6.4	6.5	12.9
1930	137.9	99.1	85.6	184.7	103.2	77.5	180.8	121.5	49.2	170.8	125.6	40.8	166.4
1931	6.9	0.2	6.6	6.9	0.2	6.6	6.9	3.2	3.7	6.9	3.2	3.7	6.9
1932	111.0	72.6	86.6	159.2	76.8	78.5	155.4	95.9	49.7	145.7	100.1	41.3	141.4
1933	152.2	142.1	90.7	232.8	146.1	89.4	235.6	166.3	59.0	225.3	170.3	50.5	220.9
1934	55.0	15.4	88.7	104.1	15.4	81.9	97.3	29.7	50.0	79.8	29.7	50.0	79.8
1935	12.3	0.7	11.6	12.3	0.7	11.6	12.3	5.6	6.6	12.3	5.6	6.6	12.3
1936	20.4	2.1	19.5	21.7	2.1	19.5	21.7	10.9	10.7	21.7	10.9	10.7	21.7
1937	70.1	23.9	84.7	108.6	28.5	76.6	105.2	58.8	49.1	107.9	69.7	40.8	110.5
1938	23.2	2.1	22.0	24.1	2.1	22.0	24.1	12.4	11.6	24.1	12.4	11.6	24.1
1939	5.6	0.2	5.3	5.6	0.2	5.3	5.6	2.6	2.9	5.6	2.6	2.9	5.6
1940	22.1	1.7	20.4	22.1	1.7	20.4	22.1	11.4	10.6	22.1	11.4	10.6	22.1
1941	7.5	0.3	7.1	7.5	0.3	7.1	7.5	3.9	3.5	7.5	3.9	3.5	7.5
1942	96.3	52.0	82.1	134.1	56.3	74.0	130.4	73.5	47.0	120.5	77.7	38.7	116.5
1943	12.1	0.6	11.5	12.1	0.6	11.5	12.1	6.1	6.0	12.1	6.1	6.0	12.1
1944	203.8	220.0	72.6	292.6	224.3	72.6	296.9	242.8	54.8	297.7	247.1	46.6	293.7
1945	32.6	7.4	60.8	68.2	7.4	52.8	60.2	26.8	24.5	51.3	26.8	24.5	51.3
1946	25.1	1.6	23.4	25.1	1.6	23.4	25.1	12.4	12.6	25.1	12.4	12.6	25.1
1947	13.4	0.7	12.7	13.4	0.7	12.7	13.4	6.6	6.8	13.4	6.6	6.8	13.4
1948	7.0	0.4	6.6	7.0	0.4	6.6	7.0	3.5	3.5	7.0	3.5	3.5	7.0
1949	80.0	37.1	95.5	132.6	42.9	91.6	134.6	64.8	63.6	128.4	74.7	55.3	130.1
1950	21.0	2.7	26.7	29.5	2.7	22.5	25.2	12.9	12.3	25.2	12.9	12.3	25.2
1951	10.1	0.5	9.6	10.1	0.5	9.6	10.1	5.3	4.8	10.1	5.3	4.8	10.1
1952	40.5	14.0	67.2	81.2	14.0	67.2	81.2	23.9	41.0	65.0	23.9	41.0	65.0
1953	72.4	25.9	81.6	107.5	31.4	76.7	108.2	64.3	48.8	113.1	75.3	40.5	115.8
1954	47.9	13.4	73.8	87.3	13.4	70.6	84.0	28.9	42.3	71.3	28.9	42.3	71.3
1955	22.1	5.5	30.1	35.7	5.5	30.1	35.7	19.5	16.8	36.4	19.5	16.8	36.4
1956	58.8	18.8	90.3	109.1	18.8	90.3	109.1	40.8	54.8	95.7	40.8	54.8	95.7
1957	8.1	0.1	7.9	8.1	0.1	7.9	8.1	3.7	4.3	8.1	3.7	4.3	8.1
1958	26.9	9.9	45.2	55.1	9.9	45.2	55.1	20.8	27.0	47.8	20.8	27.0	47.8
1959	201.6	168.0	82.6	250.6	178.8	82.6	261.4	187.6	70.1	257.8	192.0	61.7	253.7
1960	20.6	1.0	45.3	46.3	1.0	37.2	38.3	10.1	10.5	20.6	10.1	10.5	20.6
1961	123.6	146.4	78.4	224.8	133.5	78.4	211.9	149.9	64.2	214.1	154.2	55.7	210.0
1962	66.1	16.5	117.8	134.4	16.5	109.8	126.3	42.0	54.6	96.6	42.0	54.6	96.6
1963	14.7	0.7	14.0	14.7	0.7	14.0	14.7	6.8	7.9	14.7	6.8	7.9	14.7
1964	29.0	3.8	30.8	34.7	3.8	30.8	34.7	18.0	16.6	34.7	18.0	16.6	34.7
1965	21.0	6.9	32.6	39.6	6.9	32.6	39.6	21.8	18.4	40.3	21.8	18.4	40.3
1966	17.6	1.9	17.4	19.4	1.9	17.4	19.4	9.9	9.5	19.4	9.9	9.5	19.4
1967	168.7	169.1	90.8	260.0	173.1	89.5	262.6	196.1	56.6	252.7	200.0	48.1	248.2
1968	14.4	0.7	20.4	21.2	0.7	13.7	14.4	6.5	7.8	14.4	6.5	7.8	14.4
1969	11.3	0.6	10.7	11.3	0.6	10.7	11.3	5.6	5.7	11.3	5.6	5.7	11.3
1970	83.6	51.5	94.9	146.4	54.0	94.8	148.9	65.1	79.4	144.6	69.8	71.2	141.1
1971	16.3	0.7	32.8	33.6	0.7	24.7	25.5	8.0	8.3	16.3	8.0	8.3	16.3
1972	8.2	0.3	7.8	8.2	0.3	7.8	8.2	3.9	4.2	8.2	3.9	4.2	8.2
1973	56.5	20.7	86.8	107.6	18.1	78.7	96.8	32.4	51.6	84.0	38.9	43.3	82.2
1974	5.3	0.1	5.2	5.3	0.1	5.2	5.3	2.4	2.8	5.3	2.4	2.8	5.3
1975	16.9	2.9	19.5	22.5	2.9	19.5	22.5	12.0	10.5	22.5	12.0	10.5	22.5
1976	31.8	9.9	45.1	55.0	9.9	45.1	55.0	30.6	25.3	55.9	30.6	25.3	55.9
1977	72.5	25.0	90.0	115.0	25.0	90.0	115.0	73.8	38.7	112.6	73.8	38.7	112.6
1978	112.8	68.3	95.1	163.4	70.6	92.7	163.4	89.9	62.2	152.2	97.1	54.0	151.1
1979	22.1	2.5	30.0	32.5	2.5	24.2	26.7	10.6	16.0	26.7	10.6	16.0	26.7
1980	12.7	0.5	12.2	12.7	0.5	12.2	12.7	7.0	5.7	12.7	7.0	5.7	12.7
1981	28.0	9.9	39.7	49.6	9.9	39.7	49.6	24.0	13.7	37.8	24.0	13.7	37.8
1982	11.3	5.8	15.8	21.6	5.8	15.8	21.6	16.2	5.4	21.6	16.2	5.4	21.6
1983	22.4	6.6	33.8	40.4	6.6	33.8	40.4	22.0	13.6	35.7	22.0	13.6	35.7
1984	107.6	62.6	82.2	144.8	66.8	78.8	145.6	86.4	49.2	135.6	90.6	40.9	131.5
1985	22.2	1.7	27.3	29.0	1.7	22.6	24.3	13.3	11.0	24.3	13.3	11.0	24.3
1986	20.4	4.7	27.0	31.8	4.7	27.0	31.8	16.1	16.2	32.3	16.1	16.2	32.3
1987	3.3	0.0	3.3	3.3	0.0	3.3	3.3	1.4	1.9	3.3	1.4	1.9	3.3
1988	28.5	6.5	35.4	41.9	6.5	35.4	41.9	22.6	19.5	42.1	22.6	19.5	42.1
Avera	46.5	26.1	44.5	70.6	26.9	42.4	69.3	39.6	25.8	65.4	41.1	23.6	64.7

Table D.3.2 SUMMARY OF ARTIFICIAL RECHARGE BY DAMS (2/2)

(Unit:MCM)

Year	Natural Recharge	Case-5 Active Storage Mol : 30.0 MCM Khadeji : -			Csae-6 Active Storage Mol : - Khadeji : 35.5 MCM			Case-7 Active Storage Mol : - Khadeji : 30.0 MCM		
		Rec. from Rem. Basin	Recharge from Dam	Total Recharge	Rec. from Rem. Basin	Recharge from Dam	Total Recharge	Rec. from Rem. Basin	Recharge from Dam	Total Recharge
1929	12.9	6.4	6.5	12.9	7.3	5.5	12.9	7.3	5.5	12.9
1930	137.9	127.9	36.2	164.1	127.0	38.6	165.6	129.5	33.8	163.3
1931	6.9	3.2	3.7	6.9	4.0	2.9	6.9	4.0	2.9	6.9
1932	111.0	102.4	36.7	139.1	101.4	39.1	140.6	104.0	34.3	138.4
1933	152.2	172.6	45.9	218.5	174.4	40.6	215.1	177.0	35.8	212.8
1934	55.0	31.1	46.3	77.5	38.6	33.5	72.1	38.6	33.5	72.1
1935	12.3	5.6	6.6	12.3	7.3	4.9	12.3	7.3	4.9	12.3
1936	20.4	10.9	10.7	21.7	12.8	8.8	21.7	12.8	8.8	21.7
1937	70.1	75.9	35.9	111.9	71.8	38.0	109.9	78.6	32.9	111.5
1938	23.2	12.4	11.6	24.1	13.8	10.3	24.1	13.8	10.3	24.1
1939	5.6	2.6	2.9	5.6	3.1	2.4	5.6	3.1	2.4	5.6
1940	22.1	11.4	10.6	22.1	12.4	9.7	22.1	12.4	9.7	22.1
1941	7.5	3.9	3.5	7.5	3.9	3.5	7.5	3.9	3.5	7.5
1942	96.3	80.1	33.9	114.1	78.3	37.5	115.9	80.9	32.4	113.3
1943	12.1	6.1	6.0	12.1	6.7	5.4	12.1	6.7	5.4	12.1
1944	203.8	249.4	41.8	291.3	245.3	37.4	282.7	248.0	32.2	280.3
1945	32.6	26.8	24.5	51.3	25.9	18.7	44.6	25.9	18.7	44.6
1946	25.1	12.4	12.6	25.1	14.3	10.8	25.1	14.3	10.8	25.1
1947	13.4	6.6	6.8	13.4	7.6	5.8	13.4	7.6	5.8	13.4
1948	7.0	3.5	3.5	7.0	3.9	3.1	7.0	3.9	3.1	7.0
1949	80.0	80.8	50.4	131.3	84.0	38.3	122.3	90.8	33.4	124.3
1950	21.0	12.9	12.3	25.2	15.0	10.2	25.2	15.0	10.2	25.2
1951	10.1	5.3	4.8	10.1	5.3	4.7	10.1	5.3	4.7	10.1
1952	40.5	24.0	40.8	64.8	29.6	27.3	57.0	29.6	27.3	57.0
1953	72.4	56.2	35.6	91.9	76.6	38.4	115.1	57.6	33.2	90.9
1954	47.9	28.9	42.3	71.3	33.7	29.2	62.9	33.7	29.2	62.9
1955	22.1	19.5	16.8	36.4	22.4	13.5	35.9	22.4	13.5	35.9
1956	58.8	40.8	54.8	95.7	49.5	37.1	86.6	50.0	36.7	86.7
1957	8.1	3.7	4.3	8.1	4.4	3.6	8.1	4.4	3.6	8.1
1958	26.9	20.8	27.0	47.8	23.4	18.7	42.1	23.4	18.7	42.1
1959	201.6	194.5	57.0	251.5	196.5	53.1	249.6	199.3	48.0	247.3
1960	20.6	10.1	10.5	20.6	11.6	9.0	20.6	11.6	9.0	20.6
1961	123.6	156.4	51.1	207.6	162.3	41.9	204.2	165.1	36.8	202.0
1962	66.1	42.0	54.6	96.6	49.5	38.4	88.0	49.5	38.4	88.0
1963	14.7	6.8	7.9	14.7	8.6	6.1	14.7	8.6	6.1	14.7
1964	29.0	18.0	16.6	34.7	20.5	14.1	34.7	20.5	14.1	34.7
1965	21.0	21.8	18.4	40.3	19.4	14.2	33.6	19.4	14.2	33.6
1966	17.6	9.9	9.5	19.4	11.5	7.9	19.4	11.5	7.9	19.4
1967	168.7	202.3	43.5	245.8	203.1	43.2	246.3	205.6	38.1	243.8
1968	14.4	6.5	7.8	14.4	8.5	5.8	14.4	8.5	5.8	14.4
1969	11.3	5.6	5.7	11.3	6.4	4.9	11.3	6.4	4.9	11.3
1970	83.6	73.3	66.4	139.8	77.9	38.1	116.1	82.5	32.9	115.5
1971	16.3	8.0	8.3	16.3	9.1	7.2	16.3	9.1	7.2	16.3
1972	8.2	3.9	4.2	8.2	4.5	3.6	8.2	4.5	3.6	8.2
1973	56.5	43.4	38.5	82.0	43.4	37.6	81.0	48.7	32.6	81.4
1974	5.3	2.4	2.8	5.3	3.0	2.3	5.3	3.0	2.3	5.3
1975	16.9	12.0	10.5	22.5	13.5	9.0	22.5	13.5	9.0	22.5
1976	31.8	30.6	25.3	55.9	35.3	20.0	55.3	35.3	20.0	55.3
1977	72.5	73.8	38.7	112.6	57.7	52.0	109.8	63.3	47.0	110.3
1978	112.8	102.0	49.1	151.2	106.3	40.7	147.0	112.5	35.8	148.3
1979	22.1	10.6	16.0	26.7	18.5	8.1	26.7	18.5	8.1	26.7
1980	12.7	7.0	5.7	12.7	6.2	6.5	12.7	6.2	6.5	12.7
1981	28.0	24.0	13.7	37.8	23.6	26.4	50.1	23.6	26.4	50.1
1982	11.3	16.2	5.4	21.6	11.2	10.4	21.6	11.2	10.4	21.6
1983	22.4	22.0	13.6	35.7	20.2	20.7	41.0	20.2	20.7	41.0
1984	107.6	92.9	36.0	129.0	90.8	39.8	130.6	93.4	34.9	128.3
1985	22.2	13.3	11.0	24.3	12.7	11.6	24.3	12.7	11.6	24.3
1986	20.4	16.1	16.2	32.3	20.9	11.0	32.0	20.9	11.0	32.0
1987	3.3	1.4	1.9	3.3	1.9	1.4	3.3	1.9	1.4	3.3
1988	28.5	22.6	19.5	42.1	26.0	15.8	41.9	26.0	15.8	41.9
Avera	46.5	41.6	22.3	63.9	43.1	19.6	62.7	43.8	18.3	62.1

Table D.3.3 CALCULATION RESULTS OF ARTIFICIAL RECHARGE BY MOL DAM (1/11)

		Mol Dam (Active Storage: 35.0 MCM)								Artificial Recharge		
Year	Month	Inflow (MCM)	Release from Dam (MCM)	W.L. of Reservoir (EL.m)	Storage Volume (MCM)	Runoff at Khadeji (MCM)	Runoff at N.H.B. (MCM)	Natural Recharge (MCM)	Rec. from Rem. Basin (MCM)	Recharge from Dam (MCM)	Total Recharge (MCM)
1929	1	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1929	2	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1929	3	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1929	4	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1929	5	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1929	6	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1929	7	4.1	4.1	156.5	0.0	3.8	8.8	8.8	4.6	4.1	8.8
1929	8	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1929	9	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1929	10	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1929	11	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1929	12	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1930	1	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1930	2	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1930	3	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1930	4	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1930	5	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1930	6	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.4	0.4	0.8
1930	7	134.0	0.0	169.5	34.1	98.3	272.1	127.7	114.8	0.0	114.8
1930	8	4.5	16.9	165.8	21.1	3.5	12.4	4.4	7.9	16.9	24.9
1930	9	0.4	20.4	157.1	0.8	0.3	1.1	1.1	0.6	20.4	21.1
1930	10	0.4	1.3	156.5	0.0	0.3	0.8	0.8	0.3	1.3	1.7
1930	11	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1930	12	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1931	1	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1931	2	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1931	3	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1931	4	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1931	5	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1931	6	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1931	7	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1931	8	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1931	9	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1931	10	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1931	11	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1931	12	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1932	1	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1932	2	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1932	3	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1932	4	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1932	5	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1932	6	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1932	7	107.8	0.0	169.5	34.1	78.3	218.5	102.9	89.8	0.0	89.8
1932	8	4.5	18.0	165.5	20.1	3.8	11.7	1.6	7.1	18.0	25.2
1932	9	0.7	20.3	156.6	0.1	0.4	1.5	1.5	0.8	20.3	21.2
1932	10	0.5	0.6	156.5	0.0	0.3	0.9	0.9	0.4	0.6	1.1
1932	11	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1932	12	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1933	1	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1933	2	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1933	3	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1933	4	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1933	5	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1933	6	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1933	7	162.3	0.0	169.5	34.1	120.0	330.1	154.8	141.2	0.0	141.2
1933	8	14.4	6.6	169.5	34.2	11.7	40.9	18.1	18.4	6.6	25.1
1933	9	4.9	18.3	165.5	20.3	3.7	11.1	5.4	6.1	18.3	24.5
1933	10	1.3	21.2	156.6	0.1	0.7	2.2	2.2	0.9	21.2	22.1
1933	11	0.9	1.1	156.5	0.0	0.7	1.7	1.7	0.8	1.1	1.9
1933	12	0.9	0.9	156.5	0.0	0.7	1.7	1.7	0.7	0.9	1.7
1934	1	0.9	0.9	156.5	0.0	0.6	1.6	1.6	0.7	0.9	1.6
1934	2	0.8	0.8	156.5	0.0	0.6	1.5	1.5	0.7	0.8	1.5
1934	3	0.8	0.8	156.5	0.0	0.6	1.5	1.5	0.6	0.8	1.5
1934	4	0.7	0.7	156.5	0.0	0.5	1.4	1.4	0.6	0.7	1.4
1934	5	0.7	0.7	156.5	0.0	0.5	1.3	1.3	0.6	0.7	1.3
1934	6	0.7	0.7	156.5	0.0	0.5	1.3	1.3	0.6	0.7	1.3
1934	7	40.9	7.2	169.1	32.9	27.3	82.5	35.7	20.7	7.2	27.9
1934	8	2.3	20.9	163.3	13.9	1.9	4.8	4.8	2.4	20.9	23.3
1934	9	0.8	14.7	156.5	0.0	0.6	1.5	1.5	0.7	14.7	15.4

Table D.3.3 CALCULATION RESULTS OF ARTIFICIAL RECHARGE BY MOL DAM (2/11)

Year	Month	Mol Dam (Active Storage: 35.0 MCM) Inflow (MCM)	Release from Dam (MCM)	W.L. of Reservoir (EL.m)	Storage Volume (MCM)	Runoff at Khadeji (MCM)	Runoff at N.H.B. (MCM)	Natural Recharge (MCM)	Artificial Recharge: Rec. from Rem. Basin (MCM)	Recharge from Dam (MCM)	Total Recharge (MCM)
1934	10	0.7	0.7	156.5	0.0	0.5	1.4	1.4	0.6	0.7	1.4
1934	11	0.7	0.7	156.5	0.0	0.5	1.3	1.3	0.6	0.7	1.3
1934	12	0.7	0.7	156.5	0.0	0.5	1.3	1.3	0.6	0.7	1.3
1935	1	0.6	0.6	156.5	0.0	0.5	1.2	1.2	0.5	0.6	1.2
1935	2	0.6	0.6	156.5	0.0	0.4	1.2	1.2	0.5	0.6	1.2
1935	3	0.6	0.6	156.5	0.0	0.4	1.1	1.1	0.5	0.6	1.1
1935	4	0.6	0.6	156.5	0.0	0.4	1.1	1.1	0.5	0.6	1.1
1935	5	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1935	6	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1935	7	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1935	8	0.5	0.5	156.5	0.0	0.3	0.9	0.9	0.4	0.5	0.9
1935	9	0.4	0.4	156.5	0.0	0.3	0.9	0.9	0.4	0.4	0.9
1935	10	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1935	11	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1935	12	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1936	1	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1936	2	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1936	3	0.3	0.3	156.5	0.0	0.2	0.7	0.7	0.3	0.3	0.7
1936	4	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1936	5	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1936	6	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1936	7	6.9	6.9	156.5	0.0	5.9	14.7	13.4	7.7	6.9	14.7
1936	8	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1936	9	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1936	10	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1936	11	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1936	12	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1937	1	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1937	2	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1937	3	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1937	4	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1937	5	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1937	6	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1937	7	62.9	1.2	169.5	34.1	44.1	127.2	58.1	63.7	1.2	64.9
1937	8	2.5	20.5	164.0	15.6	2.0	5.4	5.4	2.9	20.5	23.4
1937	9	0.3	16.0	156.5	0.0	0.3	0.7	0.7	0.3	16.0	16.4
1937	10	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1937	11	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1937	12	0.8	0.8	156.5	0.0	0.7	1.7	1.7	0.9	0.8	1.7
1938	1	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1938	2	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1938	3	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1938	4	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1938	5	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1938	6	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1938	7	2.0	2.0	156.5	0.0	2.2	4.6	4.6	2.5	2.0	4.6
1938	8	6.7	6.7	156.5	0.0	5.8	14.2	13.3	7.4	6.7	14.2
1938	9	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1938	10	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1938	11	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1938	12	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1939	1	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1939	2	0.4	0.4	156.5	0.0	0.4	0.9	0.9	0.4	0.4	0.9
1939	3	0.5	0.5	156.5	0.0	0.5	1.1	1.1	0.5	0.5	1.1
1939	4	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1939	5	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1939	6	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1939	7	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1939	8	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1939	9	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1939	10	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1939	11	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1939	12	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1940	1	0.7	0.7	156.5	0.0	0.6	1.5	1.5	0.8	0.7	1.5
1940	2	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1940	3	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1940	4	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1940	5	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1940	6	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2

Table D.3.3 CALCULATION RESULTS OF ARTIFICIAL RECHARGE BY MOL DAM (3/11)

Year	Month	Mol Dam (Active Storage: 35.0 MCM) Inflow (MCM)	Release from Dam (MCM)	W.L. of Reservoir (EL.m)	Storage Volume (MCM)	Runoff at Khadeji (MCM)	Runoff at N.H.B. (MCM)	Natural Recharge (MCM)	Artificial Recharge Rec. from Rem. Basin (MCM)	Recharge from Dam (MCM)	Total Recharge (MCM)
1940	7	4.0	4.0	156.5	0.0	3.7	8.5	8.5	4.5	4.0	8.5
1940	8	4.3	4.3	156.5	0.0	4.0	9.2	9.2	4.8	4.3	9.2
1940	9	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1940	10	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1940	11	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1940	12	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1941	1	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1941	2	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1941	3	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1941	4	0.1	0.1	156.5	0.0	0.0	0.2	0.2	0.0	0.1	0.2
1941	5	0.1	0.1	156.5	0.0	0.0	0.1	0.1	0.0	0.1	0.1
1941	6	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1941	7	2.4	2.4	156.5	0.0	2.5	5.3	5.3	2.8	2.4	5.3
1941	8	0.1	0.1	156.5	0.0	0.0	0.1	0.1	0.0	0.1	0.1
1941	9	0.1	0.1	156.5	0.0	0.0	0.1	0.1	0.0	0.1	0.1
1941	10	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1941	11	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1941	12	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1942	1	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1942	2	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1942	3	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1942	4	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1942	5	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1942	6	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1942	7	89.5	0.0	169.5	34.1	64.4	181.4	85.6	72.2	0.0	72.2
1942	8	3.4	20.3	164.5	16.7	2.9	7.4	7.4	4.0	20.3	24.3
1942	9	0.3	17.0	156.5	0.0	0.2	0.6	0.6	0.3	17.0	17.4
1942	10	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1942	11	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1942	12	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1943	1	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1943	2	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1943	3	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1943	4	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1943	5	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1943	6	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1943	7	3.6	3.6	156.5	0.0	3.4	7.6	7.6	4.0	3.6	7.6
1943	8	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1943	9	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1943	10	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1943	11	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1943	12	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1944	1	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1944	2	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1944	3	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1944	4	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1944	5	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1944	6	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1944	7	105.5	0.0	169.5	34.1	76.6	214.0	100.8	87.7	0.0	87.7
1944	8	135.3	0.0	169.5	34.2	99.4	282.0	97.7	134.9	0.0	134.9
1944	9	8.2	7.8	169.4	33.9	6.5	27.6	2.3	19.4	7.8	27.2
1944	10	2.1	20.6	163.7	14.8	1.4	4.3	1.6	2.2	20.6	22.8
1944	11	1.0	15.9	156.5	0.0	0.8	1.9	1.9	0.8	15.9	16.8
1944	12	1.0	1.0	156.5	0.0	0.7	1.8	1.8	0.8	1.0	1.8
1945	1	1.2	1.2	156.5	0.0	0.9	2.3	2.3	1.1	1.2	2.3
1945	2	0.9	0.9	156.5	0.0	0.7	1.7	1.7	0.7	0.9	1.7
1945	3	0.9	0.9	156.5	0.0	0.7	1.6	1.6	0.7	0.9	1.6
1945	4	0.8	0.8	156.5	0.0	0.6	1.6	1.6	0.7	0.8	1.6
1945	5	0.8	0.8	156.5	0.0	0.6	1.5	1.5	0.6	0.8	1.5
1945	6	0.8	0.8	156.5	0.0	0.6	1.4	1.4	0.6	0.8	1.4
1945	7	15.1	14.7	156.6	0.1	12.2	34.1	15.1	18.9	14.7	33.6
1945	8	0.9	1.1	156.5	0.0	0.6	1.7	1.7	0.7	1.1	1.8
1945	9	0.7	0.7	156.5	0.0	0.5	1.4	1.4	0.6	0.7	1.4
1945	10	0.7	0.7	156.5	0.0	0.5	1.3	1.3	0.6	0.7	1.3
1945	11	0.7	0.7	156.5	0.0	0.5	1.3	1.3	0.5	0.7	1.3
1945	12	0.7	0.7	156.5	0.0	0.5	1.2	1.2	0.5	0.7	1.2
1946	1	0.6	0.6	156.5	0.0	0.4	1.2	1.2	0.5	0.6	1.2
1946	2	0.6	0.6	156.5	0.0	0.4	1.1	1.1	0.5	0.6	1.1
1946	3	0.6	0.6	156.5	0.0	0.4	1.1	1.1	0.4	0.6	1.1

Table D.3.3 CALCULATION RESULTS OF ARTIFICIAL RECHARGE BY MOL DAM (4/11)

Year	Month	Mol Dam (Active Storage: 35.0 MCM) Inflow (MCM)	Release from Dam (MCM)	W.L. of Reservoir (EL.m)	Storage Volume (MCM)	Runoff at Khadeji (MCM)	Runoff at N.H.B. (MCM)	Natural Recharge (MCM)	Artificial Recharge Rec. from Rem. Basin (MCM)	Recharge from Dam (MCM)	Total Recharge (MCM)
1946	4	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1946	5	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1946	6	0.5	0.5	156.5	0.0	0.3	0.9	0.9	0.4	0.5	0.9
1946	7	4.9	4.9	156.5	0.0	4.4	10.2	10.2	5.3	4.9	10.2
1946	8	2.2	2.2	156.5	0.0	2.3	4.9	4.9	2.6	2.2	4.9
1946	9	0.5	0.5	156.5	0.0	0.3	0.9	0.9	0.4	0.5	0.9
1946	10	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1946	11	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1946	12	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1947	1	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1947	2	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1947	3	0.3	0.3	156.5	0.0	0.2	0.7	0.7	0.3	0.3	0.7
1947	4	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1947	5	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1947	6	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1947	7	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1947	8	3.0	3.0	156.5	0.0	3.0	6.5	6.5	3.4	3.0	6.5
1947	9	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1947	10	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1947	11	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1947	12	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1948	1	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1948	2	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1948	3	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1948	4	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1948	5	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1948	6	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1948	7	1.0	1.0	156.5	0.0	1.1	2.4	2.4	1.3	1.0	2.4
1948	8	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1948	9	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1948	10	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1948	11	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1948	12	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1949	1	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1949	2	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1949	3	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1949	4	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1949	5	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1949	6	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1949	7	26.3	11.0	163.7	14.7	16.4	53.2	20.0	16.9	11.0	27.9
1949	8	52.2	4.1	169.5	34.2	35.9	105.4	47.0	51.2	4.1	55.4
1949	9	4.1	19.5	164.9	18.3	3.3	8.7	8.7	4.5	19.5	24.1
1949	10	0.5	18.8	156.5	0.0	0.4	0.9	0.9	0.4	18.8	19.2
1949	11	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.4	0.4	0.8
1949	12	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1950	1	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1950	2	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1950	3	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1950	4	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1950	5	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1950	6	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1950	7	8.3	8.3	156.5	0.0	7.0	17.8	13.6	9.5	8.3	17.8
1950	8	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1950	9	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1950	10	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1950	11	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1950	12	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1951	1	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1951	2	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1951	3	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1951	4	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1951	5	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1951	6	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1951	7	1.5	1.5	156.5	0.0	1.8	3.7	3.7	2.1	1.5	3.7
1951	8	0.9	0.9	156.5	0.0	1.0	2.1	2.1	1.2	0.9	2.1
1951	9	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1951	10	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1951	11	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1951	12	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3

Table D.3.3 CALCULATION RESULTS OF ARTIFICIAL RECHARGE BY MOL DAM (5/11)

Year	Month	Mol Dam (Active Storage: 35.0 MCM) Inflow (MCM)	Release from Dam (MCM)	W.L. of Reservoir (EL.m)	Storage Volume (MCM)	Runoff at Khadeji (MCM)	Runoff at N.H.B. (MCM)	Natural Recharge (MCM)	Artificial Recharge Rec. from Rem. Basin (MCM)	Recharge from Dam (MCM)	Total Recharge (MCM)
1952	1	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1952	2	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1952	3	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1952	4	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1952	5	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1952	6	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1952	7	38.1	7.8	168.2	29.4	25.2	76.9	32.3	19.8	7.8	27.7
1952	8	1.7	21.0	161.7	9.7	1.4	3.4	3.4	1.7	21.0	22.8
1952	9	0.5	10.2	156.5	0.0	0.7	1.3	1.3	0.8	10.2	11.1
1952	10	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1952	11	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1952	12	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1953	1	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1953	2	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1953	3	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1953	4	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1953	5	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1953	6	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1953	7	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1953	8	64.8	0.7	169.5	34.2	45.6	131.0	60.1	69.0	0.7	69.7
1953	9	3.3	19.5	164.7	17.5	2.8	7.4	7.4	4.0	19.5	23.5
1953	10	0.3	17.9	156.5	0.0	0.3	0.7	0.7	0.3	17.9	18.3
1953	11	0.3	0.3	156.5	0.0	0.3	0.6	0.6	0.3	0.3	0.6
1953	12	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1954	1	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1954	2	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1954	3	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1954	4	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1954	5	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1954	6	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1954	7	4.6	4.6	156.5	0.0	4.2	9.8	9.8	5.1	4.6	9.8
1954	8	1.0	1.0	156.5	0.0	1.1	2.3	2.3	1.3	1.0	2.3
1954	9	32.8	8.6	166.5	23.6	21.1	66.1	26.8	18.4	8.6	27.0
1954	10	2.0	21.2	158.9	4.0	1.6	3.8	3.8	1.7	21.2	23.0
1954	11	0.4	4.4	156.5	0.0	0.3	0.7	0.7	0.3	4.4	4.8
1954	12	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1955	1	0.3	0.3	156.5	0.0	0.3	0.6	0.6	0.3	0.3	0.6
1955	2	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1955	3	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1955	4	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1955	5	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1955	6	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1955	7	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1955	8	0.8	0.8	156.5	0.0	0.9	1.9	1.9	1.1	0.8	1.9
1955	9	12.6	12.6	156.5	0.0	10.3	28.3	14.0	15.6	12.6	28.3
1955	10	0.4	0.4	156.5	0.0	0.2	0.7	0.7	0.2	0.4	0.7
1955	11	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1955	12	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1956	1	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1956	2	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1956	3	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1956	4	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1956	5	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1956	6	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1956	7	36.7	8.2	167.8	27.6	24.0	73.9	30.8	19.4	8.2	27.7
1956	8	13.0	16.3	166.6	23.8	10.6	28.8	15.7	15.7	16.3	32.1
1956	9	1.7	20.5	159.3	4.6	1.0	2.9	2.9	1.2	20.5	21.7
1956	10	2.2	6.9	156.5	0.0	1.9	4.5	4.5	2.3	6.9	9.2
1956	11	0.5	0.5	156.5	0.0	0.3	0.9	0.9	0.4	0.5	0.9
1956	12	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1957	1	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1957	2	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1957	3	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1957	4	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1957	5	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1957	6	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1957	7	0.3	0.3	156.5	0.0	0.4	0.8	0.8	0.4	0.3	0.8
1957	8	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1957	9	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5

Table D.3.3 CALCULATION RESULTS OF ARTIFICIAL RECHARGE BY MOL DAM (6/11)

Year	Month	Mol Dam (Active Storage: 35.0 MCM) Inflow (MCM)	Release from Dam (MCM)	W.L. of Reservoir (EL.m)	Storage Volume (MCM)	Runoff at Khadeji (MCM)	Runoff at N.H.B. (MCM)	Natural Recharge (MCM)	Artificial Recharge: Rec. from Rem. Basin (MCM)	Recharge from Dam (MCM)	Total Recharge (MCM)
1957	10	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1957	11	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1957	12	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1958	1	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1958	2	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1958	3	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1958	4	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1958	5	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1958	6	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1958	7	22.5	11.8	161.9	10.1	15.5	47.6	17.5	16.4	11.8	28.3
1958	8	1.3	11.5	156.5	0.0	0.8	2.2	2.2	0.9	11.5	12.4
1958	9	0.9	0.9	156.5	0.0	1.0	2.1	2.1	1.2	0.9	2.1
1958	10	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1958	11	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1958	12	0.5	0.5	156.5	0.0	0.4	1.1	1.1	0.5	0.5	1.1
1959	1	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1959	2	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1959	3	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1959	4	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1959	5	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1959	6	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1959	7	78.0	0.0	169.5	34.1	55.6	157.8	73.8	60.8	0.0	60.8
1959	8	5.9	18.9	165.6	20.6	5.2	13.6	6.8	7.7	18.9	26.6
1959	9	121.9	0.0	169.5	34.2	89.0	248.6	110.4	113.5	0.0	113.5
1959	10	5.2	19.3	165.3	19.5	3.9	11.2	2.6	6.0	19.3	25.3
1959	11	1.7	20.2	157.0	0.8	1.4	3.7	3.7	1.9	20.2	22.2
1959	12	0.8	1.6	156.5	0.0	0.6	1.5	1.5	0.6	1.6	2.3
1960	1	0.8	0.8	156.5	0.0	0.6	1.5	1.5	0.6	0.8	1.5
1960	2	0.7	0.7	156.5	0.0	0.5	1.4	1.4	0.6	0.7	1.4
1960	3	0.7	0.7	156.5	0.0	0.5	1.4	1.4	0.6	0.7	1.4
1960	4	0.7	0.7	156.5	0.0	0.5	1.3	1.3	0.6	0.7	1.3
1960	5	0.6	0.6	156.5	0.0	0.5	1.2	1.2	0.5	0.6	1.2
1960	6	0.6	0.6	156.5	0.0	0.5	1.2	1.2	0.5	0.6	1.2
1960	7	2.7	2.7	156.5	0.0	2.7	5.8	5.8	3.1	2.7	5.8
1960	8	1.0	1.0	156.5	0.0	1.1	2.4	2.4	1.3	1.0	2.4
1960	9	0.6	0.6	156.5	0.0	0.4	1.1	1.1	0.5	0.6	1.1
1960	10	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1960	11	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1960	12	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1961	1	0.5	0.5	156.5	0.0	0.3	0.9	0.9	0.4	0.5	0.9
1961	2	0.8	0.8	156.5	0.0	0.6	1.5	1.5	0.7	0.8	1.5
1961	3	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.4	0.4	0.8
1961	4	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1961	5	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1961	6	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1961	7	42.4	6.7	169.5	34.1	28.5	85.6	37.0	21.5	6.7	28.3
1961	8	53.8	2.5	169.5	34.2	37.3	110.0	43.9	53.0	2.5	55.6
1961	9	46.2	1.3	169.5	34.2	31.5	97.2	24.0	68.8	1.3	70.2
1961	10	6.0	20.1	165.3	19.5	4.8	12.1	8.3	6.1	20.1	26.2
1961	11	1.3	20.6	156.5	0.0	0.9	2.3	2.3	0.9	20.6	21.6
1961	12	1.1	1.1	156.5	0.0	0.8	2.0	2.0	0.9	1.1	2.0
1962	1	1.0	1.0	156.5	0.0	0.8	1.9	1.9	0.8	1.0	1.9
1962	2	1.0	1.0	156.5	0.0	0.7	1.9	1.9	0.8	1.0	1.9
1962	3	0.9	0.9	156.5	0.0	0.7	1.8	1.8	0.8	0.9	1.8
1962	4	0.9	0.9	156.5	0.0	0.7	1.7	1.7	0.7	0.9	1.7
1962	5	0.9	0.9	156.5	0.0	0.7	1.6	1.6	0.7	0.9	1.6
1962	6	0.8	0.8	156.5	0.0	0.6	1.5	1.5	0.7	0.8	1.5
1962	7	10.2	10.2	156.5	0.0	8.5	22.3	14.7	12.0	10.2	22.3
1962	8	2.7	2.7	156.5	0.0	2.7	5.8	5.8	3.1	2.7	5.8
1962	9	32.4	8.8	166.3	22.9	20.8	65.1	26.8	18.3	8.8	27.1
1962	10	2.5	21.2	158.9	3.9	1.9	4.7	4.7	2.1	21.2	23.4
1962	11	0.8	4.8	156.5	0.0	0.7	1.6	1.6	0.7	4.8	5.6
1962	12	0.8	0.8	156.5	0.0	0.6	1.6	1.6	0.7	0.8	1.6
1963	1	0.8	0.8	156.5	0.0	0.6	1.5	1.5	0.7	0.8	1.5
1963	2	0.7	0.7	156.5	0.0	0.6	1.4	1.4	0.6	0.7	1.4
1963	3	0.7	0.7	156.5	0.0	0.5	1.4	1.4	0.6	0.7	1.4
1963	4	0.7	0.7	156.5	0.0	0.5	1.3	1.3	0.6	0.7	1.3
1963	5	0.6	0.6	156.5	0.0	0.5	1.2	1.2	0.5	0.6	1.2
1963	6	0.6	0.6	156.5	0.0	0.5	1.2	1.2	0.5	0.6	1.2

Table D.3.3 CALCULATION RESULTS OF ARTIFICIAL RECHARGE BY MOL DAM (7/11)

Year	Month	Mol Dam (Active Storage: 35.0 MCM) Inflow (MCM)	Release from Dam (MCM)	W.L. of Reservoir (EL.m)	Storage Volume (MCM)	Runoff at Khadeji (MCM)	Runoff at N.H.B. (MCM)	Natural Recharge (MCM)	Artificial Recharge Rec. from Rem. Basin (MCM)	Recharge from Dam (MCM)	Total Recharge (MCM)
1963	7	0.6	0.6	156.5	0.0	0.4	1.2	1.2	0.5	0.6	1.2
1963	8	0.6	0.6	156.5	0.0	0.4	1.1	1.1	0.5	0.6	1.1
1963	9	0.5	0.5	156.5	0.0	0.4	1.1	1.1	0.5	0.5	1.1
1963	10	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1963	11	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1963	12	0.5	0.5	156.5	0.0	0.4	0.9	0.9	0.4	0.5	0.9
1964	1	0.4	0.4	156.5	0.0	0.3	0.9	0.9	0.4	0.4	0.9
1964	2	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.4	0.4	0.8
1964	3	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1964	4	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1964	5	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1964	6	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1964	7	8.9	8.9	156.5	0.0	7.5	19.4	13.8	10.5	8.9	19.4
1964	8	3.5	3.5	156.5	0.0	3.3	7.4	7.4	3.9	3.5	7.4
1964	9	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1964	10	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1964	11	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1964	12	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1965	1	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1965	2	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1965	3	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1965	4	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1965	5	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1965	6	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1965	7	14.8	14.6	156.5	0.0	12.0	33.6	14.1	18.7	14.6	33.4
1965	8	0.7	0.7	156.5	0.0	0.5	1.3	1.3	0.6	0.7	1.3
1965	9	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1965	10	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1965	11	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1965	12	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1966	1	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1966	2	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1966	3	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1966	4	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1966	5	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1966	6	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1966	7	7.1	7.1	156.5	0.0	6.0	15.0	13.2	7.9	7.1	15.0
1966	8	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1966	9	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1966	10	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1966	11	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1966	12	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1967	1	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1967	2	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1967	3	4.1	4.1	156.5	0.0	3.8	8.9	8.9	4.8	4.1	8.9
1967	4	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1967	5	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1967	6	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1967	7	181.9	0.0	169.5	34.1	134.9	370.2	173.1	159.0	0.0	159.0
1967	8	19.1	1.6	169.5	34.2	15.2	54.1	27.0	25.0	1.6	26.6
1967	9	5.3	16.4	166.2	22.6	3.8	13.5	7.0	8.1	16.4	24.5
1967	10	1.0	21.2	157.8	2.0	0.7	1.9	1.9	0.8	21.2	22.1
1967	11	0.8	2.9	156.5	0.0	0.6	1.6	1.6	0.7	2.9	3.6
1967	12	0.8	0.8	156.5	0.0	0.6	1.5	1.5	0.7	0.8	1.5
1968	1	0.8	0.8	156.5	0.0	0.6	1.5	1.5	0.6	0.8	1.5
1968	2	0.7	0.7	156.5	0.0	0.5	1.4	1.4	0.6	0.7	1.4
1968	3	0.7	0.7	156.5	0.0	0.5	1.3	1.3	0.6	0.7	1.3
1968	4	0.7	0.7	156.5	0.0	0.5	1.3	1.3	0.5	0.7	1.3
1968	5	0.6	0.6	156.5	0.0	0.5	1.2	1.2	0.5	0.6	1.2
1968	6	0.6	0.6	156.5	0.0	0.4	1.1	1.1	0.5	0.6	1.1
1968	7	0.6	0.6	156.5	0.0	0.4	1.2	1.2	0.5	0.6	1.2
1968	8	0.6	0.6	156.5	0.0	0.4	1.1	1.1	0.5	0.6	1.1
1968	9	0.5	0.5	156.5	0.0	0.4	1.1	1.1	0.5	0.5	1.1
1968	10	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1968	11	0.5	0.5	156.5	0.0	0.3	0.9	0.9	0.4	0.5	0.9
1968	12	0.5	0.5	156.5	0.0	0.3	0.9	0.9	0.4	0.5	0.9
1969	1	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1969	2	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1969	3	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8

Table D.3.3 CALCULATION RESULTS OF ARTIFICIAL RECHARGE BY MOL DAM (8/11)

Year	Month	Mol Dam (Active Storage: 35.0 MCM)				Runoff at Khadeji (MCM)	Runoff at N.H.B. (MCM)	Natural Recharge (MCM)	Artificial Recharge		
		Inflow (MCM)	Release from Dam (MCM)	W.L. of Reservoir (EL.m)	Storage Volume (MCM)				Rec. from Rem. Basin (MCM)	Recharge from Dam (MCM)	Total Recharge (MCM)
1969	4	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1969	5	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1969	6	0.3	0.3	156.5	0.0	0.2	0.7	0.7	0.3	0.3	0.7
1969	7	1.4	1.4	156.5	0.0	1.7	3.4	3.4	2.0	1.4	3.4
1969	8	0.3	0.3	156.5	0.0	0.2	0.7	0.7	0.3	0.3	0.7
1969	9	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1969	10	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1969	11	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1969	12	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1970	1	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1970	2	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1970	3	0.7	0.7	156.5	0.0	0.6	1.5	1.5	0.7	0.7	1.5
1970	4	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1970	5	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1970	6	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1970	7	33.5	9.0	166.6	23.7	21.7	67.6	27.6	18.6	9.0	27.7
1970	8	37.1	8.0	169.5	34.2	24.5	75.0	31.0	27.4	8.0	35.5
1970	9	14.7	14.2	169.4	33.9	12.1	33.2	13.4	18.5	14.2	32.8
1970	10	2.7	21.2	163.7	14.9	1.8	4.7	4.7	1.9	21.2	23.2
1970	11	0.7	15.7	156.5	0.0	0.6	1.4	1.4	0.6	15.7	16.4
1970	12	0.7	0.7	156.5	0.0	0.6	1.4	1.4	0.6	0.7	1.4
1971	1	0.7	0.7	156.5	0.0	0.5	1.3	1.3	0.6	0.7	1.3
1971	2	0.7	0.7	156.5	0.0	0.5	1.2	1.2	0.5	0.7	1.2
1971	3	0.6	0.6	156.5	0.0	0.5	1.2	1.2	0.5	0.6	1.2
1971	4	0.6	0.6	156.5	0.0	0.5	1.1	1.1	0.5	0.6	1.1
1971	5	0.6	0.6	156.5	0.0	0.4	1.1	1.1	0.5	0.6	1.1
1971	6	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1971	7	1.2	1.2	156.5	0.0	1.3	2.8	2.8	1.5	1.2	2.8
1971	8	1.1	1.1	156.5	0.0	1.1	2.4	2.4	1.3	1.1	2.4
1971	9	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.5	0.5	1.0
1971	10	0.5	0.5	156.5	0.0	0.4	0.9	0.9	0.4	0.5	0.9
1971	11	0.4	0.4	156.5	0.0	0.3	0.9	0.9	0.4	0.4	0.9
1971	12	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.4	0.4	0.8
1972	1	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1972	2	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1972	3	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1972	4	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1972	5	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1972	6	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1972	7	0.3	0.3	156.5	0.0	0.4	0.8	0.8	0.4	0.3	0.8
1972	8	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1972	9	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1972	10	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1972	11	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1972	12	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1973	1	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1973	2	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1973	3	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1973	4	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1973	5	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1973	6	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1973	7	51.2	4.3	169.5	34.1	35.2	103.4	45.9	33.6	4.3	38.0
1973	8	2.5	20.8	163.9	15.3	2.2	5.3	5.3	2.8	20.8	23.6
1973	9	0.3	15.6	156.5	0.0	0.3	0.7	0.7	0.3	15.6	16.0
1973	10	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.3	0.3	0.6
1973	11	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1973	12	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1974	1	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1974	2	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1974	3	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1974	4	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1974	5	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1974	6	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1974	7	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.2	0.2	0.4
1974	8	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1974	9	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1974	10	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1974	11	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1974	12	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3

Table D.3.3 CALCULATION RESULTS OF ARTIFICIAL RECHARGE BY MOL DAM (9/11)

Year	Month	Mol Dam (Active Storage: 35.0 MCM) Inflow (MCM)	Release from Dam (MCM)	W.L. of Reservoir (EL.m)	Storage Volume (MCM)	Runoff at Khadeji (MCM)	Runoff at N.H.B. (MCM)	Natural Recharge (MCM)	Artificial Recharge Rec. from Rem. Basin (MCM)	Recharge from Dam (MCM)	Total Recharge (MCM)
1975	1	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1975	2	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1975	3	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1975	4	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1975	5	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1975	6	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1975	7	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1975	8	8.7	8.7	156.5	0.0	7.3	18.9	13.3	10.2	8.7	18.9
1975	9	0.2	0.2	156.5	0.0	0.4	0.6	0.6	0.4	0.2	0.6
1975	10	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1975	11	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1975	12	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1976	1	0.4	0.4	156.5	0.0	0.9	1.5	1.5	1.0	0.4	1.5
1976	2	0.8	0.8	156.5	0.0	0.1	0.9	0.9	0.1	0.8	0.9
1976	3	1.4	1.4	156.5	0.0	0.2	1.7	1.7	0.2	1.4	1.7
1976	4	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1976	5	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1976	6	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1976	7	6.7	6.7	156.5	0.0	9.1	21.8	7.3	15.1	6.7	21.8
1976	8	0.9	0.9	156.5	0.0	0.4	1.4	1.4	0.5	0.9	1.4
1976	9	13.6	13.6	156.5	0.0	9.0	26.4	16.8	12.7	13.6	26.4
1976	10	0.3	0.3	156.5	0.0	0.1	0.5	0.5	0.1	0.3	0.5
1976	11	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1976	12	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1977	1	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1977	2	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1977	3	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1977	4	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1977	5	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1977	6	12.2	12.2	156.5	0.0	9.1	23.2	19.9	10.9	12.2	23.2
1977	7	22.6	0.0	166.1	22.0	53.3	101.3	34.2	48.5	0.0	48.5
1977	8	1.6	20.8	158.1	2.5	4.7	6.9	6.9	5.2	20.8	26.1
1977	9	1.1	3.7	156.5	0.0	6.2	8.5	7.8	7.4	3.7	11.1
1977	10	0.3	0.3	156.5	0.0	0.3	0.6	0.6	0.3	0.3	0.6
1977	11	0.2	0.2	156.5	0.0	0.3	0.6	0.6	0.3	0.2	0.6
1977	12	0.2	0.2	156.5	0.0	0.3	0.6	0.6	0.3	0.2	0.6
1978	1	0.2	0.2	156.5	0.0	0.3	0.6	0.6	0.3	0.2	0.6
1978	2	0.2	0.2	156.5	0.0	0.3	0.5	0.5	0.3	0.2	0.5
1978	3	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1978	4	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1978	5	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1978	6	0.3	0.3	156.5	0.0	0.7	1.1	1.1	0.8	0.3	1.1
1978	7	55.1	6.6	169.5	34.1	38.5	108.4	51.6	35.9	6.6	42.6
1978	8	63.8	4.9	169.5	34.2	31.8	112.1	44.7	52.9	4.9	57.8
1978	9	5.1	20.3	165.0	18.5	3.7	9.3	8.9	4.1	20.3	24.5
1978	10	0.6	19.2	156.5	0.0	0.5	1.2	1.2	0.5	19.2	19.8
1978	11	0.6	0.6	156.5	0.0	0.5	1.2	1.2	0.5	0.6	1.2
1978	12	0.6	0.6	156.5	0.0	0.5	1.1	1.1	0.5	0.6	1.1
1979	1	0.6	0.6	156.5	0.0	0.5	1.1	1.1	0.5	0.6	1.1
1979	2	0.7	0.7	156.5	0.0	0.7	1.6	1.6	0.8	0.7	1.6
1979	3	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1979	4	0.5	0.5	156.5	0.0	0.4	1.0	1.0	0.4	0.5	1.0
1979	5	0.5	0.5	156.5	0.0	0.4	0.9	0.9	0.4	0.5	0.9
1979	6	0.4	0.4	156.5	0.0	0.4	0.9	0.9	0.4	0.4	0.9
1979	7	0.4	0.4	156.5	0.0	0.4	0.8	0.8	0.4	0.4	0.8
1979	8	9.6	9.6	156.5	0.0	2.5	14.4	9.7	4.7	9.6	14.4
1979	9	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1979	10	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1979	11	0.4	0.4	156.5	0.0	0.3	0.8	0.8	0.3	0.4	0.8
1979	12	1.1	1.1	156.5	0.0	0.9	2.1	2.1	1.0	1.1	2.1
1980	1	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1980	2	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1980	3	0.3	0.3	156.5	0.0	0.3	0.6	0.6	0.3	0.3	0.6
1980	4	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1980	5	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1980	6	1.0	1.0	156.5	0.0	0.8	2.0	2.0	1.0	1.0	2.0
1980	7	0.7	0.7	156.5	0.0	2.6	3.5	3.5	2.8	0.7	3.5
1980	8	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1980	9	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5

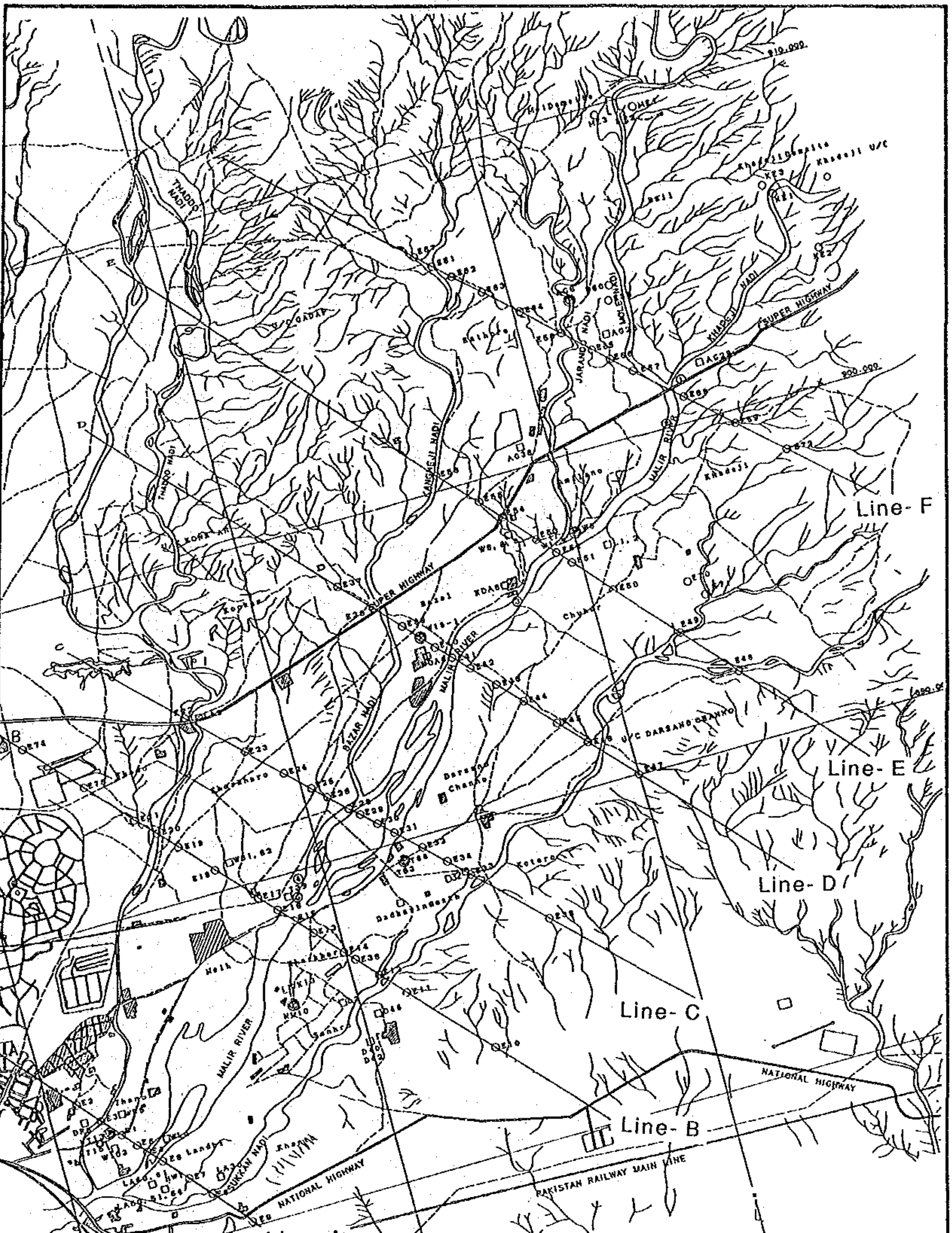
Table D.3.3 CALCULATION RESULTS OF ARTIFICIAL RECHARGE BY MOL DAM (10/11)

Year	Month	Mol Dam (Active Storage: 35.0 MCM)				Runoff at Khadeji	Runoff at N.H.B.	Natural Recharge	Artificial Recharge		
		Inflow	Release from Dam	W.L. of Reservoir	Storage Volume				Rec. from Rem. Basin	Recharge from Dam	Total Recharge
		(MCM)	(MCM)	(EL.m)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1980	10	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1980	11	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1980	12	0.8	0.8	156.5	0.0	0.5	1.4	1.4	0.6	0.8	1.4
1981	1	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1981	2	0.9	0.9	156.5	0.0	0.2	1.1	1.1	0.2	0.9	1.1
1981	3	1.0	1.0	156.5	0.0	1.0	2.2	2.2	1.2	1.0	2.2
1981	4	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1981	5	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1981	6	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1981	7	1.9	1.9	156.5	0.0	0.8	3.0	3.0	1.0	1.9	3.0
1981	8	7.8	7.8	156.5	0.0	21.4	38.6	15.9	17.8	7.8	25.6
1981	9	0.2	0.2	156.5	0.0	1.9	2.2	2.2	1.9	0.2	2.2
1981	10	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1981	11	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1981	12	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1982	1	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1982	2	0.1	0.1	156.5	0.0	0.4	0.6	0.6	0.4	0.1	0.6
1982	3	0.1	0.1	156.5	0.0	0.2	0.4	0.4	0.2	0.1	0.4
1982	4	0.1	0.1	156.5	0.0	0.2	0.4	0.4	0.2	0.1	0.4
1982	5	0.1	0.1	156.5	0.0	0.2	0.3	0.3	0.2	0.1	0.3
1982	6	0.1	0.1	156.5	0.0	0.2	0.3	0.3	0.2	0.1	0.3
1982	7	0.4	0.4	156.5	0.0	0.6	1.2	1.2	0.7	0.4	1.2
1982	8	3.2	3.2	156.5	0.0	7.4	16.2	6.0	13.0	3.2	16.2
1982	9	0.1	0.1	156.5	0.0	0.2	0.3	0.3	0.2	0.1	0.3
1982	10	0.1	0.1	156.5	0.0	0.2	0.3	0.3	0.2	0.1	0.3
1982	11	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1982	12	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1983	1	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1983	2	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1983	3	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1983	4	0.3	0.3	156.5	0.0	1.1	1.4	1.4	1.1	0.3	1.4
1983	5	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1983	6	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1983	7	0.1	0.1	156.5	0.0	1.9	2.2	2.2	2.1	0.1	2.2
1983	8	11.1	11.1	156.5	0.0	14.8	32.2	13.2	15.2	11.1	26.4
1983	9	0.9	0.9	156.5	0.0	1.8	2.8	2.8	1.9	0.9	2.8
1983	10	0.1	0.1	156.5	0.0	0.2	0.4	0.4	0.2	0.1	0.4
1983	11	0.1	0.1	156.5	0.0	0.2	0.4	0.4	0.2	0.1	0.4
1983	12	0.1	0.1	156.5	0.0	0.2	0.3	0.3	0.2	0.1	0.3
1984	1	0.1	0.1	156.5	0.0	0.2	0.3	0.3	0.2	0.1	0.3
1984	2	0.1	0.1	156.5	0.0	0.2	0.3	0.3	0.2	0.1	0.3
1984	3	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1984	4	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1984	5	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1984	6	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1984	7	0.4	0.4	156.5	0.0	0.2	0.7	0.7	0.2	0.4	0.7
1984	8	108.2	0.0	169.5	34.2	66.5	204.9	97.6	83.4	0.0	83.4
1984	9	4.8	20.4	164.9	18.1	4.2	9.3	4.9	4.5	20.4	24.9
1984	10	0.4	18.5	156.5	0.0	0.3	0.8	0.8	0.4	18.5	18.9
1984	11	0.4	0.4	156.5	0.0	0.3	0.7	0.7	0.3	0.4	0.7
1984	12	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1985	1	0.3	0.3	156.5	0.0	0.3	0.7	0.7	0.3	0.3	0.7
1985	2	0.3	0.3	156.5	0.0	0.3	0.6	0.6	0.3	0.3	0.6
1985	3	0.3	0.3	156.5	0.0	0.3	0.6	0.6	0.3	0.3	0.6
1985	4	0.5	0.5	156.5	0.0	0.3	0.9	0.9	0.4	0.5	0.9
1985	5	0.3	0.3	156.5	0.0	0.2	0.6	0.6	0.2	0.3	0.6
1985	6	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1985	7	7.2	7.2	156.5	0.0	8.0	16.8	14.7	9.6	7.2	16.8
1985	8	0.5	0.5	156.5	0.0	0.6	1.1	1.1	0.6	0.5	1.1
1985	9	0.3	0.3	156.5	0.0	0.2	0.5	0.5	0.2	0.3	0.5
1985	10	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1985	11	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1985	12	0.2	0.2	156.5	0.0	0.2	0.5	0.5	0.2	0.2	0.5
1986	1	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1986	2	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1986	3	0.2	0.2	156.5	0.0	0.2	0.4	0.4	0.2	0.2	0.4
1986	4	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1986	5	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1986	6	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3

Table D.3.3 CALCULATION RESULTS OF ARTIFICIAL RECHARGE BY MOL DAM (11/11)

Year	Month	Mol Dam (Active Storage: 35.0 MCM)				Runoff at Khadeji	Runoff at N.H.B.	Natural Recharge	Artificial Recharge		
		Inflow (MCM)	Release from Dam (MCM)	W.L. of Reservoir (EL.m)	Storage Volume (MCM)	(MCM)	(MCM)	(MCM)	Rec. from Rem. Basin (MCM)	Recharge from Dam (MCM)	Total Recharge (MCM)
1986	7	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1986	8	13.3	13.3	156.5	0.0	9.2	27.2	15.3	13.9	13.3	27.2
1986	9	0.7	0.7	156.5	0.0	0.1	0.9	0.9	0.2	0.7	0.9
1986	10	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1986	11	0.2	0.2	156.5	0.0	0.1	0.4	0.4	0.1	0.2	0.4
1986	12	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1987	1	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1987	2	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1987	3	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1987	4	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1987	5	0.1	0.1	156.5	0.0	0.1	0.3	0.3	0.1	0.1	0.3
1987	6	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1987	7	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1987	8	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1987	9	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1987	10	0.1	0.1	156.5	0.0	0.0	0.2	0.2	0.0	0.1	0.2
1987	11	0.1	0.1	156.5	0.0	0.0	0.2	0.2	0.0	0.1	0.2
1987	12	0.1	0.1	156.5	0.0	0.0	0.1	0.1	0.0	0.1	0.1
1988	1	0.1	0.1	156.5	0.0	0.0	0.1	0.1	0.0	0.1	0.1
1988	2	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1988	3	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1988	4	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1988	5	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1988	6	0.0	0.0	156.5	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1988	7	8.1	8.1	156.5	0.0	6.8	17.5	13.1	9.4	8.1	17.5
1988	8	10.2	10.2	156.5	0.0	8.5	22.7	13.4	12.4	10.2	22.7
1988	9	0.2	0.2	156.5	0.0	0.1	0.3	0.3	0.1	0.2	0.3
1988	10	0.1	0.1	156.5	0.0	0.1	0.2	0.2	0.1	0.1	0.2
1988	11	0.1	0.1	156.5	0.0	0.0	0.2	0.2	0.0	0.1	0.2
1988	12	0.1	0.1	156.5	0.0	0.0	0.2	0.2	0.0	0.1	0.2
MCM/YR		44.8	23.6	157.3	23.1	33.9	93.2	46.5	41.1	23.6	64.7

FIGURES



Legend

- ○ Electric Resistivity Survey
- ② Infilteration Test and Soil Sampling
- Ⓟ Pumping Test
- □ Well

0 1 2 3 4 5Km

Fig. D.2-1 Location Map of Investigations

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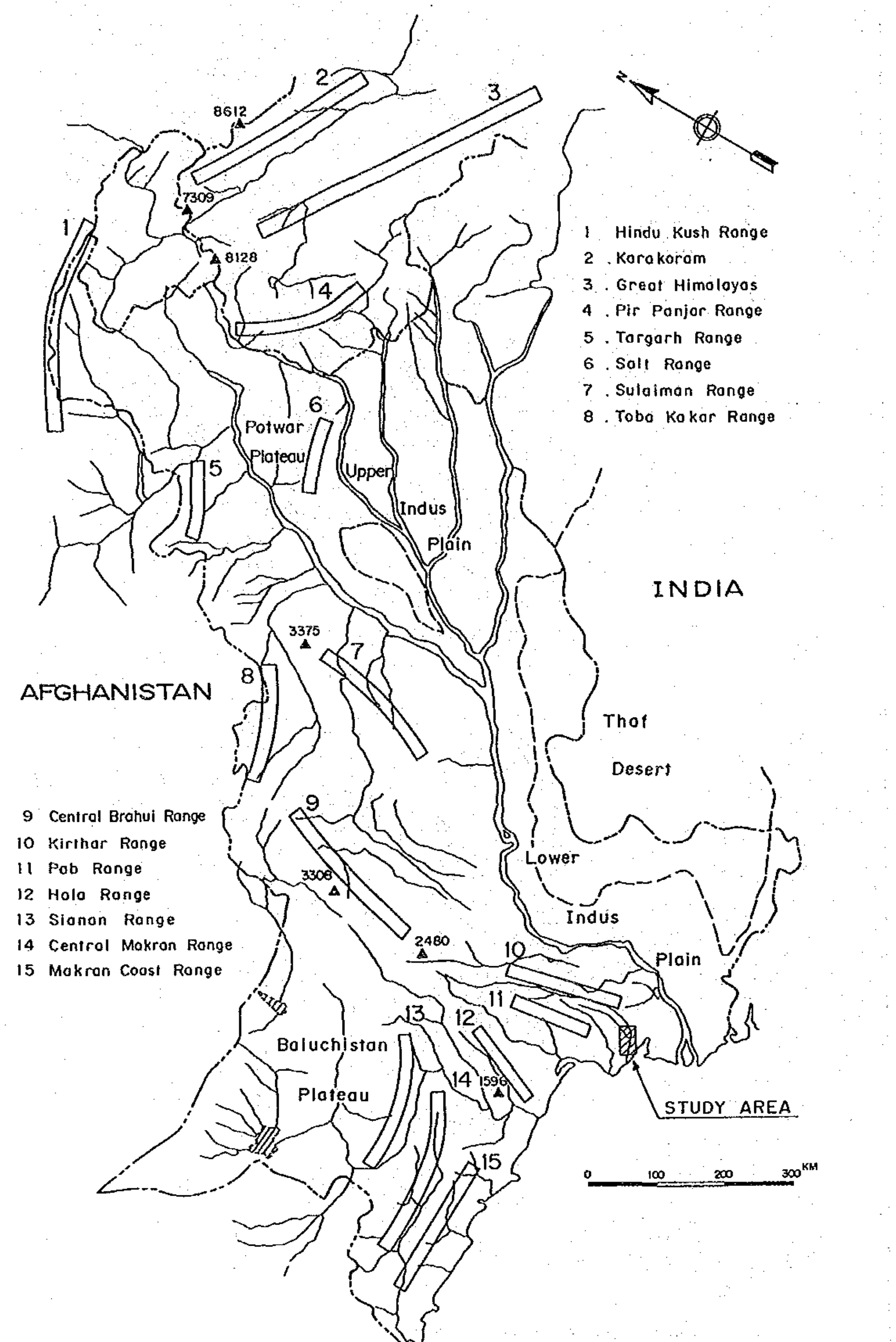

Fig. D.2-2 Geological Map of Pakistan

ISLAMIC REPUBLIC OF PAKISTAN GOVERNMENT OF SIND
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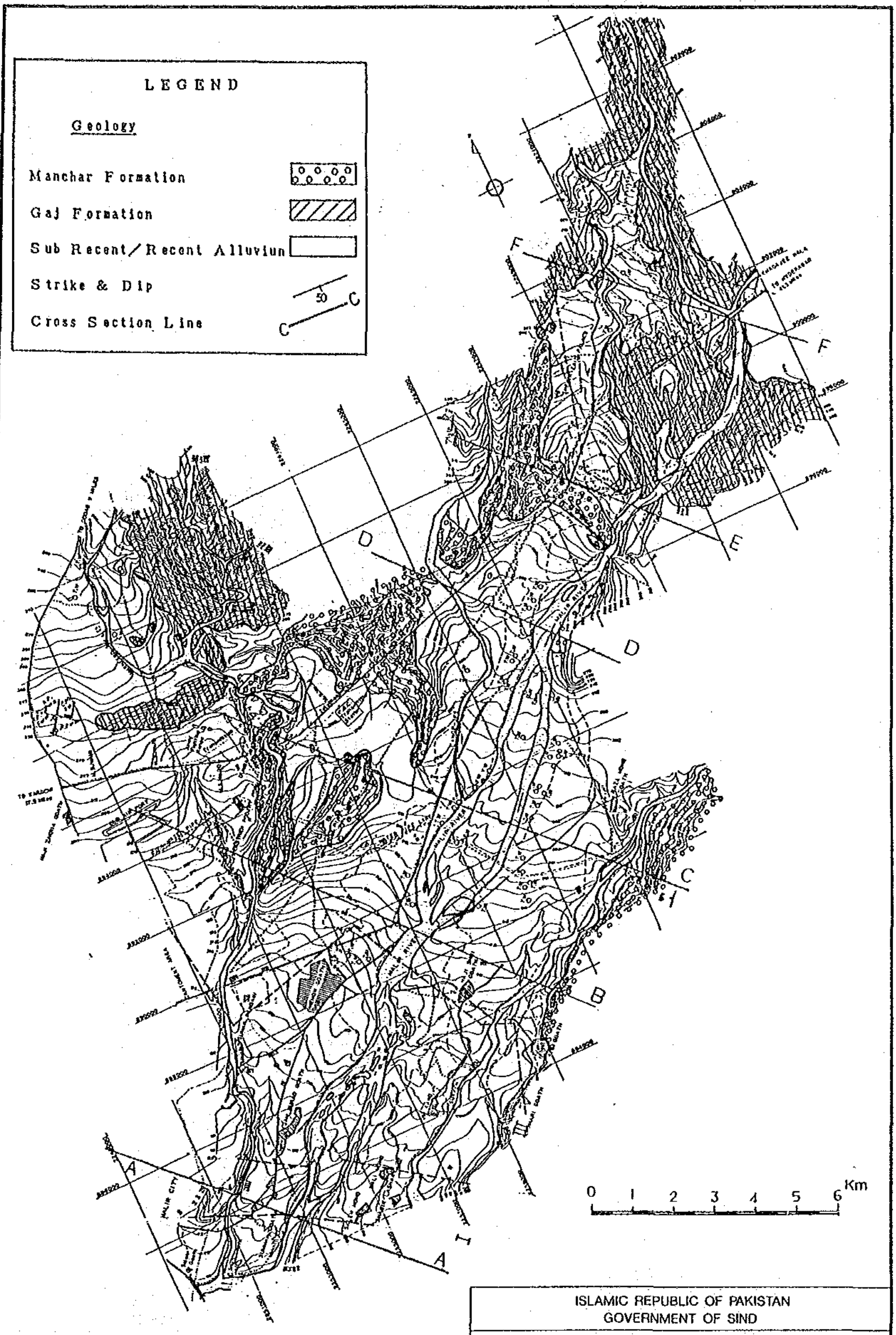

Fig. D.2-3 Geological Map of Study Area

ISLAMIC REPUBLIC OF PAKISTAN GOVERNMENT OF SIND
FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN THE MALIR BASIN
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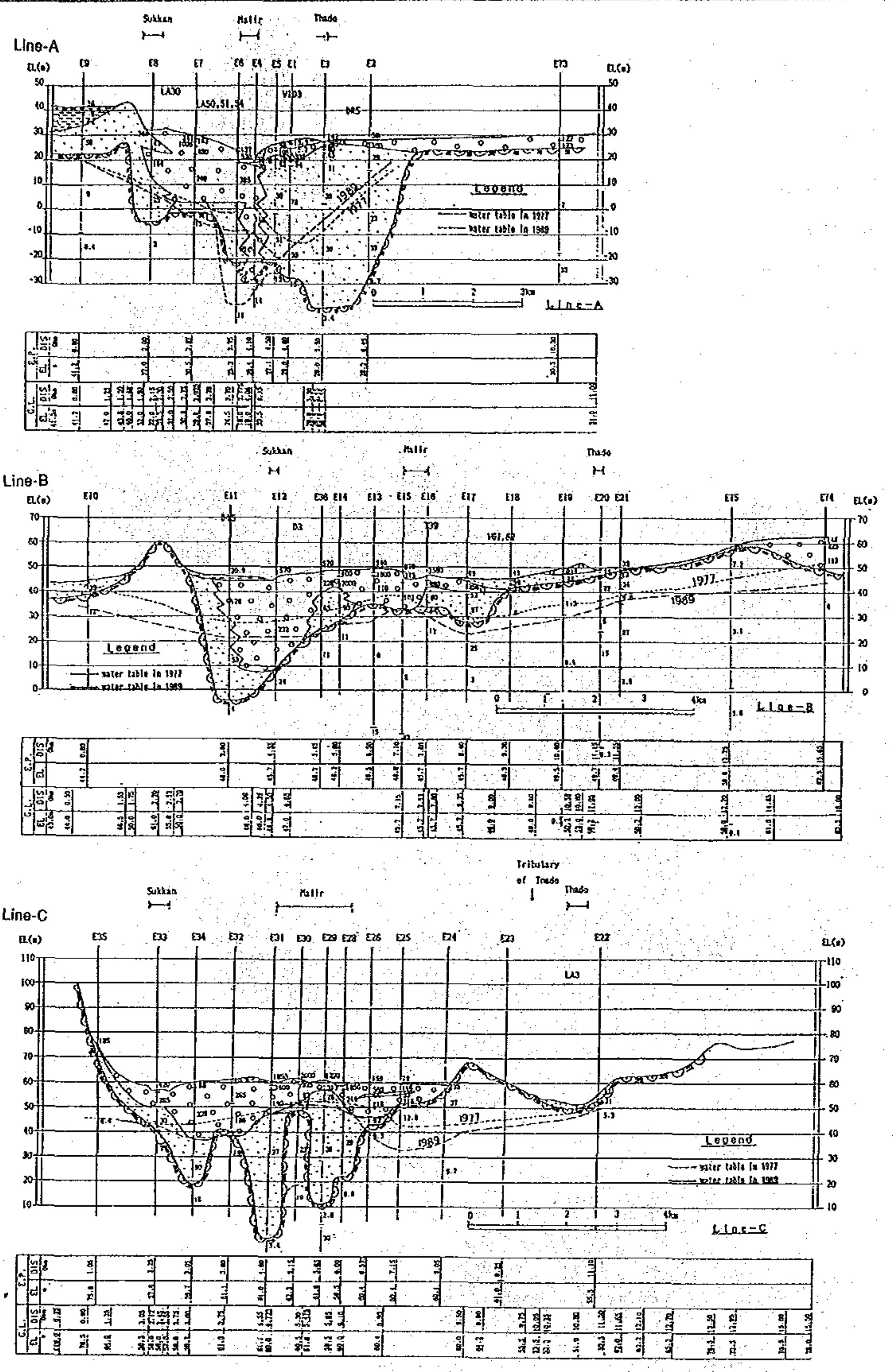

Periods	Symbol	Hydrogeology		True Resistivities of Individual layers. unit: ohm-meters
Quaternary deposits		Aquifer	Gravelly layer	100 ~ 3000
		Aquitard	Arenaceous layer	20 ~ 100
		Aquiclude	Argillaceous layer	5 ~ 20
Pliocene-Tertiary		Aquifuge	Manchar formation	0.4 ~ 40
Miocene-Tertiary		Aquifuge	Gaj formation	7 ~ 20 (30 ~70)

Fig. D.2-4 Hydrogeological Profiles (1/2)

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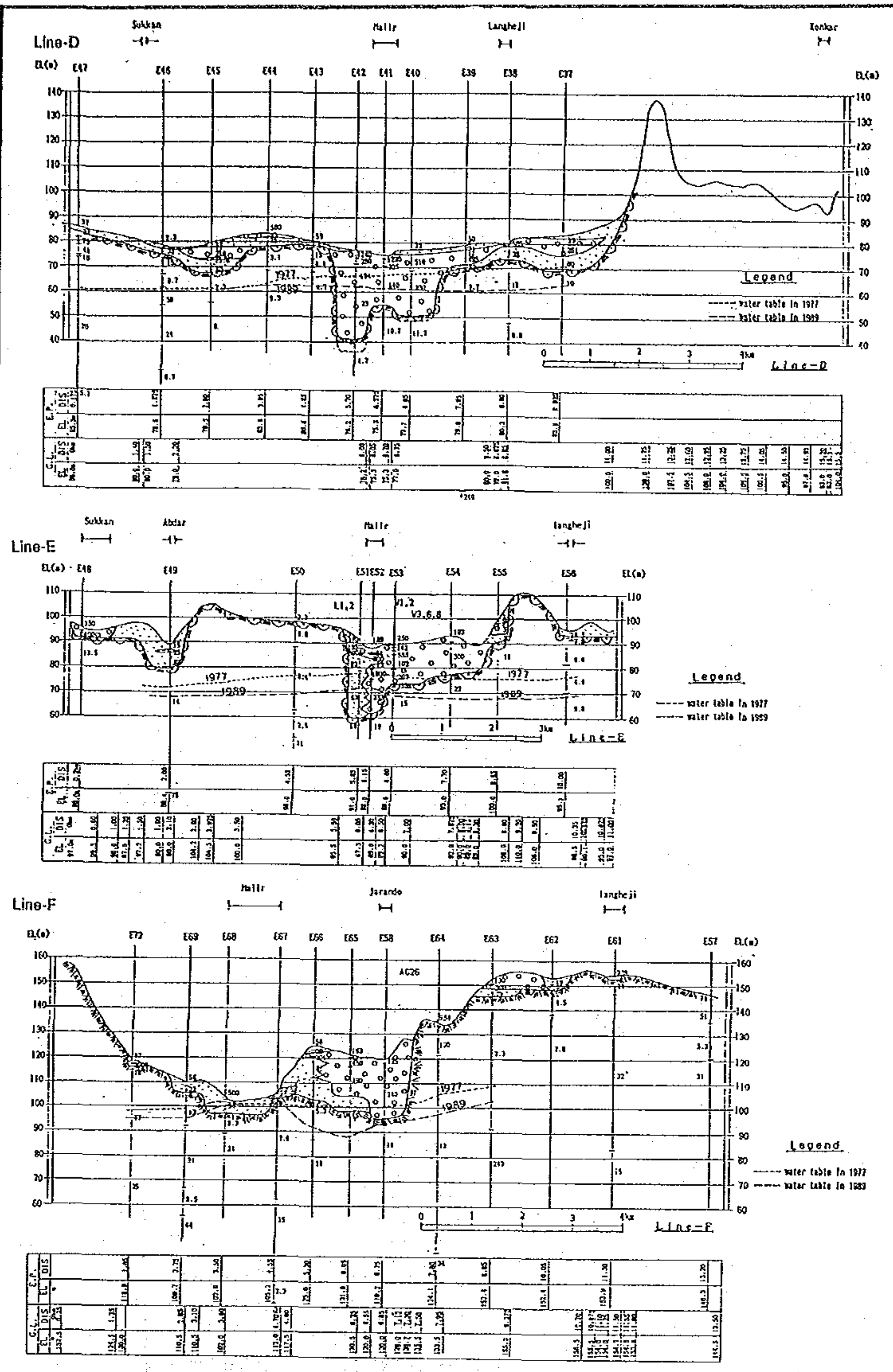

Periods	Symbol	Hydrogeology		True Resistivities of individual layers. unit: ohm-meters
Quaternary deposits		Aquifer	Gravelly layer	100 ~ 3000
		Aquitard	Arenaceous layer	20 ~ 100
		Aquiclude	Argillaceous layer	5 ~ 20
Pliocene-Tertiary		Aquifuge	Manchar formation	0.4 ~ 40
Miocene-Tertiary		Aquifuge	Gaj formation	7 ~ 20 (30 ~70)

Fig. D.2-4 Hydrogeological Profiles (2/2)

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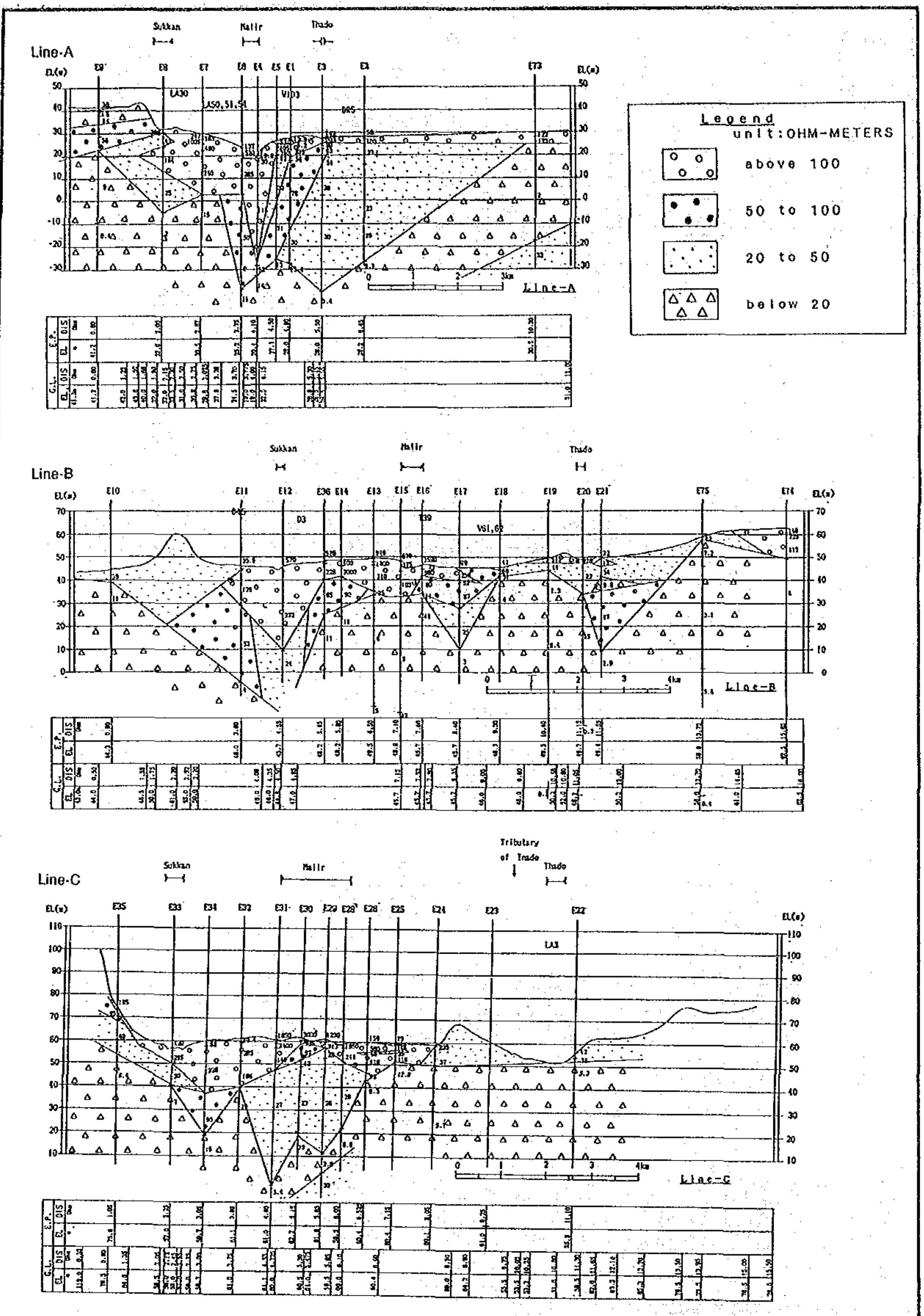

Fig. D.2-5 Electric Resistivity Profiles (1/2)

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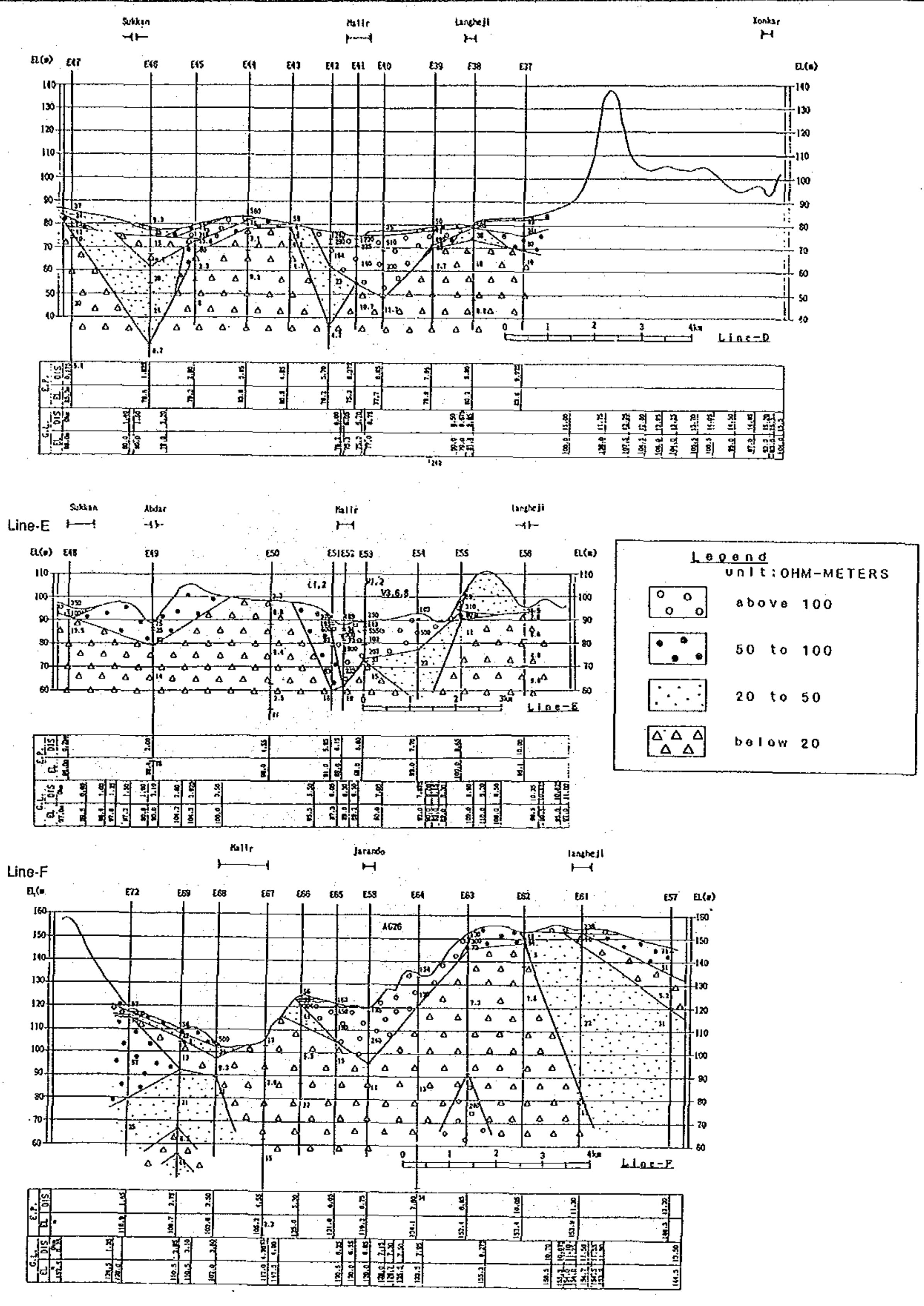

Fig. D.2-5 Electric Resistivity Profiles (2/2)

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FEASIBILITY STUDY ON
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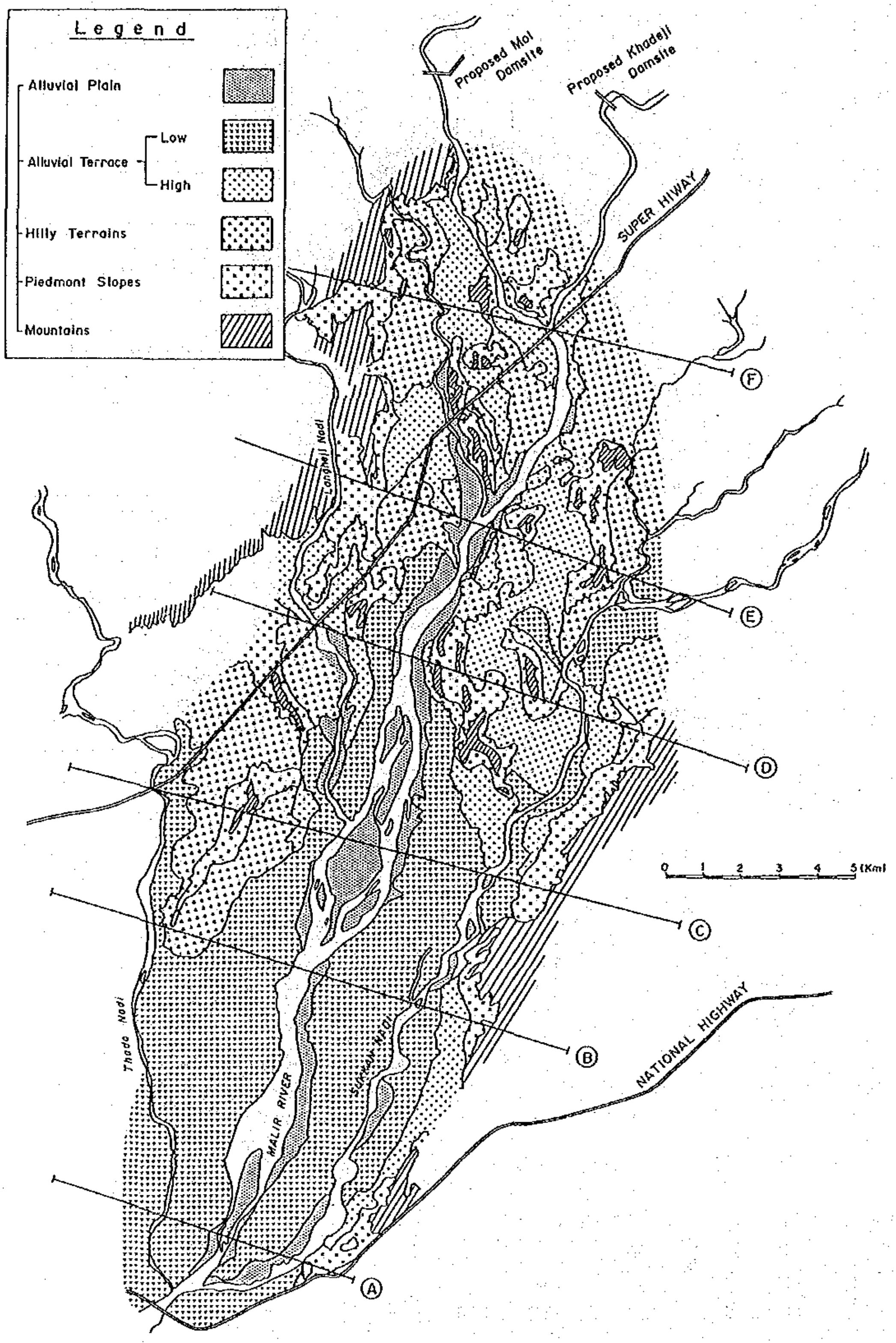

Fig. D.2-6 Geomorphological Map of Study Area

ISLAMIC REPUBLIC OF PAKISTAN GOVERNMENT OF SIND
FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN THE MALIR BASIN
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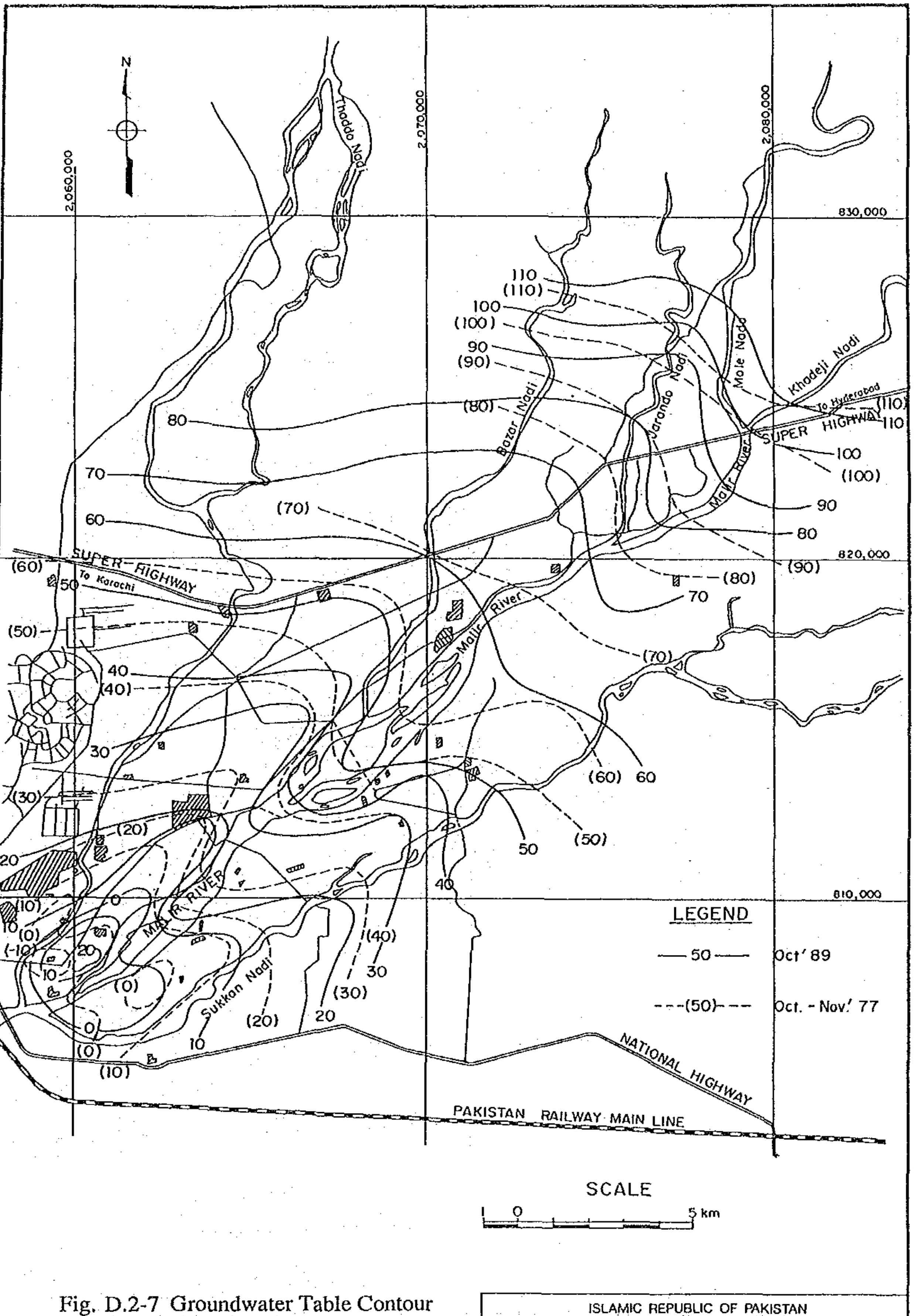

Fig. D.2-7 Groundwater Table Contour Map in 1977 & 1989

ISLAMIC REPUBLIC OF PAKISTAN
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FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN THE MALIR BASIN

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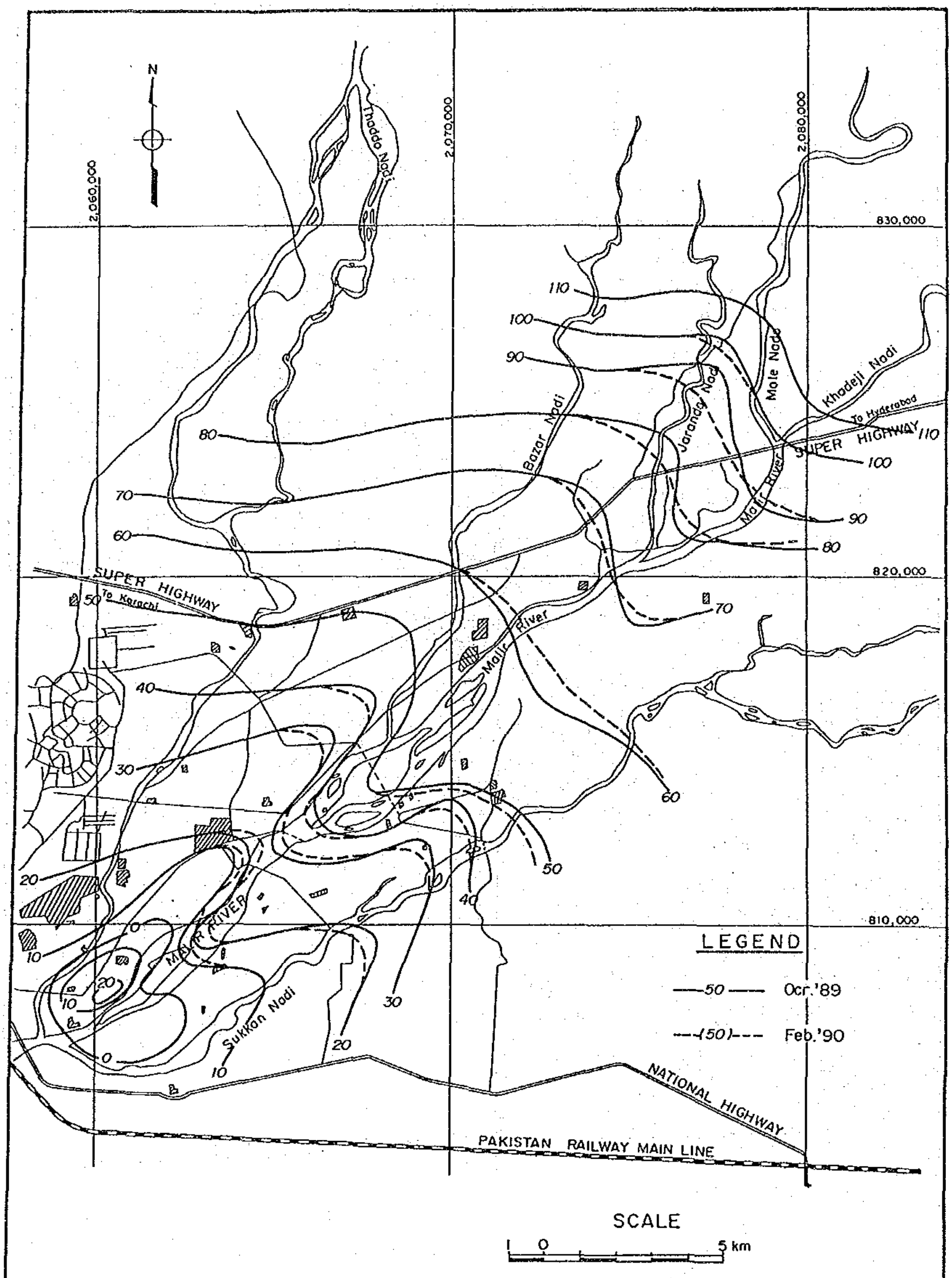

Fig. D.2-8 Groundwater Table Contour Map in 1989 & 1990

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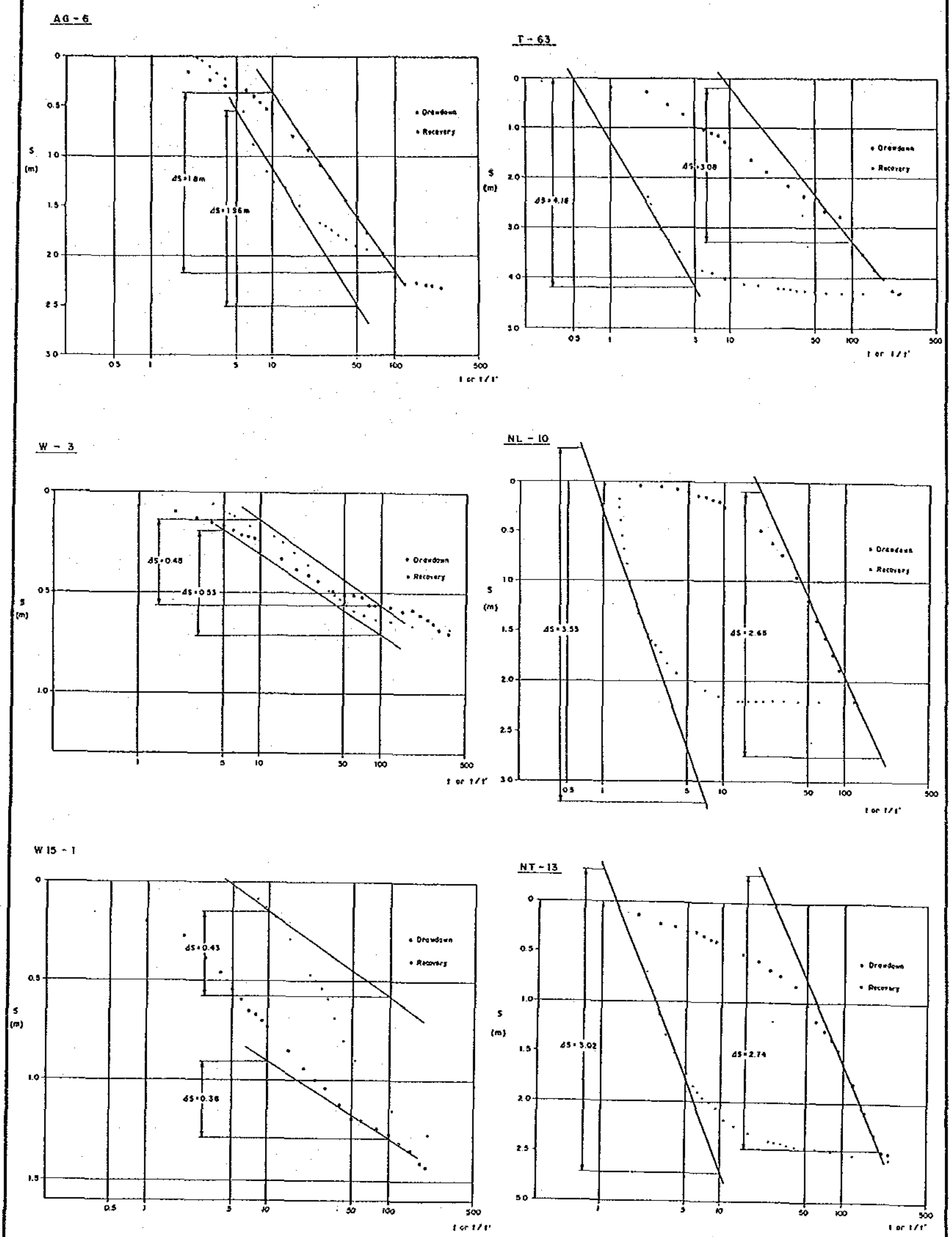

Fig. D.2-9 Results of Pumping Tests

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IN THE MALIR BASIN

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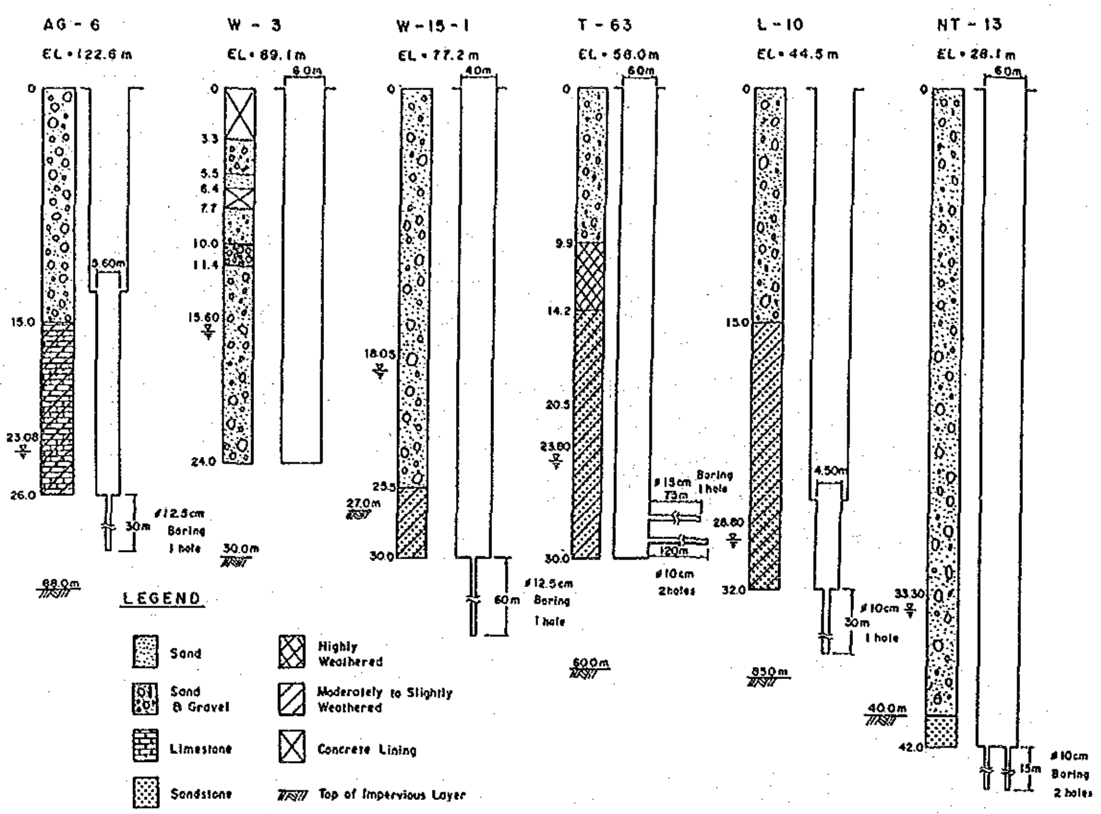

Fig. D.2-10 Profiles of Pumping Test Wells

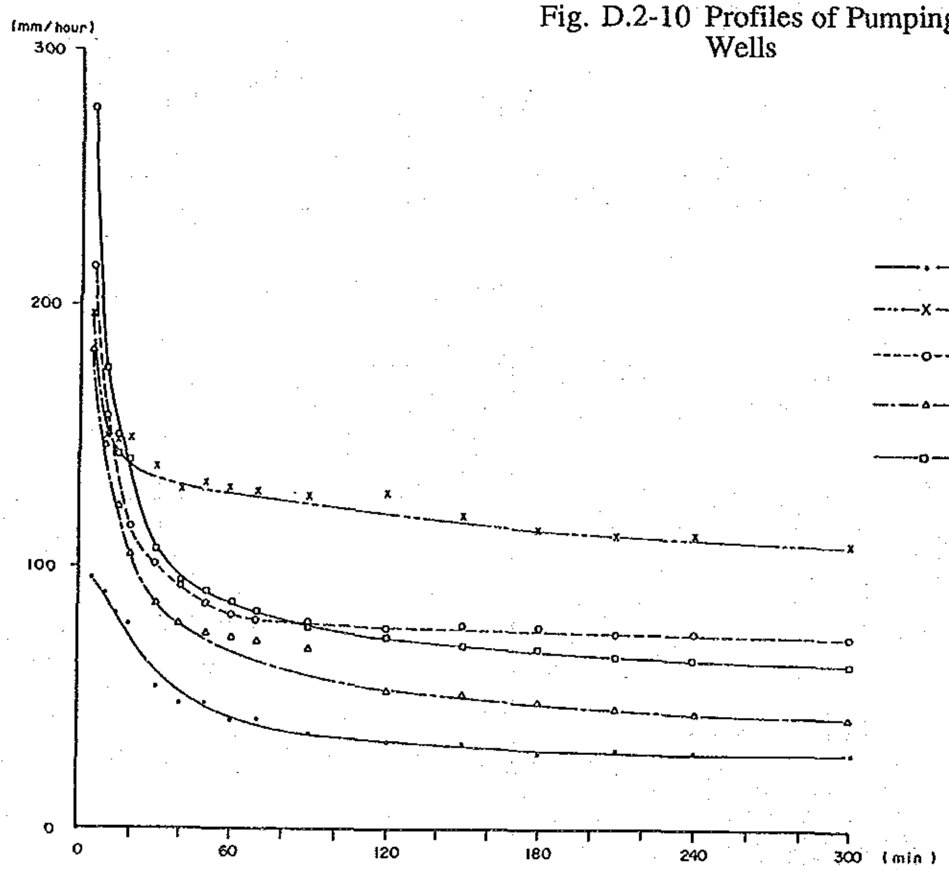

Fig. D.2-11 Results of Infiltration Test

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FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN THE MALIR BASIN
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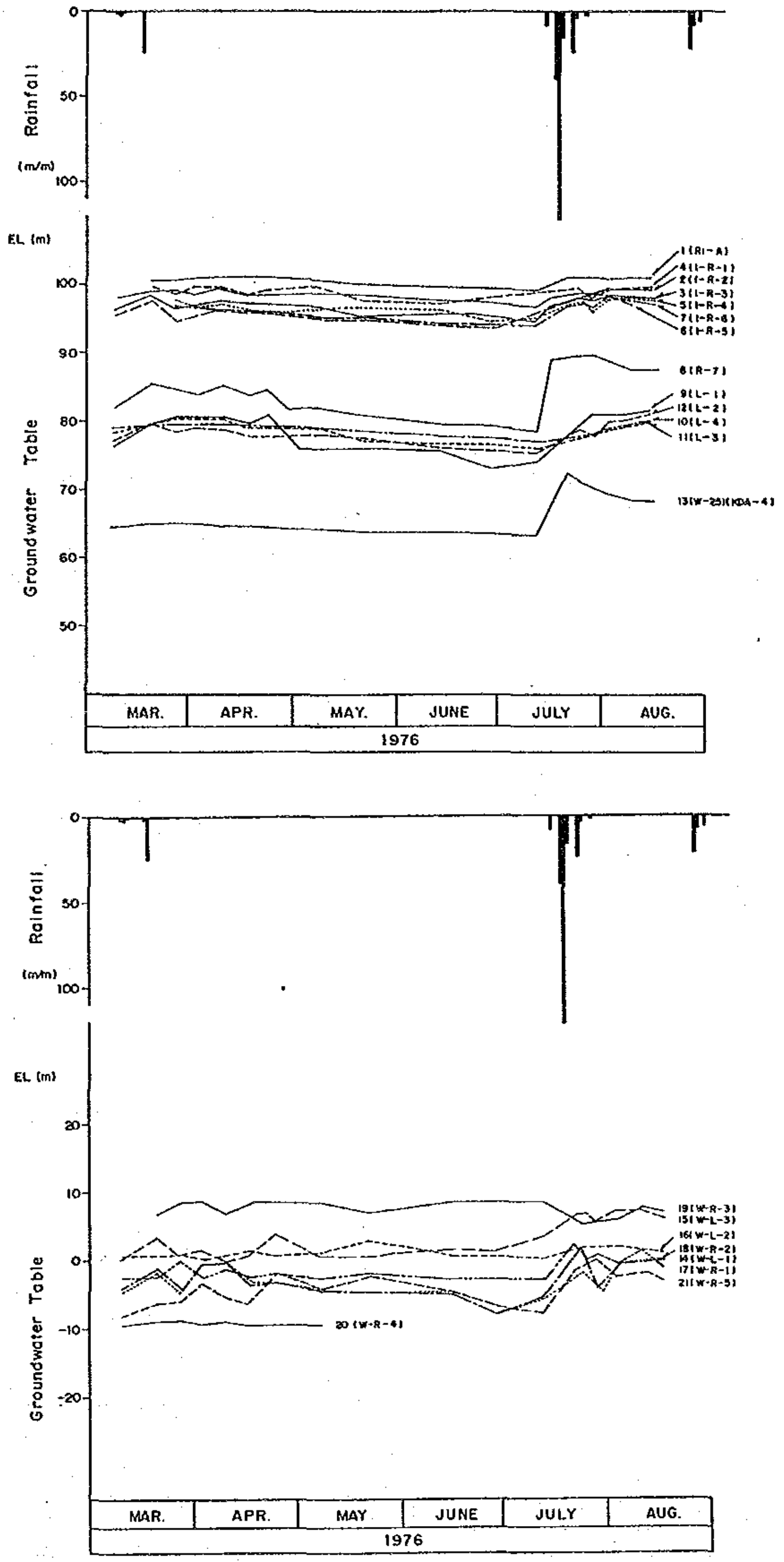

Fig. D.2-12 Relationship between Rainfall and Groundwater Table (1/3)

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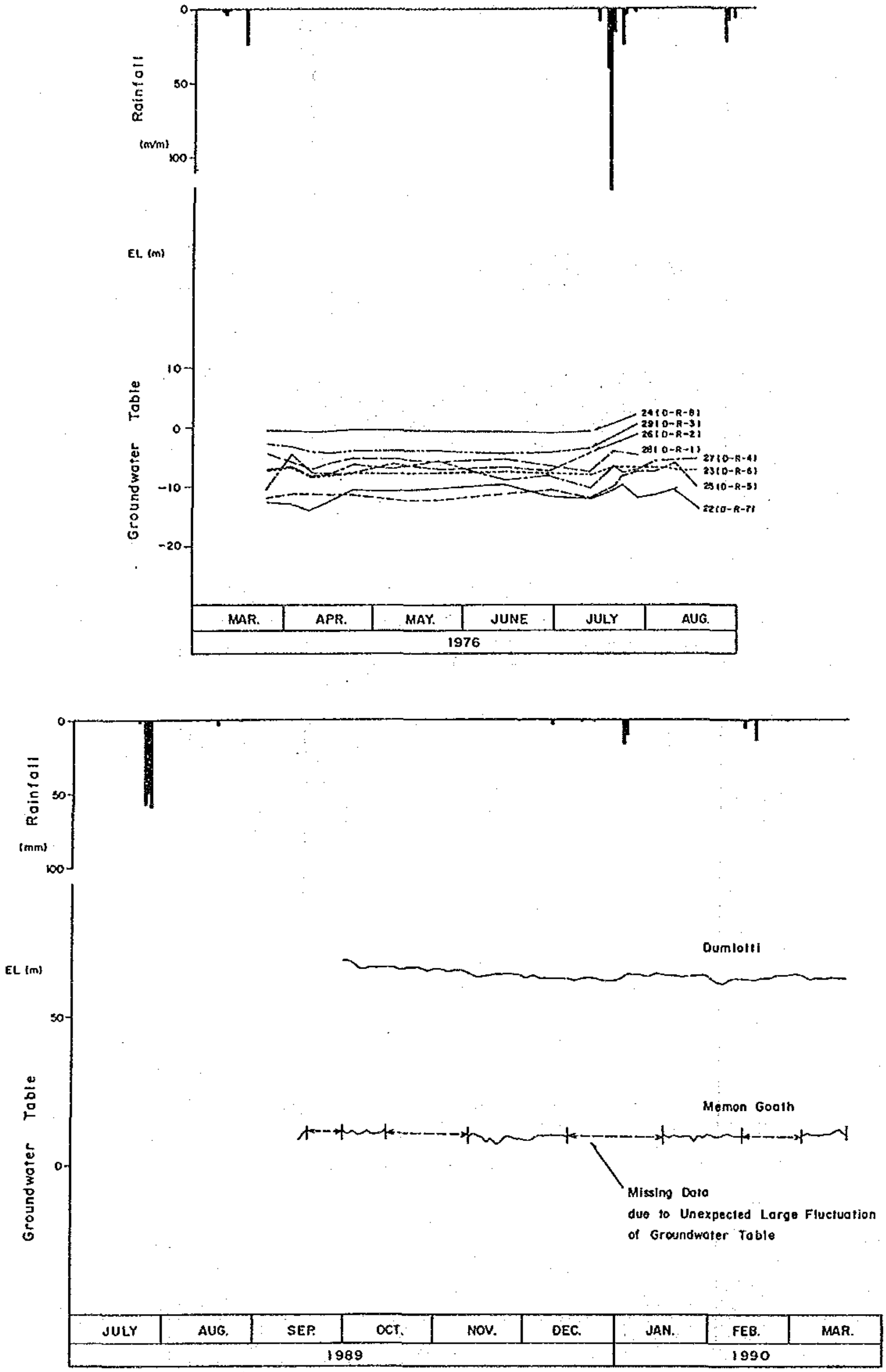

Fig. D.2-12 Relationship between Rainfall and Groundwater Table (2/3)

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FEASIBILITY STUDY ON
WATER RESOURCES DEVELOPMENT PROJECT
IN THE MALIR BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

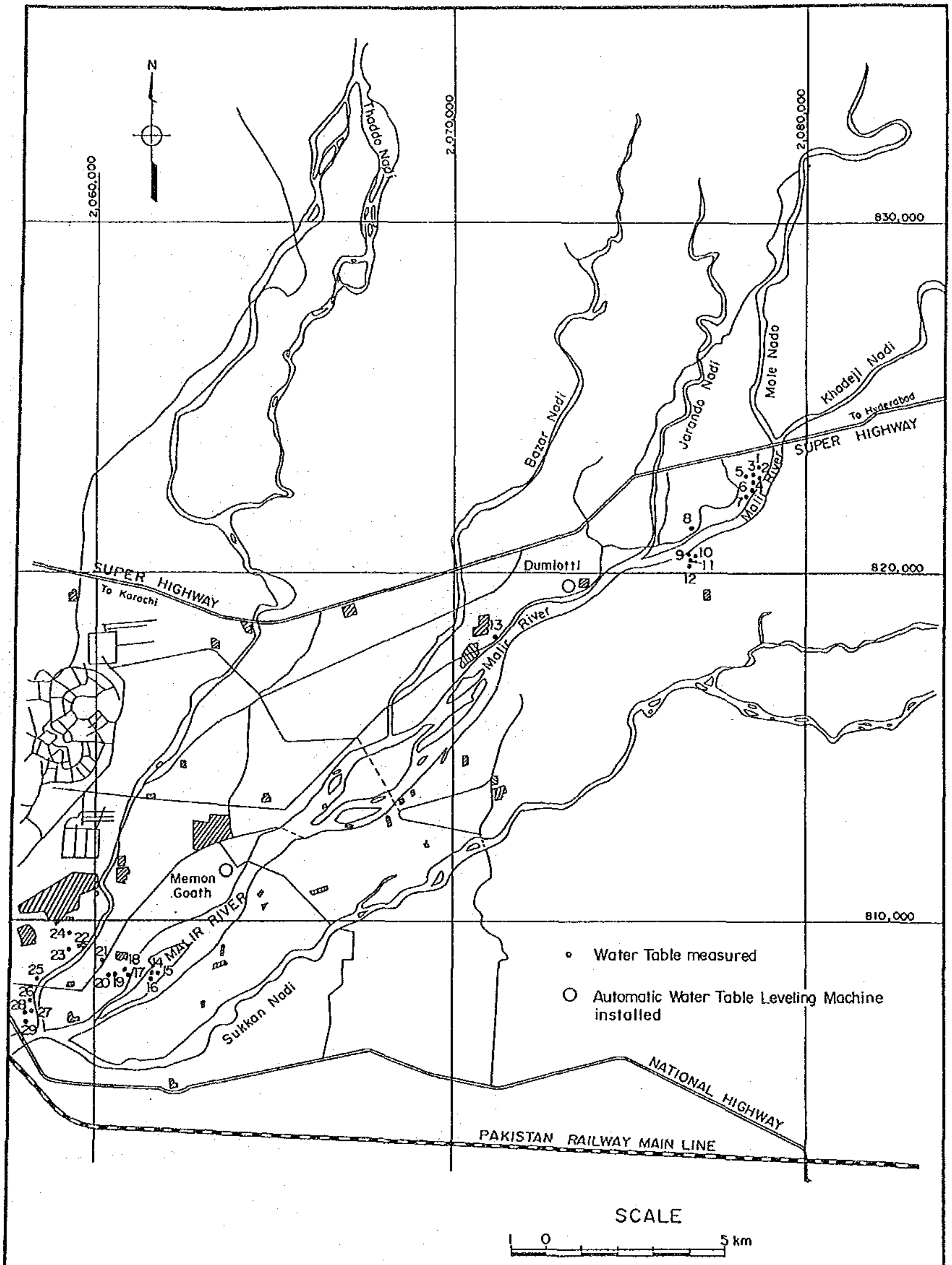

Fig. D.2-12 Relationship between Rainfall and Groundwater Table (3/3)

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GOVERNMENT OF SIND

FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN THE MALIR BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

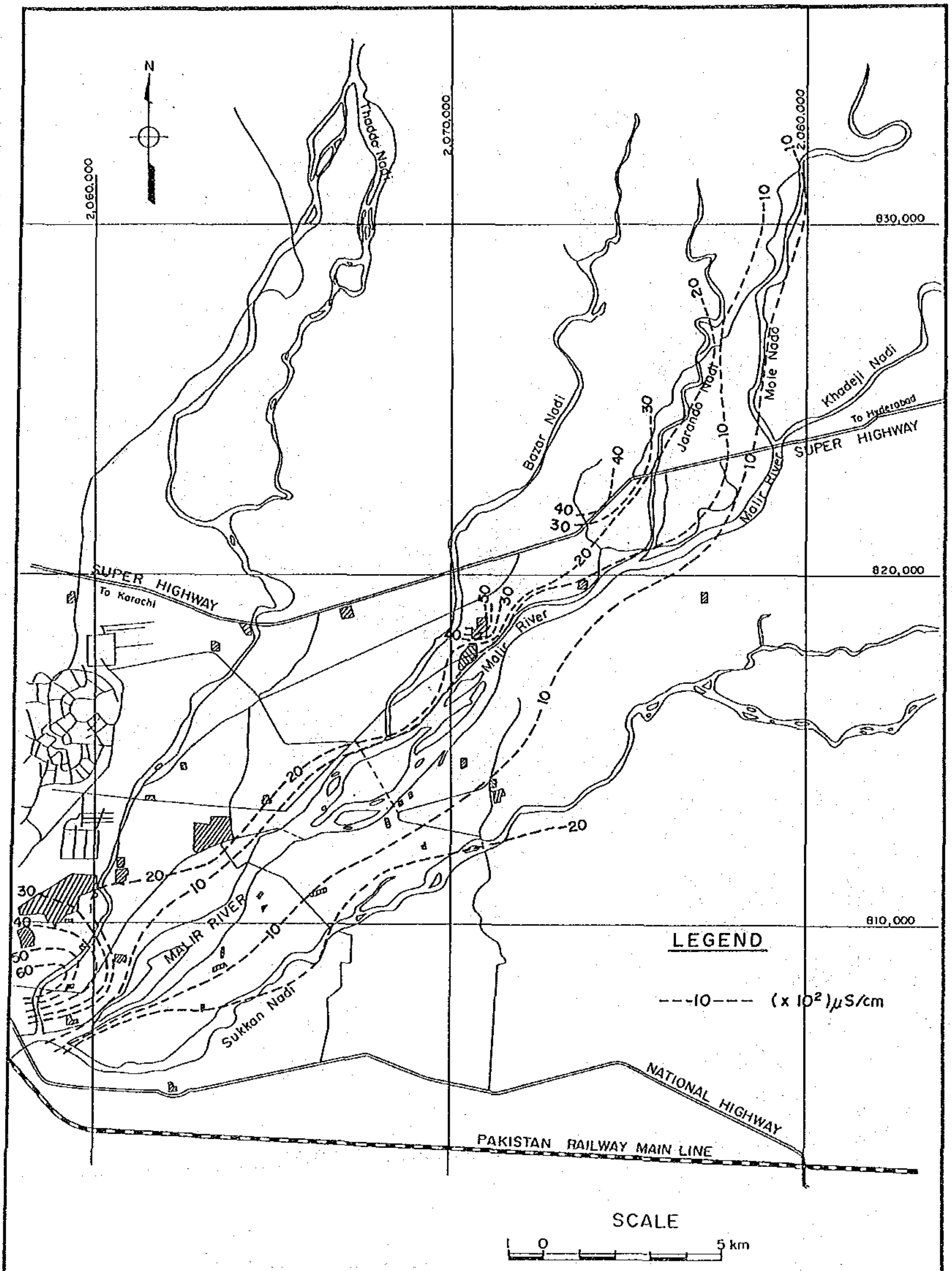

Fig. D.2-13 Distribution of Electric Conductivity

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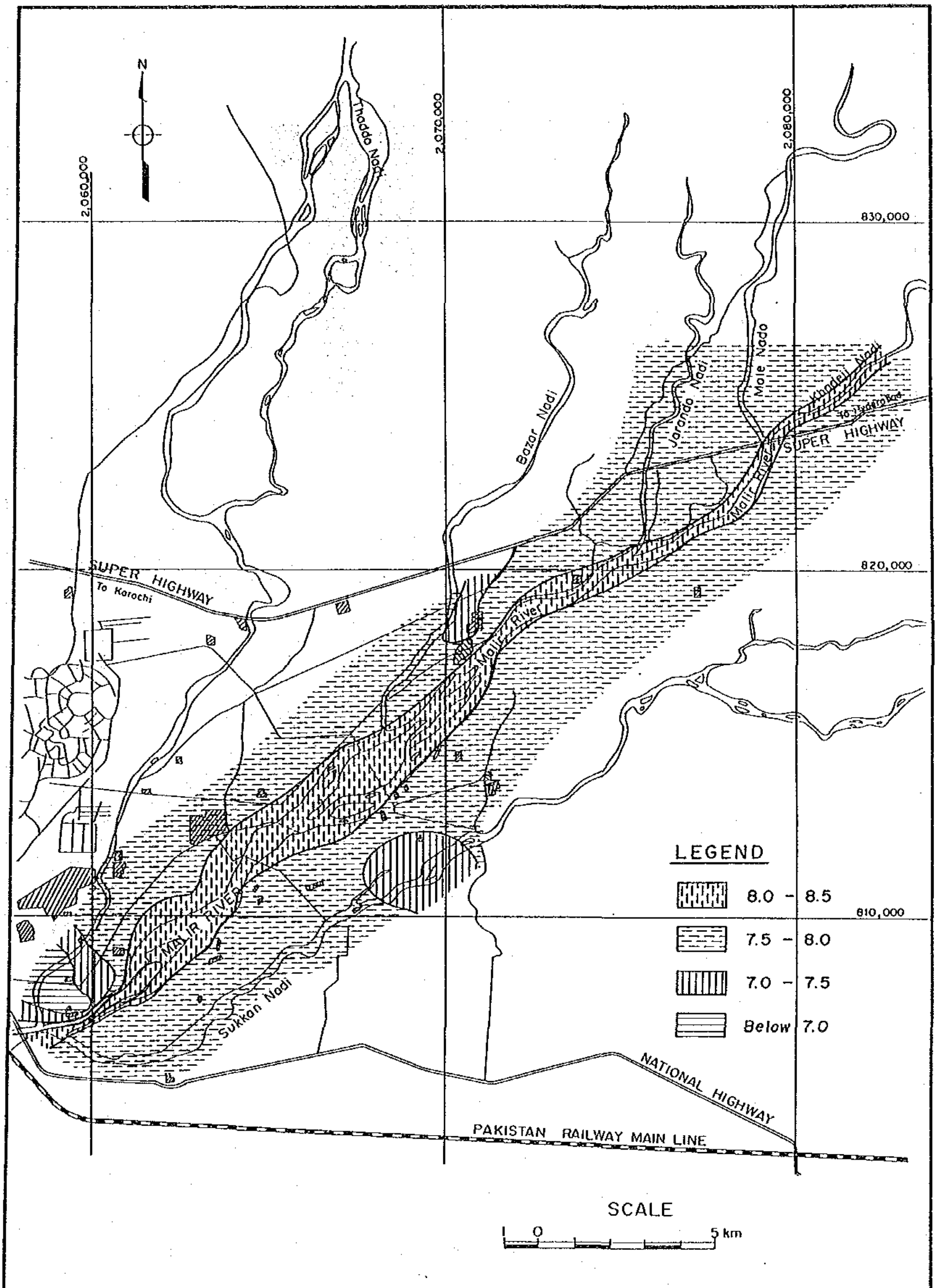

Fig. D.2-14 Distribution of pH

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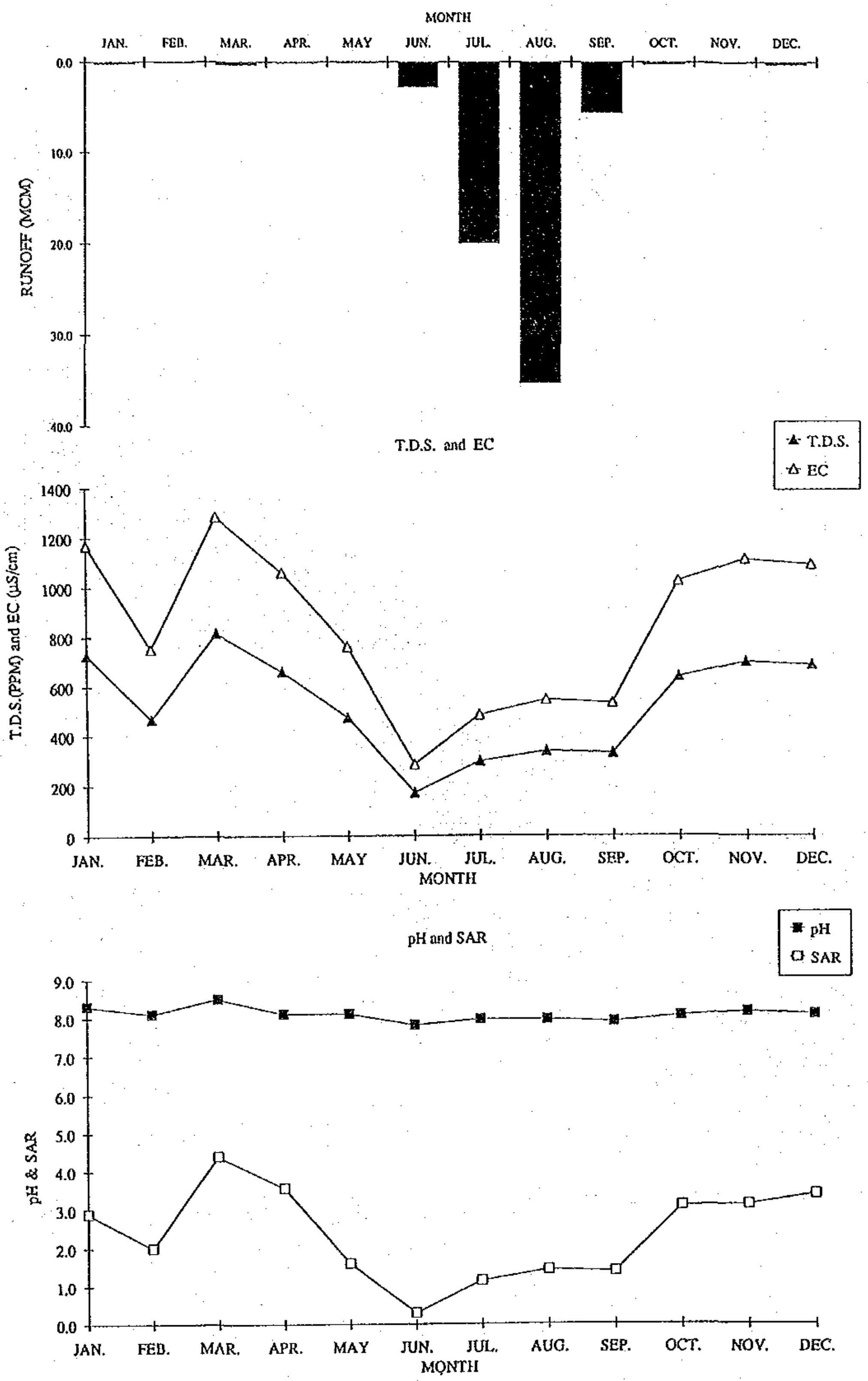

Fig. D.2-15 Water Quality of River Runoff

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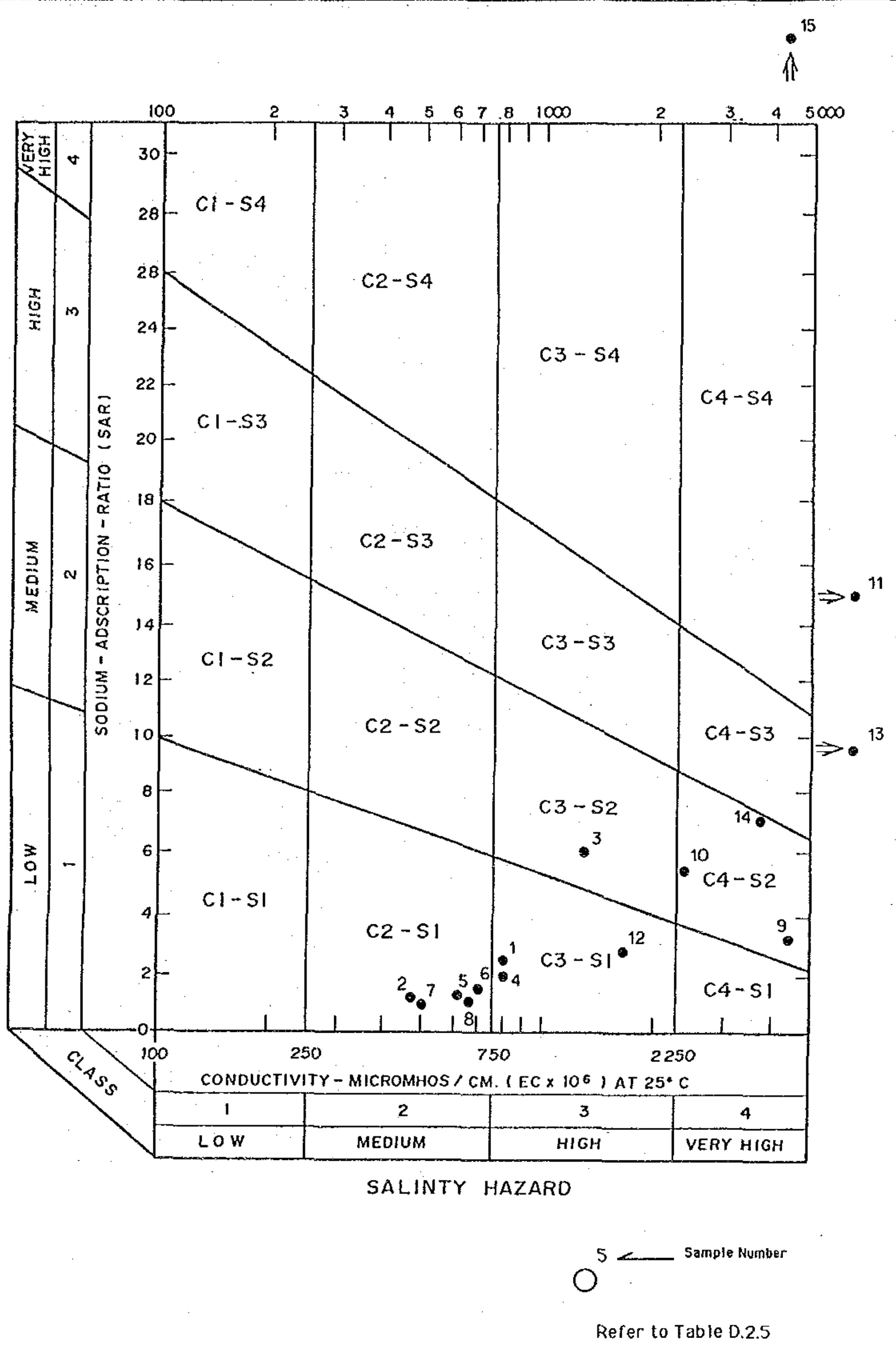

Fig. D.2-16 Classification of Irrigation Water

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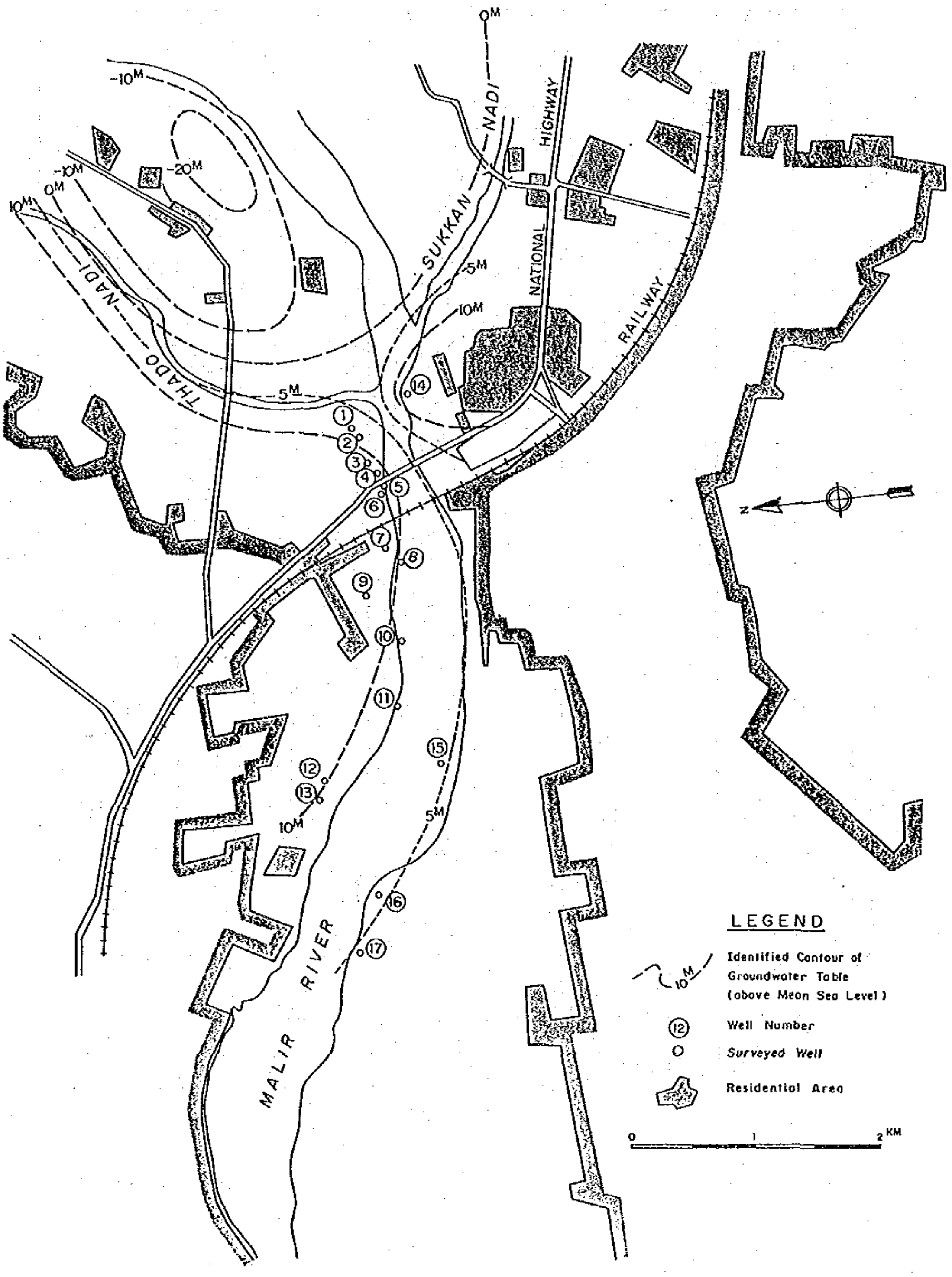

Fig. D.2-17 Investigation for Saline Water Intrusion

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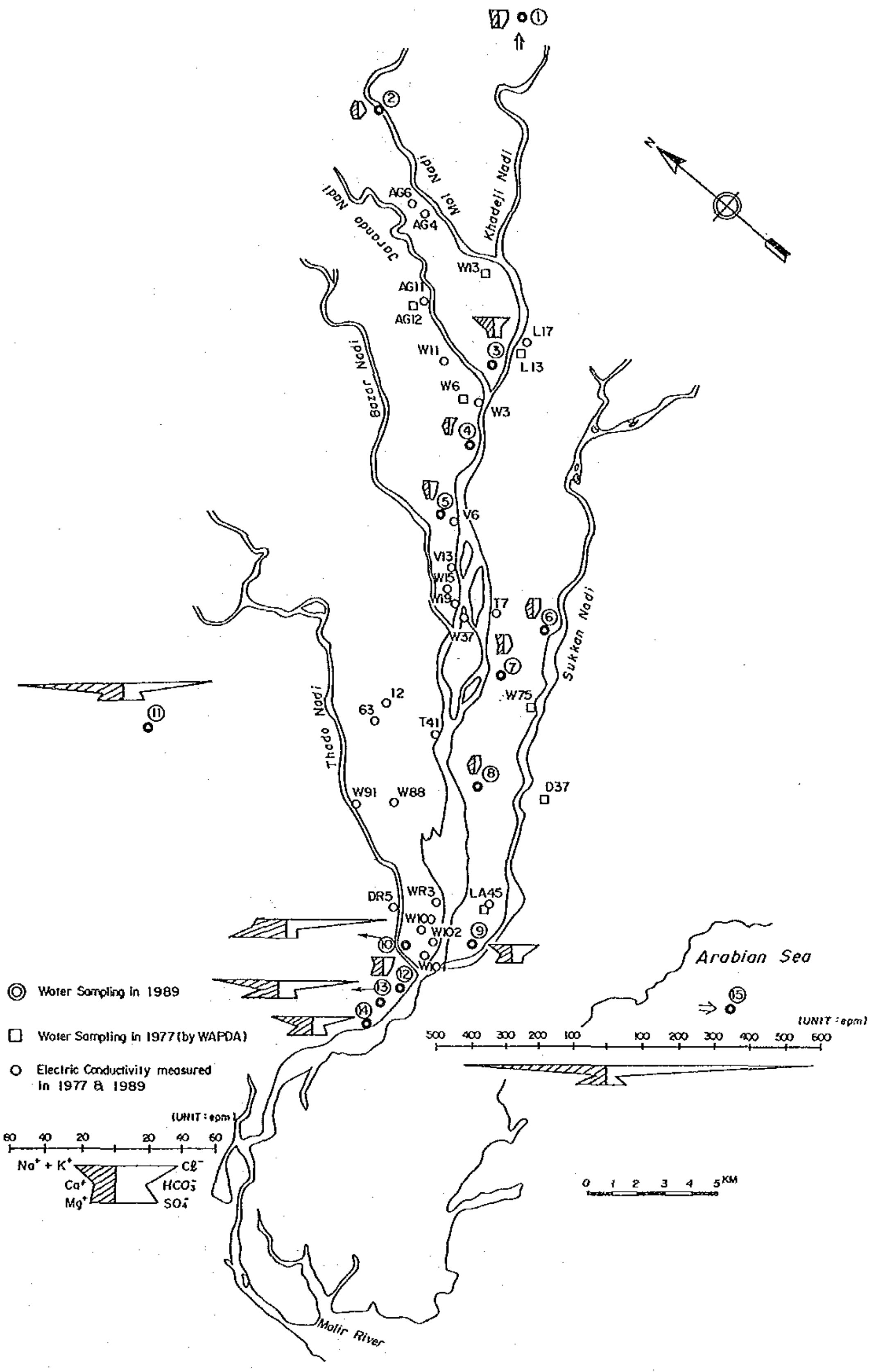

Fig. D.2-18 Location Map of Sampling for Water Quality Analysis

ISLAMIC REPUBLIC OF PAKISTAN GOVERNMENT OF SIND
FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN THE MALIR BASIN
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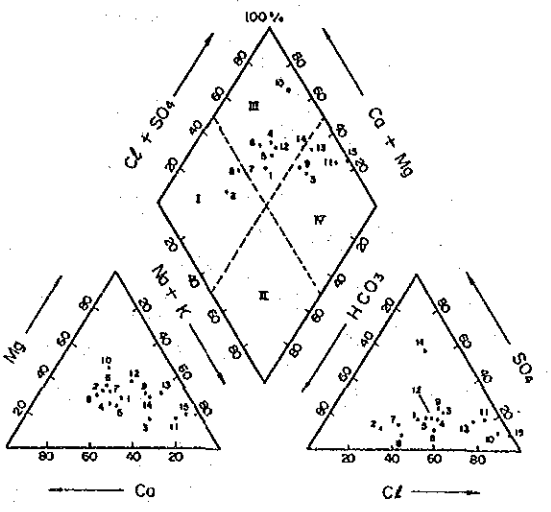
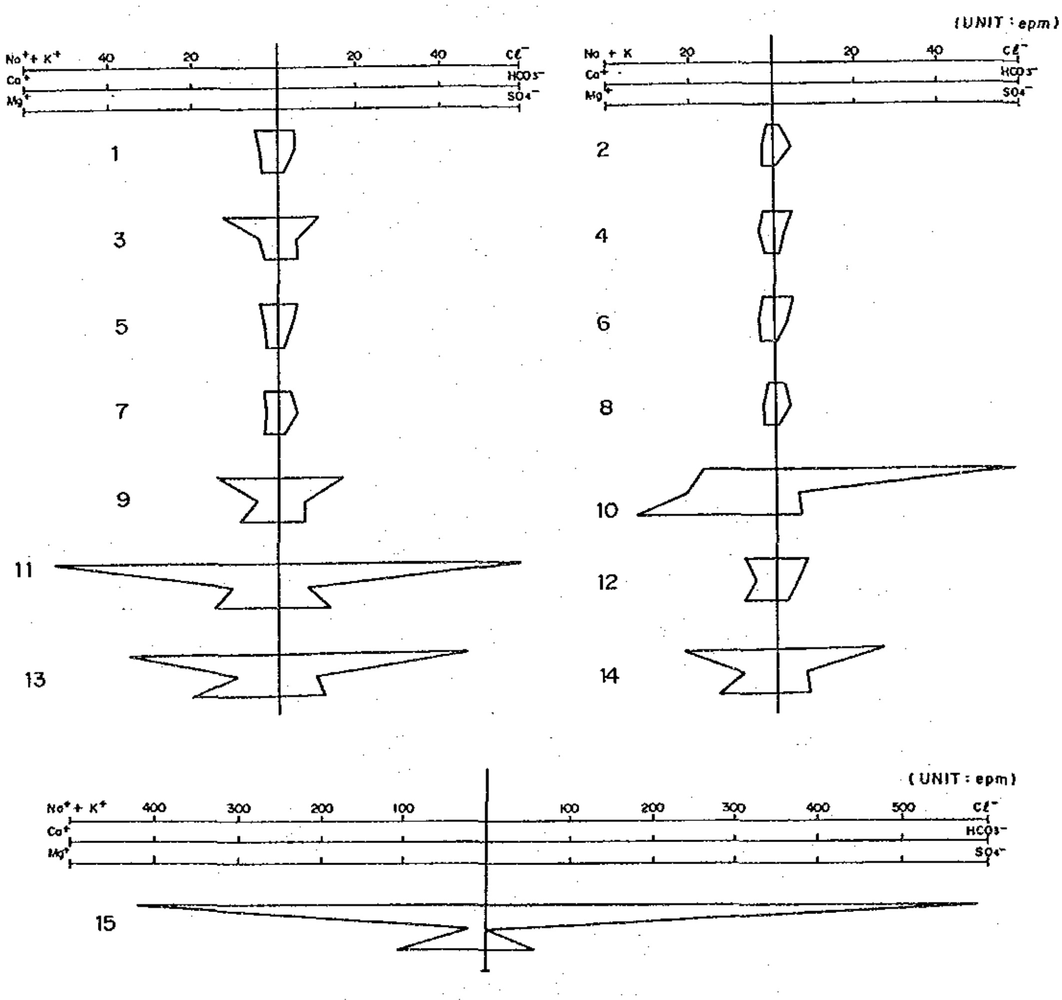


Piper Diagram



Simple Pattern Diagram

Fig. D.2-19 Results of Water Quality Analysis

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FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN THE MALIR BASIN
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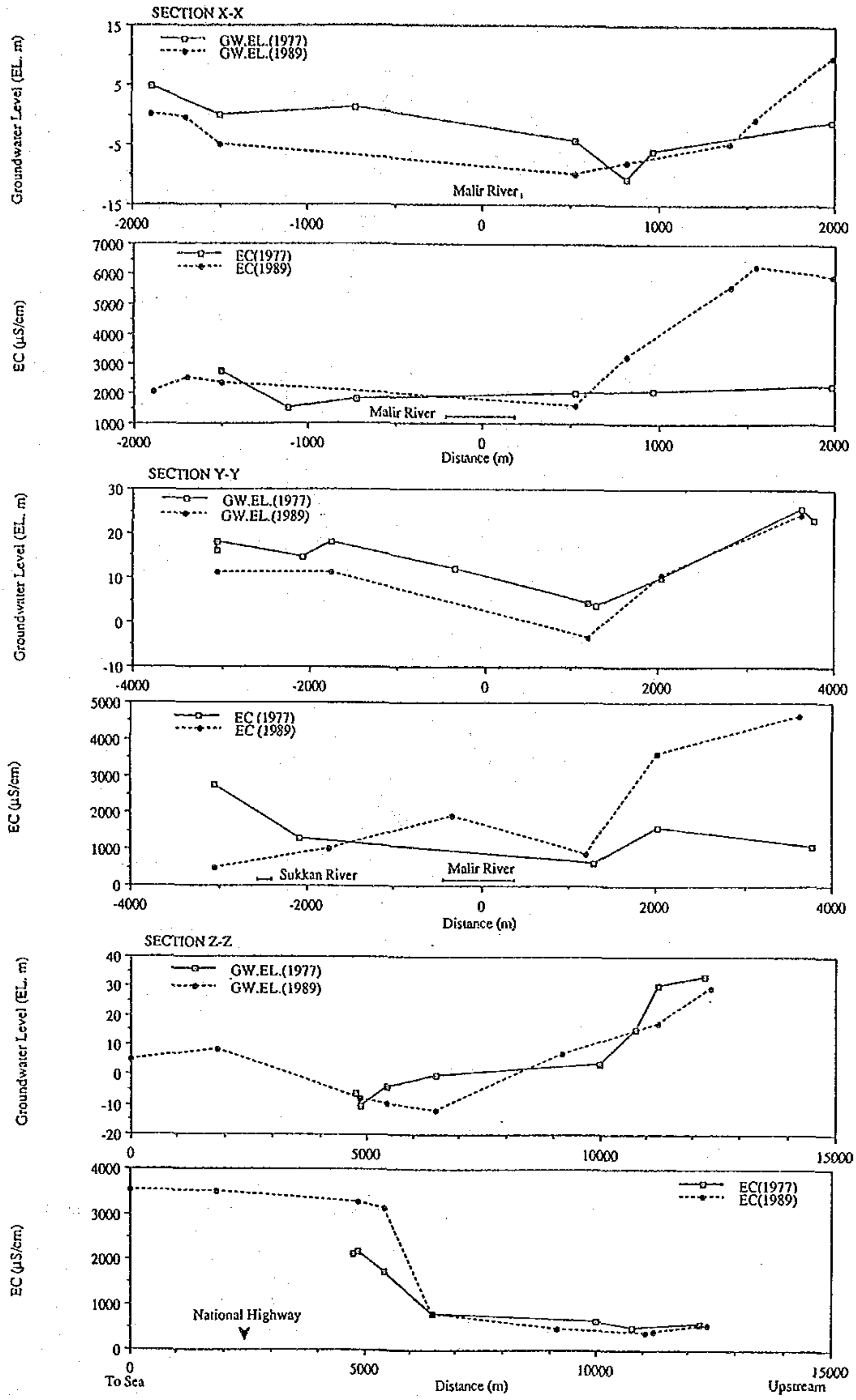

Fig. D.2-20 Groundwater Table and Electric Conductivity in 1977 & 1989 (1/2)

ISLAMIC REPUBLIC OF PAKISTAN GOVERNMENT OF SIND
FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN THE MALIR BASIN
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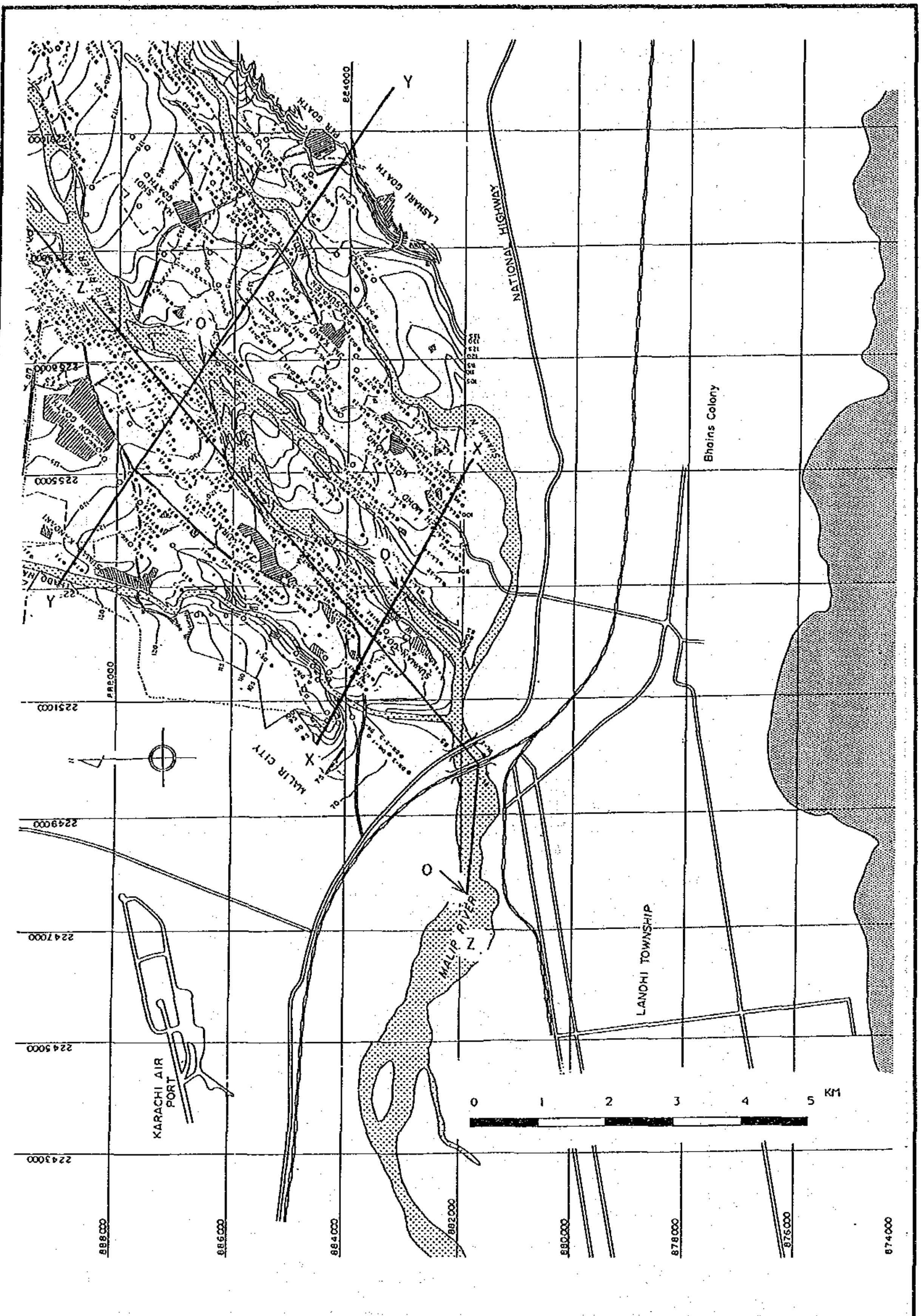

Fig. D.2-20 Groundwater Table and Electric Conductivity in 1977 & 1989 (2/2)

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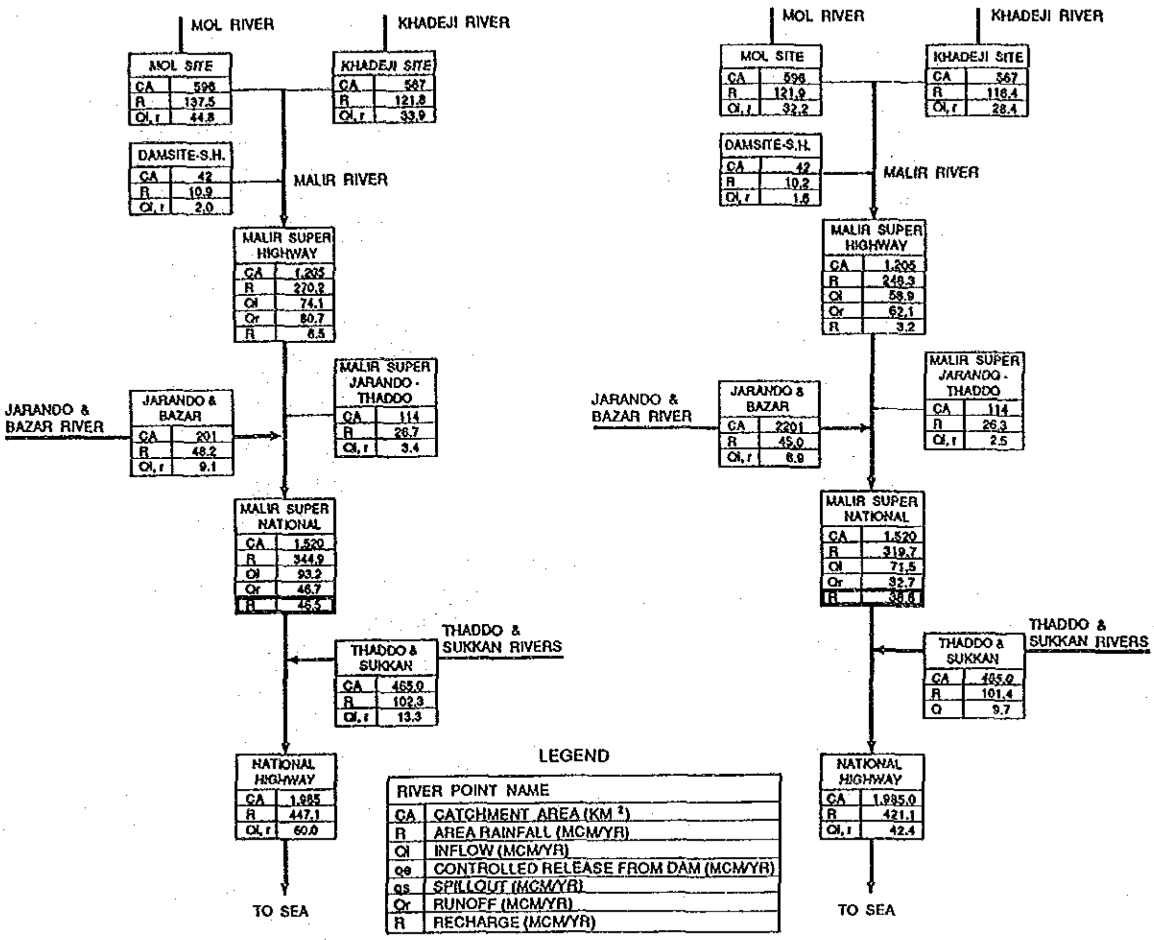

1. Natural Condition (1929 - 1988)

2. Natural Condition (1977 - 1988)

Fig. D.3-1 Water Balance (Natural Condition)

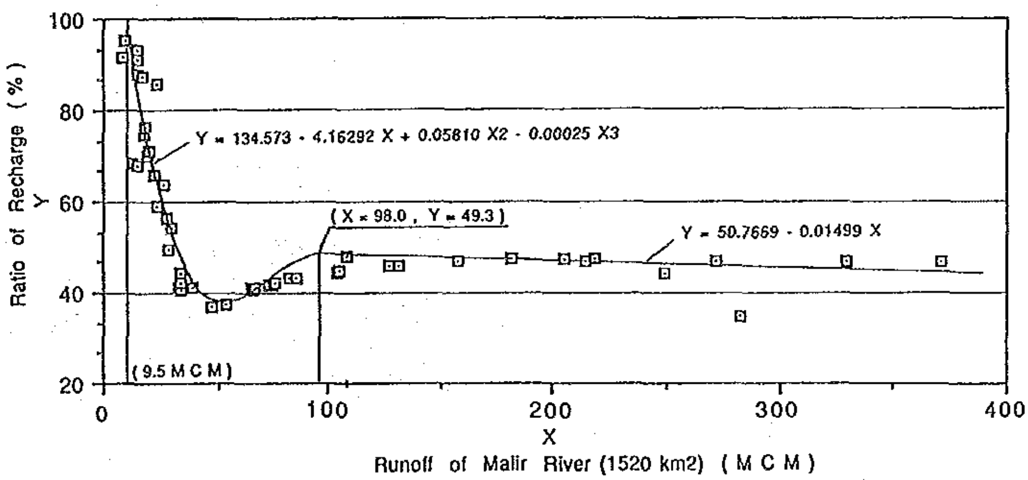

Fig. D.3-2 Relationship between River Runoff and Recharge to Aquifer

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FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN THE MALIR BASIN
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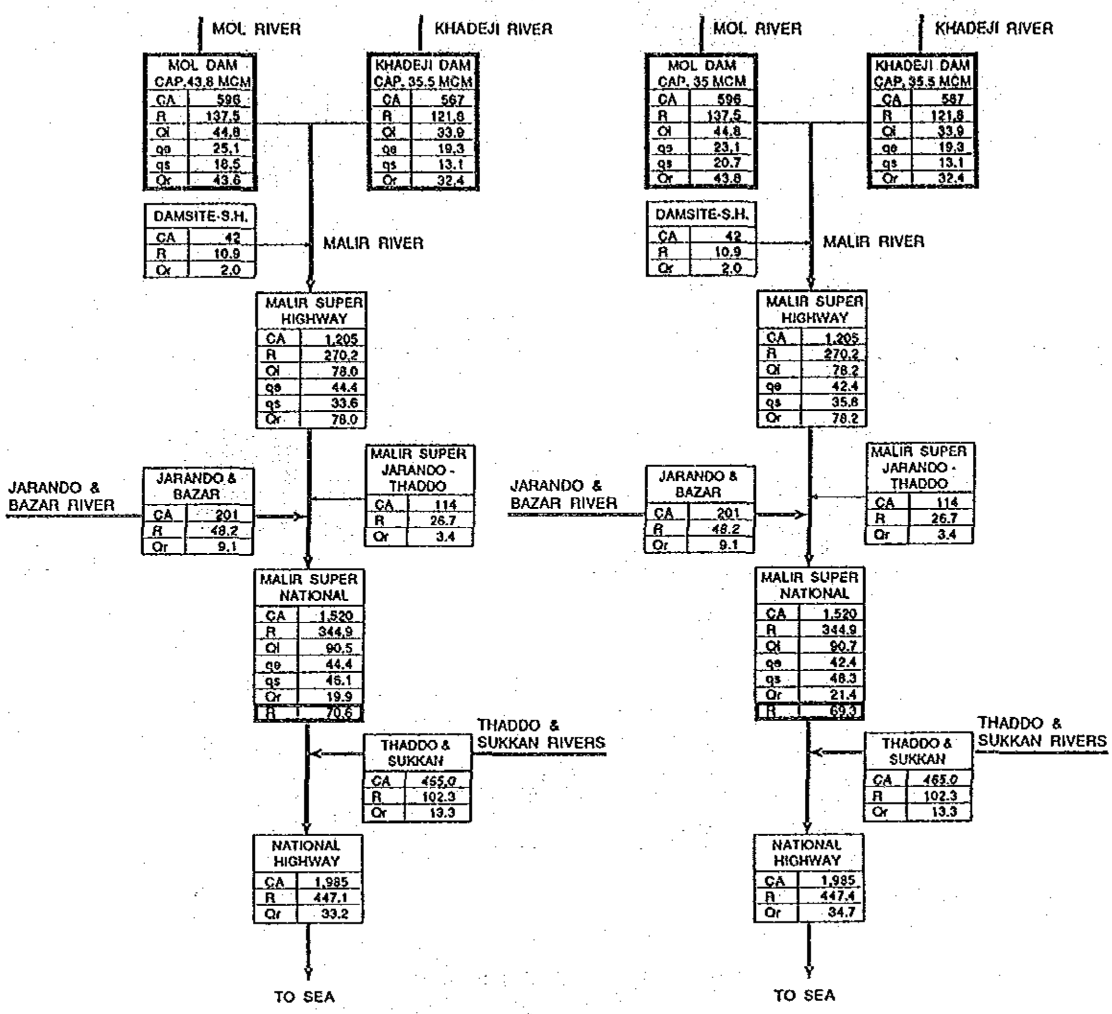

Case-1 Khadeji Dam : 35.5 MCM
Mol Dam : 43.8 MCM
(1929 - 1988)

Case-2 Khadeji Dam : 35.5 MCM
Mol Dam : 35.0 MCM
(1929 - 1988)

LEGEND

RIVER POINT NAME	
CA	CATCHMENT AREA (KM^2)
R	AREA RAINFALL (MCM/YR)
QI	INFLOW (MCM/YR)
qe	CONTROLLED RELEASE FROM DAM (MCM/YR)
qs	SPILLOUT (MCM/YR)
Qr	RUNOFF (MCM/YR)
R	RECHARGE (MCM/YR)

Fig. D.3-3 Artificial Recharge of Aetertenatuie Case (1/3)

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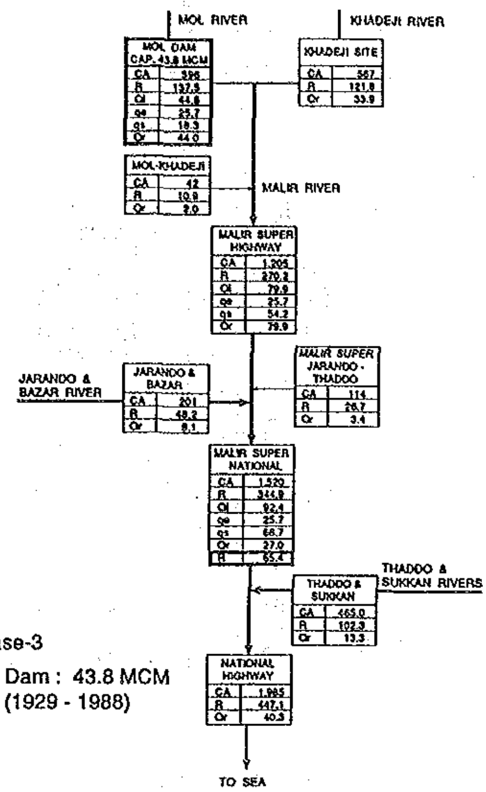
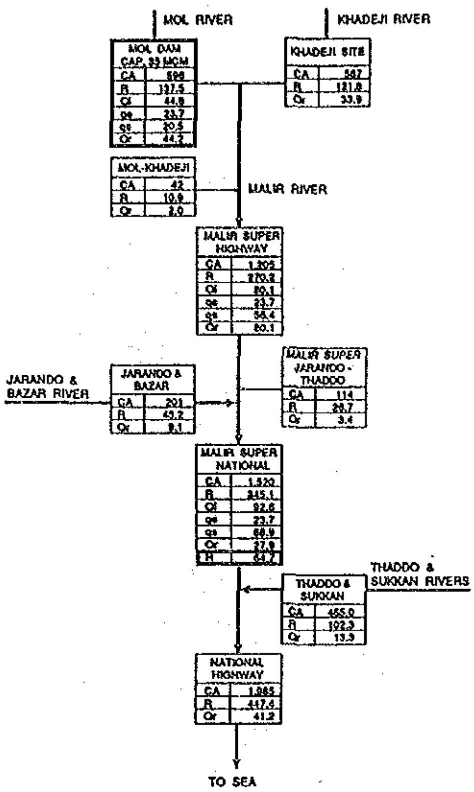
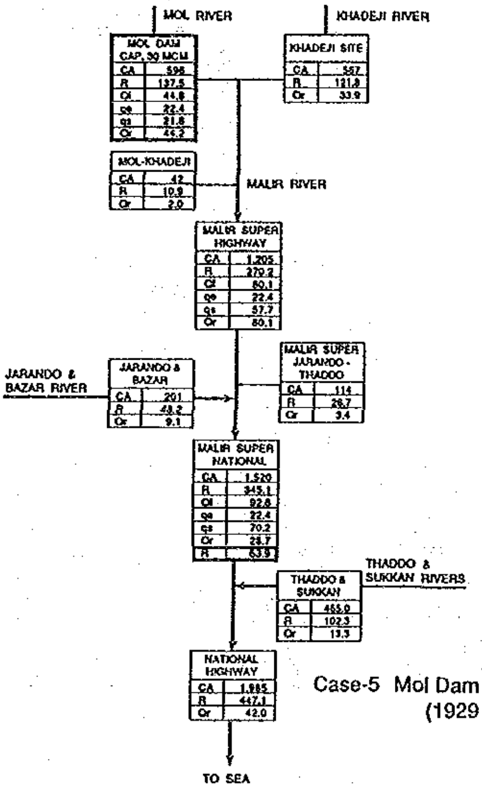


Case-3

Mol Dam : 43.8 MCM
(1929 - 1988)



Case-4 Mol Dam : 35 MCM
(1929 - 1988)



Case-5 Mol Dam : 30 MCM
(1929 - 1988)

LEGEND

RIVER POINT NAME	
CA	CATCHMENT AREA (KM ^{2})
R	AREA RAINFALL (MCM/YR)
Qi	INFLOW (MCM/YR)
qe	CONTROLLED RELEASE FROM DAM (MCM/YR)
qs	SPILLOUT (MCM/YR)
Qr	RUNOFF (MCM/YR)
R	RECHARGE (MCM/YR)

Fig. D.3-3 Artificial Recharge of Aetertenatuie Case (2/3)

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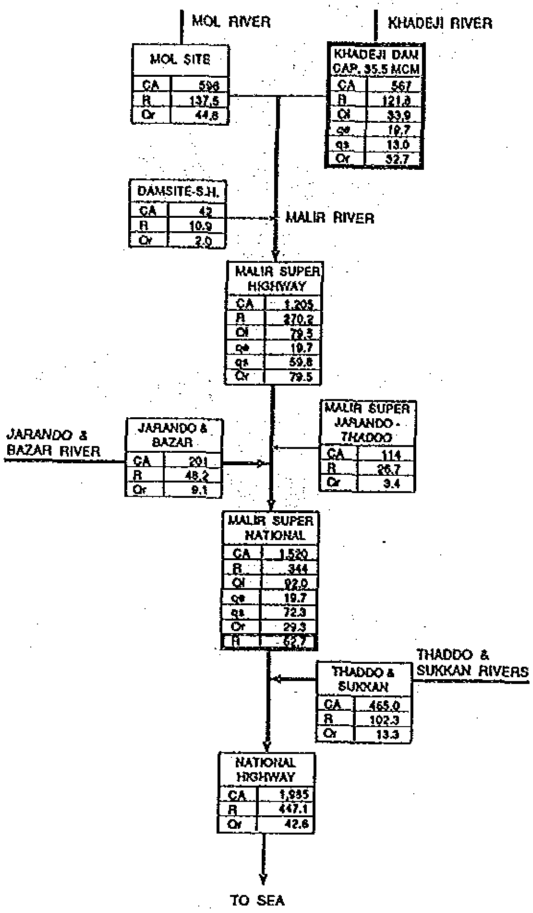
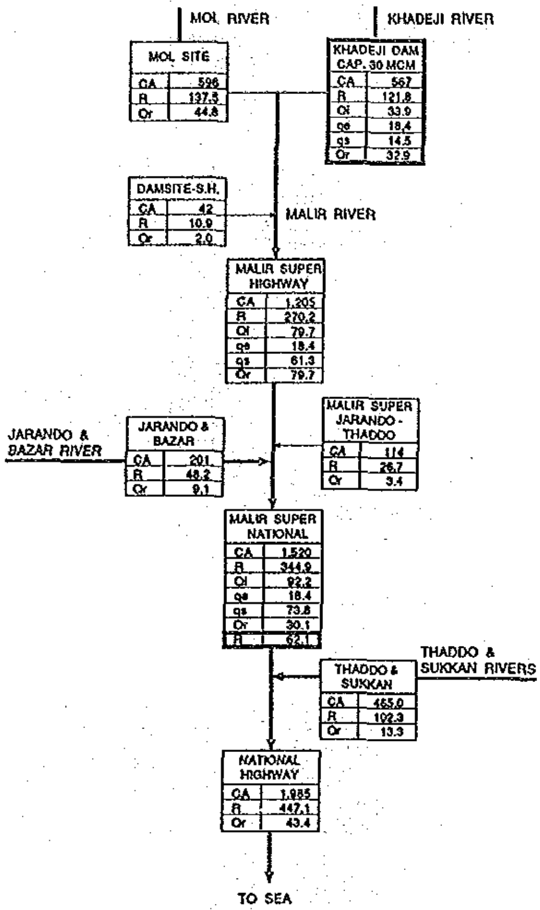


Case-6 Khadeji Dam : 35.5 MCM
(1929 - 1988)



Case-7 Khadeji Dam : 30 MCM
(1929 - 1988)

LEGEND

RIVER POINT NAME	
CA	CATCHMENT AREA (KM ^{2})
R	AREA RAINFALL (MCM/YR)
QI	INFLOW (MCM/YR)
qe	CONTROLLED RELEASE FROM DAM (MCM/YR)
qs	SPILLOUT (MCM/YR)
Qr	RUNOFF (MCM/YR)
R	RECHARGE (MCM/YR)

Fig. D.3-3 Artificial Recharge of Aetertenatuie Case (3/3)

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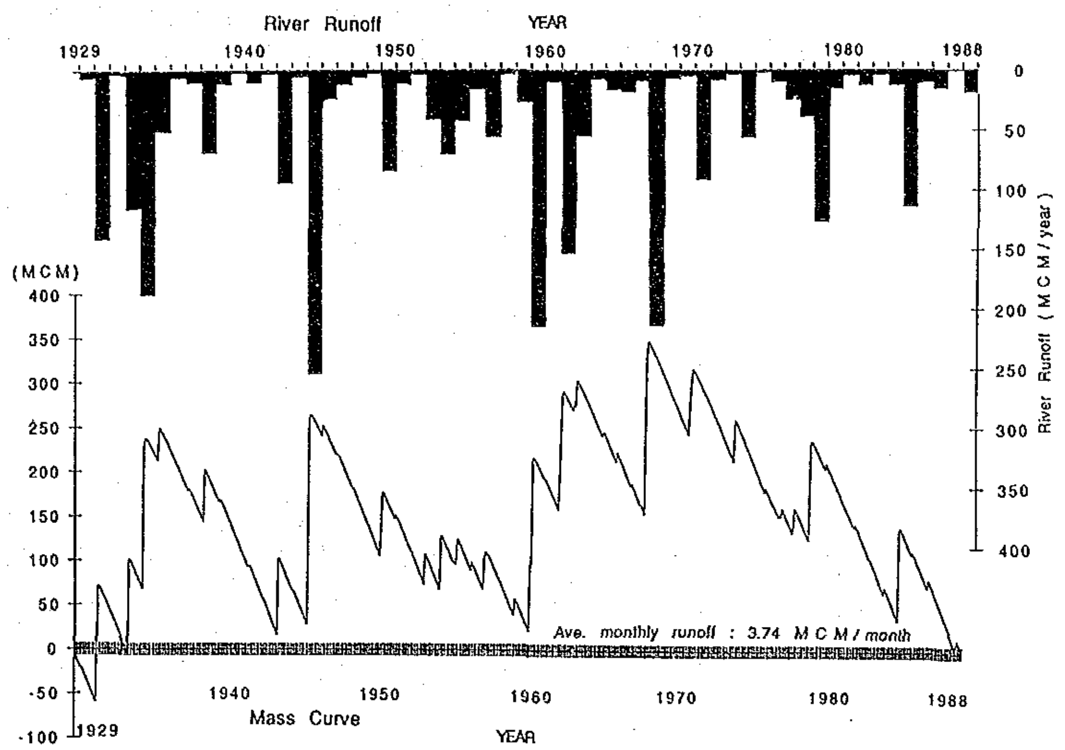
MOL RIVER AT DAM SITE



KHADEJI RIVER AT DAM SITE

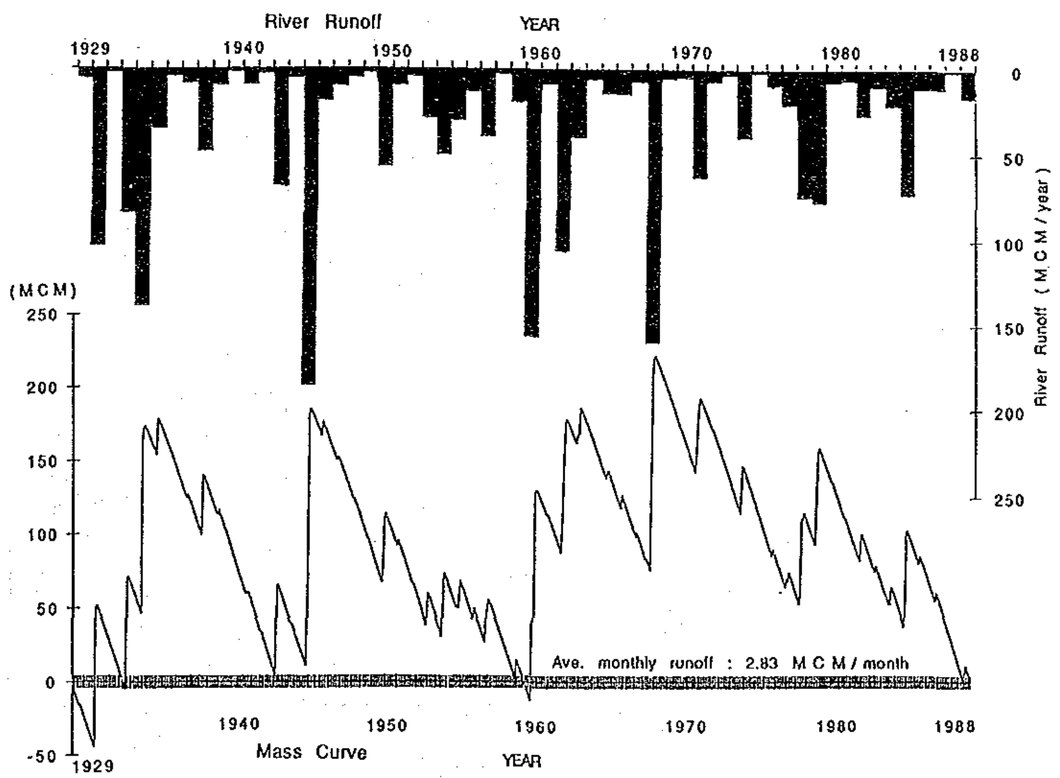


Fig. D.3-4 River Runoff Pattern and Masscurve at Mol and Khadeji Damsites

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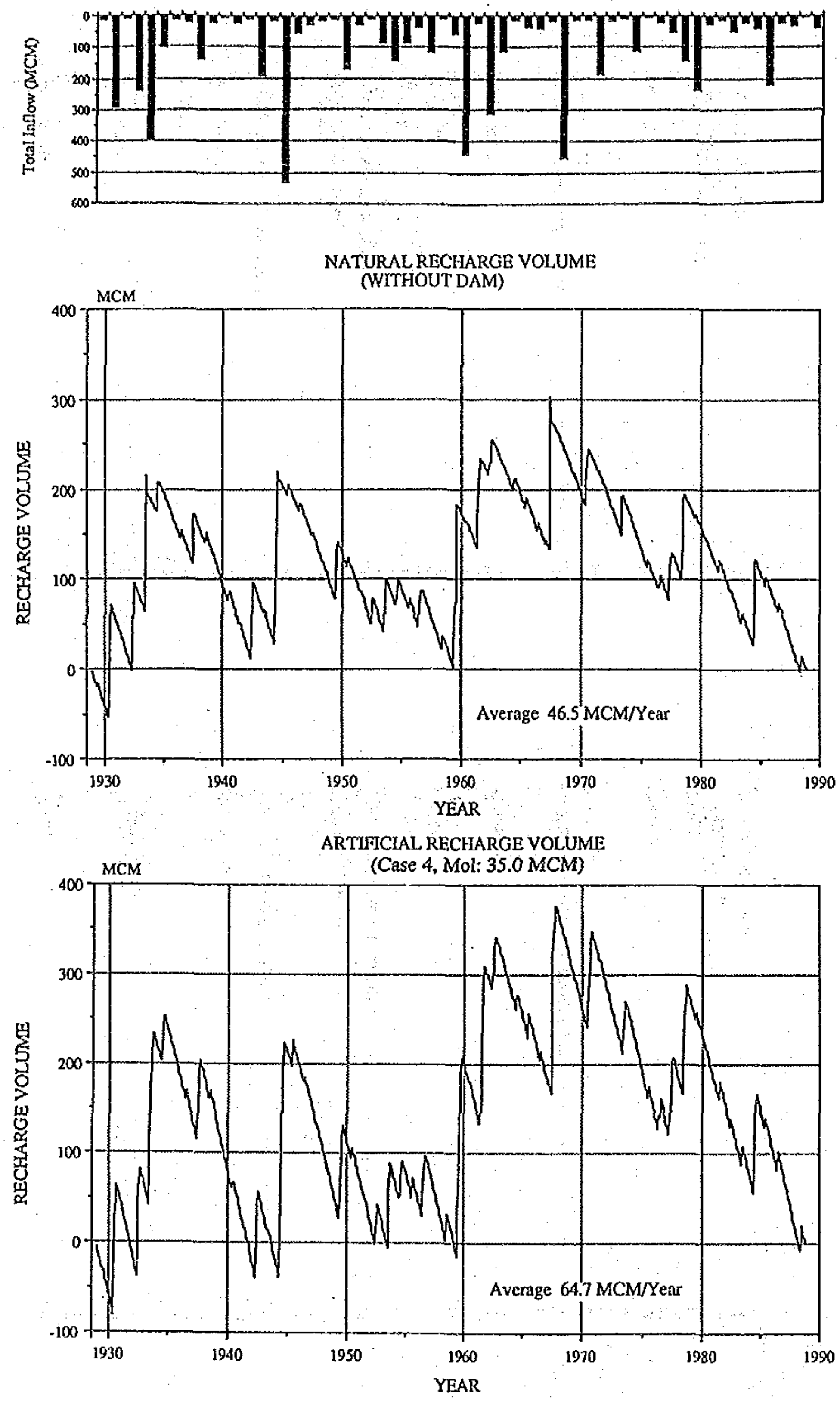

Fig. D.3-5 Masscurves of Natural and Artificial Recharge by Mol Dam(35MCM)

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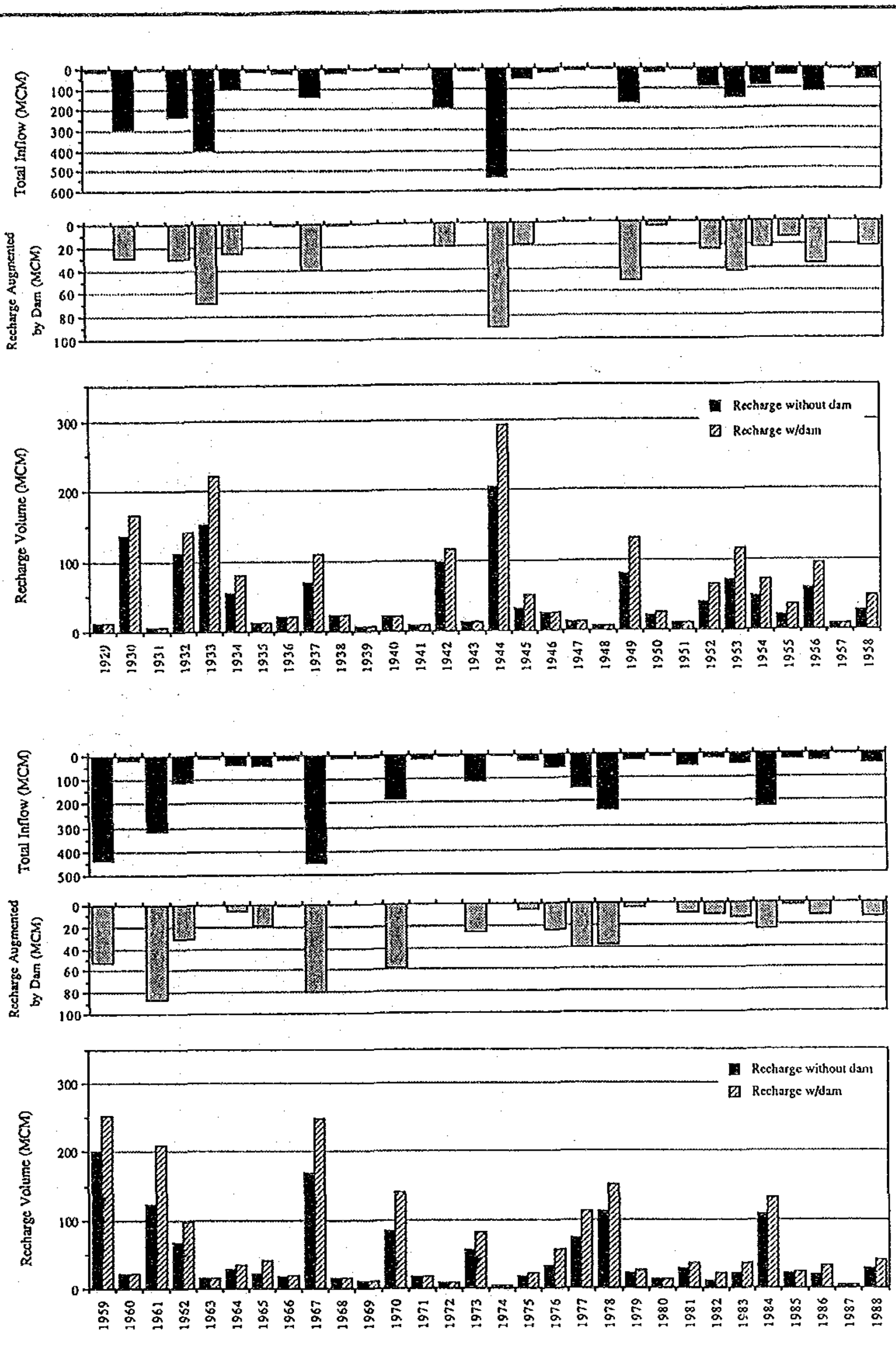

Fig. D.3-6 Artificial Recharge by Dam
(Case 4, Mol: 35.0 MCM)

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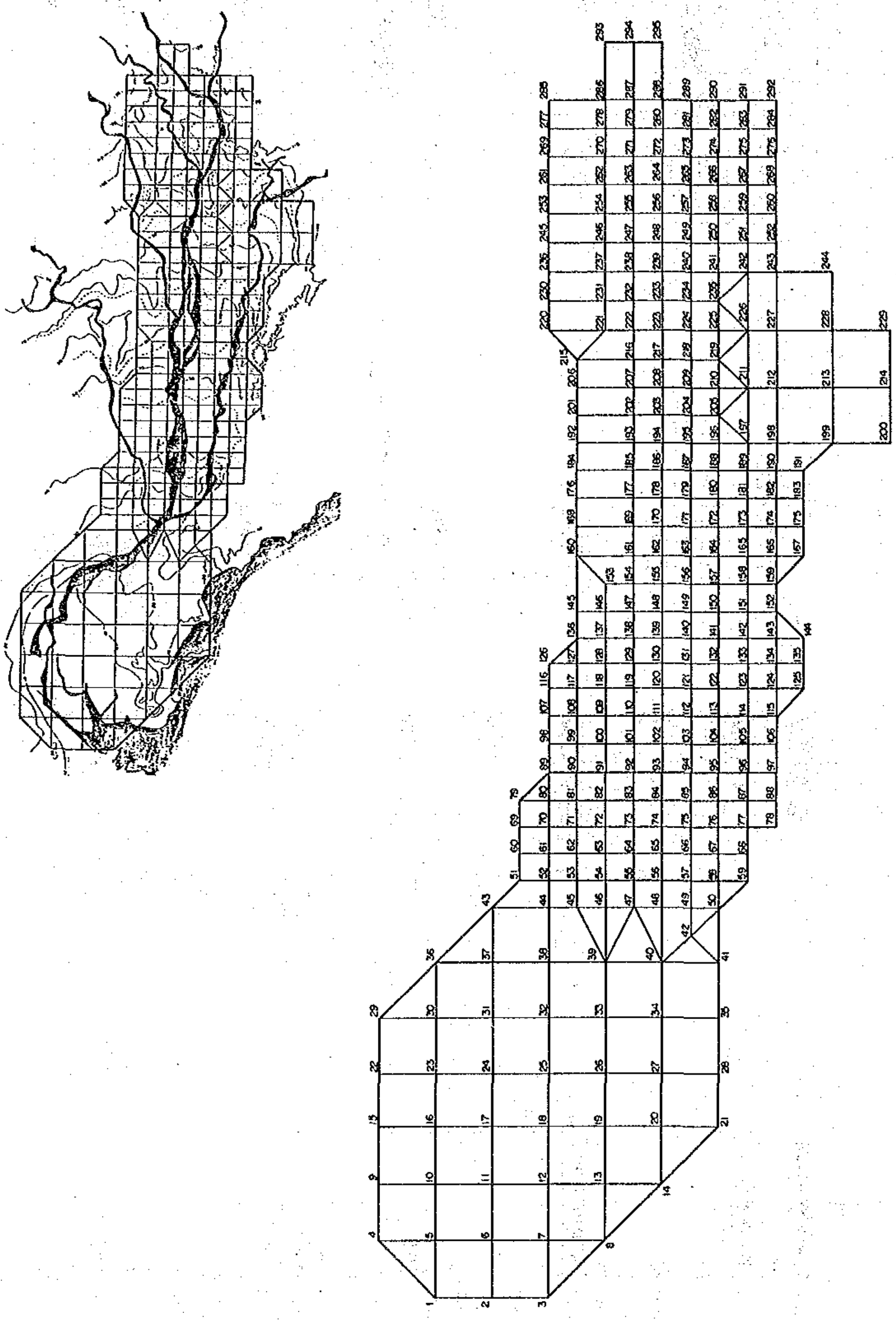

Fig. D.4-1 Groundwater Simulation Model

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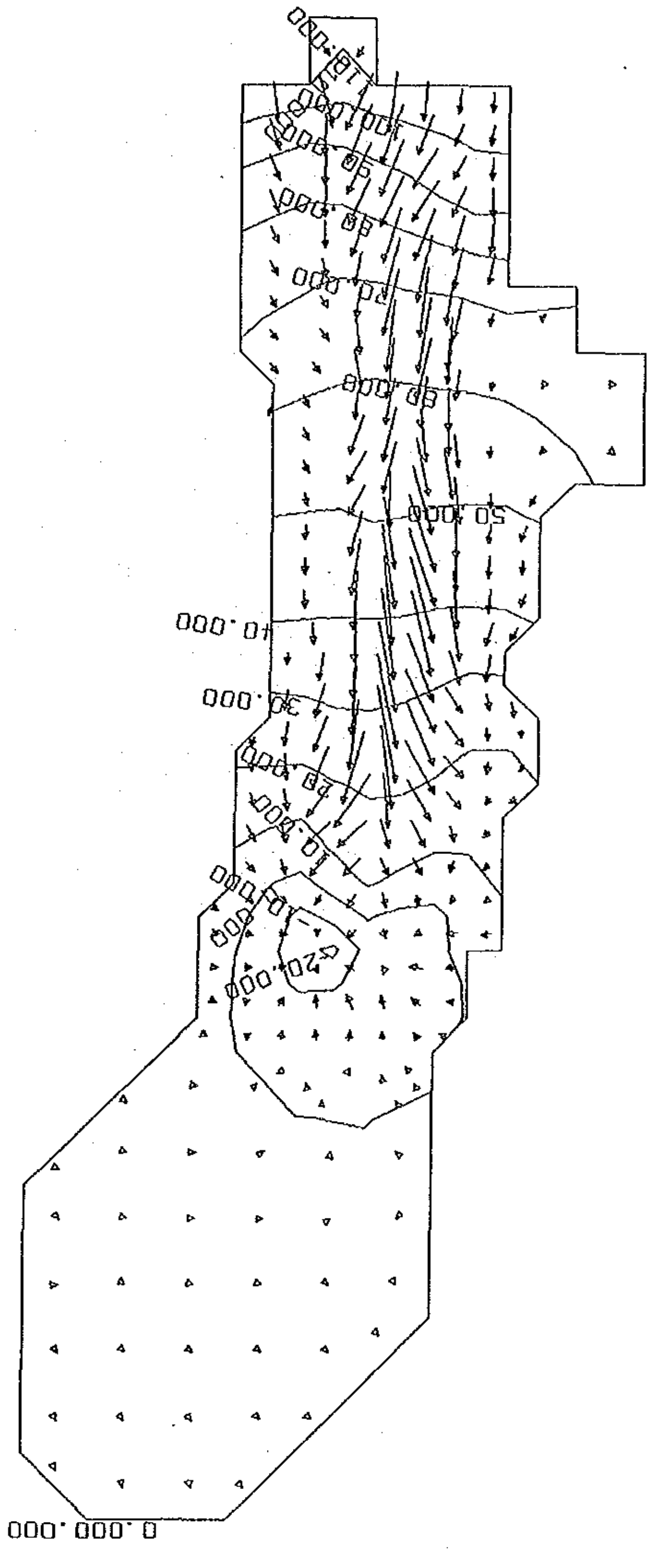

Fig. D.4-2 Calculated Groundwater Table Contour Map

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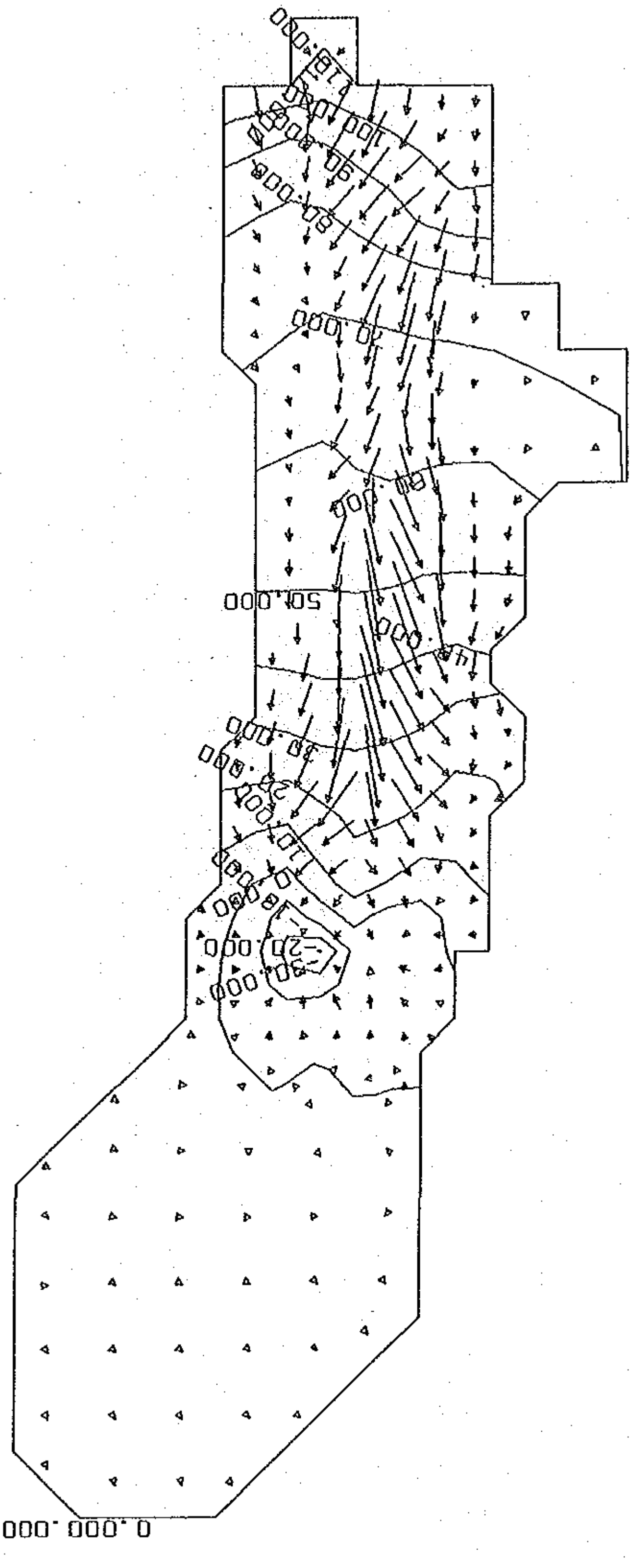

Fig. D.4-3 Predicted Groundwater Table Contour Map

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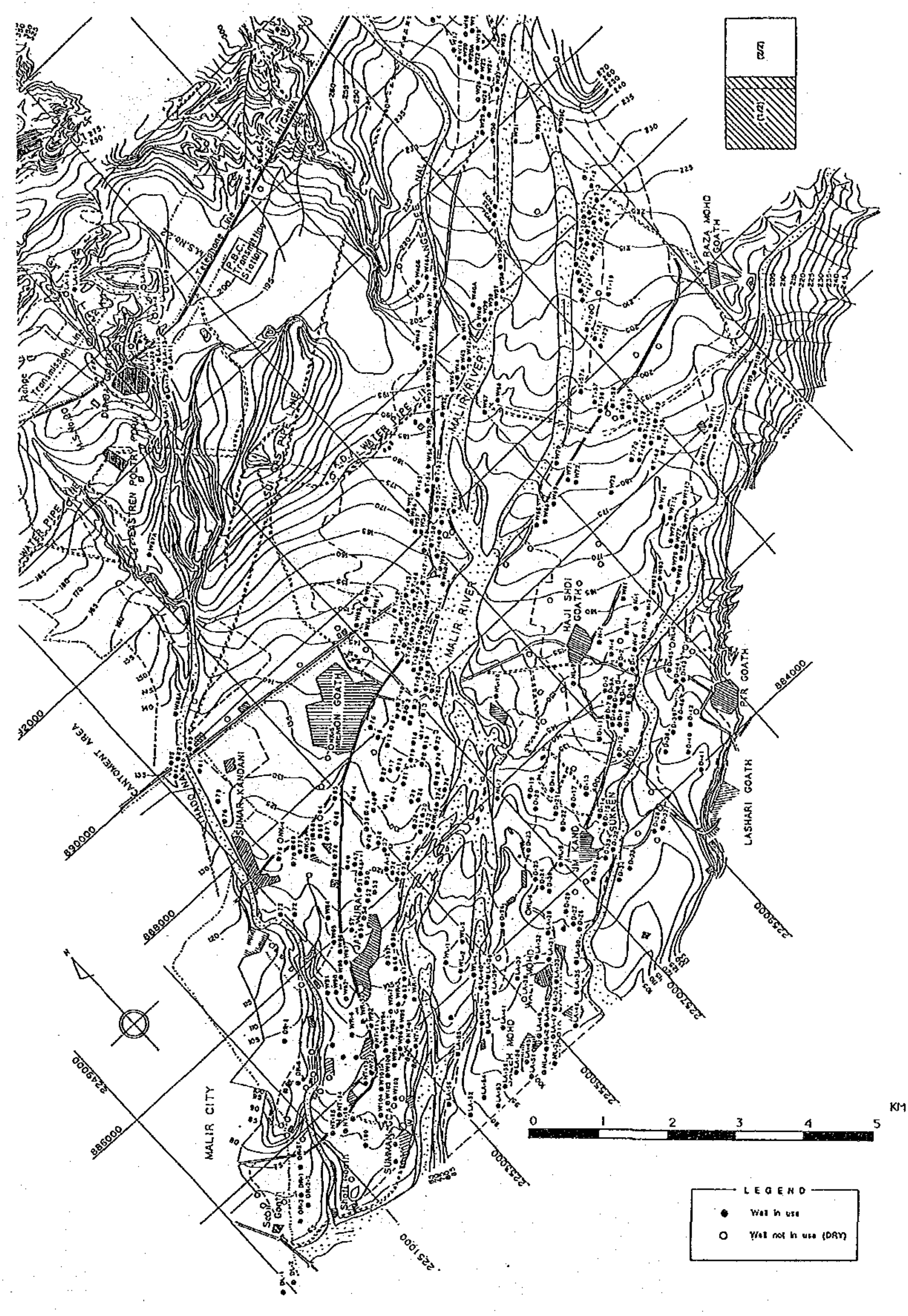

Fig. D.5-1 Distribution of Wells (1/2)

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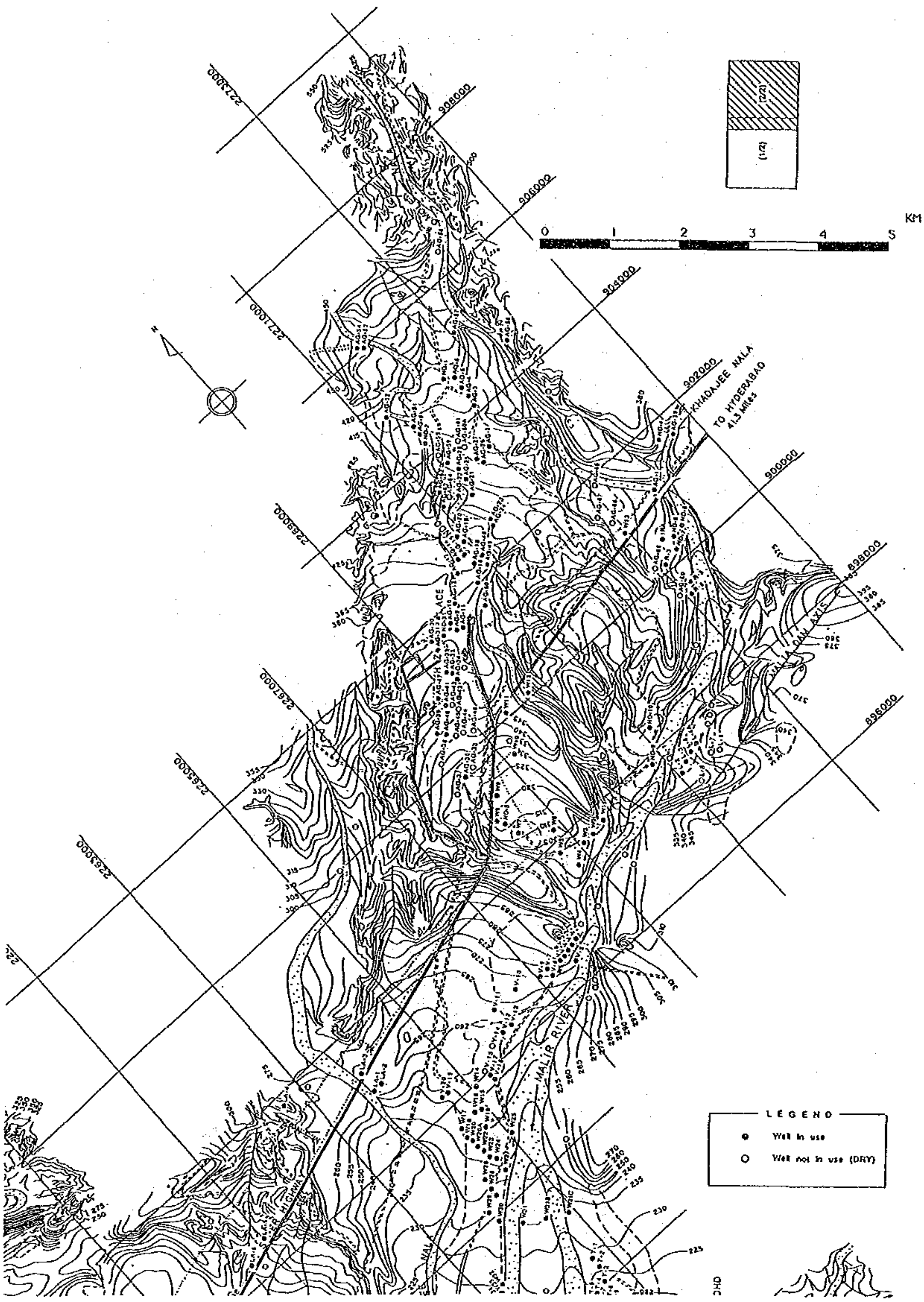

Fig. D.5-1 Distribution of Wells (2/2)

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