ISLAMIC REPUBLIC OF PAKISTAN
GOVERNMENT OF SINDH

FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN MALIR BASIN

EXECUTIVE SUMMARY

NOVEMBER 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

ISLAMIC REPUBLIC OF PAKISTAN GOVERNMENT OF SINDH FEASIBILITY STUDY ON WATER RESOURCES

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PREFACE

In response to a request from the Government of the Islamic Republic of Pakistan, the Japanese Government decided to conduct a feasibility study on the Water Resources Development Project in Malir Basin and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Pakistan a survey team headed by Mr. Kunio IRIE, Nippon Koei Co., Ltd., and composed of members from the same company and Nippon Giken Inc., three times between August 1989 and August 1990.

The team held discussions with the officials concerned of the Government of Pakistan, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

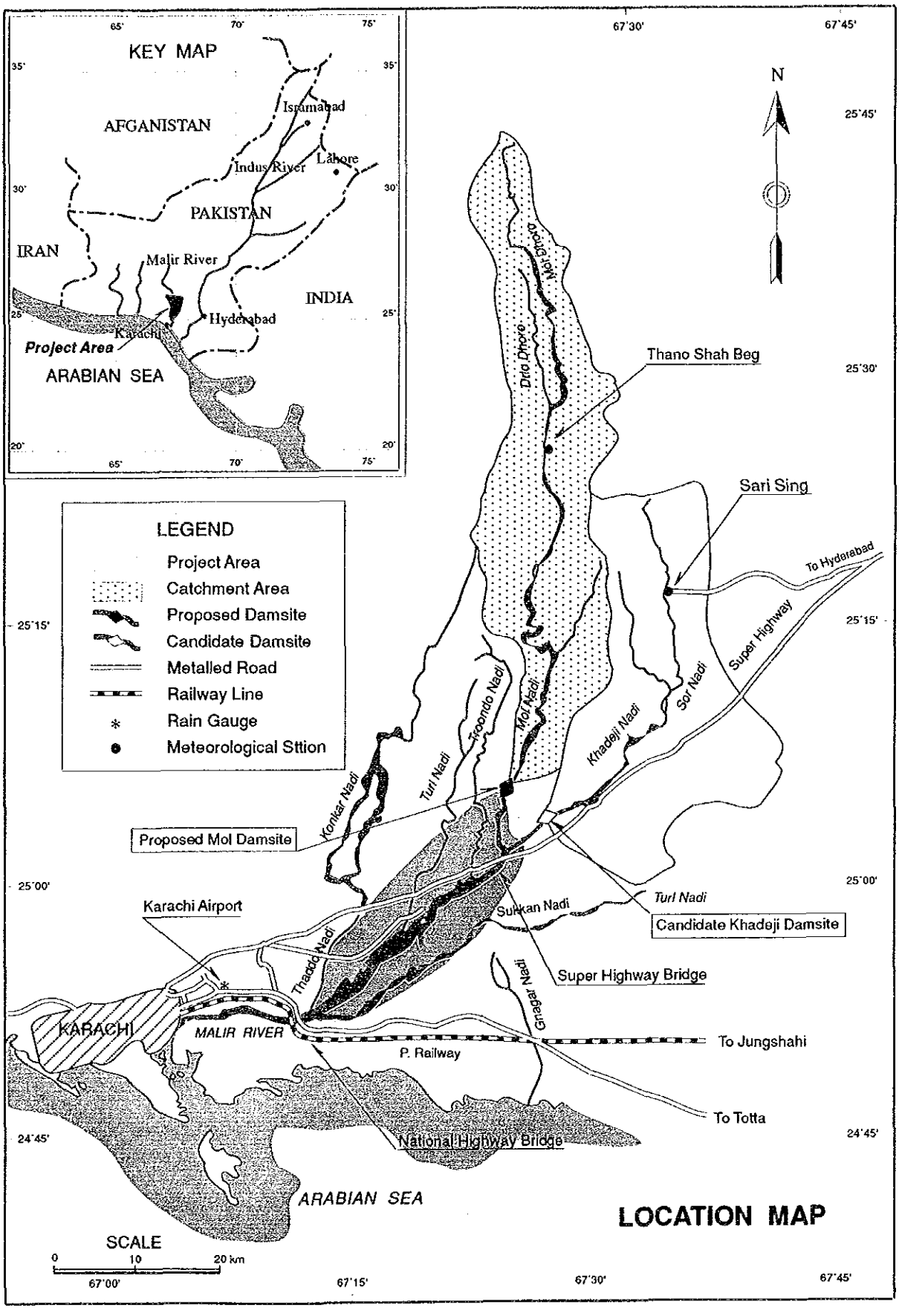
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincerest appreciation to the officials concerned of the Government of the Islamic Republic of Pakistan for their close cooperation extended to the team.

November 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency


KEY MAP
AFGANISTAN
Islamabad
Indus River
Lahore
PAKISTAN
IRAN
Malir River
INDIA
Hyderabad
Karachi
Project Area
ARABIAN SEA
LEGEND
Project Area
Catchment Area
Proposed Damsite
Candidate Damsite
Metalled Road
Railway Line
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Meteorological Sttion
N
Thano Shah Beg
Sari Sing
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Mol Dhoro
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Sol Nadi
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Gragar Nadi
KARACHI
MALIR RIVER
P. Railway
To Jungshahi
To Totta
National Highway Bridge
ARABIAN SEA
SCALE
0 10 20 km
LOCATION MAP
65°
70°
75°
67°30'
67°45'
67°00'
67°15'
35°
30°
25°
20°
25°45'
25°30'
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24°45'

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WATER RESOUCES DEVELOPMENT PROJECT
IN MALIR BASIN

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SUMMARY AND RECOMMENDATIONS

1. INTRODUCTION

01. This Report is prepared in accordance with the Scope of Work for the Feasibility Study on the Water Resources Development Project in Malir Basin agreed upon between the Government of Sindh (GOS), Islamic Republic of Pakistan, and the Japan International Cooperation Agency (JICA) in February 1989. The objectives of the study are to formulate the water resources and agricultural development plan in the Malir river basin by augmenting irrigation water through artificial recharge to groundwater through construction of storage dam(s) on the Khadeji and/or Mol tributaries of the Malir river, and also to verify the feasibility of the project.

02. Due to excessive extraction of groundwater, which has resulted in a drop in groundwater table year by year, a critical shortage has developed in both irrigation and potable water supply, combined with sea water intrusion into the basin aquifer. In 1967, a preliminary study on water resources development in the basin was carried out and a reconnaissance report was prepared. In 1979, a study on the project was carried out and a feasibility report on Water Resources Development in the Malir Basin was prepared by WAPDA. In 1984, a project document on Water Resources Development in the Malir Basin was prepared by National Engineering Services Limited, Pakistan (NESPAK) for the purpose of recasting the summary and recommendations of the feasibility report on the basis of information and data incorporated in the feasibility report.

03. GOS has had a keen interest in developing the water resources of the Malir river basin for a long time. In 1988, GOS therefore requested GOJ to carry out a feasibility study on Water Resources Development Project in the Malir Basin including agricultural development. In response to the GOS's request, GOJ decided to conduct the feasibility study and entrusted the study to JICA. JICA sent a Preliminary Survey Team in January 1989, and the Scope of Work and Minutes of Meeting were agreed upon and signed on 6th February 1989.

2. BACKGROUND

04. Pakistan extends from 23° to 37° north latitude and from 61° to 76° east longitude. The total land area of the country is 79.6 x 10^6 ha comprising 44.7 x 10^6 ha for non-cultivation area, 3.2 x 10^6 ha for forest area, 11.1 x 10^6 ha for cultivated waste area, and 20.6 x 10^6 ha for cultivated area or about 26% of total area. The irrigated area is 15.8 x 10^6 ha or 76% of the cultivated area. In Sindh Province, the total land area is 14.1 x 10^6 ha. Cultivated land of about 5.6 x 10^6 ha is located on the Sindh plain which extends along the Indus river and its tributaries.

05. Total population of Pakistan was 84.2 million in 1981. The projected population was 105.4 million in 1988 based on the average growth rate (1972 - 1981) of 3.1% per annum. If the population growth continues at the above rate, it will reach 150 million by 2000. The Gross Domestic Product (GDP) in 1988/89 at constant prices of 1980/81 amounted to Rs. 404,140 x 10^6 among which the agricultural sector shared about 26%. The annual growth rate in GDP was 5.1%, and the per capita income at constant prices was Rs. 3,910.

06. According to the Seventh Five Year Plan (1988-93), agriculture remains the mainstay of Pakistan's economy accounting for over 23% of GDP and employing about 50% of the labour force. The agricultural production growth rate in Pakistan for the years 1988 - 89 was about 6% per year. The growth rate in major crops was 7.8%, 3.2% for minor crops, 5.9% in livestock, 3.9% in forestry and 0.5% in fishing. Major and minor crops, livestock and fishing lagged behind the plan targets, and only forestry achieved the plan target. However, the average annual growth rate of the agriculture sector during period of the Sixth Five Year Plan (1983-87) was 3.8% against a target of 4.9%. Although the growth target was not achieved, Pakistan has become self-sufficient in food grains. The production of rice and wheat was below the targets set in the plan. In case of the rice, a shortage of water at the transplanting stage, less rainfall, pest damages and lack of high-yielding variety seeds resulted in a decrease in production. Wheat production was also affected by adverse weather conditions in 1986-88.

3. THE STUDY AREA

07. The study area is located in the Malir river basin which is situated about 20 km north-east of Karachi city, the provincial capital of Sindh as shown in Fig. 1. The Malir river is formed by the confluence of the Khadeji and Mol rivers near the Super Highway bridge with a catchment area of 1,205 km^2 at the confluence. After the confluence, it runs about 48 km towards southwest and drains into the Arabian Sea near Karachi. The study area extends on both sides of the Malir river between the proposed Mol damsite located at about 7.2 km upstream of the confluence of the Mol and Khadeji rivers and National Highways, and covers a flood plain of 24,230 ha in gross.

08. The annual average rainfall at Karachi airport (1929-1988) is 219 mm, of which about 78% occurs during the three months from July to September in the monsoon season. The hottest month is May and the mean daily maximum and minimum temperatures are 35.2°C and 25.8°C at Karachi airport. The coolest month is January and the mean daily maximum and minimum temperatures are 25.7°C and 10.1°C respectively. Mean relative humidity varies from 79% in August to 51% in January. Mean pan evaporation reaches 14.7 mm/day in May, and an annual average of 10.4 mm/day at Super Highway bridge. The average monthly wind speed at Karachi airport varies between 4.7 m/sec in June and 1.4 m/sec in December. The mean meteorological data in the study area are illustrated in Fig. 2.

09. The total population in the study area was 30,100 persons in 1961 and increased to 65,600 persons in 1981. The population is estimated to have been increased to 90,400 by 1989 based on the overall growth rate of 5.3% from 1972 to 1981 for Karachi East District. It is estimated that about 53% of the population is male and 47% female. Population density is estimated at 373 persons/km which is about three times the average for Sindh Province of 135 persons/km, but considerably lower than that for Karachi East District as a whole, which is 783 persons/km. The total number of households is estimated at 16,270 with an average household size of 5.6 persons.

10. The Soil Survey of Pakistan was carried out in the WAPDA study area over a total extent of 29,210 ha which covers the flood plains formed by the Malir river and its surrounding highland. According to the previous study and field surveys, a high coincidence was recognized between distribution patterns of major soils and landforms. The landforms were classified into four (4) units for which seven (7) soil associations were identified as summarized in the following table:

Landform	Geological Era	Soil Association	Extent (ha)
1. Sub-recent flood plain	Quaternary	Meheb	6,460
2. Old piedmont plain less eroded	Late Pleistocene	Iddu, Mauripur and Mindiari	11,560
3. Old dissected piedmont plain	Late Pleistocene	Laundhi and Pipri	8,580
4. Very old dissected gravelly piedmont terrace	Middle Pleistocene	Monze	2,610
Total			29,210

11. Land capability was assessed for the soils of the WAPDA area in order to classify the suitability of soils for general agricultural purposes including grazing and forestation (Ref. 01). Land capability was classified into four (4) and summarized as follows:

Land Capability Class	Area (ha)	(%)
Class I	6,210	21
Class II	9,570	33
Class III	11,190	38
Class IV	2,240	8
Total	29,210	100

12. The present land use pattern is closely related to topographic conditions, soil conditions and availability of irrigation water. The land use is classified into five (5) categories i.e., (a) orchard fields, (b) irrigated upland fields, (c) rainfed upland fields, (d) fallow land and (e) non-agricultural land. The irrigated fields have been developed to the maximum possible extent depending on availability of groundwater in the Malir river basin. In recent years, however, irrigated fields have decreased due to reduced availability of irrigation water as summarized below:

Land Category	WAPDA Study 1978		JICA Study 1988/89	
	(ha)	(%)	(ha)	(%)
Agricultural Land	4,070	13.9	3,220	13.3
- Orchard fields (irrigated)	1,380	(4.7)	1,200	(5.0)
- Upland fields (irrigated)	2,690	(9.2)	1,540	(6.3)
- Upland fields (rain-fed)	(-)		480	(2.0)
Fallow Land	1,590	5.4	2,920	12.1
Non-agricultural Land	23,550	80.7	18,090	74.6
Total	29,210	100	24,230	100

13. The 1979 WAPDA study presented a breakdown of the land tenure situation in the study area in 1978, from Karachi East District Revenue Office records. Data for 1978 indicated that 53% of all farmers were tenants, whose farm land was owned by other persons, on a share cropping basis. The tenants operated on about 38% of the total area of land, with an average farm size of 6.1 ha. Owners, directly farming their own land, accounted for 27% of all farmers and 36% of the registered land area, with an average farm size of 12.1 ha. An intermediate category of owner-tenant (owning and farming part of the land and farming another part owned by other persons on a share-cropping basis) accounted for the remaining 20% of farmers and 26% of the registered land area. The average farm size of owner-tenants was 11.5 ha, similar to that of owner farmers.

14. The volume of crop production in the study area has been estimated on the basis of the estimates of cropped area and crop yields as set out above. The study area is estimated to produce some 6,900 tons of fodder from a cropped area of 570 ha, some 8,600 tons of vegetables from 1,960 ha, and 5,980 tons of fruit from 1,200 ha. The volume of crop production is summarized in the following table:

Crop	Cropped Area ha	Volume ton	Yield ton/ha
Fodder	570	6,910	12.1
Vegetables	1,960	8,610	4.4
Fruit	1,200	5,980	5.0
All	3,730	21,500	-

15. The hydrogeological profile of the area is classified mainly into three zones, namely, permeable, slightly permeable and impermeable zone. The phreatic aquifer of the Quaternary deposits is the main aquifer in the study area. The phreatic aquifers mainly comprise alluvial deposits distributed along the Malir river, and consisting of layers of sand and gravels with silty sand layers. The dimensions of alluvial deposits in various 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)

16. For last 12 years from 1977 to 1989, the groundwater table has been lowered due to overdraft of groundwater as illustrated in Fig. 3. Groundwater depression 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. The annual net withdrawal from the aquifer from 1977 to 1988 is estimated at about 8.0 MCM and accordingly the average annual drawdown is 0.43 m, which shows a more rapid drawdown than projected by WAPDA. The total groundwater volume in the phreatic aquifer in 1977 and 1989 is estimated as 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 MCM
Average annual drawdown of groundwater table				0.43 m

17. Water quality of surface runoff in the Malir river is excellent and categorized as medium salinity and low alkalinity (C_2S_1) according to the USDA standard of water classification. Little change in pH distributions was recorded in 1989/1990 in comparison with data collected in 1977. pH values vary from 7.6 to 8.3 in general. According to the distribution of EC in the study area, EC of around 1,000 µS/cm is found along the Malir river and its value increases as the distance from the river increases. EC values of groundwater analysed in 1989 show generally higher values than those recorded in 1977 at wells located in the downstream area. Groundwater in the project area is classified generally as C_2S_1 and C_3S_1 according to the USDA standard except for water sampled from the groundwater depression in Thano and Laundhi Union Councils, and is moderate to medium high salinity hazard and low sodium (alkalinity) hazard for irrigation purposes. However groundwater in the depression is classified as high salinity hazard and medium alkalinity hazard (C_4S_2). The chemical contents are almost permissible for irrigation water except in the southern part of the depression mentioned above.

18. As the previous studies indicated that there is 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), tritium content analysis and hydrogeological information. As a result of salt 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.

19. As seen in Fig. 4, well construction was accelerated in the 1960's and it was continued in the 1970's and 1980's. Due to excessive withdrawal of groundwater, the depth of dugwells became deeper and deeper every decade and this fact shows that the groundwater table is declining at the rate of about 5 - 7 m per decade as seen in Fig. 5. Especially in the areas of Thano and Laundhi Union Councils, drawdown of groundwater table is remarkable, and abandaned wells are increasing sharply as also shown in Fig. 4. In the project area which is delineated based on the hydrogeological condition and its recharge mechanism in the study area, there are 466 production wells, and a summary of the production wells is shown below:

Diameter of Discharge Pipe mm (inch)	Nos. of Production Wells				
		Upper R. Stretch	Middle R. Stretch	Lower R. Stretch	
	Project Area	Darsano Chano U.C.	Konkar U.C.	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

20. 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 consumer's record in 1987/88 (KESC), pumped water from the production wells was estimated to be about 35.5 MCM in 1987/88 and is summarized in the following table. Actual irrigation water supply in 1987/88 was limited to about 80% of the necessary irrigation water requirement. This means that crops and plants in the project area are used to facing shortage of irrigation water supply, due to long drought over the last 20 years.

Item	Unit	River Stretch			Whole Project Area	Diversion Water Requirement
		Upper	Middle	Lower		
1. Nos. of Pumped	Nos.	102	201	163	466	-
2. Pumped Volume	MCM	11.5	15.2	8.8	35.5	44.3
3. Unit Pumping Volume	1,000 m^3	113	76	54	76	-

4. POTENTIAL WATER RESOURCES DEVELOPMENT

21. Natural recharge into the basin phreatic aquifers is estimated to have been 46.5 MCM/yr from 1929 to 1988 and 38.8 MCM/yr from 1977 to 1988, as summarized in the following table and scematically shown in Fig. 6.

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

22. A comprehensive water balance in the basin aquifer as a whole is shown in the following 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.

Unit: MCM/yr

Simulation Period : 1977-1988					
A. Recharge			B. Withdrawal		
1. Natural recharge	38.8		1. Irrigation water		48.7
2. Deep percolation (irrigation)	7.3		2. Potable water supply to Karachi		2.7
3. Deep percolation (domestic water)	0.3		3. Domestic water		1.9
4. Total (A)	46.4		4. Groundwater discharge to sea		1.3
			5. Total (B)		54.6
C. Balance (A - B)		-8.2			
D. Measure net withdrawal from the aquifer		-8.0			

23. Several important projects were executed during the decade, which will be affected by implementation of this project, especially by the Khadeji dam. A part of the existing two lanes and other two lanes under construction of the Super Highway from Karachi to the north will be submerged under the Khadeji reservoir, requiring relocation costs. Moreover, the Khadeji dam axis touches the Precision Engineering Complex (PEC) of Pakistan International Airline (PIA) belonging to the Ministry of Defence, and clearance between the proposed surcharge water level (EL. 166.3 m) in the previous study and the lowest ground elevation (EL. 169 m) of the Complex is only 2.7 m. Therefore, in order to avoid submergence of the Super Highway, to minimize the costs, as well as to give more clearance to the PEC, the maximum surcharge elevation of the Khadeji dam would be fixed at EL. 163 m. The maximum allowable surcharge elevation of the Mol reservoir is about EL. 175 m which shows the allowable topographic limitation as also studied by WAPDA. The following table summarises the implications:

Item		Unit	Khadeji Dam	Mol Dam
1.	Maximum Allowable Surcharge Level	EL. m	163.0	175.2
2.	Surcharge Depth	m	3.9	3.4
3.	Normal Full Water Level (Max. NFWL)	EL. m	159.1	171.8
4.	Maximum Gross Storage Capacity	MCM	45.7	54.5
5.	Dead Storage Capacity	MCM	10.2	10.7
6.	Minimum Water Level	EL. m	149.0	156.5
7.	Maximum Live Storage Capacity	MCM	35.5	43.8

24. Recharge to the phreatic aquifer in the upper and lower stretches should be kept equal as far as possible. If discharge from the dam is small, most of the water will be recharged to groundwater but only in the upper river stretch. On the other hand, if 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 an important factor for the dam operation. Allowable discharge from the dam(s) is estimated at 8 m^3/sec (21 MCM/month).

25. The dam(s) operation rule is set to release water from the dam(s), which corresponds to the balance between the allowable discharge of 8 m^3/sec and the runoff from the remaining catchment area. If the runoff from the remaining catchment area exceeds the allowable discharge, no water will be released from the dam(s). Only the balance of water is released, when runoff is less than the allowable discharge. Artificial recharge is calculated for various alternative cases, and 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		
Live 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 the Remaining Basin and Dam Spillout	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	

26. The area which could be irrigated by groundwater augmented by construction of the project dam(s) is estimated at 4,100 to 4,860 ha depending on the combination of dams and live storage capacity as summarized in the following table. Comparison of the seven (7) alternatives is made based on the Internal Rate of Return (EIRR), Benefit Cost Ratio (B/C), and Net Present Value (B-C). The results are summarized below:

Unit: MCM

Item	Case-1 Khadeji + Mol	Case-2 Khadeji + Mol	Case-3 Mol Only	Case-4 Mol Only	Case-5 Mol Only	Case-6 Khadeji Only	Case-7 Khadeji Only
Live Reservoir Capacity:							
Khadeji ;	35.5	35.5	-	-	-	35.5	30.0
Mol ;	43.8	35.0	43.8	35.0	30.0	-	-
1. Total recharge to phreatic aquifer	70.6	69.3	65.4	64.7	63.9	62.7	62.1
2. Water supply to Karachi	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Domestic water supply	2.3	2.3	2.3	2.3	2.3	2.3	2.3
3. Natural discharge to sea	1.3	1.3	1.3	1.3	1.3	1.3	1.3
4. Available groundwater for irrigation	66.0	64.7	60.8	60.1	59.3	58.1	52.5
5. Net irrigation withdrawal per 1,000 ha	---------- 13.4 - 13.9 (Cropping Intensity = 1.5) ------						
6. Possible irrigation area (ha)	4,860	4,760	4,450	4,350	4,270	4,160	4,100
7. Total economic project cost (10^6 Rs.)	1,451	1,426	659	633	621	793	784
8. Net incremental economic benefit (10^6 Rs.)	104.7	102.5	95.2	93.7	91.3	89.6	88.3
9. EIRR (%)	5.18	5.15	10.40	10.60	10.53	8.40	8.37
10. B/C *1	0.67	0.66	1.33	1.36	1.35	1.05	1.05
11. B-C *1 (10^6 Rs.)	-412	-408	188	196	187	36	33

Remarks: *1 Discount rate of 8% is applied.

As seen in the above table, the Mol dam with a live storage capacity of 35.0 MCM (Case-4) is the most economical of the seven, and the optimum scale of the Mol dam is determined as follows:

Item	Unit	Mol Dam
1. Dam Type		Rockfill (Zone Type)
2. Crest Elevation	EL. m	175.3
3. Maximum Water Level	EL. m	173.0
4. Normal Full Water Level	EL. m	169.6
5. Dead Water Level	EL. m	156.5
6. Dam Height	m	48.8
7. Gross Storage Capacity	MCM	45.7
8. Dead Storage Capacity	MCM	10.7
9. Live Storage Capacity	MCM	35.0
10. Dam Volume	10^3m^3	1,720

27. Applying the average annual recharge amount of 64.7 MCM/yr (Case-4, Mol dam; 35.0 MCM), and the same model with the aquifer parameters, further simulation of groundwater is performed to assess the future groundwater condition. As may be seen in Fig. 10, there is a general tendency for the groundwater table along the river stretch in the upper project area to rise and for the cone depression of groundwater table in the downstream area to fall. Hence, it is recommended that continuous groundwater monitoring is essential to evaluate the analysis, and groundwater management is also necessary for sustainable use of groundwater.

5. THE PROJECT

28. The project is formulated to maximize the potential agricultural benefits through efficient use of land and water resources. The main concept of the project are:

- To increase groundwater recharge by construction of the dam(s),
- To expand irrigation area to maximum extent through augmentation of artificial groundwater recharge,
- To sustain groundwater resource through monitoring and management,
- To supply vegetables and fruit to the greater Karachi market,
- To increase crop yields through introduction of intensive farming practices,
- To improve the socio-economic situation and to increase employment opportunities in the area,
- To maintain a green belt located near the greater Karachi city, and
- To improve organization to ensure the above strategies.

29. Out of 24,200 ha of the study area, the project area to be benefited by augmentation of groundwater recharge is delineated based on the existence of the phreatic aquifer. The phreatic aquifer in the Malir river basin extends over on both sides of the river between the National Highway and the proposed Mol damsite as shown in Fig. 11. Finally based on an economic comparison of the development plans, the possible irrigation area is found to be 4,350 ha. The following table shows the present land use in the study and project areas, and the future without and with the project:

Unit: ha

Land Category	Study Area	Project Area		
	in 1989	in 1989	Without Project	With Project
Agricultural Land	3,220	2,700	2,500	4,450
- Orchard fields (irrigated)	1,200	1,180	1,000	1,000
- Upland fields (irrigated)	1,540	1,420	1,400	3,350
- Upland fields (rain-fed)	480	100	100	100
Fallow Land	2,920	2,800	3,000	1,050
Non Agricultural Land	18,090	8,400	8,400	8,400
Total	24,230	13,900	13,900	13,900

30. The climate in the project area, generally characterized by the summer and winter seasons having warm and relatively dry as well as sufficient sunshine hours, is very favorable for cultivation of fodder, vegetables and fruit crops throughout the year. No significant variation of yields for major crops is observed in the year-round cultivation which is now being practiced by the farmers in the project area. The proposed cropping pattern is finally

determined in consideration of profitability, marketability, peak water requirements, labour requirement, etc. as shown in Fig. 12. A summary is presented in the following table:

Unit: ha

Crops	WAPDA Study		JICA Study		
	Area in 1977	Proposed Project	Present Condition	Without Project	With Project
Summer season					
Fodder	590	700	150	150	150
Vegetables	2,100	2,280	1,270	1,250	3,200
Fruit	1,380	1,380	1,180	1,000	1,000
Sub-total	4,070	4,360	2,600	2,400	4,350
Winter season					
Fodder	370	450	50	40	50
Vegetables	1,520	1,740	310	290	2,100
Sub-total	1,890	2,190	360	330	2,150
Total	5,960	6,550	2,960	2,730	6,500
(Cropping intensity)	(1.46)	(1.50)	(1.14)	(1.14)	(1.50)

31. Based on the proposed cropping pattern, the cropped area, crop yields and total crop production under both "with project" and "without project" conditions are estimated summarized in the following table.

Unit: tons

Item	Without Project	With Project	Increment
Production			
Fodder crops	2,340	4,400	2,060
Vegetables	6,960	46,650	39,690
Fruit	4,760	7,250	2,490
Total production	14,060	58,300	44,240

32. The annual costs and income without project and with project at full development stage are summarized in the following table. Total income from crop production (at constant 1989 prices) is projected to increase from Rs. 18.4 million under without project to Rs. 112.0 million under with project at full development. Incremental annual income from crop production is projected to be Rs. 93.6 million at the full development stage.

Unit: 10^3 Rs.

Item	Without Project	With Project	Increment
Net Crop Income			
Fodder	282	754	472
Vegetable	9,810	96,375	86,565
Fruit	8,351	14,895	6,544
Total	18,443	112,024	93,581

33. The average owner/owner-tenant operated farm would increase from 6.7 ha to 16.5 ha, and the average tenant operated farm from 3.4 ha to 8.3 ha. Farm cost, income and gross margin estimates are based on composite crop group estimates derived as previously described. Costs, income and gross margin for the typical owner and tenant operated farms are summarized as follows:

Items	Unit	Owner Operated Farm			Tenant Operated Farm		
		Without Project	With Project	Increment	Without Project	With Project	Increment
1. Average Holding Size	ha	12.1	12.1	-	6.1	6.1	-
2. Cropped Area	ha	6.7	16.5	9.8	3.4	8.3	4.9
3. Crop Production	tons	34.6	148.2	99.9	17.5	74.7	57.3
4. Gross Income	10^3 Rs.	83.9	412.1	268.2	42.0	208.0	166.0
5. Production Cost	10^3 Rs.	37.0	126.2	89.2	13.6	46.3	32.7
6. Landlord's Share	10^3 Rs.	n.a.	n.a.	n.a.	21.0	104.0	83.0
7. Gross Margin	10^3 Rs.	45.9	285.9	179.0	7.4	57.7	50.3
8. Labour Income	10^3 Rs.	n.a.	n.a.	n.a.	8.5	28.9	20.4
9. Family Income	10^3 Rs.	45.9	285.9	240.0	15.9	86.6	70.7
10. Labour Requirement	man-day	344	1,146	813	169	579	410

Remarks: n.a. means "not applicable".

34. The Mol dam is designed as a rockfill dam with an impervious center core. A general map, geological section, and standard cross section are shown in Figs. 13 to 16 and salient features of the Mol dam is presented in Table 2. The maximum height of dam is 48.8 m above the foundation, the crest of elevation is designed at EL. 175.3 m with a freeboard of 2.3 m including crest road pavement of 0.5 m thick, and the dam has 10 m top width. The length of the dam crest is 2,347 m including 848 m of the main dam and 1,499 m of the saddle dam. The slopes of the dam faces are designed at 1:2.5 for the upstream and 1:2.0 for the downstream. The total embankment volume of the dam will be about 1,730 x 10^3 m^3.

35. A pilot demonstration farm will play an important role in the project to achieve the project target by demonstrating advanced irrigation and farming techniques. The principal objectives of the pilot demonstration farm will be (1) to demonstrate advanced irrigation techniques (especially sprinkler and drip irrigation methods) in order to save irrigation water which results in increase of irrigation area, and (2) to demonstrate advanced farming techniques. It is proposed that the pilot demonstration farm be sited within the Plant Introduction Center at Saleh Mohammed Goth, Laundhi Union Council, which is situated in the southern part of the project area. Out of 10 ha (25 acres), only 2.4 ha (6 acres) are at present used for orchard research and the remaining 7.6 ha (19 acres) are fallow due to the limited irrigation water supply. There is also a section of extension services which belongs to the Agriculture, Livestock and Fisheries Department of GOS. Therefore, most favorable

circumstance are available in the center to establish a pilot demonstration farm as shown in Fig. 17.

36. The implementation period of the project is assumed to be four (4) years from 1991 to 1995 as shown in Fig. 18. The whole of 1991 would be required for detailed design and mobilization. Actual construction works would be commenced in 1992. Dam construction including excavation, foundation treatment, embankment, appurtenant structures, etc. will need three (3) years in all. The dam embankment would be commenced in 1993 and be completed in March 1995. The construction of the pilot demonstration farm will be commenced in late 1992 and be completed before the monsoon in 1993. Demonstration and field research will be commenced from the monsoon season in 1993.

37. Total project cost is estimated to be Rs. 685.6 million (US$31.9 million equivalent) consisting of Rs. 531.0 million (US$24.7 million equivalent) for foreign currency portion and Rs. 154.6 million (US$7.2 million equivalent) for local currency portion, as presented in Table 3, and summarized below:

Unit: Rs. 10^6

	Major Item	Foreign Currency	Local Currency	Total
1.	Preparatory works	27.0	5.9	32.9
2.	Mol dam	362.6	76.8	439.4
3.	Causeway	2.4	3.8	6.2
4.	Pilot demonstration farm	10.4	2.9	13.3
5.	Project office	0.4	0.8	1.2
6.	O&M equipment	10.3	0.0	10.3
7.	Physical contingency	58.2	12.8	71.0
8.	Administration cost	0.0	6.7	6.7
9.	Engineering services	59.6	16.4	76.0
10.	Price contingency	0.0	28.6	28.6
	Grand Total	530.9	154.7	685.6

6. PROJECT ORGANIZATION AND MANAGEMENT

38. Irrigation and Power Department (IPD) of GOS will be the executing agency for implementation of the project. IPD will appoint a project manager for the Malir Project Office to coordinate the execution of the project, which will be established near the Mol dam as shown in Fig. 19. Function of the office will include approval of construction methods and schedules, preparation of design revisions, construction progress, coordination of contracted works, monitoring of construction progress, work quantities and quality control, approval of payment, etc. as well as groundwater monitoring and establishment of a Groundwater Users Association of beneficiary farmers.

39. After completion of construction, the Malir project office will be re-organized into the Project O&M Office under IPD for operation and maintenance of the dam and groundwater monitoring in cooperation with the Groundwater Users Association as shown in Fig. 20. The dam O&M section will be responsible for operation of the dam to maximize recharge to the groundwater in the basin aquifers, and maintenance of the dam and the river course. Another groundwater management section will be totally responsible for management of groundwater to maintain suitable groundwater levels and to ensure the sustainable development and utilization of groundwater.

40. In order to maintain suitable groundwater levels, pumping of groundwater must be controlled and regulated. For this, it is recommended that a water extraction management system and the Groundwater Users Association should be established as discussed in the preceding section. The functions of the water management section of the Malir Project Office are firstly to monitor the groundwater table and pumping records in the project area periodically and to establish guidelines for water extraction from each well. The monitoring works should gradually be transferred from the Malir Project Office under IPD to the Association, and the Association will finally be responsible for all groundwater management works.

41. In order to demonstrate the proposed improved farming practices with high inputs and to introduce new irrigation technology, a demonstration farm is proposed. Demonstration of high yields of crops with improved farming practices will give farmers incentives to adopt the new technology. Further expansion of the cultivated area will be expected through the introduction of water-saving irrigation technology such as sprinkler and drip irrigation methods.

7. PROJECT EVALUATION

42. The project is evaluated from the economic, financial and socio-economic points of view. Firstly economic evaluation is made based on the following assumptions:

(1) The construction period of dam would be four (4) years including one (1) year of detailed design and preparatory works.
(2) Economic useful life of the project would be 50 years.
(3) All prices are expressed in constant late 1989 prices.
(4) The exchange rate of US$1.00 = Rs. 21.5 = ¥150.0 would be used throughout.

Economic agricultural benefit of the project at full development stage is estimated at Rs. 93.7×10^6 while economic cost of the project is estimated at Rs. 632.8×10^6. Considering other minor costs (annual O&M costs and replacement cost) and benefit (cost saving of further well deepening and electricity), EIRR, B/C and NPV are calculated. The results are as follows:

EIRR	=	10.6%	
B/C	=	1.36	(at a discount rate of 8%)
NPV	=	Rs. 196.4×10^6	(at a discount rate of 8%)

43. Financial evaluation of the project is made by the analysis of the typical farm budgets. With the implementation of the project, farm income will increase by 3 or 4 times of income in without project condition, irrespective of the type of land tenure. Incremental benefit per hectare between with and without project conditions will be Rs.4,920 for tenant farmer and Rs. 16,600 for owner operator. Assuming the per capita average annual national expenditure of Rs. 5,300 is target income, about 400 families or more than 50% of the total beneficiaries (owner, owner/tenant and tenant farmers) in the project area will reach to the target in with-project conditon. The project can be justified financially.

44. The major expected socio-economic impacts of the project is enumerated as below:

(1) Stable supply of water,
(2) Increase of Employment opportunities,
(3) Increase of crop production and stable supply of the products to the Karachi city,
(4) Increase of farmers' income,
(5) Improvement of water quality,
(6) Flood mitigation effects,
(7) The use of fertilizer and agro-chemicals, and
(8) Demonstration effect of pilot farm

8. RECOMMENDATIONS

45. Early Implementation of the Project

The Malir basin has played an important role for a long time in supplying agricultural products such as fruit, vegetables, etc. and in supplying potable water to Karachi city. Despite the fact that demand for such agricultural products is increasing due to rapid population growth of Karachi, agricultural land in the project area is decreasing year by year mainly due to overdraft of groundwater from the potential aquifers in the basin, which will further be accelerated unless appropriate countermeasures are provided for augmentation of recharge to and proper management of the aquifers. It is, therefore, recommended that the necessary arrangements for early implementation of the project be taken as soon as possible.

46. Establishment of Pilot Demonstration Farm

Fruit and vegetable crop yields achieved by producers in the project area are significantly lower than those generally achieved in Sindh and much below national averages. The restoration of a reliable and properly managed supply of water under the proposed project would create the conditions for development of more intensive fruit and vegetable production in the project area. The project itself, however, would make only a limited contribution to the intensification of crop production in the project area through augmentation of recharge to the aquifers. It is therefore essential to establish a pilot demonstration farm in order to achieve the desired increase in crop yields.

47. Groundwater Management

Proper groundwater management should be carried out strictly for sustainable groundwater use in order to prevent serious groundwater mining and deterioration of water quality, in coordination with implementation of the project. Otherwise, decrease of potential groundwater resources as seen at present in the project area may occur again in the future, even if increased recharge to the aquifers can be provided by the project. No legal framework for groundwater resources development exists in the Province or in the project area. It is strongly recommended that a section of IDP be established for proper groundwater management, including development of necessary regulations for groundwater resources development, and to monitor and maintain the aquifer level/status in the project area as well as to ensure proper utilization of potential groundwater resources, in collaboration with the proposed Groundwater Users Association.

TABLES

Table 1 SALIENT FEATURES OF KHADEJI AND MOL DAMS PROPOSED BY WAPDA

		Unit	Khadeji Dam	Mol Dam
a)	General			
	Location		7.2 km upstream of Super Highway Bridge at a distance of about 50 km from Karachi.	8.3 km upstream of Super Highway Bridge.
	River		Khadeji tributary of Maril River	Mol tributary of Maril River
	Type of dam		Concrete Gravity	Earthfill (Homogenious)
	Purpose		Groundwater recharge (Irrigation + Flood + Drinking Water Supply)	Groundwater recharge (Irrigation + Flood + Drinking Water Supply)
b)	Hydrology			
	Catchment area	km^2	567	611
	Mean annual rainfall	mm	217	217
	Mean annual runoff	MCM	31.2	33.7
c)	Reservoir			
	Livestorage	MCM	32.3	33.2
	Flood control storage	MCM	22.4	17.8
	Dead storage	MCM	7.2	7.7
	Gross storage	MCM	61.9	58.7
	Maximum reservoir area	km^2	14.2	6.3
d)	Dam			
	Type		Concrete Gravity	Earthfill (Homogenious)
	Maximum height	m	39.0	44.2
	Length of crest	m	381	2,347
	Top width	m	9.1	12.2
	Top elevation of dam	EL. m	168.6	177.1
	Nomal full water level	EL. m	162.6	170.7
	Maximum water level	EL. m	166.3	174.7
	Slope: Upstream		1 : 0.1	1 : 3.0
	Downstream		1 : 0.7	1 : 2.0
e)	Spillway			
	Type		Overflow (gated)	Submerged weir (ungated)
	Gates	No. x m x m	5 x 12.2 x 6.1	-
	Capacity	m^3/sec	3,830	3,720
	Reservoir absorption	MCM	48.6	23.2
	Surcharge for design flood	m	3.7	4.0
	Crest elevation	EL. m	156.5	170.7
	Energy dissipation		Stilling Basin (energy dissipation by hydraulic jump)	No Stilling Basin
f)	Off-take Structure		1.8 m dia circular conduit with 1.8 m x 1.8 m control gate at inlet end through middle of overflow section discharge directly into main stilling basin.	1.8 m dia tunnel with control gate at outlet end and emergency control gate at inlet end with stilling basin on downstream end.
	Outfall Channel		-	6.5 ft. wide channel with 1-1/2 : 1 side slope discharging into natural Nullah.
g)	Irrigation System		Recharging aquifer by controlled releases from Khadeji & Mol Dams	
h)	Cropping Area	ha	5,670	
	Drinking Water Supply	MCM	13.4	

Table 2 SALIENT FEATURES OF MOL DAM

		Unit	Mol Dam
a)	General		
	Location		8.3 km upstream of Super Highway Bridge.
	River		Mol tributary of Maril River
	Type of dam		Rockfill (Zone type)
	Purpose		Groundwater recharge (Irrigation + Domestic Water Supply)
b)	Hydrology		
	Catchment area	km^2	596
	Mean annual rainfall	mm	231
	Mean annual runoff	MCM	44.9
c)	Reservoir		
	Livestorage	MCM	35.0
	Flood control storage	MCM	0.0
	Dead storage	MCM	10.7
	Gross storage	MCM	45.7
	Maximum reservoir area	km^2	5.5
d)	Dam		
	Type		Rockfill (Zone type)
	Maximum height	m	48.8
	Length of crest	m	2,347
	Top width	m	10.0
	Crest elevation of dam	EL. m	175.3
	Nomal full water level	EL. m	169.6
	Maximum water level	EL. m	173.0
	Slope: Upstream		1 : 2.5
	Downstream		1 : 2.0
	Dam volume	10^3 m^3	1,720
e)	Spillway		
	Type		Submerged weir (ungated)
	Portable maximum flood	m^3/sec	4,280
	Design capacity	m^3/sec	4,100
	Surcharge for design flood	m	3.4
	Crest elevation	EL. m	169.6
	Energy dissipation		No Stilling Basin
f)	Off-take Structure		2.4 m dia tunnel with control gate at outlet end and emergency control gate at inlet end with stilling basin on downstream end.
	Outfall Channel		Channel into natural Nullah.
g)	Irrigation System		Recharging aquifer by controlled releases from Mol Dam
h)	Irrigation Area (Cropped area)	ha	4,350 (6,500)
	Domestic Water Supply	MCM	3.3

Table 3 PROJECT COST FOR MOL DAM (35 MCM)

Unit: Rs.10^6

Item	Foreign Currency	Local Currency	Total
1. Direct Construction Cost			
1.1 Preparatory Works	27.0	5.9	32.9
1.2 Mol Dam	362.6	76.8	439.4
A. Main Dam	212.3	36.5	248.8
B. Saddle Dam	10.9	2.0	12.9
C. Spillway	51.8	16.7	68.5
D. Intake Facility	68.9	13.2	82.1
E. Diversion Works	9.9	3.5	13.4
F. Access Road	8.8	3.8	12.6
G. Land Acquisition	0.0	1.1	1.1
1.3 Causeway	2.4	3.8	6.2
1.4 Pilot Demonstration Farm	10.4	2.9	13.3
1.5 Project Office	0.4	0.8	1.2
Sub-total	402.8	90.2	493.0
2. Procurement of O & M Equipment	10.3	0.0	10.3
3. Physical Contingency	58.2	12.8	71.0
4. Administration Cost	0.0	6.7	6.7
5. Engineering Services	59.6	16.4	76.0
Sub-total	530.9	126.1	657.0
6. Price Contingency	0.0	28.6	28.6
Grand Total	530.9	154.7	685.6

FIGURES

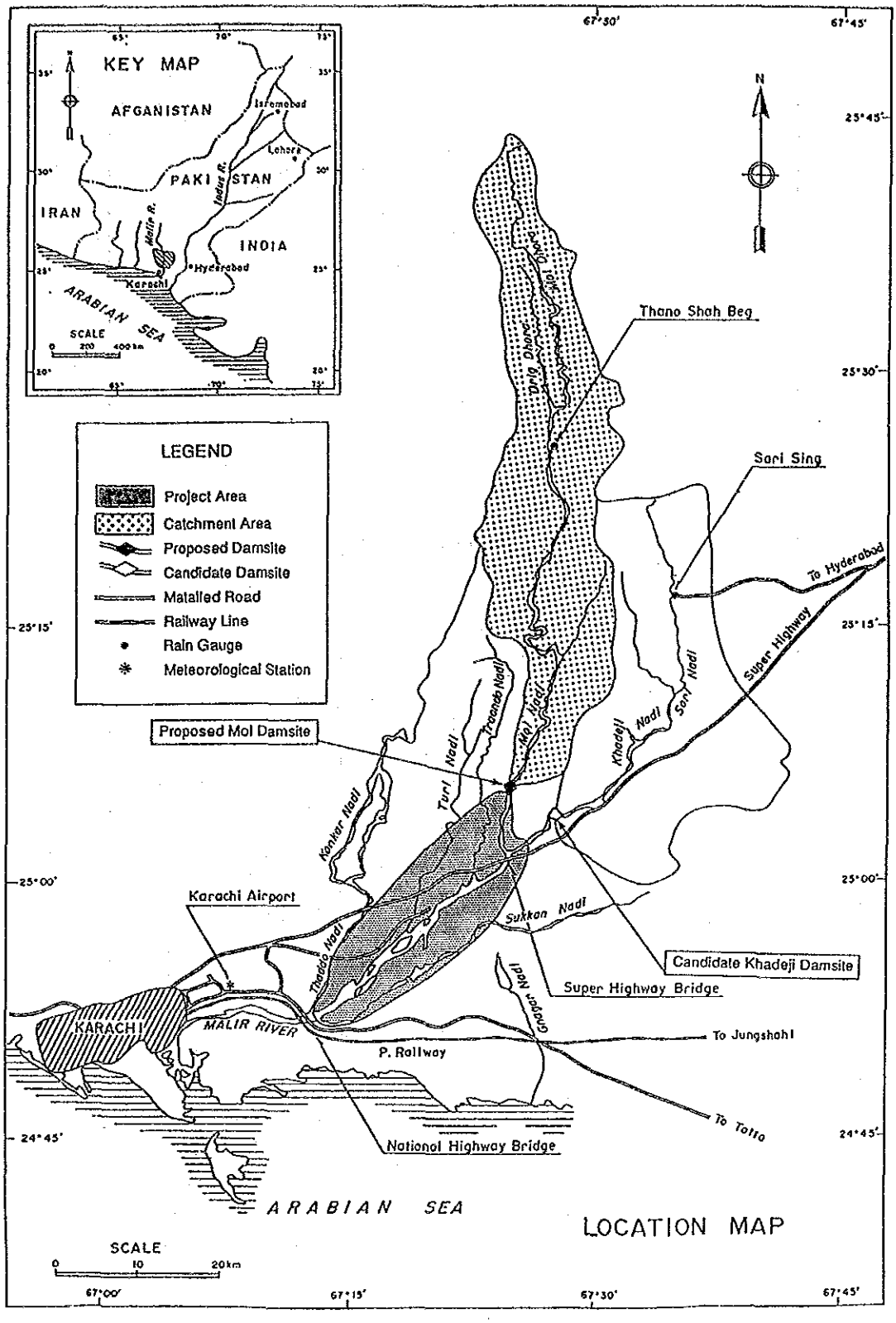

Fig. 1 Location Map

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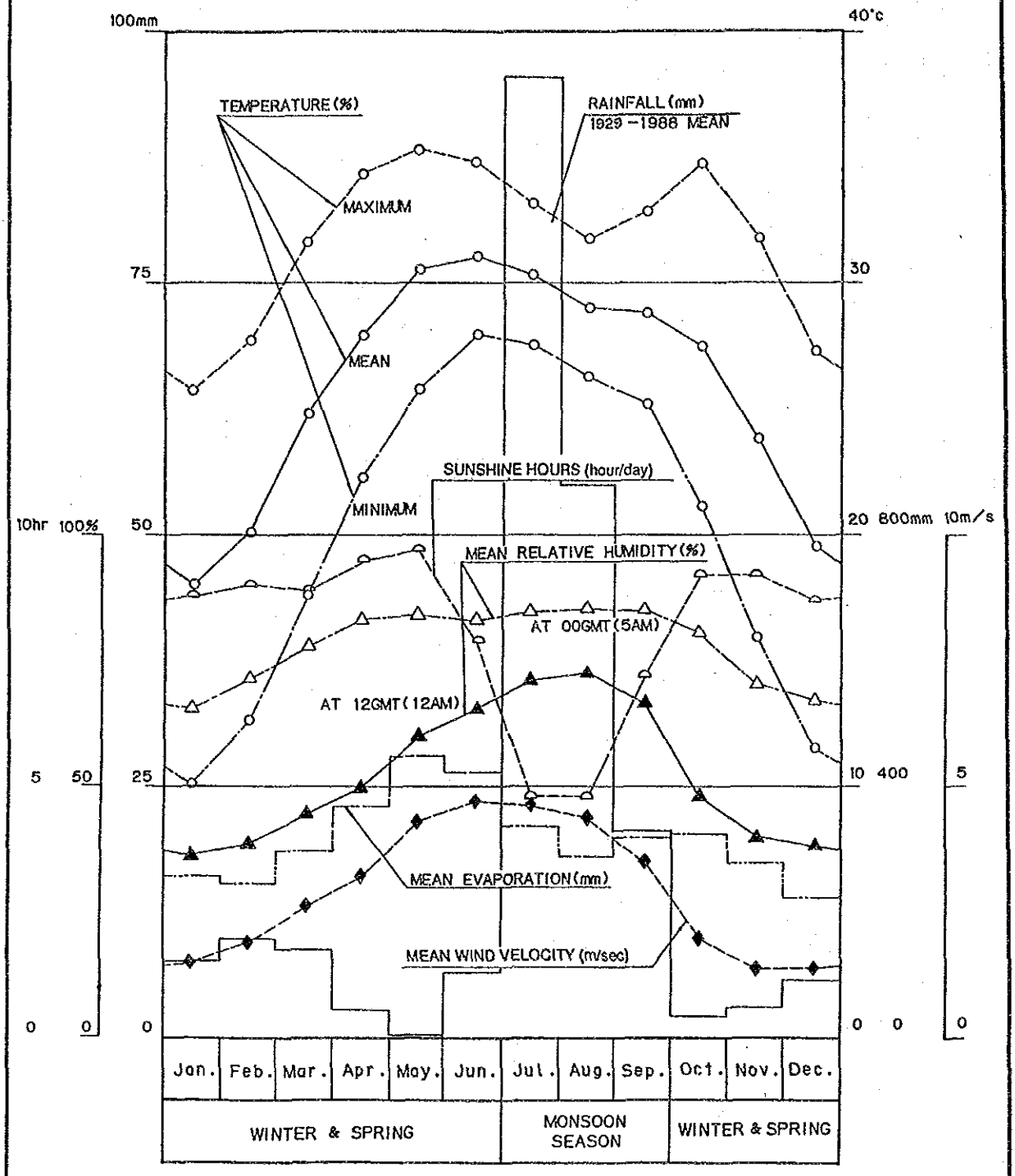

Fig. 2 Meteorological Characteristics

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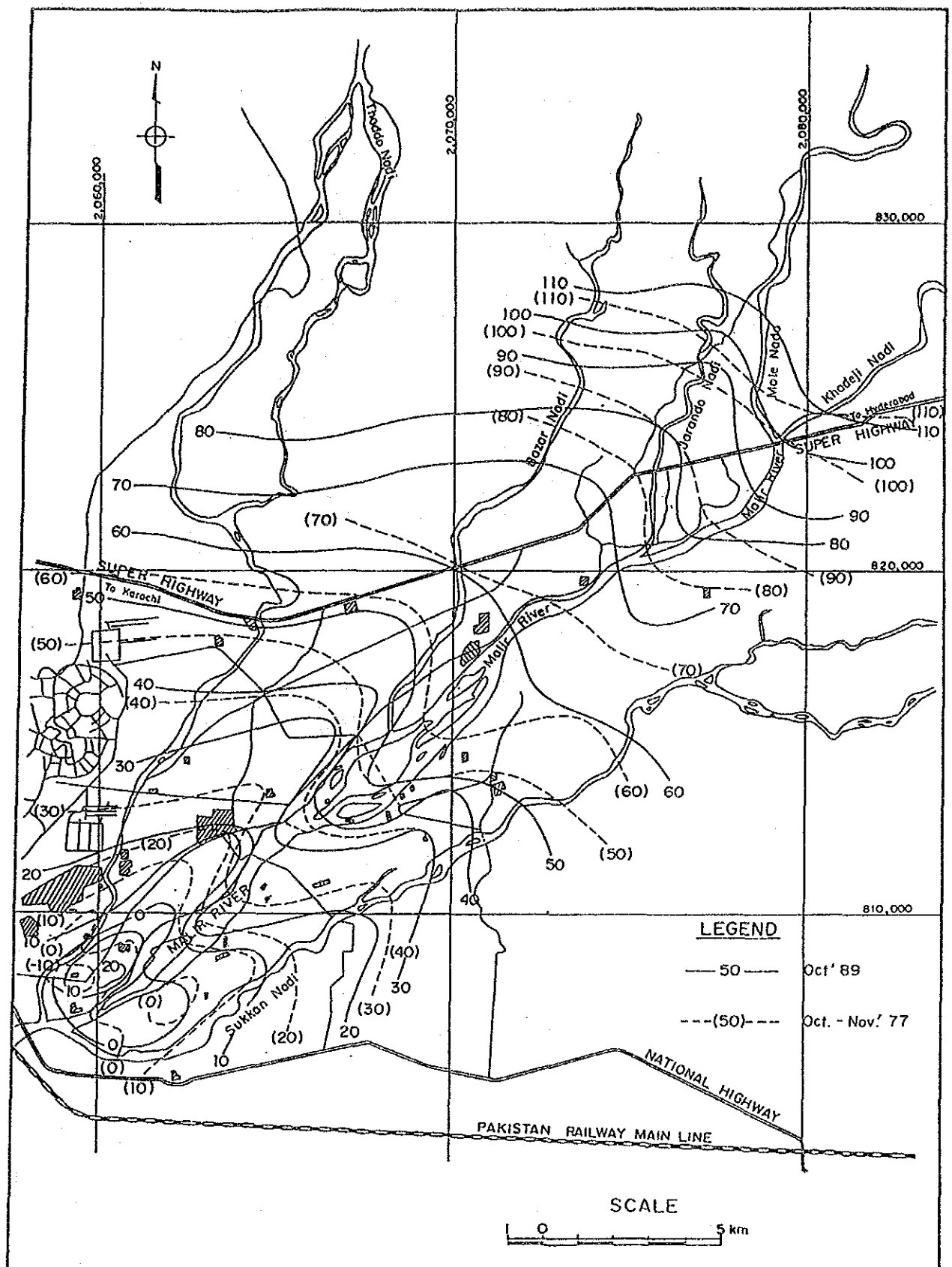

Fig. 3 Groundwater Contour Map in 1977 and 1989

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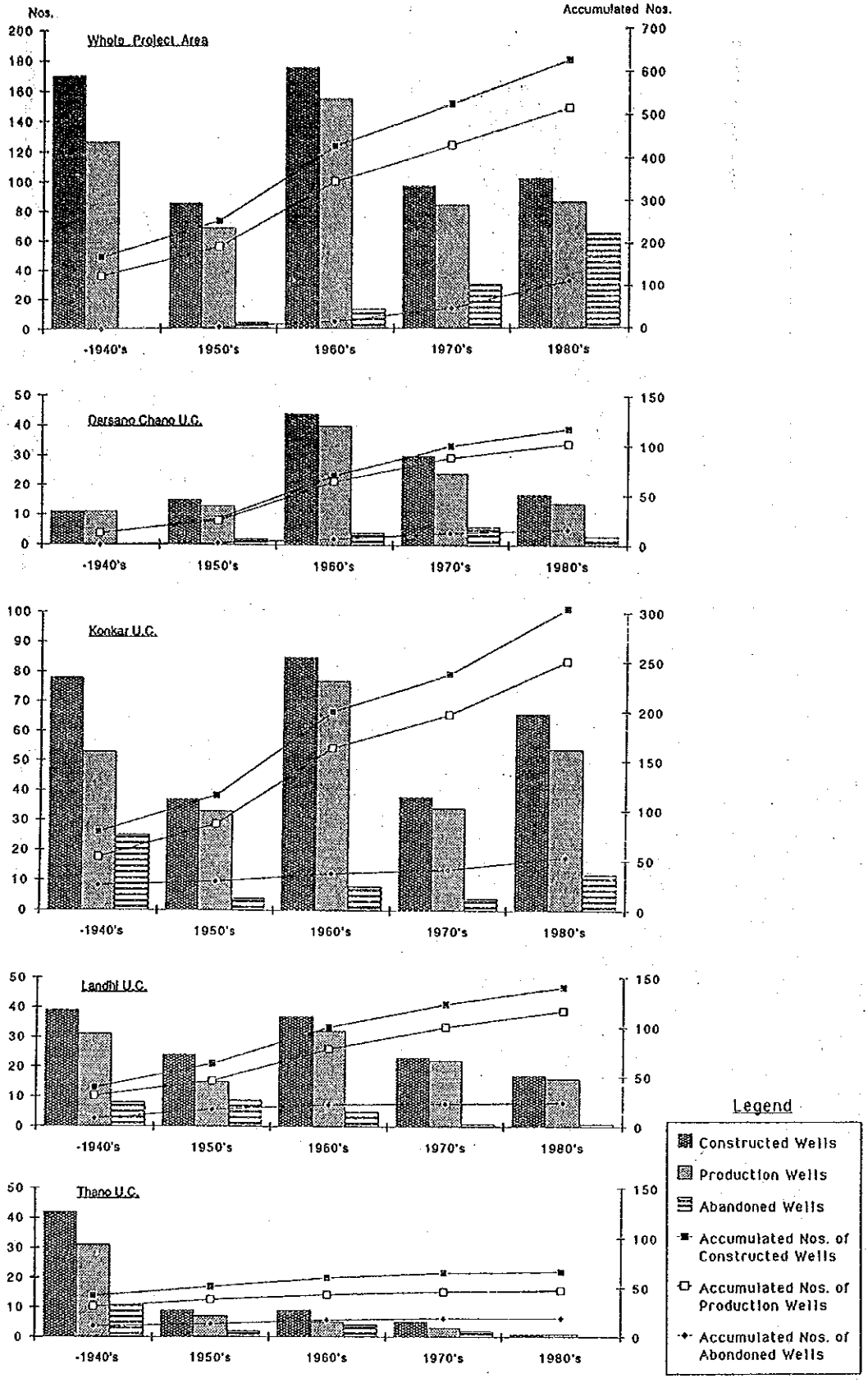

Fig. 4 History of Well Construction in the Study Area

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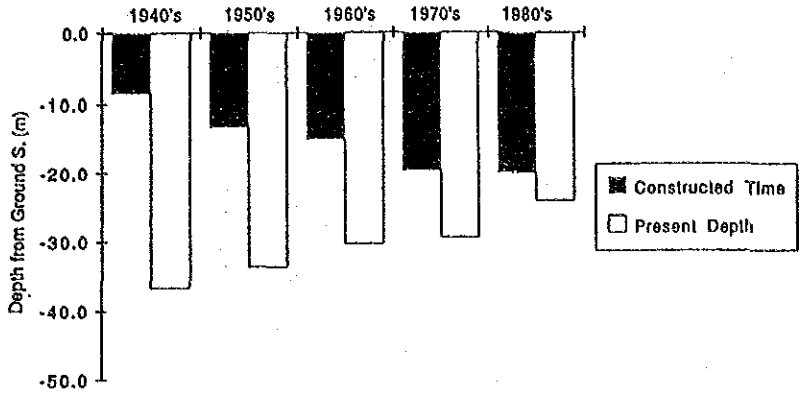
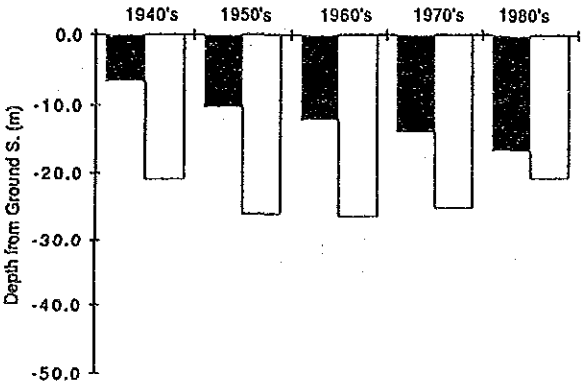
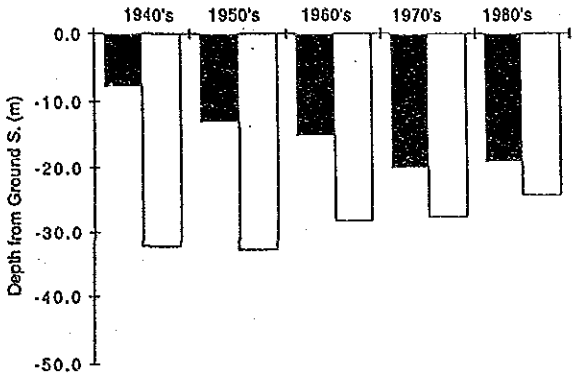
1. Whole Project Area



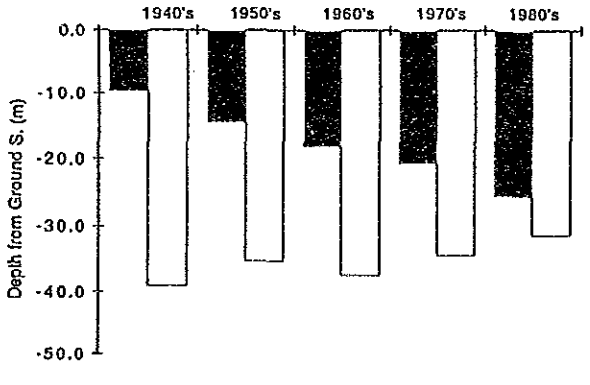
2. Darsano Chano U.C.



3. Konkar U.C.



4. Laundhi U.C.



5. Thano U.C.

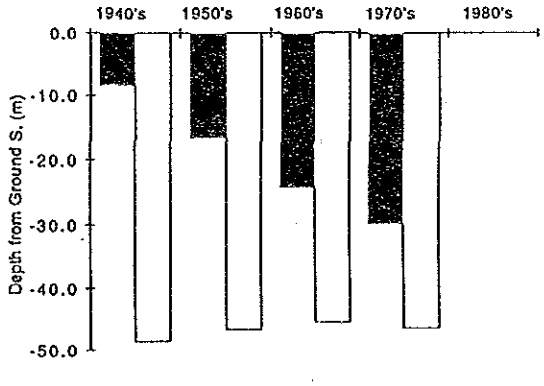


Fig. 5 Depth of Production Dugwells in Each Decade

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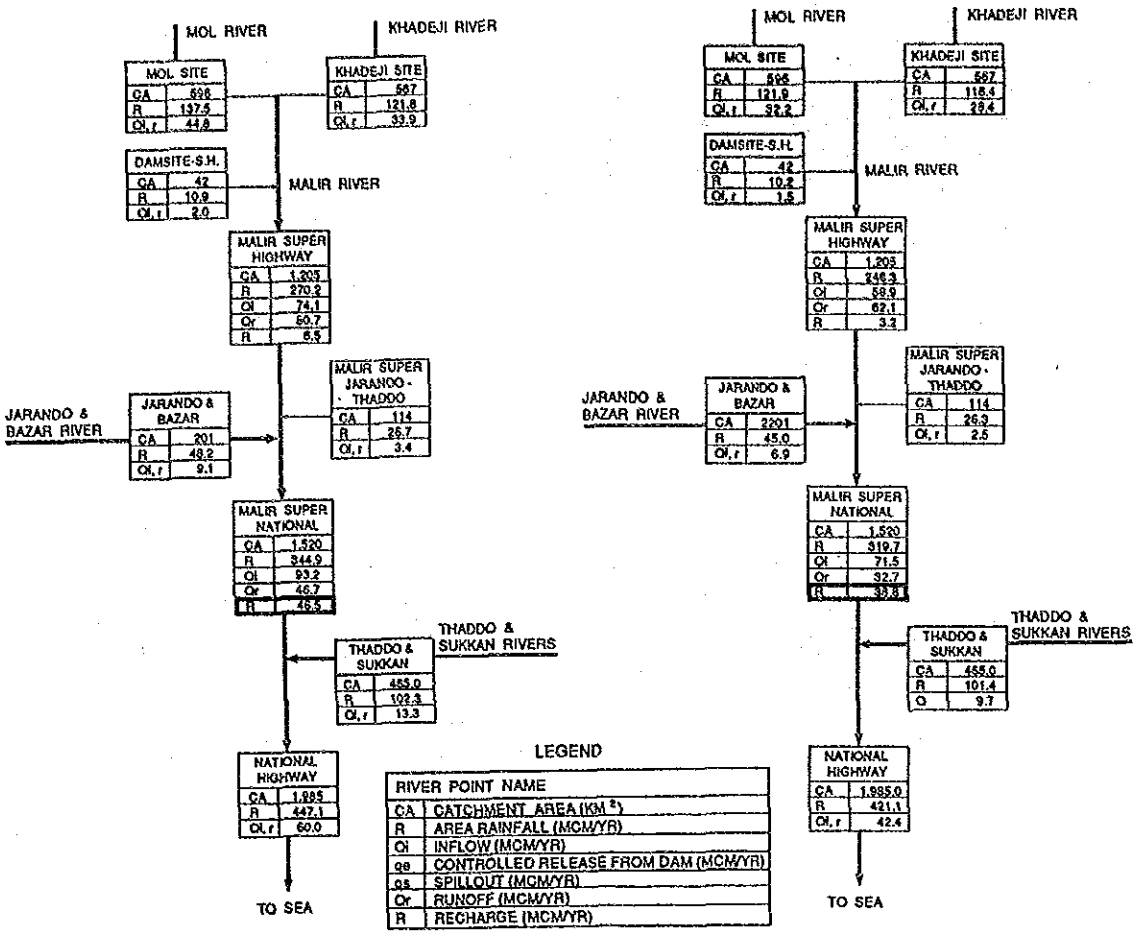

1. Natural Condition (1929 - 1988)

2. Natural Condition (1977 - 1988)

Fig. 6 Water Balance (Natural Condition)

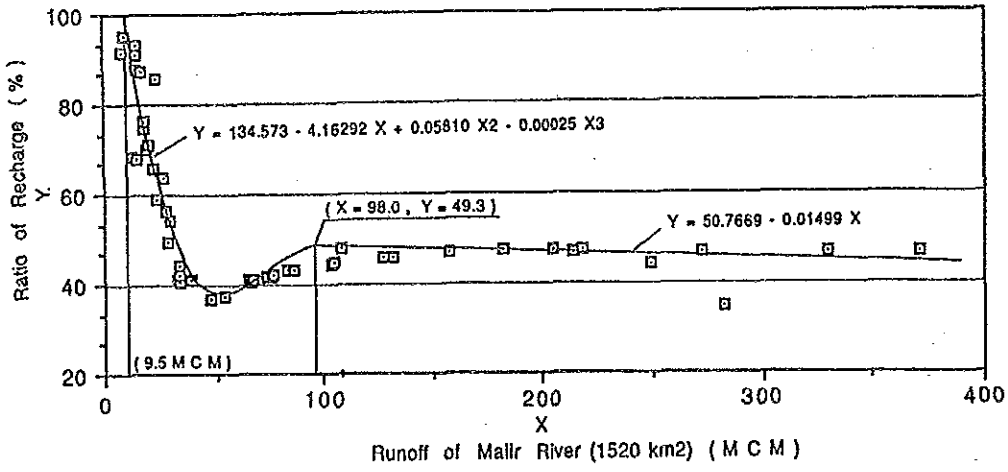

Fig. 7 Relationship between River Runoff and Recharge to Aquifer

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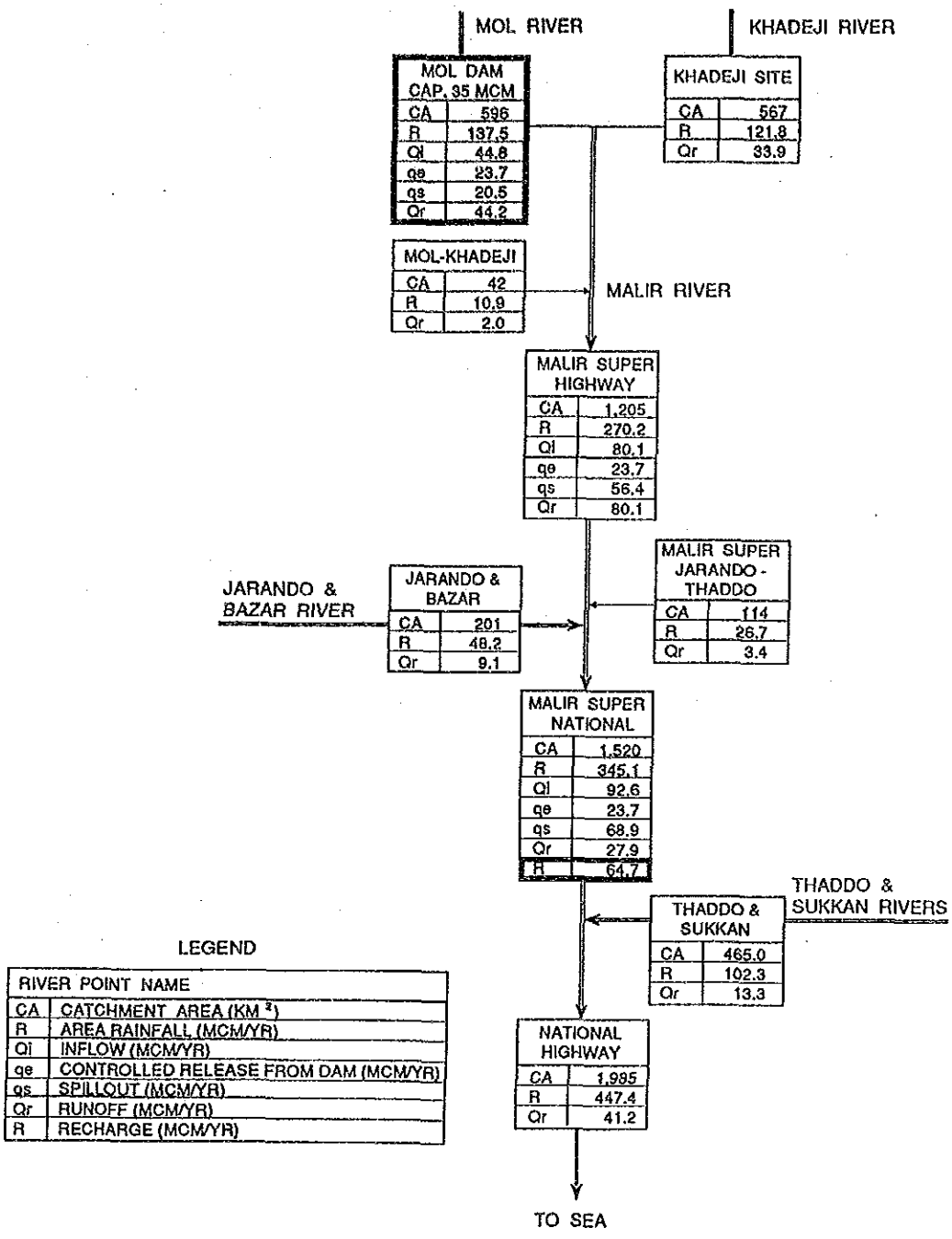

Case-4 Mol Dam : 35 MCM
(1929 - 1988)

Fig. 8 Water Balance with Mol Dam
(Case 4; 35 MCM)

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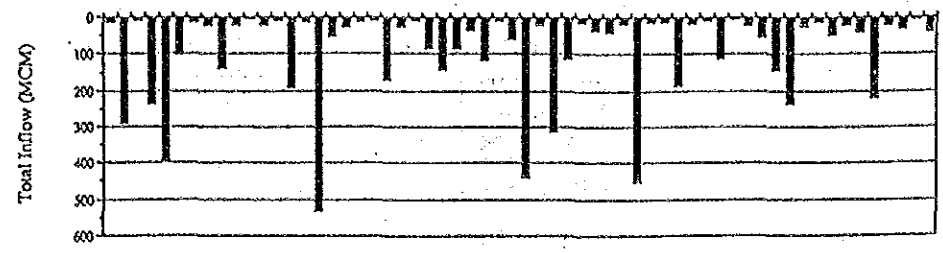

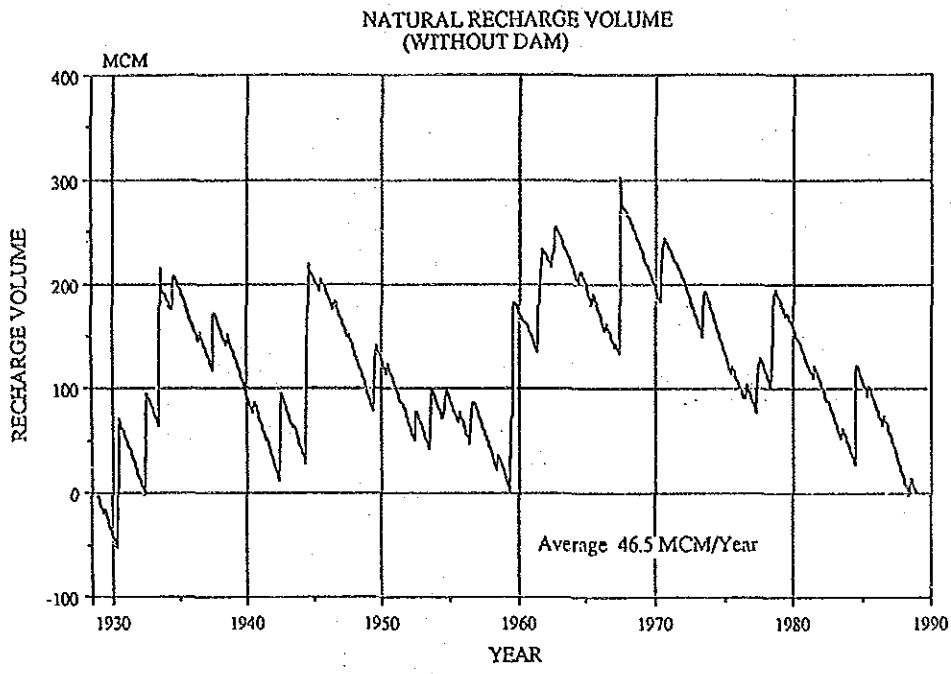

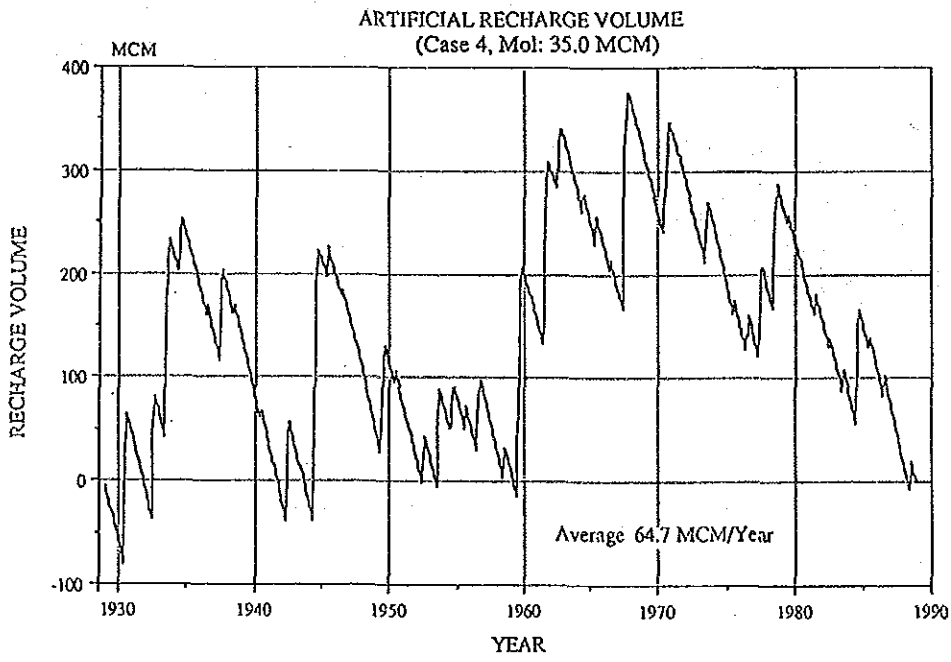

Fig. 9 Masscurves of Natural and Artificial Recharge by Mol Dam (Case 4; 35 MCM)

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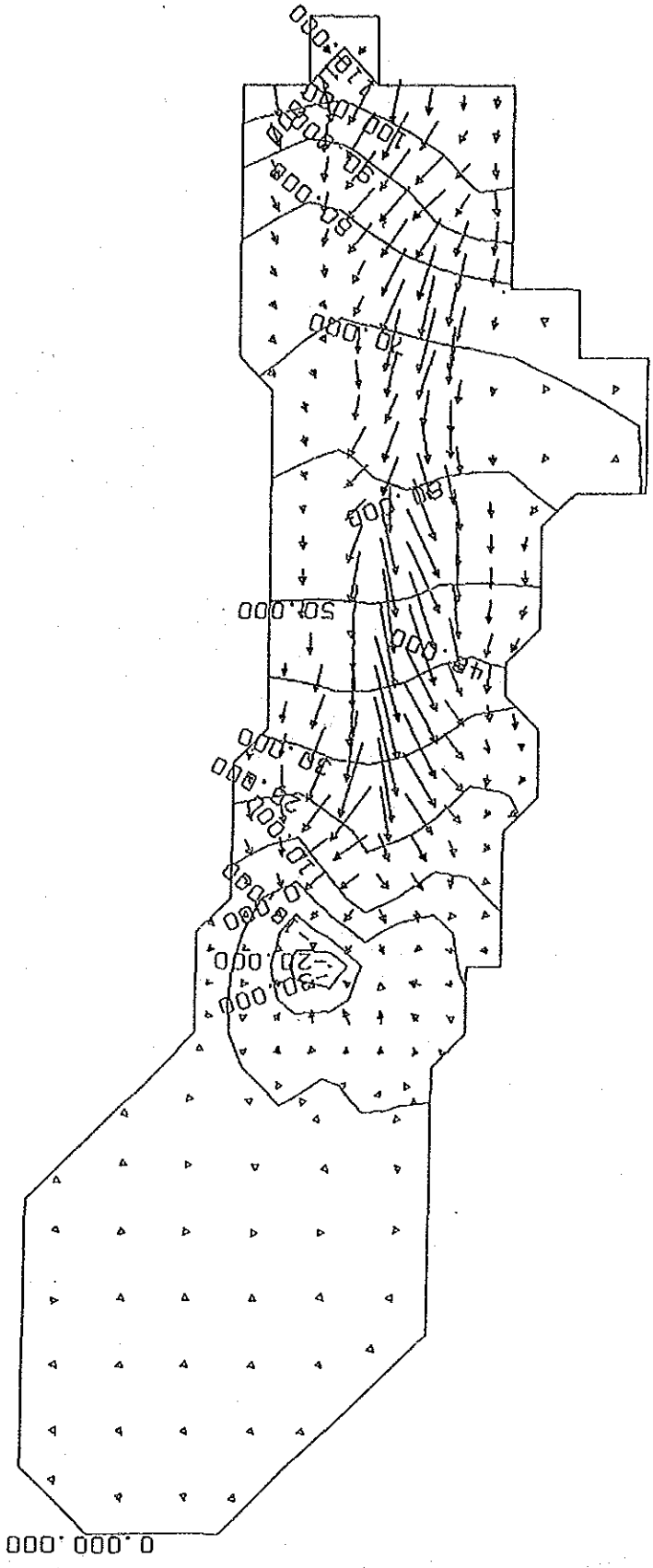

Fig. 10 Predicted Groundwater Table and Movement (with Mol Dam; 35 MCM)

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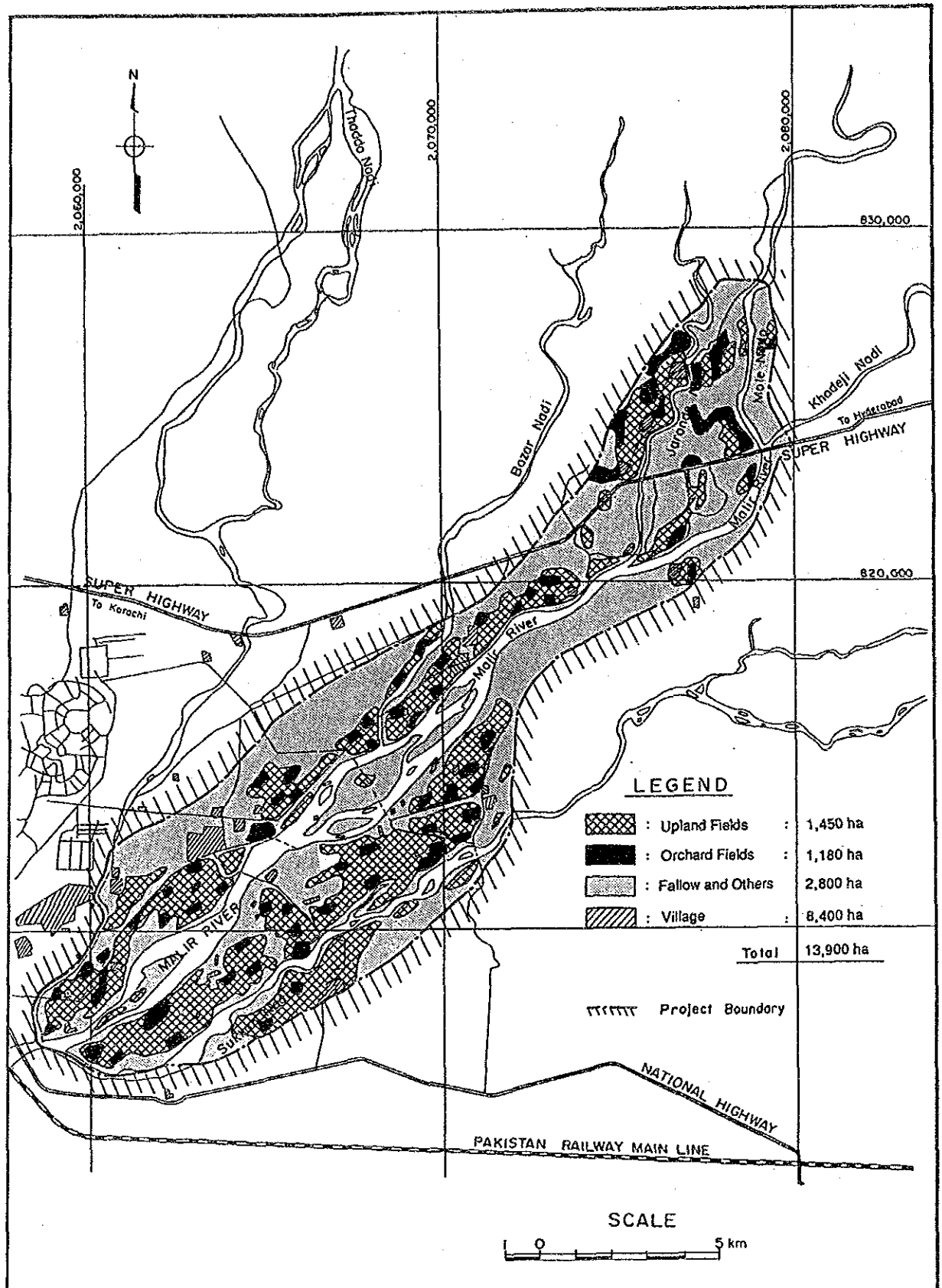

Fig. 11 Project Boundary and Land Use

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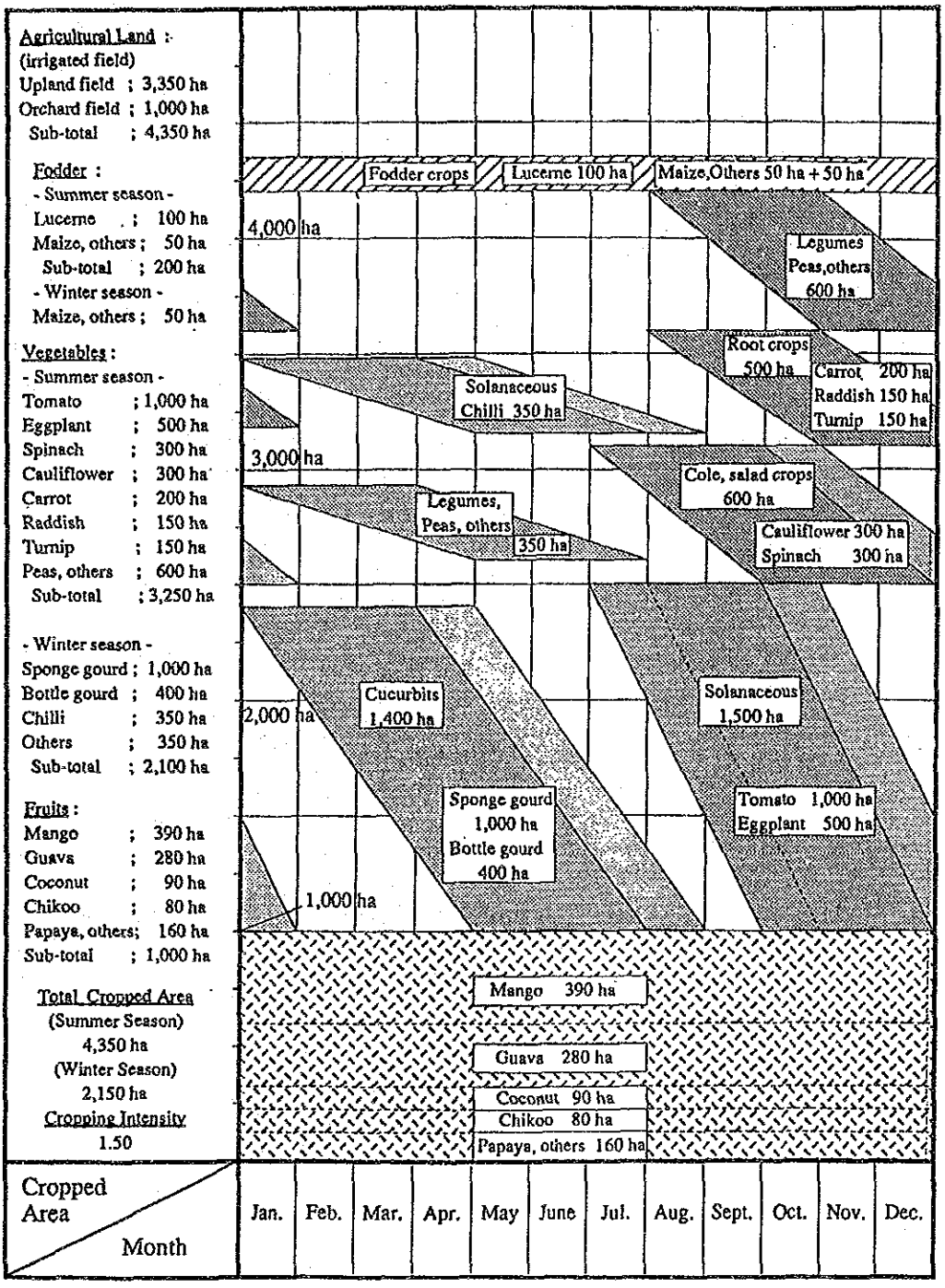

Fig. 12 Proposed Cropping Pattern (with Project)

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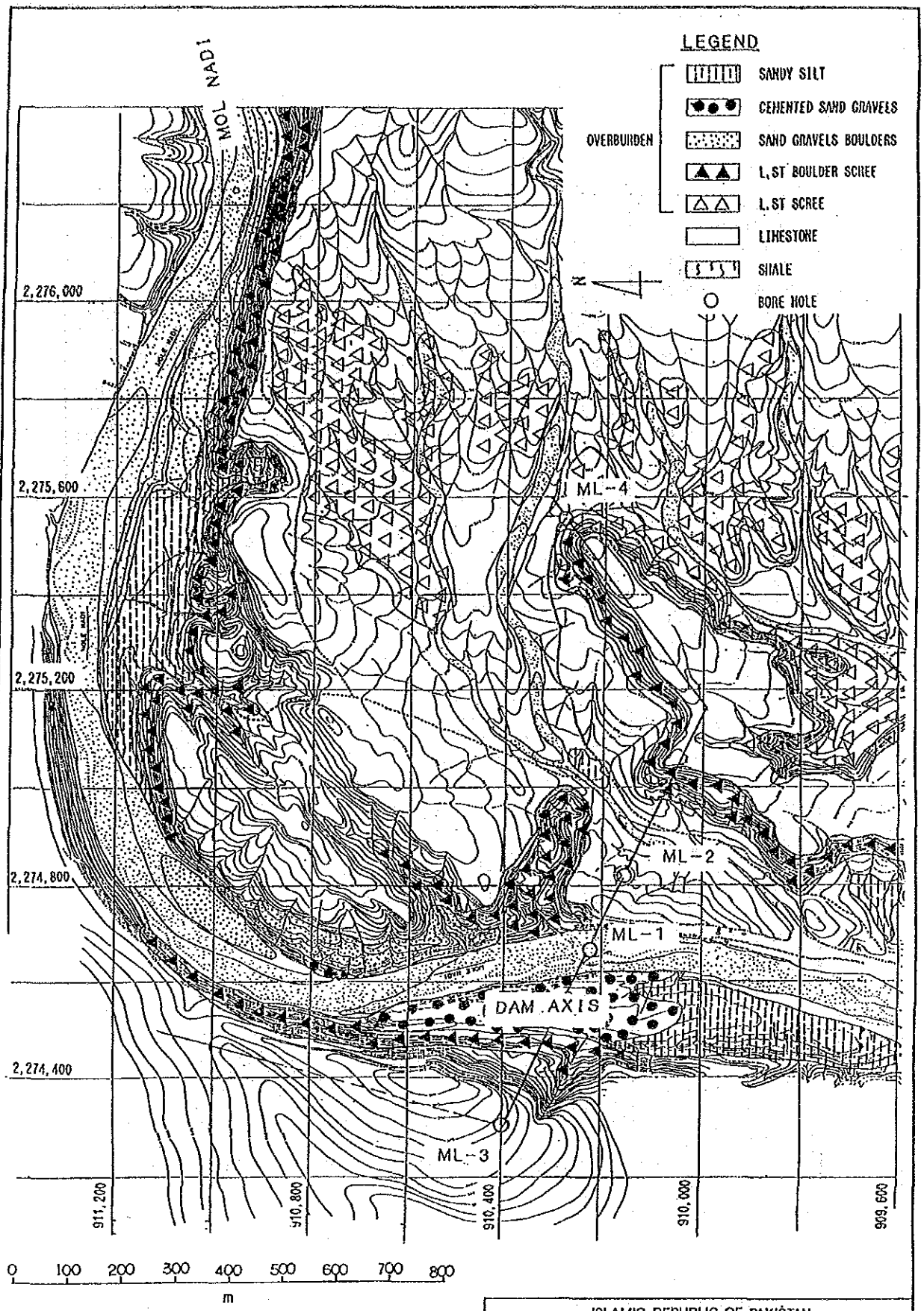

Fig. 13 Geological Map of Mol Damsite

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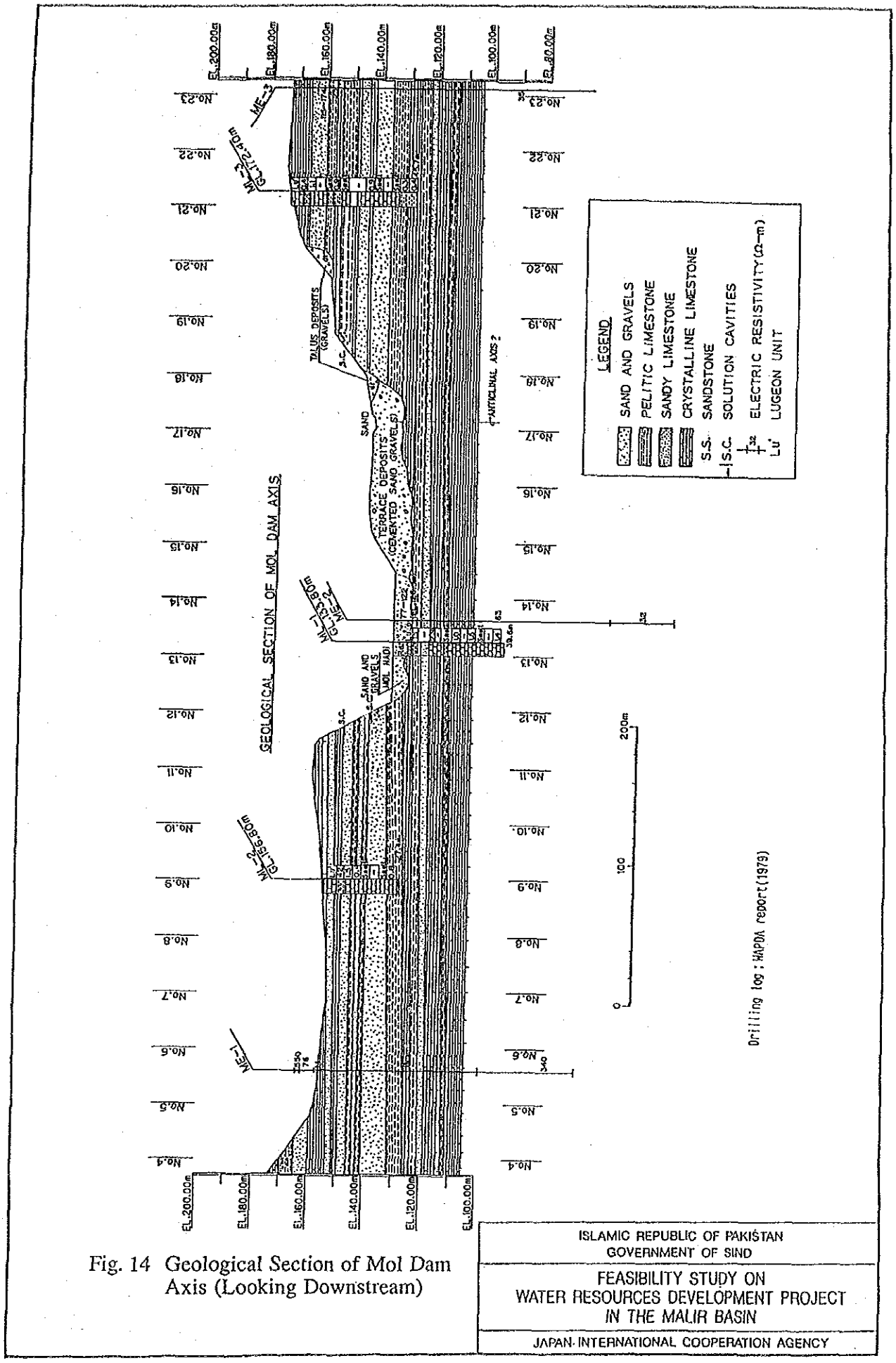

Fig. 14 Geological Section of Mol Dam Axis (Looking Downstream)

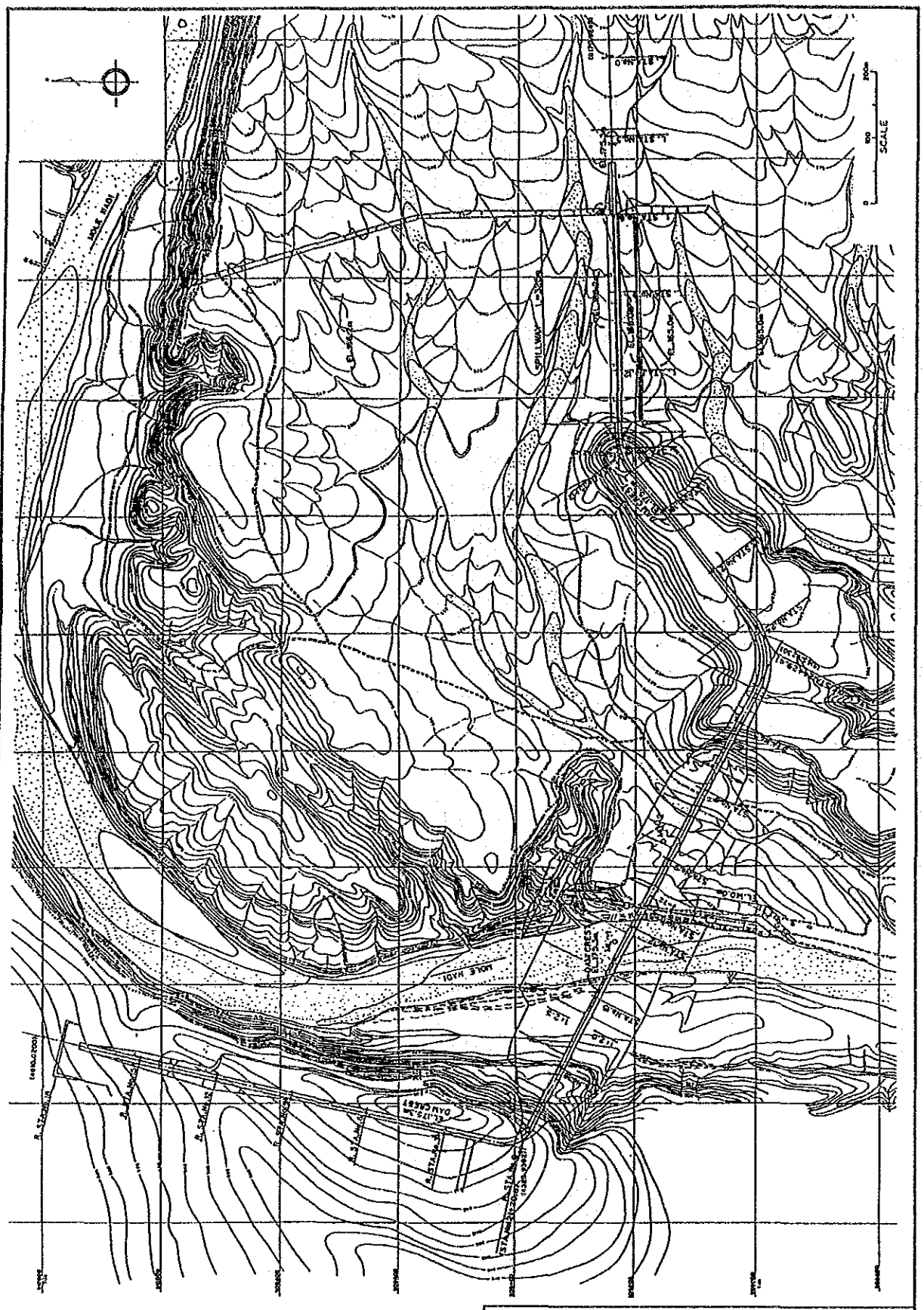

Fig. 15 General Plan of Mol Dam

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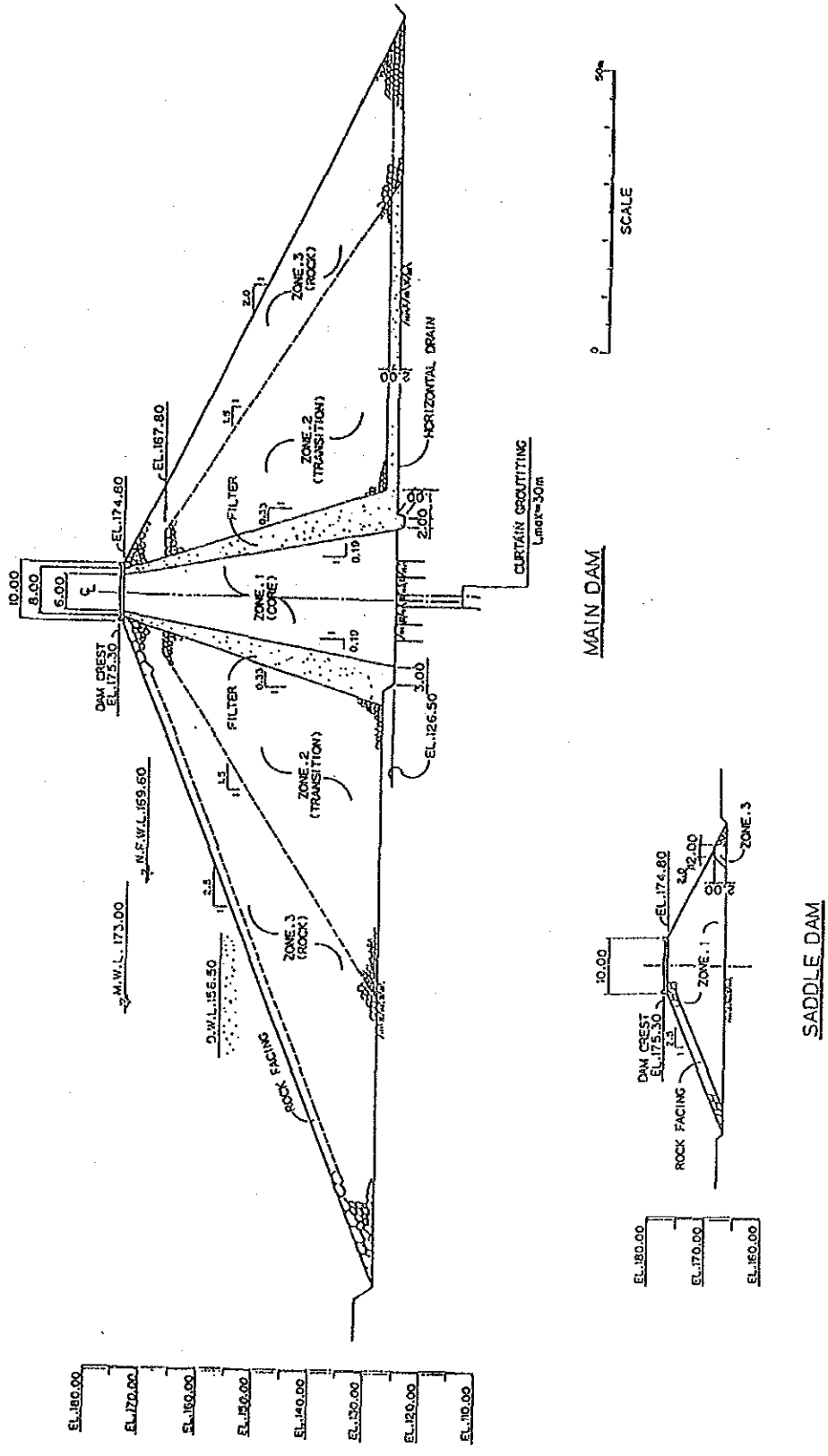

Fig. 16 Standard Section of Mol Dam

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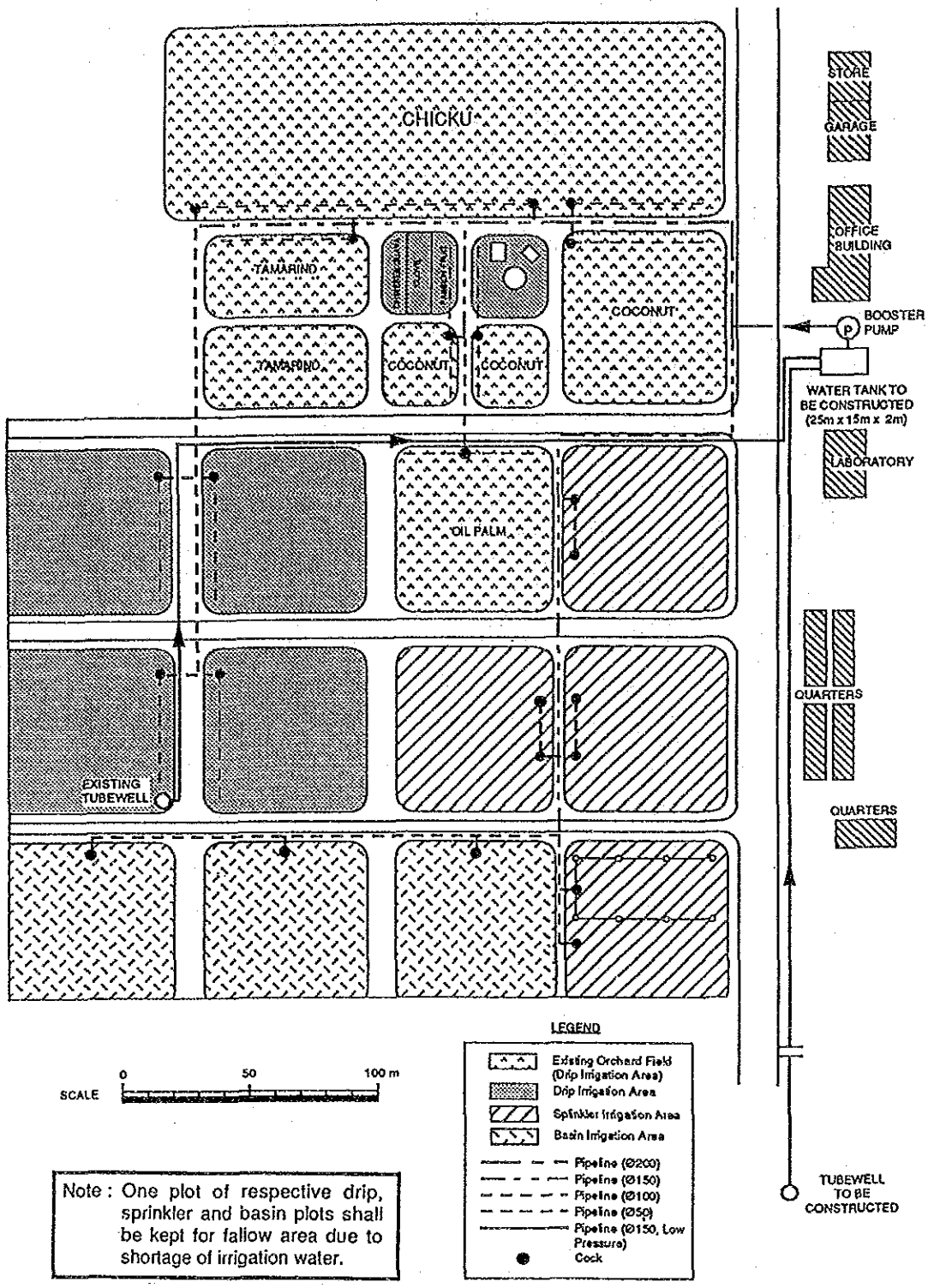

Fig. 17 General Layout of Pilot Demonstration Farm

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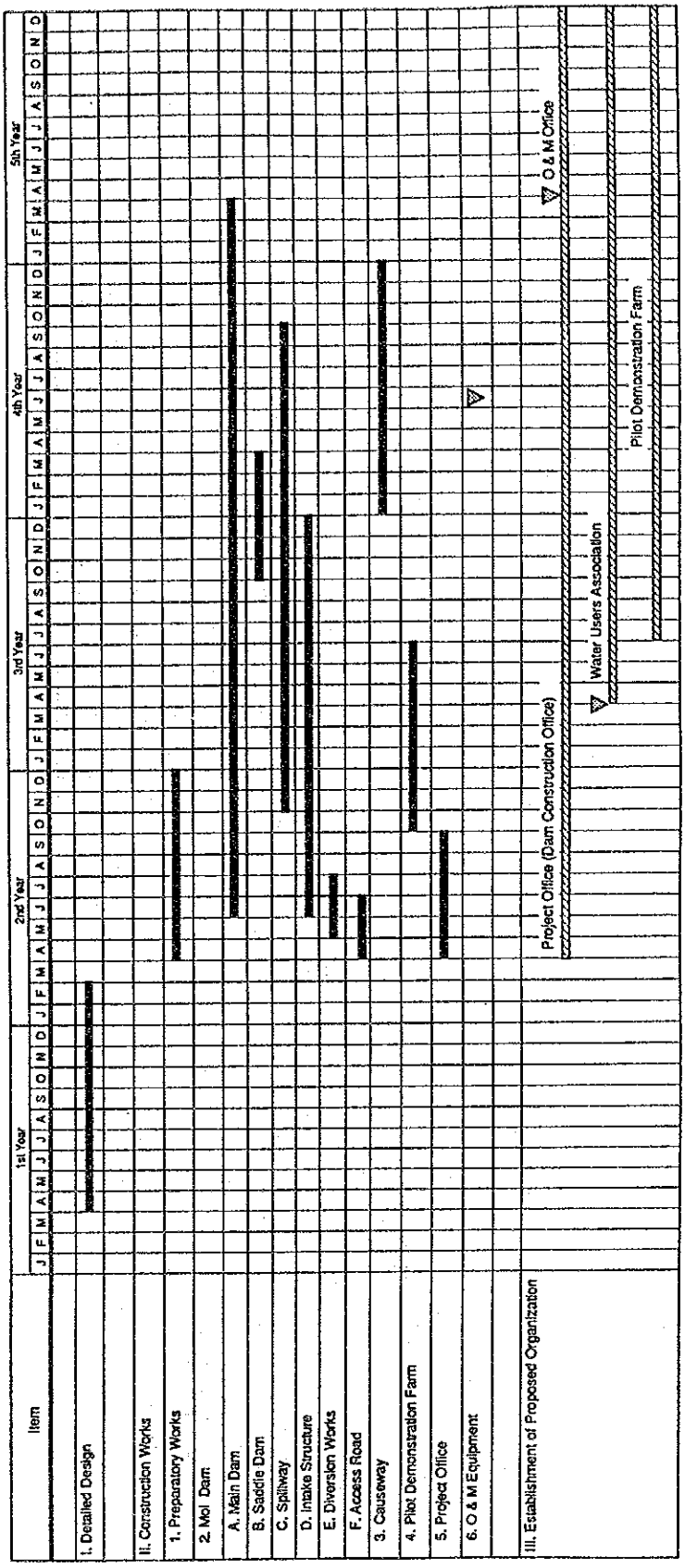

Fig. 18 Project Implementation Schedule

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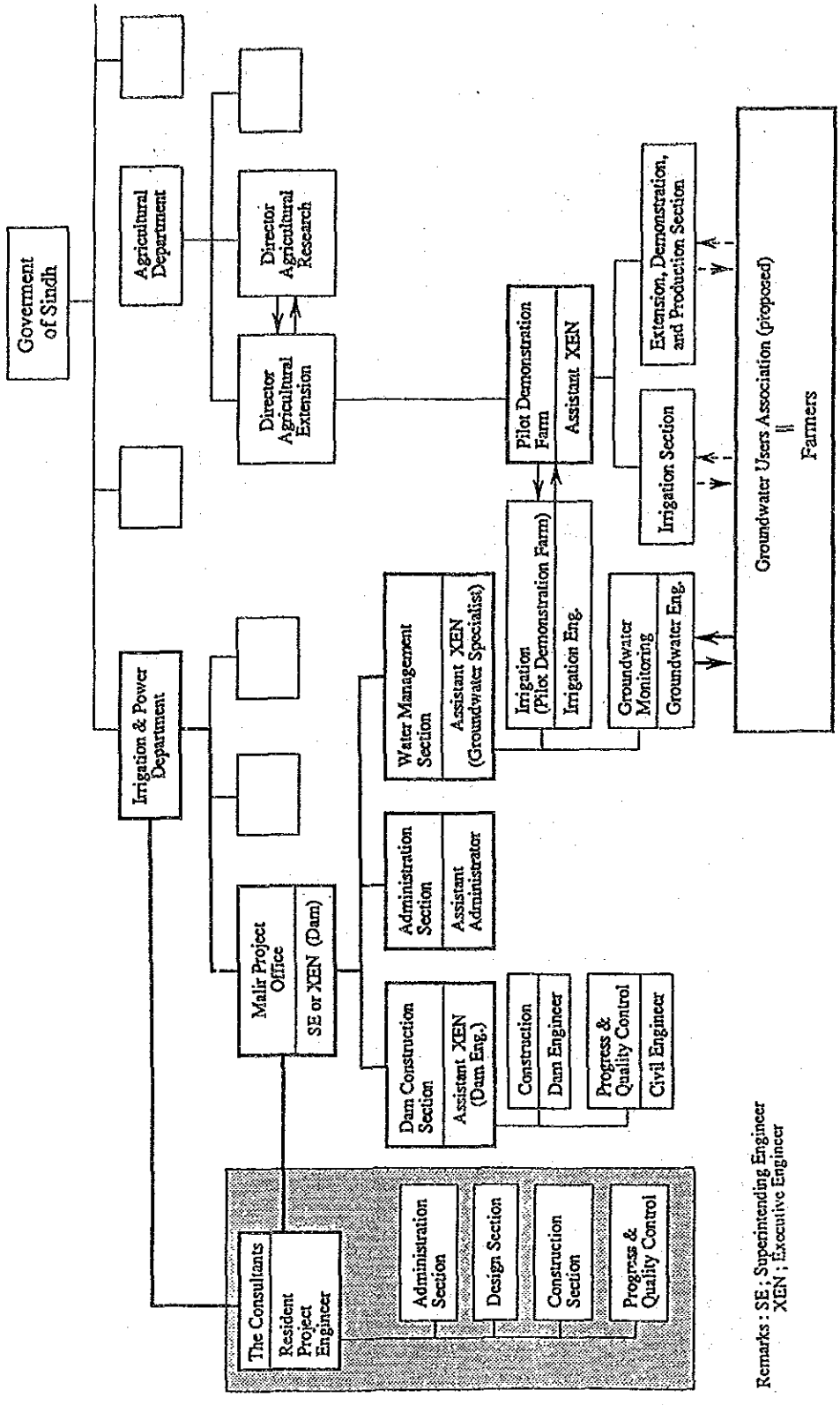

Fig. 19 Organization for Project Implementation

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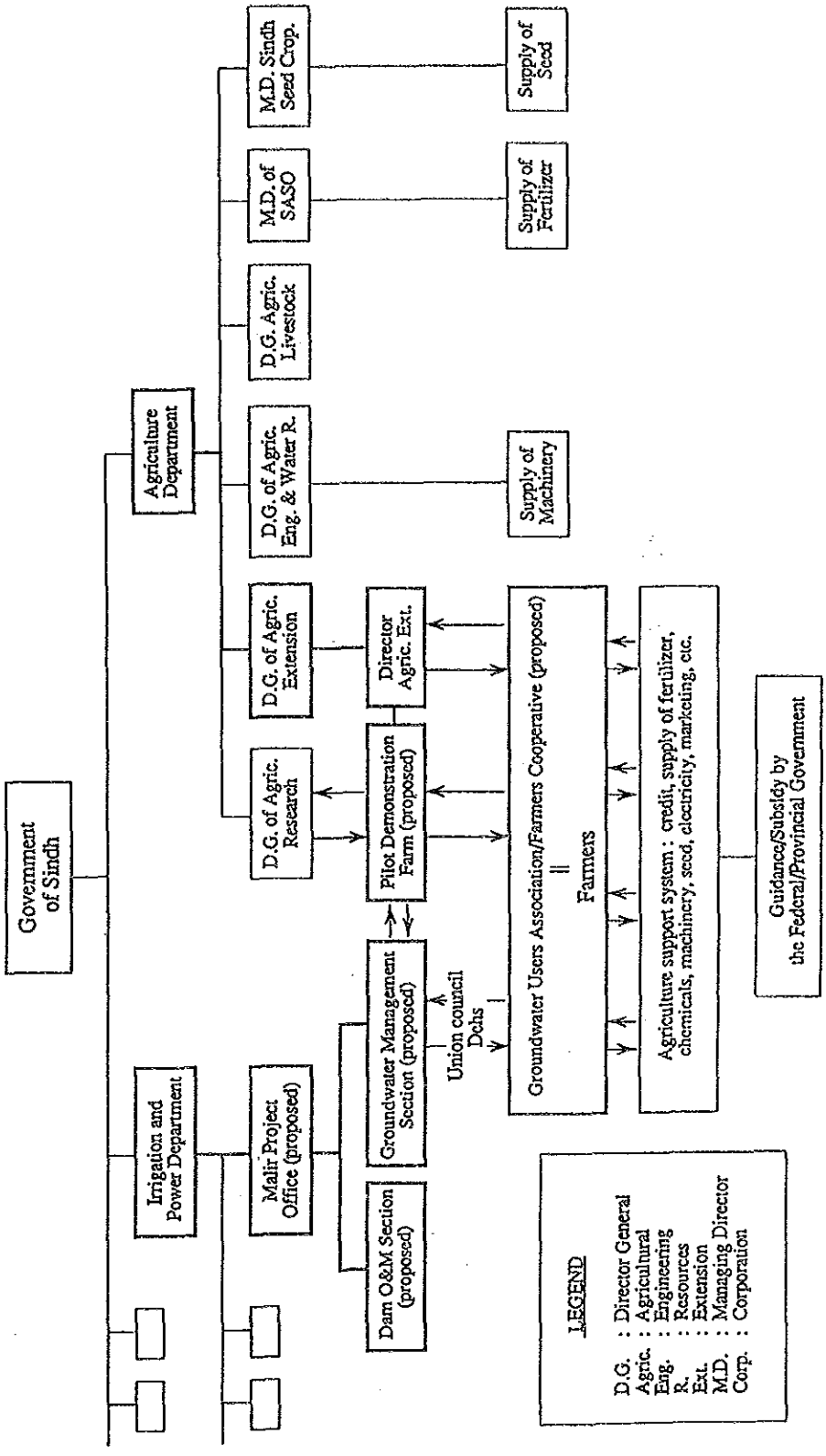

Fig. 20 Organization for Operation and Maintenance of the Project

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