In case of the above, the mean annual sediment yield was estimated at 2.25 million tons from intake structures to distribution point at both projects. As shown in Table 3-30, Appendix, the contents of suspended load (in percent) could be divided into three classes by grain size, and the sandy materials will be silted in the canal. The contents of sandy materials were measured by about 30 per cent of the total value based on observation data in the Indus Basin.

As a result of the said evaluation, the sandy materials is 0.675 million tons (675,000/2.60 = 260,000 CM) of the total sediment yield in the Desert Pat Feeder Canal.

3) Water Quality

During the investigation at the Project site, the water samples were taken from the Desert Pat Feeder Canal, and were analyzed at Water and Soil Laboratory of Hydrogeology Directorate of WAPDA, Quetta. The results of analysis are tabulated in Table III.2-32, Appendix.

III.2.4. Geology and Soils

Conservation of the existing farm lands and reclamation of the waste lands for increasing agricultural production under reasonable supply of irrigation water would be a very important prerequisite for successful contribution to the national food security.

Objectives of the soil survey in relation with the geological features of the Project Area are:

a) to conduct soil profile observations for checking the results of the existing soil surveys, and

b) to investigate problems which will be derived from soil properties and water quality for improving agricultural managements aiming to increase farm products.

1) Geology

The survey area is composed of the alluvial deposits between the Marri - Bugti Hills and the Indus River. Geological features including the Area are shown in Fig. III.2-1.

The piedmont deposits (Qpd) transported from the Hills which are formed with sedimentary rocks of Tertiary (Tmp) cover most part of the eastern area. The flood plain deposits (Qbf) transported by the braided streams from the north spread on more than a half of the Area, mainly west side of the railway (Nuttal - Jacobabad). On this plain, braided streams brought new deposits (Qbr), recently in the Quaternary, which stretch along the eastern part of the Area.

The Indus River deposits (Qcm and Qmx), early recent in the Quaternary, form the higher and lower terraces in the marginal south-western part and the extreme east part near the Guddu Barrage, respectively.

These alluvial covers forming the Kachhi Plain are very thick, thousands of feet at places and have fairly finer textures except the piedmont deposits (Qpd) which are composed of coarse detrital materials from the adjacent high lands.

2) Soils

a) Soil Survey

Soil Survey Project of Pakistan were initiated in 1964 by FAO/UNDP with the help of USA and the Netherlands. From 1972

Pakistan Government succeeded the Survey to make 1:250,000-scaled soil maps and had covered a half of the country up to 1979. Considering very short span of the field observation, the survey was focussed to examinations of the soil profiles as many as possible and to analyses of the soil samples in the field.

The profile survey was carried out in March, 1982 in cooperation with Jhatpat Office of Irrigation and Power Department, Baluchistan Government and Mr. Malik Zahur Ahmad, Research Officer, Soil Salinity and Water-table Surveys, Planning Division, WAPDA, Lahore.

The number of pit survey was 25 only in total because of the limited survey term. The soil samples taken from each of the soil profiles totaled 102 and were analysed for pH and electrical conductivity (EC) after air-drying and grinding them in the base camp (Rest House, Jhatpat). Portable pH and EC Meters could serve well for these analyses.

The water samples were taken at the same time as the pit survey from the Main Canal, distributories and stagnant pools. Twenty eight samples were subjected to the same analysis as the soil samples. Location of pit and water sampling sites is given in Fig.III.2-2.

Out of all soil samples, 24 samples of six soil profiles were sent to the laboratory of Soil Salinity and Watertable Surveys, WAPDA, Lahore for further physical and chemical analyses. The results of field and laboratory analyses and profile descriptions are arranged in Appendix III.2-4.

b) Soil Classification

The soils of the area developed on the Kachhi Plain consist of two different parent materials. Major part of the area has soils developed in the piedmont sediments brought down by the torrents from the Marri-Bugti and other hills in the north. They are calcareous

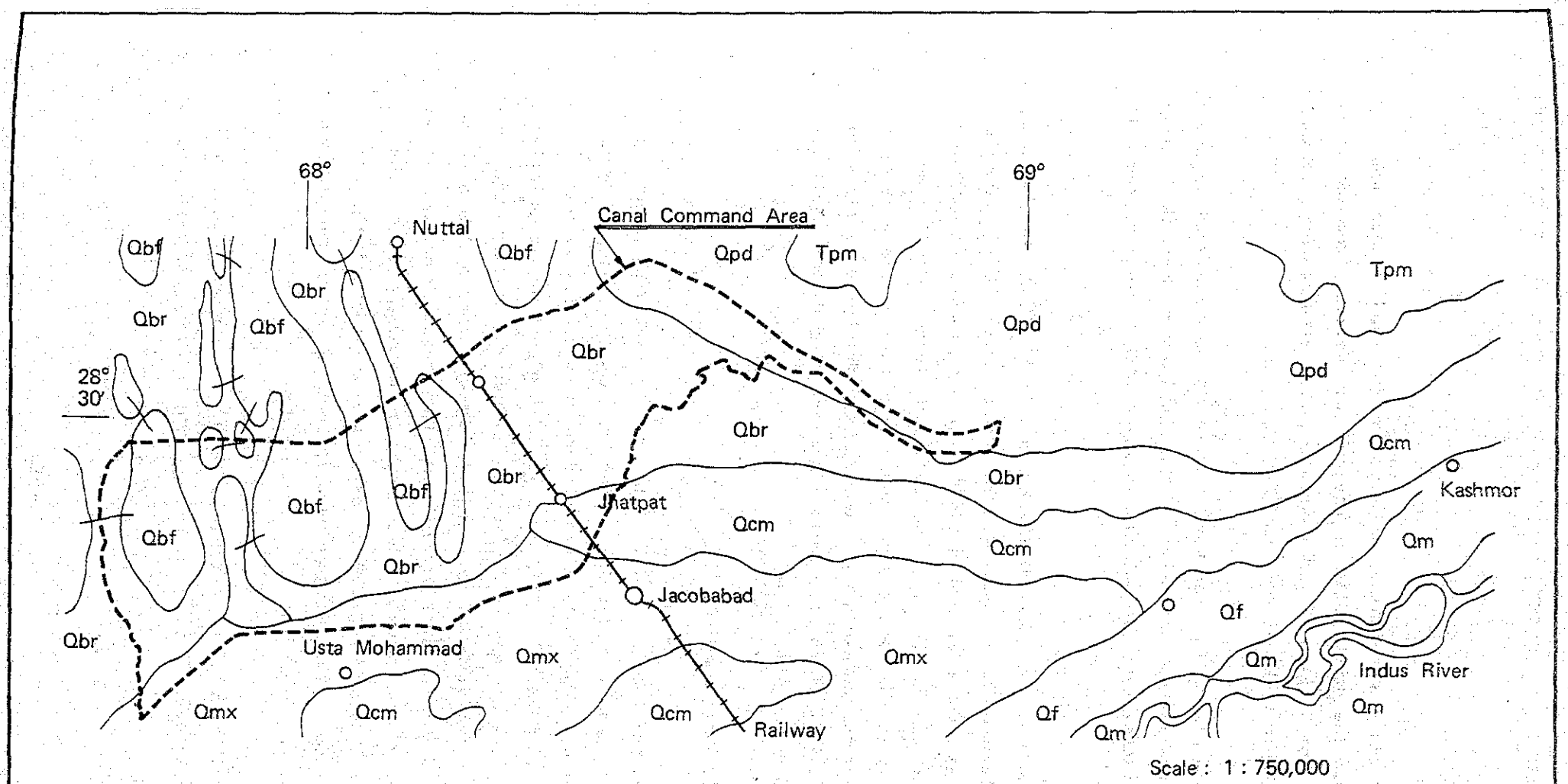


Fig. III.2-1 Geological Map around the Pat Feeder Canal Command Area

due to Tertiary materials: mainly shales, sand stones and limestones. The other soils of the area are derived from the Indus River alluvium origins of which are calcareous sedimentary, igneous and metamorphic rocks of the Himalayas.

At some places near the border areas the both materials are more or less contaminated each other on the flood plains through frequent stream torrents, resulting in developing a wide variety of the soil types.

FAO/UNESCO - Soil Map of the World (VII-1, 1977) classifies the soils of Kachhi Plain into one group unit of Yermosols. Haplic Yermosols are dominant and divided into two phases, Yh 27-2a (non-saline) and Yh 26-2/3 a (saline). The former occupies most of the Plain while the latter distributes from the eastern part of the Plain to northwards along the Indus River. The boundary lines cuts the Command Area of the Pat Feeder Canal at around RD 328 and goes down to Jacobabad side.

i) General Soil Features

As was pointed out already, the soils in the Project Area have developed on the flat alluvial plains, and they are mostly medium to fine textured except small areas of sand dune and its vicinity. The soil color is 10YR 7/3 to 6/3 when dry with almost no accumulation of humus under the hot and arid climate. Structural development is very weak in general; platy (stratified) or blocky (homoginized) structure are observed more or less according to the frequency and age of the depositions. Consistency, when dry, is extremely high; the compactness ranges 20 to 30 as expressed as index of the Soil Hardness Tester, presumably being able to surpress or stop the root growth.

Overall high clay content of swelling property gives an excellent feature of hexagonal surface cracks every where the soil is

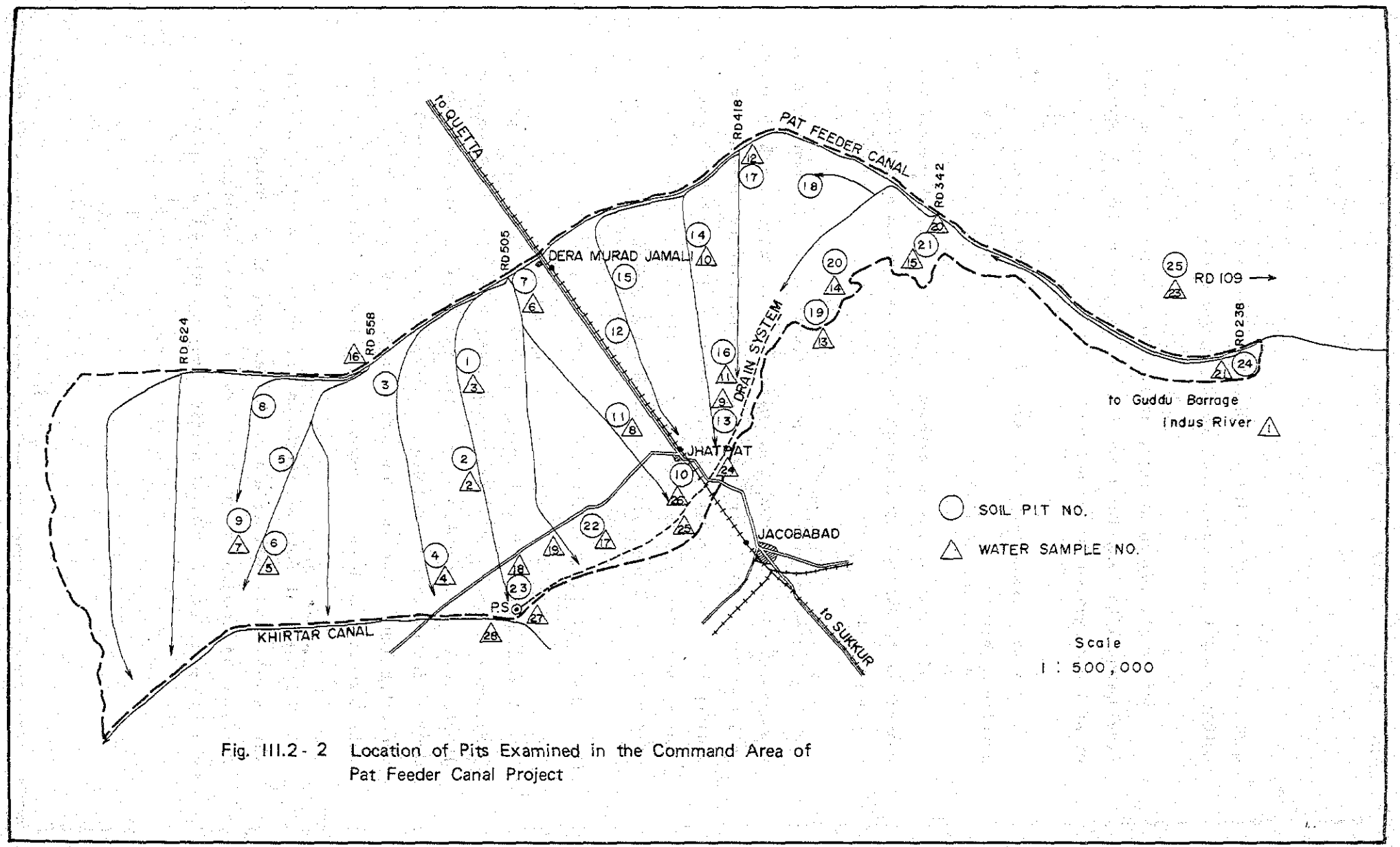


Fig. III.2 - 2 Location of Pits Examined in the Command Area of Pat Feeder Canal Project

dried up on the fallow fields. pH ranges from 8.5 to 9.3, moderately alkaline due to the calcarious nature of the soils.

Almost all layers of the profile give moderately distinct color development with Benzidin reagent solution, indicating the presence of active manganese in the soils.

In some profiles very fine gypsum crystallines and oxidized iron mottles appear.

Varying salt status is noteworthy in the Area; it ranges from non-saline to strongly saline not only in the surface soil but also in the subsoil.

Vegetation is also quite characteristic in species and extent to the Area of arid soil conditions with a scarce rainfall and a variant soil salinity. Moreover, long-lasted uncontrolled grazing and felling have considerably deteriorated the vegetation cover both in density and quality. The circumstances have been recognized as one of causes of soil degradation progressing globally.

ii) Soil Series and Associations

According to the Soil Survey of Pakistan that followed the comprehensive soil classification system, USDA (7th Approximation, 1969), soils in Jacobabad - Usta Mohammad Area are divided into 34 Soil Series excluding sand dune (35), marshland (36), river-bed (37) and urban land. The soil map was printed, however, with a unit of Soil Association which was composed of a few Soil Series.

Only several Soil Associations are major; Jhatpat Association (31) ranks first forming almost 80 per cent of the total area, followed by Katchar Association (28) and Kundi Association (34) Chhater Association (29), stratified coarse-textured soil, appears

Fig. III. 2-3 SOIL MAP

LEGEND: MAPPING UNITS (SOIL ASSOCIATION)

Active and Recent River Plains:

1	Shahdara, flooded	Level Plains
2	Rustam, flooded	
3	Sodhra complex	

Subrecent River Plains:

4	Bagh	Basins and Level Plains
5	Humayun	
6	Jacobabad	
7	Lodra	
8	Missan	
9	Pacca	
12	Saltanpur	
16	Nabipur	Cannel Infills
18	Bahadarpur	Meander Bars and Levees
20	Jagan	
21	Jarwar	
24	Rojhan	

Recent Piedmont Plains:

27	Bolan	Level Plains
28	Katchar	Undulating Plains
29	Chhater	

Subrecent Piedmont Plains

30	Guddu	Level Plains
31	Jhatpat	
32	Kandhkot	
34	Kundi	

Miscellaneous Areas

35	Dune Land
36	Marshland

(For full descriptions, see Reconnaissance Soil Survey, Jacobabad-Usta Mohammad, SOIL SURVEY OF PAKISTAN, 1972)

KACHHI DISTRICT

67° 45' E

68° 00' E

68° 30' E

28° 30' N

28° 15' N

PAT FEEDER CANAL

to QUETTA

DERA MURAD JAMALI

JHATPAT

JACOBABAD

to SUKKUR

USTA MOHAMMAD

SCALE 1 : 250,000

0 2 4 miles 6 8 10

Fig. III. 2-3 SOIL MAP OF THE PAT FEEDER CANAL COMMAND AREA

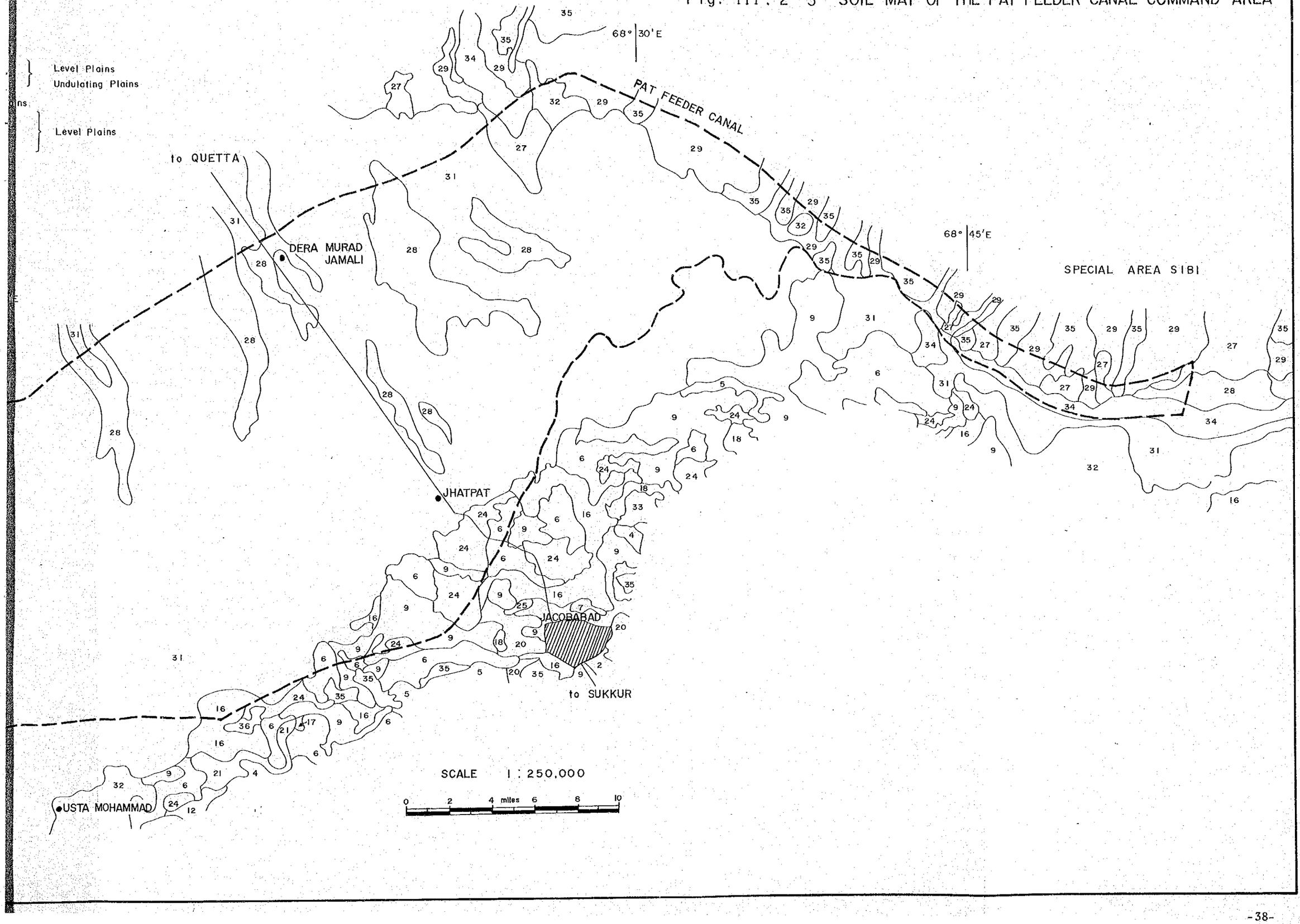


Table III.2-1 Soil Series and Area of their Associations Distributing in the Command Area of the Pat Feeder Canal Project

Parent Material Soil Stratum Form Salinity and Alkalinity Texture and Others	Series Name	Map Symbol No. (Association)	Area of Association	
			(acre)	(%)
A. River Alluvium Deposits				
2. Homogenized Soils				
2-1 Non-saline, non-alkali, without mottles				
2-1-2 Loams	Nabipur	(16)	3,140	0.5
2-2 Non-saline, non-alkali, with mottles				
2-2-6 Silty clays	Pacca	(9)	7,400	1.1
2-3 Saline, non-alkali, without mottles				
2-4 Saline, non-alkali, with mottles				
2-4-2 Silt loams and v.f. sandy loams	Rojhan	(24)	7,590	1.1
2-4-4 Silty clays, gypsum specks	Jacobabad	(6)	4,920	0.7
B. Piedmont Alluvium Deposits				
1. Stratified Soils				
1-1 Loamy sands and sands, excess-drained	Chhater	(29)	20,220	2.9
1-3 Silt loams and v.f. sandy loams	Bolan	(27)	15,520	2.3
1-4 Silty clay loams, mod.f.variant	Katchar			
1-5 Silty clays	"	(28)	51,390	7.5
2. Homogenized Soils				
2-1 Non-saline, non-alkali				
2-1-1 Clays, not underlain by river al.	Kundi	(34)	29,790	4.3
2-1-2 Clays, not underlain by river alluvium structured to more than 90 cm depth	Jhatpat	(31)	530,720	77.1
2-1-3 Clays, underlain by r.a. below 60 cm	Kandhkot	(32)	8,690	1.3
C. Miscellaneous Areas				
Dune Land		(35)	8,620	1.2
		Total	688,000	100.0

Source: Reconnaissance Soil Survey-(Jacobabad-Usta Mohammad), Soil Survey of Pakistan, MFA 1972.

rather frequently contiguous to dune lands in the eastern part of the Area through areal extent is very small.

Jhatpat Soil Series is characterized by fine textured soils (SiC) of subrecent piedmont alluvium of moderately well-developed structure. The WAPDA Soil Survey having been conducted since 1977 has realized a predominance of moderately fine texture (SiCL) with less medium and without any fine texture (SiC). Structure development also seemed to vary widely in this Series. The present survey also found several lands within the Jhatpat Association areas, where other Soil Series different from the Associating series were included. Fig. III.2-3 is a soil map of the Command Area scaled at 1:250,000 in which partly corrections were made based on these survey results. Table III.2-1 gives a brief explanation of these Soil Series and extent of their Associations.

Further detailed survey will be needed mostly for the Jhatpat Association area with additional care of soil ssalinity in order to extend better soil managements to increase land productivity.

c) Land Capability Classification

According to the Provinsional Map of Soil Degradation Risks, recently compiled by FAO (1981), the Kachhi Plain Area (Yh 27-2a) and the alluvium along the Indus River (Yh 26-2/3a) are designated as lands with moderate wind erosion, moderate to strong salinization and high physical degradation by waterlogging and irrigation. These assessments are understood to suggest that an urgent motion must be taken on the use and conservation of the lands by appraising the soil potentiality properly.

As described already, the soils in the Command Area have more or less limitations in general agricultural uses of the land. Land capability is evaluated with these limitations and the land area classified with their relative suitability for sustained field crops or for grazing.

Table III.2-2 Land Capability Classification of Soils in the Pat Feeder Canal Command Area

Class	Sub-class	Limitations	Soil Series, Variant	Acreage (acre)	Percent (%)
I	irI	No or only slight limitations	Pacca anthropic surface variant (9) Nabipur (16) Bolan (27) Bolan loam variant (27)	14,740	2.1
II	irIIs	Minor limitations; fine textured; rather slowly permeable; or slightly surface saline	Pacca (9) Pacca moderately deep (9) Pacca slightly saline (9) Nabipur fine surface (16) Nabipur moderately coarse variant (16) Bolan moderately coarse variant (27) Katchar (28) Katchar moderately fine variant (28) Jhatpat (31) Jhatpat overwash (31) Jhatpat slightly saline (31) Kandhkot (32) Kundi (34)	620,370	90.2
	irIIa	Slightly saline/ sodic	Nabipur slightly saline (16)	-	-
III	irIIIw	Imperfectly drained; fine tex.; slightly saline	Pacca imperfectly drained (9) Pacca imperfectly drained slightly saline (9)	6,900	1.0
	irIIIa	Moderately saline/sodic or strongly saline but with gypsum; high water table within 10f	Jacobabad (6) Jacobabad imperfectly drained (6) Rojhan (27) Rojhan fine surface (27) Rojhan imperfectly drained (27)	12,530	1.8
IV	irIVw	Fine tex.; seepage	Pacca pooly drained (9)	-	-
	irIVs	Sandy;see page	Chhater (29)	23,200	3.4
VIII	VIIIe	Undulating; erosion	Shifting sand (35)	10,260	1.5
			Total	688,000	100.0

Source: Reconnaissance Soil Survey, Jacobabad-Usta Mohammad, Soil Survey of Pakistan, 1972.

i) General Land Classification

The classification method adopted by Soil Survey of Pakistan has basically similar structure to the USDA Land Capability Classification (USA-Soil Conservation Service, 1961). The method has two level of generalization: Land Capability Class and Land Capability Subclass. The class numerals, I to VIII, are prefixed with "ir" on the assumption of irrigation.

The second grouping, subclass, is designated by the kinds of limitations which are expressed in the small letters following the class numeral.

In Table III.2-2 are excerpted the results in land classification of the soils occuring in the Project Area. These results show a very simple pattern that almost all lands of the Area are ranked at Class irIIs with minor limitations of clayey texture or slight surface salinity. It may not seem to supply informations enough to conduct extension work for the farmers. As a matter of fact, not a few lands have been observed to assume saline phase to an extent of affecting the crop growth.

ii) Classification with Soil Salinity

The WAPDA has surveyed the Indus Basin since 1977 and has released data pertaining to the selected projects with survey units totaling 21 million acres of irrigated areas. Subsequently, they have issued "Atlas of Soil Survey Results for Province-wise Projects" in 1981. It comprises many areal maps scaled at 1:250,000 on soil salinity, water table depth, groundwater quality and soil textural groups. The Command Area of the Pat Feeder Canal Project extends over three maps, 34 p - 39 D - 39 H of the Atlas. These maps are of necessity very useful to grasp overall features of the Project, but appearing not enough to get more precise status of the soil hazards. For example, the soil profile chemical condition map illustrates only

Table III.2-3 New Class Criteria for Soil Profile Salinity Evaluation

Soil Depth (cm)	Soil Sample No.	Class and Sub-class of Salinity											
		I		II			III			IV		V	
		a	b*	a	b	c	a	b	c	a	b	a	b
0- 45	1-2	1	1	1	1	2	2	2	3	3	3	4	4
45- 90	3	1	1-2	1-2	3-4	1-2	1-2	3-4	1-2	1-2	3-4	1-3	4
90-180	4	1	1-2	3-4	1-4	1-2	3-4	1-4	1-2	3-4	1-4	1-4	1-4

Note : 1) Salinity numbers, 1-4, see Fig.III.2-4.

2) Salinity of 0-45cm soil shows average value of sample 1 and 2.

3) SAR is further evaluated only for average value of sample 1 and 2 by designating x as its value is 13-23, and y as more than 23. For examples, IIcx: Vay.

* This b does not include 1-1-1 soils.

Table III.2-4 Area of Soil Profile and Frequency of Surface Sodicity in the Pat Feeder Canal Project Area

Class	Sub-class	Area (acre)	Percent (%)	Frequency of Surface Sodicity (%)
I	a	225,400	32.8	-
	b	137,100	19.9	0.2x+0.1y
	Sub-total	362,500	52.7	0.2x+0.1y
II	a	56,500	8.2	-
	b	34,400	5.0	-
	c	43,900	6.4	0.3x
	Sub-total	134,800	19.6	0.3x
III	a	12,200	1.8	0.3x
	b	56,200	8.2	0.6x
	c	12,200	1.8	0.8x+0.1y
	Sub-total	80,600	11.8	1.7x+0.1y
IV	a	2,700	0.4	0.1x
	b	42,000	6.1	2.3x+0.2y
	Sub-total	44,700	6.5	2.4x+0.2y
V	a	11,900	1.7	0.8x+0.7y
	b	22,200	3.2	1.0x+1.8y
	Sub-total	34,100	4.9	1.8x+2.5y
Unknown		31,300	4.5	-
Total		688,000	100.0	6.4x+2.9y

Source: WAPDA original data used for Atlas, 34P, 39D and 39H, planning Division(1977-1979).

Note: Refer to Table III.2-3 for surface sodicity.

Fig. III.2-4 Distributio
Feeder C
Original

Legend : Class and Subclass of Soil Profile Salinity

Map Symbol No.		Ia	Ib	2	3	4	5	6	7	8	9	10	11
Soil depth (cm)	Soil Sample No.	I a	I b *	II a	II b	II c	III a	III b	III c	IV a	IV b	V a	V b
0-45	1-2	1	1	1	1	2	2	2	3	3	3	4	4
45-90	3	1	1-2	1-2	3-4	1-2	1-2	3-4	1-2	1-2	3-4	1-3	4
90-180	4	1	1-2	3-4	1-4	1-2	3-4	1-4	1-2	3-4	1-4	1-9	1-4

Note : 0 ····· Lack of data

Remarks : Salinity of the Layer Samples is evaluated with its Electrical Conductivity of Saturation extract(ECe) as follows :

1 —— < 4 mmhos : 2 —— 4-8 mmhos : 3 —— 8-15 mmhos :

4 —— > 15 mmhos

* Not including 1-1-1 soils.

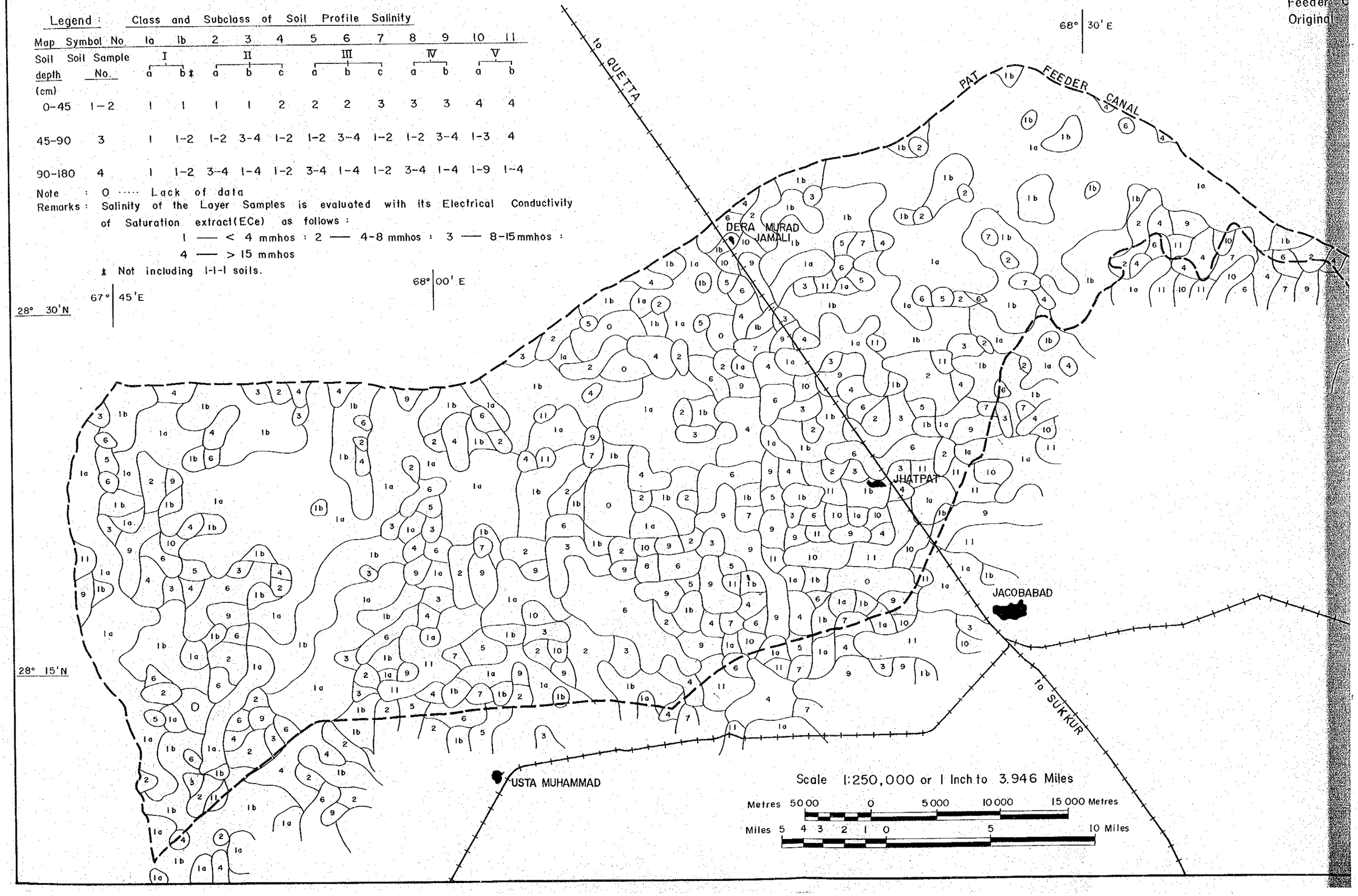
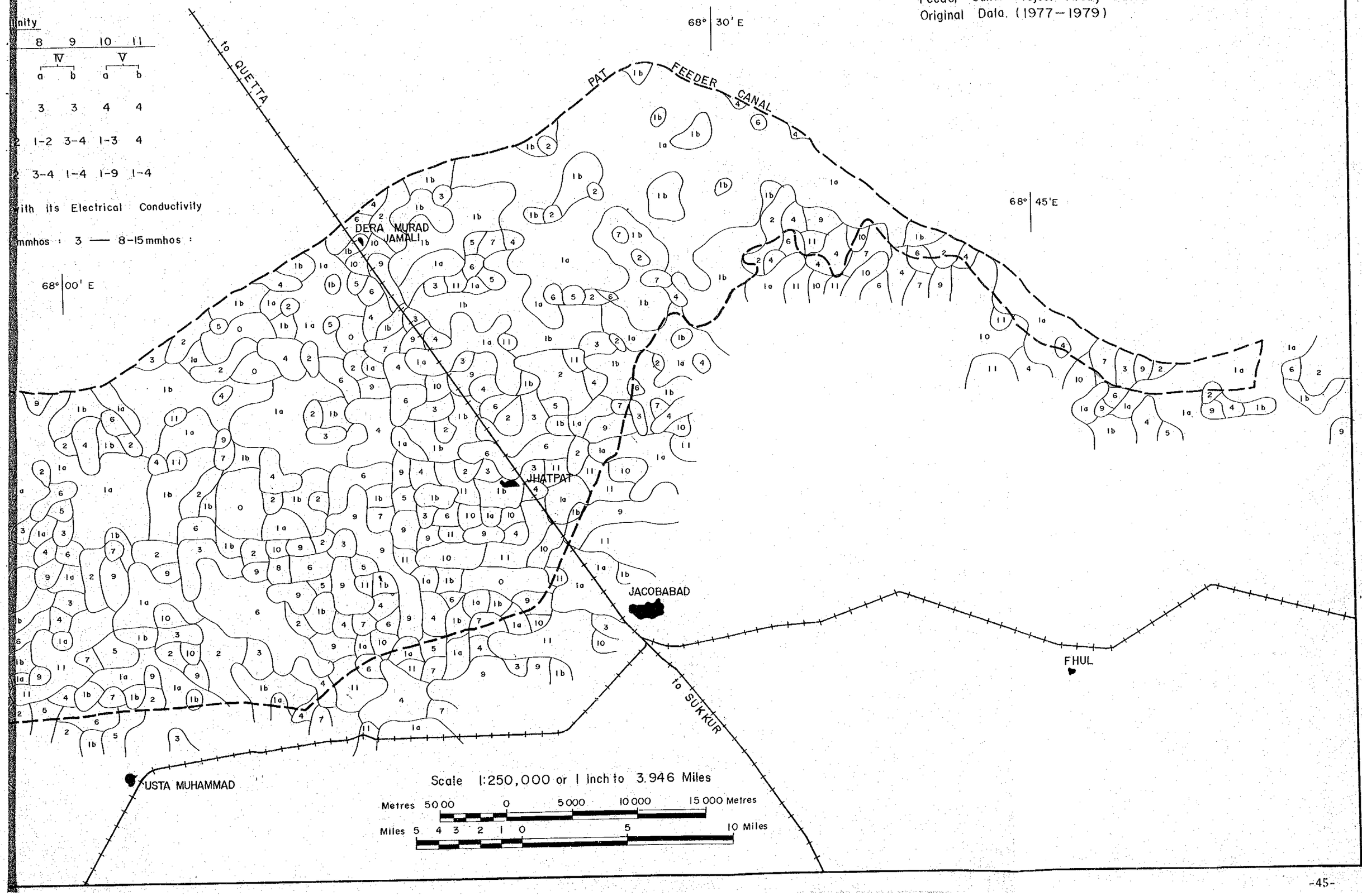


Fig. III.2-4 Distribution of Soil Profile Salinity in the Pat Feeder Canal Project Area, Based on WAPDA Original Data. (1977–1979)



the presence of salinity (ECe > 4 mmhos) or sodicity (SAR > 13) irrespective of the soil depth where they appear. As a result more than 60 per cent of the Canal Command has been designated to the groups of saline or sodic soils. So far as the crop production is concerned, important is where and how severely they appear in the soil profile in view of their influences to the root-growing zone.

Therefore, the present study has intended to establish a comprehensive classification of the profile salinity by investigating the original data of the Project Survey, which were copied by WAPDA Laboratory at Lahore. Table III.2-3 describes the criteria on five Classes and their Subclasses for the profile salinity. These express progressively increasing grades of the hazards, that is, the direct influence of surface salinity and the risk of surface salinization due to the upward movements of subsoil salts. Fig. III.2-4 is the map newly drawn for the area according to the criteria. Extents of these Classes are presented in Table III.2-4 to show reasonable distribution of the salinity.

Soil sodicity is one of the limitations in connection with salinity. Owing to its affection, however, to the soil productivity as estimated from the calcareous property of both soil and irrigation water, only the surface sodicity within 18 inches from the surface was checked as is shown in Table III.2-4. Its depiction was omitted in the map because an extent is minor and closely related to the salinity class in the ascending order.

iii) Classification Combined with Soil Profile Salinity

Finally, re-classification has been attempted by involving the profile salinity appraisal. For this purpose, four groups, A to D, have been set up among Sub-classes according to the estimated damage grades of the soil salinity.

Table III.2-5 Land Capability Classification with Profile Salinity of the Soils in the Pat Feeder Canal Project Area

Map Symbol No.	Class Sub-class	Main limitations	Soil Series, variant, phase or other area	Area (acre)	Percent (%)
1	irI	None or only slight limitations	Bolan, Bolan loam variant (27)	11,390	1.7
2	irIIs	Fine textured, slowly permeable	Pacca (9), Nabipur (16), Bolan mod.Co., (27), Katchar (28), Jhatpat (31), Kandhkot (32), Kundi (34)	222,510	32.3
3	irIIa	Fine textured, slightly saline/ sodic	Nabipur slightly saline (16), Jhatpat slightly saline (31)	335,790	48.8
4	irIIIw	Fine textured, poorly drained	Pacca poorly drained (9)	5,440	0.8
5	irIIIs	Fine sandy, rapidly permeable	Pacca imperfectly drained and slightly saline (9)	-	-
6	irIIIa	Mod. to fine tex., moderately saline	Jacobabad (6), Jhatpat (31), Katchar (28)	51,740	7.5
7	irIVs	Sandy textured, seepage	Chhater (29)	16,630	2.4
8	irIVa	Mod. to fine tex., strongly saline	Jhatpat (31), Katchar (28), Kundi (34) Rojhan (24)	33,110	4.8
9	VIIc-s	Topography, sandy/saline/ poorly drained	Chhater (29)	2,360	0.4
10	VIII	Undulating, sandy, wind erosion	Dune land (35)	9,030	1.3
			Total	688,000	100.0

Note: The map was drawn by combining Land Capability Map (Soil Survey of Pakistan) with WAPDA original data of soil salinity/sodicity (see Table III.2-49 of Appendix III.2.4).

Fig III.2-5 Land
Prof

68° 30'E

67° 45'E

68° 00'E

28° 30' N

28° 15' N

PAT FEEDER CANAL

to QUETTA

DERA MUARD JAMALI

JHATPAT

JACOBABAD

to SUKKUR

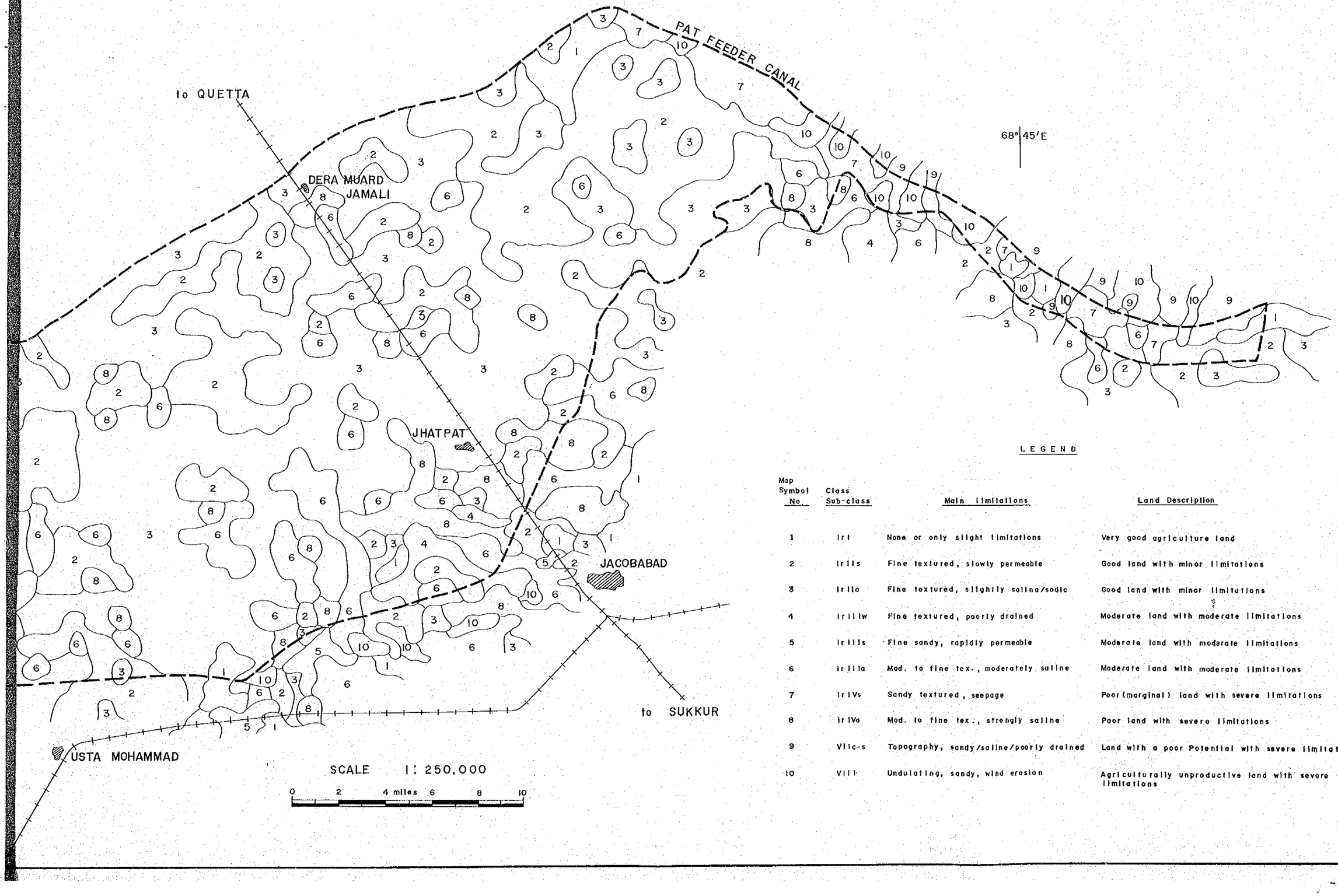
USTA MOHAMMAD

SCALE 1: 250,000

0 2 4 miles 6 8 10

Map Symbol No.	Class Sub-class	
1	IrI	None or ...
2	IrIIs	Fine textur...
3	IrIIa	Fine textur...
4	IrIIIw	Fine textur...
5	IrIIIs	Fine sandy ...
6	IrIIIa	Mod. to ...
7	IrIVs	Sandy tex...
8	IrIVa	Mod. to ...
9	VIIc-s	Topograph...
10	VIII	Undulati...

Fig III.2-5 Land Capability Classes in the pat Feeder Canal Project Area, Combined with Soil Profile Salinity



LEGEND

Map Symbol No.	Class Sub-class	Main limitations	Land Description
1	Ir I	None or only slight limitations	Very good agriculture land
2	Ir IIs	Fine textured, slowly permeable	Good land with minor limitations
3	Ir IIa	Fine textured, slighily saline/sodic	Good land with minor limitations
4	Ir IIIw	Fine textured, poorly drained	Moderate land with moderate limitations
5	Ir IIIs	Fine sandy, rapidly permeable	Moderate land with moderate limitations
6	Ir IIIa	Mod. to fine tex., moderately saline	Moderate land with moderate limitations
7	Ir IVs	Sandy textured, seepage	Poor (marginal) land with severe limitations
8	Ir IVa	Mod. to fine tex., strongly saline	Poor land with severe limitations
9	VIIc-s	Topography, sandy/saline/poorly drained	Land with a poor Potential with severe limitations
10	VIII	Undulating, sandy, wind erosion	Agriculturally unproductive land with severe limitations

The Land Classes have been thus newly decided by combining the former Classes with the salinity groups, A to D. The map presented in Fig.III.2-5 is the result of this combined classification. Table III.2-5 gives the overall relations among Classes, limitations and soil units found in the Project Area.

The proposed land capability classification method is still tentative but will more fit to the actual soil conditions of the area concerned.

An additional caution must be taken for the presence of gypsum in the soils on its effect to control the sodium accumulation. Compared with the profile salinity distribution, gypsum appears to be in vague correlations with the increasing salinity. At present, gypseous status may not necessarily be added to the land classification criteria with the following reasons:

(1) No quantitative data are available for evaluating the gypsum activity for desalinization.

(2) Judging from the lower SAR (< 10) of the irrigation water, severe alkalinization may not occur for the time being in this Area.

Detailed data and discussions in this paragraph are referred to in Land Capability Classification of Appendix III.2-4.

d) Problems and Recommmendations

As mentioned already, the soils of the Area have more or less inferior properties for crop production. Several problems will arise from these circumstances and then countermeasures for the must be examined.

i) Soil Classification

It is uncertain whether Jhatpat Soil Association, fine textured (SiC) with or without weak structure development, is the most dominant all over in its extent. Because most of the extent areas show rather moderately fine texture (SiCL) together with medium texture (SiL) in the light of WAPDA Project Survey as well as of the present survey. Although the discrepancy is not so serious further detailed soil survey for this Soil Association will produce a good result not only in the more accurate genetic classification but also in the better land potential appraisal.

ii) Soil Salinity and Alkalinity

Around the Command Area, five soil series have been reported to be saline but non-alkali. These are very minor in extent except Rojhan Series (24) which distributes on the land between Jhatpat and Jacobabad. According to the field analysis in the present survey, not only in saline Soil Series but also some profiles in non-saline ones showed a strong salinity much higher than 4 mmhos which is designated as a harmful limit to the crop growth.

It has been quite common to abandon cultivation in the marginal strip lands where irrigation or seepage water is standing in part and evaporates to develop salt crust.

As was often reported on the irrigation projcts in this country, soil salinity problem has become of paramount importance because unsatisfactory irrigation and drainage systems are apt to cause salinity hazards to the field crops by accumulating salts and sometimes by withdrawing them from the saline ground water to the surface especially in the areas of hot and arid climate.

Behaviour of salts in the soil under irrigation and drainage management should be studied in the concerned field. This will provide useful data for leaching method. A periodical monitoring of soil salinity by means of EC measurement with water extracts of the soils must be scheduled as has been carried on the Punjab Doab Regions.

Soil alkalinity or sodicity is a second problem. It incidentally causes dispersion of the clay particles resulting in the collapse of structures and pore system followed by the decrease in water permeability. This may raise more difficulties in the future extension of mechanized farming. Therefore, continuous survey on this item is needed though the extent is not yet so prevalent under existing conditions.

iii) Water Quality and Irrigation Method

Quality of the Indus River water for irrigation use has no trouble both in constituent and concentration of the dissolved salts besides the problem of sediments contained.

For irrigation techniques, a continuous care must be taken not to cause the surface salt accumulation since the downward movement of water is considerably limited due to the laminated or less developed structure of the clayey soil. In this regard drip or spray irrigation are not suitable, but intermittent ridge irrigation or basin irrigation are recommended in view of the technical easiness under the present level of farming. Perennial irrigation is not so recommended to most of the crop fields even in case of rice cultivation. Main reasons for this are as follows:

(1) Alternating wet and dry condition is necessary to develop the soil structure.

(2) Avoidance of the linkage between irrigated water and groundwater, the level of which is generally deep more than 10 ft but salt concentration exceeds 3,000 ppm.

In either case, these conditions for complete drain system is required to be realized at the possibly earliest stage. The present drain system which is connected with the Khirtar Canal by pumping should be thoroughly examined on its functions and repaired, if necessary.

iv) Soil Fertility and Managements

According to the profile observation and analytical data of Soil Survey of Pakistan, the soils of the Area are extremely deficient in nitrogen due to the rapid decomposition of organic matter under the arid climate condition. While they are rich in calcium and magnesium because of the calcareous parent materials. Potassium may be no problem in the presence of easily-weathered minerals in the soils. Available phosphorus, however, seems to be deficient, too, judging from the results of the field trials conducted in Sukkur District.

Considering extremely high pH of the calcaric soils prevailing over the Project Area, physiologically acidic fertilizers, e.g. ammonium sulfate and superphosphate, can be better used.

Organic fertilizers, which are compost and green manures, are highly recommended though difficult to be extended. Deep-rooting legume crops or grasses are quite effective not only in organic matter supply but also in subsoil improvement especially of its physical condition. Active manganese does not seems deficient in the soils. A systematic study on the minor elements need to be performed in the near future.

In view of the clayey soil properties, the following soil managements will be desired:

(1) Ploughing the soils at an optimum moisture

(2) Avoidance of frequent ploughing and excessive irrigation

(3) Deep ploughing and adequate leaching management at least once several years.

v) Land Capability Classification

In land capability evaluation, Class and Subclass were decided for irrigated agriculture because it has been the most popular culture method here. The Subclass IIs with some inherent hazards such as fine texture covered almost 90 per cent of the whole Area, the other units being minor in extent according to the Land Class Map made by Soil Survey of Pakistan. This Subclass IIs consists of Jhatpat, Katcher and Kundi Soil Associations, in most of which the soils are clayey and slightly permeable.

Due to the same reason as the soil classification, the soils of these clayey Soil Associations should be re-surveyed in detail with a view to get more accurate presence of soil hazards in this Area. An attempt was made in this report to classify the lands further with profile salinity distribution which was drawn from WAPDA original survey data. The results were already discussed and arranged, thus enabling to produce a revised Land Class Map. The further investigation should be made for rectify this map through detailed soil survey for the Area.

For such intensive processing of the survey data, an electronic computer will preferably be introduced by coding soil profile characteristics, analytical results and their monitored data.

III.3. Present Agriculture

III.3.1. Present Land Use

There are no detailed data available on the present land use of the Project Area except the "Present Land Use Map" prepared by WADDA (See Appendix III.3-1, Fig. III.3-1) and the land use statistics of each village provided by Land Revenue Offices (see Appendix III.3-1, Table III.3-1). An attempt to use the lands at satellite imagery map was also constrained to the restricted use due to definitely short period of study.

Based on the planimeter measurements and the said land use statistics (1979/80), the total area of the Project is estimated at 688,000 acres (278,000 ha). Out of this about 612,000 acres (248,000 ha) are commanded by the Pat Feeder Canal (Appendix Table III.3-3).

Furthermore total cultivated area available at present is about 509,700 acres comprising 192,700 acres as the net sown area and 317,000 acres remaining as fallows. The total of the net sown area includes only 6.7 per cent of the area sown more than twice (about 13,000 acres) (Appendix III.3-3).

The total uncultivated area is about 124,800 acres of which 19,200 acres are not available for cultivation and 105,600 acres are the cultivable waste. The total annual cropped area computed on the basis of average from 1978/79 to 1980-81 cover about 239,600 acres or 47 per cent of the presently cultivated area (Appendix III.3-3).

Excluding the very small area of the reforestated lands which are located between the national highway and the railway, there is no land under forest or lands in any other category in the Project Area but the difference between the total Project Area and the total recorded area might correspond to the area under barren lands which

are mainly located upstream along the Pat Feeder Canal and also in the southern part of Jhatpat.

According to the aforesaid "Present Land Use Map" and the information provided by Agriculture Department Office on the present land use, unavailability of irrigation water is the major reason why only 47 per cent of the total cultivated area (239,600 acres) are under cultivation and about 17 per cent, or 105,600 acres of the total project area is covered by the culturable waste lands (Appendix Tables III.3-3 and III.3-4).

It is said in the Reconnaissance Soil Survey of Jacobabad-Usta Mohammad that the Pat Feeder commanding area has been designed for dry Kharif crops mainly sorghum. Therefore, the crop choice is restricted although the soils permit a wider range of crops, and the winter crops, mainly consisting of wheat and oilseeds, are almost Bosi, which means the winter crops in the summer fallow lands with a single large irrigation at the time of sowing, especially until 1978/79 when the Tarbera Dam started to supply water.

The Project Area includes some problematic areas of "Water logging and salinity" in and around the barren area and ill-drainage area of down-stream of the Pat Feeder Canal (after RD558) flooded several times during the past ten years. The floods have damaged not only Kharif crops but also daily life.

III.3.2. Farm Household and Land Tenure

1) Farm Household and Farm Labour

The Project Area extends over five Tehsils covering as a part of the whole area of Nasirabad. The total number of persons and households in the Project Area were estimated at 244,000 and 37,000, respectively, which are equivalent to 62 and 65 per cent, respectively, of the total of each item of Nasirabed District (Appendix Table III.3-5).

The farm households in the Project Area is 28,000, occupying about 76 per cent of the total. The total population of the farm households was estimated at 184,800, and the average population per farm household is 6.6 while the working population for farming is less than 3.4 per farm household (Appendix Table III.3-5).

2) Farm Size and Land Tenure

The followings are the summary of land tenure and farm size based on the data of Nasirabad District published in the Agriculture Census 1972.

Table III.3-1. Land Tenure in Nasirabad

(Unit: Households, acres, %)

Item	Owner	Owner cum tenant	Tenant	Total
1. No. of Farm Household	(15.4%) 3,390	(6.4%) 1,393	(78.2%) 17,188	(100%) 21,971
2. Farm Area	(23.7%) 138,941	(16.0%) 93,511	(60.3%) 352,623	(100%) 585,075
3. Farm Area per a Farm	40.1	67.1	20.5	26.6

Source: "Pakistan Census of Agriculture, 1972", Agricultural Census Organization

In the Cencus, the data on land tenure in 1972 were classified by three principal categories; the owner cultivated, the owner-cum-tenant cultivated and the tenant cultivated. The number of farms under these categories are 3,390, 1,393 and 17,183, respectively, and the total farm households 21,971 in the area where corresponds to the present area of Nasirabad District (Appendix Table III.3-8). The average size of the farm corresponding to each category is 41.0, 67.1 and 20.5 acres, respectively, whereas the average size of all categories is reported by 26.6 acres against 13.0

acres of the average in entire country. This indicates that average size of the farms in the Project Area is more than twice of the country's average.

In most cases of land tenancy in the Project Area, the share-cropping system on the half-share basis is dominant in payment on the rent.

Table III.3-2. Number of Farm Households by Size of Holding in Nasirabad

Size of Holding (acre)	Number of Farm Households
Total	21,971 (100%)
under 1.0	- (-)
1.0 - 2.5	212 (1.0)
2.5 - 5.0	511 (2.3)
5.0 - 7.5	786 (3.6)
7.5 - 12.5	4,689 (21.3)
12.5 - 25.0	9,493 (43.2)
25.0 - 50.0	4,553 (20.7)
50.0 - 150.0	1,490 (6.8)
150.0 and over	237 (1.1)

Source: "Pakistan Census of Agriculture
See Appendix Table III.3-8.

The farm size of almost all farm households ranges from 7.5 to 50 acres occupying 85 per cent, out of which those with a farm size of 12.5 to 25.0 acres predominate in numbers, accounting 43 per cent of the total. This tendency is considered to be the same as that in the Project Area.

III.3.3. Cropping Pattern and Production

Agriculturally, Project Area is one of the most productive area in the Baluchistan Province. Inspite of this, 69 per cent of the total command area is left as fallow lands or cultivable waste lands, and single cropping pattern is practiced exclusively.

The cropping intensity in terms of the percentage of the annual cropped area to the total command area of the Project is as low as 39 per cent. The summer or Kharif cropping starts in May to June after shutdown period of canals and ends in September to October. During this period, rice, sorghum, sesamum and sugarcane are planted. The winter or Rabi cropping starts in October to November with planting of wheat, rapes and mustard, gram and berseem, mainly. Summer crops cover about 40 percent of the total annual cropped area and winter crops cover the remaining 60 per cent (Appendix Table III.3-4). The area sown more than twice a year covers only few per cent of the total net sown area, as mentioned above. The major cropping pattern followed are as illustrated below;

Present Cropping Pattern

	Kharif		Rabi
(a)	Paddy	+	Pulses (gram, etc.)
(b)	Paddy	+	Fallows
(c)	Upland crops (Sorghum, sesamum, etc.)	+	Upland crops (Wheat, rapes & mustard, etc.)
(d)	Upland crops (Sorghum, sesamum, etc.)	+	Fallow
(e)	Fallow	+	Upland crops (Wheat, rapes & mustard, berseem, etc.)

The cropping calendar of each pattern with the estimated area coverage is shown in Fig. III.5-1. The pulses followed by rice are commonly practiced, which is so-called Dubari Crops" that means winter crops by utilizing the residual soil moisture of the previous cropping without any irrigation.

As seen in Appendix III.3-1, Table III.3-4, considerably large amount of area decrease is seen for the area under sorghum for these last ten years, whereas rice, wheat and sugarcane have increased

rapidly in their cropped acreage, especially since 1978-79. Other crops like sesamum, Rabi oilseeds and Rabi pulses have maintained their level of cropped area or slightly decreased. This change in cropping pattern would denote farmers intention to grow more beneficial crops like rice, sugarcane and wheat. Vegetables and fruits are grown on a fractional area being non-resistant to drought conditions resulting from the canal closure from mid-March to mid-May. The data and duration of the canal closure also make it difficult to grow the crops like cotton and sugarcane on schedule to get optimum yield, and also make farm animals deprived of green fodders continuously for six months from April to September as described below. The unit yield and production of the major crops are estimated in the Table III.3-3.

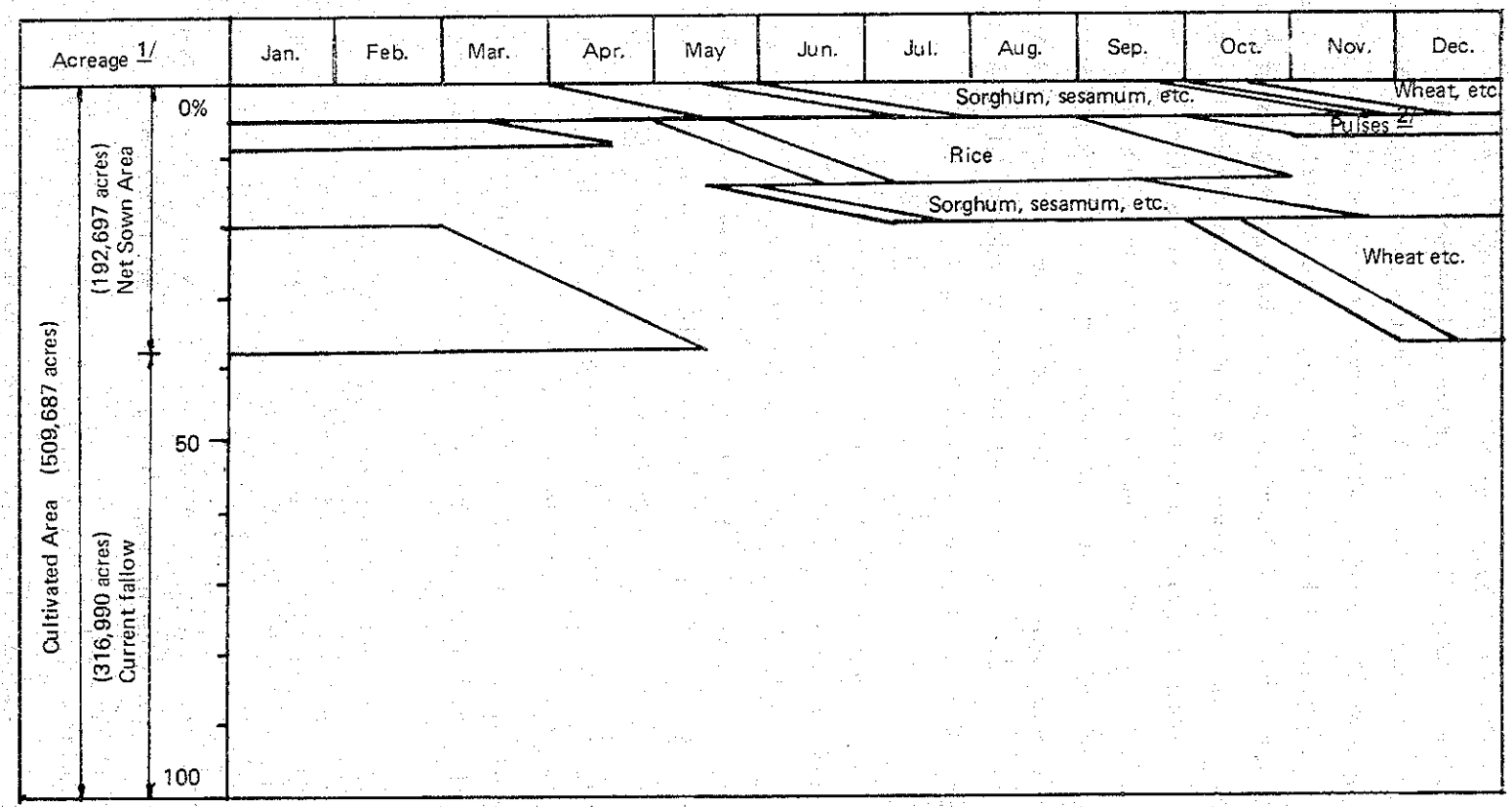
The average yield per acre for Sorghum, rice, sesamum and sugarcane is 7.1 maunds (0.66 ton/ha) 15.9 maunds (1.47 ton/ha), 5.4 maunds (0.50 ton/ha), 318 maunds (29.50 ton/ha), respectively. The yield of wheat, pulses (gram), rape seeds and mustard and berseen are 21.2 maunds (1.96 ton/ha) 78 maunds (0.72 ton/ha), 3.8 maunds (0.35 ton/ha) and 227 maunds (20.96 tons/ha), respectively. These yields are low as compared with the average yields of respective crops in the irrigated areas of the neighbouring provinces. The reason for low yield is not only shortag in irrigation water but also several other factors identified during field survey as follows;

(i) Poor water management practices due to the very limited on-farm facilities and lack of on-farm water management organization.

(ii) Inadequate extension services with limited number of staff and lack of facilities for transportation and on the job training, etc.

(iii) Inadequate supply of farm input materials and farm credits.

Fig. III 3 – 1 Present Cropping Pattern



Remarks: 1/ Refer to the cultivated area in Appendix III. 3 – 1, Table III. 3 – 3 and the cropped areas in Appendix III. 3 – 1. Table III. 3 – 4.

2/ The cropped area for the pulses followed by rice are estimated at 30% of the rice cropped area.

Table III.3-3. Present Crop Yield and Production

Crops	Harvested Area 1/ (acre, ha)	Unit Yield 2/ (Mds/acre, ton/ha)	Production (ton)
1. Sorghum	33,000 (13,400)	7.1 (0.66)	8,844
2. Rice	43,500 (17,600)	15.9 (1.47)	25,872
3. Sesamum	13,200 (5,300)	5.4 (0.50)	2,650
4. Sugarcane	5,000 (2,000)	318.1 (29.40)	58,800
5. Wheat	80,000 (32,400)	21.1 (1.96)	63,504
6. Pulses (gram)	4,000 (1,600)	7.8 (0.72)	5,600
7. Rape Seeds & Mustard	33,500 (13,600)	3.8 (0.35)	9,792
8. Berseem, etc.	27,400 (11,100)	226.8 (20.96)	232,656
Total	239,600 (97,000)		

Source: 1/ See Appendix III.3-1, Table III.3-4 (Figures are rounded)

2/ Agriculture statistics, Agriculture Dept. of Baluchistan for the Nasirabad District (1975/76 1979/80) excluding

Note: The estimated amount of dry straw for sorghum, wheat and rice are as follows:

Sorghum: 40 maund/acre (3.7 ton/ha)
Wheat : 20 maund/acre (1.8 ton/ha)
Rice : 30 maund/acre (2.8 ton/ha)

(iv) Lack of proper interest on adequate management by tenants who cultivate about 70 per cent area in the Project.

The traditional methods of crop management prevail in the Project Area except for the very limited area of intensive cultivation. Most of the crops inclusive of wheat is broadcasted in inadequately prepared lands with low quality seeds. Irrigation practices are poor and involve big loss of water which often causes crop damage in associating with the lack of drainage facilities.

It is difficult to supply irrigation water timely under the conditions that there is no systematic facilities and organization at on-farm level and the lands are often not adequately leveled. There is no large-scale fertilizer use, weeding and pest control. Also, there is no proper soil management like adding organic matters to fields despite most of the soils are clayey and structureless. The area under improved varieties covers more than 90 per cent in case of wheat and more than 80 per cent of rice are under IRRI-6 (IR6-156-2-1), according to the information of Agriculture Department Office (See Appendix III.3-3, Table III.3-17 to III.3-18).

The wheat yield in the demonstration plot which is supervised by Agriculture Department Office is as much as about 48 maunds (4.4 ton/ha) (see Appendix III.3-3, Table III.3-19). The demonstration plot yield of sesamum and rapes is also 1.6 times and 2.6 times higher than the present yield in the Project Area. As for rice yield, the result of trial in Sukkur gave high yield as much as 8.8 ton/ha in the Soil Fertility Survey. These yield data indicate that the Project Area has large possibility to attain high crop production.

III.3.4. Agricultural Credit

The major source of institutional credit in the Project Area is ADBP (Agricultural Development Bank of Pakistan) which advances all types of loans for the development of agriculture through its three branches of Dera Murad Jamali, Jhatpat and Usta Muhammad Khan. Administratively this area falls under the jurisdiction of Regional Offices Quetta.

The Bank, established in 1961 advances loans for the purposes of developing agriculture, including crop raising, orchard, livestock, dairy farming, bee keeping, sericulture and fisheries, etc.

The Bank has three kinds of loan systems for the farmers classified by repayment terms of eight, five and one year, respectively. In the Project Area, 4,670 farmers have borrowed a sum of Rs.41.5 million from the Bank since the establishment of this organization. The loaning status of agriculture is shown in the following table.

Table III.3-4. Loaning Status of Agriculture in Nasinabad

Items	Long Term Loan	(%)	Medium Term Loan	(%)	Short Term Loan	(%)	Total	(%)
1. Number of Loanees	265	(5.7)	205	(4.4)	4,200	(89.9)	4,670	(100)
2. Amount of Advanced (Million Rs.)	22.0	(53.0)	3.5	(8.5)	16.0	(38.5)	41.5	(100)
3. Amount per a Case (Rs.)	83,100		17,200		3,800		8,900	

Source: Nasirabad District Office of ADBP

See Appendix Table III.3-20.

The purposes of these loans are the long-term loan for fixed capital like tractors, etc., the medium-term loan for fixed capital like relatively small animals and carts, and the short-term loan for floating capital of seeds, fertilizers, pesticides and so on. Interests of these loans are the same at eleven percent per annum.

III.3.5. Livestock Farming

The estimated population of domestic animals and poultry in the Project Area and the ratio of the respective number of animals and fowls per farm household are shoen as follows:

Estimated Heads of Livestock in the Project Area
(1980, All Ages)

Domestic Animals	Nos. of Head	Ratio to Total Farm Household 1/
Cattle	120,366	4.3
Buffalos	12,301	0.4
Sheep	132,603	4.7
Goats	145,017	5.2
Horses	4,612	0.2
Donkeies	40,697	1.5
Camels	15,038	0.5
Chicken	118,262	4.2

Source: Livestock Department, Dara Murad Jamali (See Appendix III.3-5, Table III.3-22)

Note: 1/ Divided by 280,000 of the estimated total farm household

Based on the above data and the classified number of cattles and buffalo by sex and age in Nasirabad District in 1980 (see Appendix III.3-5, Table III.3-21), the average heads of cattle and buffalo by sex and age per farm household are estimated as follows;

Estimated Heads of Cattle and Buffalos
by Sex and Age per Farm Household

Kind	Total	3 Years and Above			Below 3 Years (Both Sex)
		Total	Male	Female	
Cattle	4.3	3.3	1.8	1.5	1.0
Buffalo	0.4	0.2	0.1	0.1	0.2
Total	4.7	3.5	1.9	1.6	1.2

The UNICEF survey in 1980 reveales that 93 per cent of the sample households in the Nasirabad district rear animals and fowls for draft use and diet and about 70 per cent of the sample households raise draft use animals, and that animals for milk and meat are raised by 90 per cent of the sample households.

Based on the above-listed ratio and the UNICEF survey, the livestock ownership by kind of animals and fowls are summalized as follows;

(i) 2.8 head of animals for draft use per household are raised by 70 per cent of farm households (out of 2.8 heads, 2.6 head are covered by bullock and 0.2 head by buffalo)

(ii) The raisers of cows and buffaloes for milk amount to about 90 per cent of the total farm household. They rear on an average 0.8 head of milk cows and 0.1 head of milk buffaloes, respectively.

(iii) The raiser of sheep/goats cover about 50 per cent of farm households. They keep about 20 head of sheep and goats on an average.

The main source of feed for these animals and fowls are farm forage, wheat and paddy straws, various crop residues and other kinds of farming by-products. One of the major problems in the Project is lack of green fodder for animals due to closure of Pat Feeder Canal.

III.3.6. Inputs Supply and Farm mechanization

1) Seeds

Agriculture Extension Office is responsible for distribution of quality seeds. But the distribution of seeds is limited to wheat

seeds of improved variety. The respective amounts of improved seeds used in the Project Area were estimated as follows:

Estimated Requirement of Seeds (Improved Varieties Only)
(1980/81)

Crop	Total of Harvested Area (acre)	Improved Varieties Per Cent (%)	Improved Varieties Area (acre)	Seed Rate (kg/acre)	Requirement (ton)
Wheat	90,000	80	72,000	37.2	3,678
Paddy	70,000	80	56,000	25.0	1,400
Sorghum	37,244	0	0	-	-

Source: Agriculture Dept. Extention Office, Dera Murad Jamali
(See Appendix III.3-17, Table III.3-17, 18)

But the distributed amount of wheat seeds in the entire province was totaled only to 1,060 tons in 1978-79. Under such circumstances, almost all farmers commonly use their own reserved seeds even in case of wheat and paddy. The mixture of other varieties are prevailing in the Project Area.

2) Fertilizer and Pesticides

Fertilizers and pesticides are supplied by the Agriculture Department. The following table shows the distributed amount of fertilizers in the Nasirabad district exclusive of Tehsil Usta Muhammad.

Distributed Fertilizers by Agriculture Department
(Nutrient Amount Base)

Year	N	P_2O_5	K_2O
1978/79	1,553	650	-
1979/80	2,218	1,236	-
1980/81	4,079	1,800	-

Source: Agriculture Department, Extension Office, Dera Murad Jamali
(See Appendix III.3-6, Table III.3-23)

Note: These amounts were distributed to the extire Nasirabad District except for Tehsil Usta Muhammad.

Based on the distributed amount of fertilizers and the farm management survey for the sample farmers in this study, the average rate of fertilizers per one acre of the cropped area was estimated at 11 kg of Nitrogen (27 kg/ha) and 5 kg of phosphate (12 kg/ha), respectively, and the rate by crop was estimated to show in the Appendix III.3-6.

The supply of pesticides is also limited. Only the approximate percentage for the total cropped area is covered by the implementation of insect control by Agriculture Department (See Appendix III.3-6, Table III.3-25). In case of pest control rendered by the Agriculture Department, the farmers bear only the cost of pesticides, which is partly subsidied. The costs of labour and equipment are borne by the Department.

3) Farm Mechanization

The present farm labour balance was estimated to show in Appendix III.3-6, Fig. III3-2, which implies that there is much excess labour in the Project Area except the peak of the demand.

In the Nasirabad district exclusive of Tehsil Usta Muhammad, 246 four-wheel tractors (mostly 50 to 70 HP) are used (See Appendix III.3-6, Table III.3-26). Power tillers, threshing machines and any other kinds of farm machines have not been introduced yet except 246 units of the said tractors, 70 units of water pumps, 100 units of hand sprayers, 12 units of power sprayers and 20 units of hand dusters. On the assumption that the 246 tractors are worked for land preparation at the area coverage of 200 acres per unit per annum, and

the land preparation by tractors covers about 20 per cent of the total cropped area. Accordingly, the animal power prevails in the Project Area for the works of land preparation, threshing and transportation.

The Department of Agriculture Engineering has posted one office at Dera Murad Jamali. But the department renders no services on agriculture mechanization although it has implemented the land leveling works on the contract base with subsidization of the machines cost, (Rs.100 per hour) through keeping seven units of one-load bulldozers out of 13 units of bulldozers (80 to 100 HP). On the assumption that one bulldozer can cover the leveling work of 250 acres per year, the land leveling services by the Department would cover only 0.3 per cent of the total cultivated area.

III.3.7. Agro-Industry

Agro-based industries in the Nasirabad district have been installed on a very limited scale. Only a few units of rice mills, small-scaled flour mills and rice-cum-flour mills are working at present as shown in Table.

Numbers of Industrial Units in Nasirabad District

Tehsil	Rice Mills	Flour Mills	Rice Cum Flour Mills	Oil Expeller	Saw Machine
Jhatpat	1	5	4	1	-
Usta Muhammad	8	5	4	-	-
Dera Murad Jamali	-	1	2	1	1
Total	9	11	10	2	1

Source: UNICEF Survey 1980

The existing rice mills, although small in capacity, are working at their full capacity. The estimated total output of these milling facilities is 90 tons of rice per day or 10,800 tons per year. In assuming that the paddy yield per acre is 0.6 tons (1.5 ton/ha) and a plant recovery rate is 66 per cent the area covered would be only about 27,000 acres out of about 198,000 acres being cropped under paddy at present in the District. Eventually the rice growers in the Project Area have to transport their produce either to the rice mills located in Jacobabad or to sell to middle men at low price. Under the circumstances, the following countermeasures are required;

(i) to install more rice mills at Dera Murad Jamali or Jhat Pat according to the existing network of yards,

(ii) for the Government to fix the bottom prices of rice to be purchased by rice millers and middle men like wheat, cotton and sugarcane, and

(iii) for Pakistan Agricultural Storage and Services Corporation (PASCO) to establish purchasing centers or to install rice mills (The related plan is now under consideration the Project Area).

There is no sugar mills within 100 mile radius in the periphery of the Project Area, and consequently the farmers have been deprived of good return. The farmers of the Project Area and Usta Mohammad through their local representatives have requested to Governor to install one sugar mill.

III.3.8. Extension and Research

1) Extension

The agriculture extension organization of the Province is headed by a director who makes reports to the provincial secretary of

Agriculture. There are one deputy director posted in each division and two extra assistant directors in the Nasirabad District, and in Dera Murad Jamali and Usta Muhammad (See Appendix III.3-7, Fig. III.3-3), agricultural officers and field assistants are working at Tehsil level and the Union Council level (unit of local administration comprising about five Villages), respectively. The Dera Murad Jamali Office is responsible for agricultural extension service to cover almost of the whole Project Area under the supervision of the extra assistant director who is assisted by one assistant plant protection officer. At present only one agricultural officer is working in the district, while two posts of agricultural officers are vacant. About 23 field assistants (Basic unit of extension service) cover the 380 thousand acres (about 193,000 acres of the Pat Feeder Canal irrigation area and the remaining non-irrigated area of the office, giving one field assistant to serve for the extensive area of 16,000 acres, approximately equivalent to the area of one Union Council. This indicates that the existing power of extension staff is far below the requirements for proper coverage.

One vehicle of the two and eight motorcycles are operative in the Dera Murad Jamali Office. None of the field assistant has an office or official accomodation where farmers may gather together and exchange opinions with him. The training so far given has not met the farmers' requirements in every respect and the present level of knowledge that the field assistant officer seems to be below the advanced farming techniques and inadequate to teach the farmers. Moreover, the extension officer procures and distributes fertilizers and seeds, being responsible for exercising plant protection and collecting agricultural data and statistics. On-farm water management is also under the responsibility of the extension staff. As the results of the farmers' intention survey, discussion with extension officers and contact with the relevant research organizations, it was revealed that there is no close relationship established among these three parties (farmers, extension officers

and research organizations) nor positive cooperation with one another to solve the day-to-day problems on farming.

2) Research

Agricultural Research conducted in the province is weak in its activity and conducts few testings of appropriate technology for the irrigated agriculture in the Kachhi Plain Area. The Agricultural Research Institute at Sariab near Quetta is only the agricultural research center available in the Province. Recently, Pakistan Agricultural Research Council has established an arid zone research center to develop trickle irrigation for horticultural crops and to pursue solutions for problems of arid zone agriculture. This research center has also been based in Quetta with different physical environments from these of the Project Area. Therefore, the recommendations by these institutions are neither applicable to practical use nor contribute to the improvement of the agriculture in the Project Area.

Under such conditions, the one of the major limitation to agriculture in the Project Area is scarcity in experimental results available on the suited modern agriculture technologies to the Project.

III.3.9. Farmers' Organization

Under the situation that the traditional land tenure and farm management systems are prevailing, there is almost no specific farmers' organizations except for the "Tractor Trolly Scheme Societies", which is newly established in three nielages for transportation (See Appendix III.3-8, Table III.3-27).

The irrigation water distribution at on-farm is one of the major constraints to the agriculture development in the Project Area

because the farmers take irrigation water directly from the distribution canal individually.

Naturally, there is no neither organization nor regulations among farmers for a systematic water management at on-farm level, which result in low crop production due to the difficulty to have timely supply of enough irrigation water and to suffer from in ill-drainage induced by the considerably large amount of water losses.

III.4. Irrigation, Drainage and On-farm Conditions

III.4.1. Irrigation Conditions

a) Present Irrigated Area

The present irrigated area under the Project is about 200,000 acres, in which the present cropping area is 95,000 acres (38,400 ha) of the total cultivable commanded area (CCA). Some of the presenty-irrigated areas in Usta Mohammad Tehsil are temporarily irrigated by the Khirthar Canal, because these lands extend in the down-stream of Umurani and Rupa Distributaries and the Pat Feeder Canal has not enough capacity (discharge) to supply irrigation water to them.

b) Existing Irrigation Facilities

The existing irrigation facilities for the commanded area of the Pat Feeder Canal consist of the Guddu Barrage Head Regulator, the Desert-Pat Feeder Canal, the Pat Feeder Canal and 13 Distributaries.

The Guddu Barrage Head Regulator is one of the structures composing the Guddu Barrage, which was constructed in 1963, and this head regulator takes the water from the Indus River to the Desert-Pat Feeder Canal. The water intake period at the Gaddu Barrage was about

six months a year before completion of the Tarbela Dam; however, since completion of Tarbela Dam the water intake has been made throughout the year except for about two months from March 15th. The head regulator has been designed at the capacity of 13,275 cusec (375.7 cu.m/sec) and maximum recorded intake volume was 12,818 cusec (362.7 cu.m/sec).

According to the hydraulic calculation, possible intake volume is about 16,800 cusec.

Desert-Pat Feeder and Pat Feeder Canal

The Desert-Pat Feeder Canal, 37,000-feet long (11,278 m) unlined earth canal, is the feeder canal to both the Pat Feeder Canal and the Desert Canal. The Pat Feeder Canal is an unlined earth canal from the head regulator at R.D 0.0 to the end at R.D 624. The total length is 118.2 miles (190.2 km).

The designed capacity of the existing Pat Feeder Canal is shown in the table below:

Designed Capacity of the Existing Pat Feeder Canal

Reach (R.D)	Design Capacity	
	Cusec	cu.m/sec
0 - 104	4,000	113.2
104 - 109	6,700	189.6
109 - 116	5,680	160.7
116 - 190	3,700	104.7
190 - 238	5,680	160.7
238 - 342	5,126	145.1
342 - 418	4,546	128.7
418 - 505	2,801	79.3
505 - 558	1,929	54.6

The maximum discharge at the head of the Pat Feeder Canal was recorded at 3,135 cusec (88.7 cu.m/sec) in August, 1979. The reasons why the recorded maximum discharge is smaller than the designed capacity are lack of the canal capacity partially and water right to the Pat Feeder Canal given by the Indus River Committee.

The Pat Feeder Canal cuts its flow for about two months from March 15. The Desert-Pat Feeder Canal and the Pat Feeder Canal from R.D 0.0 to R.D 140 and R.D 428 to R.D 624 are located in the silty loam or silty clayey loam zone. The sediment transported from the Indus has adhered to the side slope of the canal and the cross section of the canal has been kept at good conditions. The Pat Feeder Canal, running through the sand zone in its course from R.D 140 to R.D 428, has the sand sediments three to four feet high on the bottom due to erosion by rain and has been impeded in the smooth flow.

Although three plantations have been accelerated for the bank protection from erosion, a successful plantation will be a little difficult to be realized for sand zone.

The left bank of the Pat Feeder Canal is used as the operation and maintenance road cum traffic road. No gravel paving has been made on this left bank, so that vehicle traffic is very hard for two a few days right after raining because the road surface becomes mud.

The Desert-Pat Feeder Canal and the Pat Feeder Canal from R.D 0.0 to R.D 125 run through Sind Province, and the most part of the Pat Feeder Canal belongs to Baluchistan Province and is operated and maintained by the Bluchistan Government.

Distributary

There are 13 distributaries in the Project Area as tabulated below and their total length is 217.07 miles (349.3 km).

Distributaries in the Project Area

R.D. of Pat Feeder Canal	Distributary
R.D 238	Bitti Distributary
R.D 342.5	Khalan Distributary Lower Uch Distributary
R.D 418	Nasirabad Distributary Judher Distributary Temple Distributary
R.D 505	Jhatpat Distributary Muhbad Pur Distributary Ballan Distributary Bari Distributary
R.D 558	Rupa Distributary Umurani Distributary Mangsi Distributary

Of 13 distributaries in the Project Area, the Bitti Distributary commanding the cultivable area spreading along the Pat Feeder Canal for the part from R.D 238 to R.D 342. Other 12 distributaries of a total length of about 260,000 feet (79.3 km) are located over along the Pat Feeder Canal. The average between distributaries is about 21,000 feet (6.4 km). The alignment, seems to be reasonable for proper water management practices interval.

Although most part of distributaries have been kept in good condition in their cross section; the water flow has been impeded sediments and reeds in the canal in at the downstream of each distributary.

Structure

Structures of the Pat Feeder Canal and distributaries are composed of cross regulators, head regulators, plain falls, outlets, road bridges, railway bridges, flood inlets and so on. The cross regulators, head regulators and flood inleks provide only the gates,

which have been maintained in good conditions. The crests of some plain falls at the downstream of distributaries are intentionally broken in order to discharge the water during the period of the low water level. The outlets are of the pipe culvert type without gates.

The bridges provided on the Pat Feeder Canal are the national highway bridge at R.D 489 and the bridges over the cross regulators only. Therefore, the farmers in the Area usually have to cross the Pat Feeder Canal by ferry boat.

Along the distributaries, there are 17 bridges on the plain falls, however, the farmers made have the wooden bridges on the other plain falls for their use. Animals and oxcarts cross the distributaries at the shallow place of the flows.

c) Present Irrigation Conditions

The water allowance of 1.0 cusec per 100 acres (0.7 lit/s/ha) is given under the conditions of 60 per cent of crop intensity for about 200,000 acres (80,940 ha). The acreage, which has the water allowance as mentioned above, is less than 50 per cent of the cultivable commanded area, 612,000 acres (248,000 has). Notwithstanding having the water allowance, the agricultural land located at downstream cannot receive enough irrigation water because the capacity of the existing Pat Feeder Canal and distributaries is insufficient due to sediments in the canals.

under the circumstances, the widening of the Pat Feeder Canal and distributaries as well as the provision of systematized irrigation networks inclusive of those of the on-farm level are the prerequisites to the modernization of agriculture inclusive of more than 120 per cent crop intensity in both Kharif and Rabi.

III.4.2. Drainage Conditions

In the exostomg cultivable commanded area of the Pat Feeder Canal, there is no systematic drainage facilities, except in the CCA of Bitti Distributary, which is covered by the Hairdin Drainage Project. The project works started in December, 1974 and completed on June 30, 1980, and the project has been in full operation since July 1, 1980 under the Right Bank Outfall Drainage Project by the WAPDA. And the Feasibility Study on Drainage Project for the CCA of the Judher, Nasirabad and Lower Uche Distributaries is undertaken by the WAPDA. And the Feasibility Study Report would be submitted by June 1982. (See Fig. III.4-1 of Appendix III.4-1).

The Pat Feeder Canal crosses the Kachhi plain so that the flood from the mountains in the northern Kachhi has attacked the Pat Feeder Canal several times. The floods resulting in damage for the Pat Feeder Canal and its cultivable commanded area occurred in 1975, 1976 and 1978. In order to alluviate the flood damages, the five flood inlets have been constructed to flow some flood water into the Pat Feeder Canal. (See Table III.4-1 in the Appendix II.4-1).

III.4.3. On-Farm Condition

a) Water Distribution System

The irrigation canals at the on-farm level consist of main water courses, branch water courses, sub-branch water courses, internal water courses, link water courses that are specified in the Canal & Drainage Act, 1981. These facilities including outlets of the distributaries are requested to be constructed by the land owners under the permission of Superintending Engineer, with recommendation of Executive Engineer of the Pat Feeder Division, and under the supervision of the Irrigation Department. The existing outlets are of pipe turnout type without any gates, and control and measurement of the diverted water can not properly be made by the outlets.

There are some water courses at present for water supply to the farm lots of about 200,000 acres (80,900 has), which have the peak demand water allowance of 1.0 cusec per 100 acres under 60 per cent of crop intensity.

The following table shows the water course length and its intensity of the existing on-farm system developing in the upstream reach of Jhatpat and Muhbad Pur Distributaries that were studied and measured on the maps with a scale of four inches to one mile as a sample area.

Water Course Length and Its Intensity

Description	Quantities	
Total Area	35,840 ac	(14,504 has)
Irrigated Gross Area	20,000 ac	(8,094 has)
Irrigated Net Area	18,000 ac	(7,285 has)
Length of Water Course	280,000 feet	(83,344 m)
Water Course Intensity	15.6 feet/ac	(11.7 m/ha)
Number of Chak 1/	25	
Average Area of Chak	800 ac	(324 has)

As shown in the above table, the intensity of the existing water courses is at very low level for carrying out the modern irrigated agriculture and proper water management, and the length of a water course is very long as 2.12 miles (3.41 km) on an average and 4.43 miles (7.13 km) in the longest. The average acreage of a chak is as large as 800 acres on an average.

In addition to the above, the existing water courses have different shapes in their section. The water course causes the much water losses in their course. Moreover, the large chak such as 800 acres impedes appropriate irrigation water supply to actual crop water needs and successful water management.

1/ Chak is a gross area of lands fixed for irrigation on an outlet. It includs both the CCA and uncommanded area.

b) Farm Drain

There are systematic farm drains of on-farm facilities in the Project Area.

c) Farm Roads

There are a few parmanent farm road in the project area, which serve as between the villages and the main roads, not for daily farming practices. For daily works, the farmers walk into the farm lots through the field of others, which are left in fallow or non-cultivated land, since 40 per cent of the CCA is fallow.

d) Size and Shape of Farm

The size of existing farm lots commonly ranges from a half acres to two acres, and the farm lots have about one acre on an average.

III.5. Drinking Water Condition

The Pat Feeder Canal is only the sources available for drinking water as well as irrigation water in the Project Area, and almost of all the farmers in the Area can depend upon the potable water supply by the distributaries of the Pat Feeder Canal.

The potable water is usually stored in unglazed pots provided in their houses. Several numbers of these water pots are kept in full so as to serve for about two month use in taking into account the two-month cut of the Pat Feeder Canal from March 15th.

CHAPTER IV. THE PROJECT

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IV.1. Objectives and Component of The Project

IV.1.1. Objectives of The Project

The Project Area and its neighborhood have been left far behind in modernization up to present, resulting in a lower population density than the average of the Province of Baluchistan. One of the major reason of delay in modernization would be the shortage of water resources for irrigated agriculture and the existing poor agricultural infrastructural facilities inadequate for rationalized farming such as irrigation and drainage canals and on-farm facilities, which results in limited opportunities of employment and low farm income. Since the Project Area is blessed with natural conditions including soil, climate and topography for cultivation of paddy and upland crops, the potentiality of the Project Area for agriculture could be surely worked out through sufficient irrigation water supply with adequate infrastructure.

The Project aims to increase agricultural production in the Project Area by more effective use of the Indus water diverted at the existing Guddu Barrage, create employment opportunities throughout the year, and improve the living environment from the viewpoint of the rural development through the provision of assured irrigation water with improved agricultural supporting services and road system.

In order to achieve the above-mentioned objectives and to get benefit quickly in the whole Project Area, the following should be envisaged by staging manner in accordance with the proposed implementation schedule.

i) Establishment of an irrigation system inclusive of widening Desert-Pat Feeder Canal, the Pat Feeder Canal, distributaries

and minor canals for perennial irrigation for profitable crops,

ii) On-farm development for irrigated agriculture as well as for modernized agricultural practices;

iii) Provision of road networks by improving service roads along main canals and distributaries and the other roads located in the Project Area;

iv) Execution of pilot project in the Project Area to carry out trial farm (applied research) programme, demonstration of irrigation facilities, advanced farming practices and training programme; and,

v) Institutional arrangement and strengthening of agricultural supporting services for full development of the Project Area.

IV.1.2. Components

The Project includes the following components:

Civil Works

i) Irrigation Facilities

Widening and improvement of the main canals, distributaries, minor canals, and related structures.

ii) On-farm Development

Construction of on-farm facilities.

iii) Roads

Construction of road networks including the improvement of service roads and the rehabilitation of existing roads.

Pilot Project

iv) Pilot Facilities

Construction of the pilot facilities such as irrigation facilities for demonstration, laboratory facilities, training accommodation and administrative facilities.

v) Agricultural Development Program

Promotion of applied research, demonstration farm and modern farming practices.

vi) Training Programme

Training of officials concerned with agricultural development and water management, leaders and promoters of villages and farmers in the Project Area.

Agricultural Development

vii) Irrigated Agriculture

Introduction of modernized agricultural techniques under well-controlled water management.

viii) Supporting Services

Provision of necessary extension services and training, and strengthening of input supply, credit, marketing and agricultural processing.

ix) Agri-Institutions

Establishment of farmers' organizations including those for operation and maintenance of irrigation facilities and agricultural cooperative activities.

For the implementation of the Project with the above-mentioned components, sufficient construction equipment should be procured, and the appropriate number of consulting engineers and experts should be recruited.

IV.2. Project Formulation

IV.2.1. Alternatives for Agricultural Development

1) Preliminary Study in the Field Survey

A preliminary feasibility study on the Agricultural Development Project through widening of the Pat Feeder Canal was carried out in Pakistan during the field survey of about 10 weeks from the middle of February till the end of April, 1982. The preliminary study was made on two alternatives of Case-1 (available water of 8,200 cusec) and Case-2 (available water of 6,700 cusec) in accordance with the Agreement on scope of works concluded between the Ministry of Finance, Planning and Economic Affairs, Government of Pakistan and Japan International Cooperation Agency, Government of Japan on January 23, 1982. According to the Agreement, the study will be centered on Phase I of the Project as stated in the Para 3 of I assuming the availability of water of 6,700 cusec and 8,200 cusec, without going into the question of distribution of water and the water requirements (2,000 cusec) for Phase II of the Project should also be taken into account while examining the capacity of the Pat Feeder Canal System.

A study on Case-1 was made premising the available water of 8,200 cusec throughout the year. The widening of Desert Pat Feeder and the Pat Feeder Canals and distributaries, the construction of minor canals and the development of on-farm facilities were scheduled to meet the peak water requirement estimated based on the proposed cropping pattern. Likewise, a study on Case-2 was made premising the available water of 6,700 cusec, and the relevant civil works and development programme were planned to cope with the peak water requirements in the proposed cropping pattern.

2) Feasibility Study Made during The Home Office Work

Through various discussions and meetings on the preliminary study presented in the Interim Report, the feasibility study for the development of the Project was carried out as the home office work. In addition to Case-1 and Case-2 studies described in the former paragraph, Case-3 and Case-4 were taken up in the feasibility study, for which the availability of water especially in Rabi season was carefully examined. Case-3 is discussed based on the available water of 8,200 cusec in Kharif and dependable water in Rabi season while Case-4 is studied based on the available water of 6,700 cusec in Kharif and dependable water in Rabi. The irrigation facilities are designed considering the peak water requirement to appear in Kharif.

3) Results of the Alternative Studies

Results of the aforementioned alternative studies show that the cropping intensity of Case-1 in Kharif and in Rabi is 60 per cent and 95 per cent, respectively, resulting in the total cropping intensity of 155 per cent, while in Case-2, the cropping intensity in Kharif and Rabi is 50 per cent and 80 per cent, respectively, totaling 130 per cent. From an engineering point of view, it is very obvious that Case-1 development would be more beneficial than Case-2. However, the development plans in both Cases 1 and 2 have a physical difficulty in the availability of water in Rabi season, since these

plans premise that water of 8,200 cusec and 6,700 cusec will be available throughout the year.

Although the Agreement on the Study for the Project (Scope of Work) specifies the availability of water, water balance study on the Indus River at Guddu Barrage was roughly carried out, and a study was made based on the water balance study as Case-3 study has revealed that cropping intensity in Kharif and Rabi will be 60 per cent in both seasons resulting in the total cropping intensity of 120 per cent in consideration of available water at Guddu Barrage for the Project. Case-4 study led to the intensity of 50 per cent and 60 per cent in Kharif and Rabi, respectively, and the total annual cropping intensity of 110 per cent.

The development scheme of both Case-3 and Case-4 can be said technically sound and economically viable.

4) Staged Development Plan

Through the meetings held between the Government of Pakistan and the JICA Mission on the Draft Final Report, it is concluded that a supplementary study on the Staged Development Plan shall be prepared assuming that the existing cultivation and the Kharif cropping pattern are so adjusted that the peak water requirements occur in July and August, and separating the engineering works from the Agricultural Development of the area.

The Staged Development plan has seriously considered the various conditions for the implementation where the priority should be given to the completion of engineering works on the widening of the Pat Feeder Canal and the distribution system and the agricultural development project could be taken up in the 2nd phase depending upon the availability of funds. The Staged Development Plan will be discussed in detail in the Appendix as the Supplementary Study.

IV.2.2. Proposed Scheme of Development

The main structures of the Project are the widening of Desert-Pat Feeder and the Pat Feeder Canals, the improvement of distributaries, the improvement or construction of minor canals and the establishment of Pilot Project.

The salient features of the Project are shown as follows:

Project Area

Culturable Commanded Area (CCA) 612,000 acres (248,000 ha)

Proposed Cropping Area

		Case-3	Case-4	Staged Development Plan
Kharif Crops:	acre	367,200	306,000	330,500
	(ha)	(148,700)	(123,800)	(133,700)
	%	60	50	54
Rabi Crops :	acre	367,200	367,200	145,000
	(ha)	(148,700)	(148,700)	(58,700)
	%	60	60	23.7
Total :	acre	734,400	673,200	475,000
	(ha)	(297,400)	(272,500)	(192,400)
	%	120	110	77.7

Canals The same scheme is proposed in any cases.

Main Canals		
Desert-Pat Feeder Canal	7.00 Miles	(11.28 km)
Pat Feeder Canal	118.20 Miles	(190.20 km)
Total	125.20 Miles	(201.48 km)
Distributaries		
15 Distributaries	236.97 Miles	(381.36 km)
Minor Canals		
Minors	772.78 Miles	(1,243.63 km)
Total of Canals	1,134.95 Miles	(1,826.47 km)

IV.2.3. Irrigation Plan

a) Irrigation Water Requirements

(1) Reference Crop Evapotranspiration

Although observation data are necessary in any methods, there are many methods to estimate the reference crop evapotranspiration (ETo) which is equivalent to the potential evapotranspiration. There are two meteorological stations in the vicinity of the Project Area, they are, Jacobabad station and Usta Mohammed station. Observed items of these two stations are not similar each other. On the other hand, each method to estimate the ETo requires different observed data.

According to the available climate data of these meteorological stations, the monthly ETo can be calculated by Blaney-Criddle method, Radiation method and Pan evaporation method. The ETo calculated by the pan evaporation method will be applied to the Project Area, because the annual ETo and monthly peak ETo are higher than the others in this value.

(2) Crop Water Requirements

Crop water requirements for growing season can be calculated with the following formula:

$$ETcrop = Kc \times ETo$$

where ETcrop: Crop Water Requirement
Kc : Crop Coefficient
ETo: Reference Crop Evapotranspiration

Crop coefficient (Kc) can be determined, taking into consideration the crop characteristics, crop planting or sowing data, rate of crop development, length of growing season, climatic conditions, etc. Crop planting or sowing data and length of growing season of the respective proposed crops are shown in Fig.IV.3-1 of Appendix IV.3-2. Crop coefficient and crop water requirements on 10-day basis which are calculated with reference crop evapotranspiration and crop coefficient are shown in Tables IV.2-4 to IV.2-15 of Appendix IV.2-1. In this estimation, the following assumptions are made:

- Percolation rate in rice cultivation is assumed as 0.04 inch/day (1 mm/day) through the growing period of rice.
- Additional water supply for land soaking and land preparation for the rice cultivation is estimated at 10.0 inches (254 mm) as below.

Water Requirements for Land Soaking and Preparation of Rice

Item	Inch-Method (inch)	Inch-Method (mm)
1st irrigation for land soaking	2.7	68.6
2nd irrigation	4.5	114.3
3rd irrigation	2.8	71.1
Total	10.0	254.0

Note: Detail description is given in Fig.IV.2-6 of Appendix IV.2-1.

- For pre-irrigation water, two inches for all upland crops except mungbean (Pulses of Kharif) and 2.4 inches for mungbean are considered, because cultivation for seedling is very hard without soil moisture.

- The leaching water requirement was estimated based on the electrical conductivity (0.4 mmhos/cm) and crop sensitivity to electrical conductivity in accordance with the recommended method by Irrigation & Drainage Paper No.24, FAO.
  The result is that the leaching water requirement of each crop, except that of pulses in Kharif is 2.3 inches, is less than two inches. (See Table IV.2-20 of Appendix IV.2-2)

Seasonal crop water requirements in consideration of the proposed cropping calendar of each crop are calculated as follows;

Net Seasonal Crop Water Requirement

Name of Crop	Crop Water Requirement (inch)	(mm)	Peak Requirement per Day (inch)	(mm)	(time)
Sorghum	23.17	588.5	0.238	6.0	Sep. - 2
Rice	41.95	1,065.5	0.431	10.9	Jul. - 2
Oilseed (Kharif)*	16.00	406.4	0.208	5.3	Sep. - 3
Pulses (Mungbean)	20.58	522.7	0.272	6.9	Aug. - 3
Pulses (Soybean)	23.74	603.0	0.233	5.9	Aug. - 3
Sugarcane	68.97	1,751.8	0.391	9.9	Jul. - 3
Wheat	13.16	334.3	0.112	2.8	Mar. - 1
Oilseed (Rabi)*	9.39	238.5	0.112	2.2	Feb. - 1
Pulses (Rabi)*	16.11	409.2	0.134	3.4	Mar. - 1
Fodder*	13.84	351.5	0.115	2.9	Mar. - 1

Note: The following typical crops were selected in computation of crop water requirements marked * above;

Oilseed(Kharif) ----- Sunflower
Oilseed(Rabi) ----- Rape
Pulses(Rabi) ----- Gram
Fodder ----- Egyptian Clover

Table IV.2-1 Water Requirement by Cropping Pattern

Discription	Unit Water Requirement (inch)	Case 1 Area (acres)	Case 1 W.R 1/ (MAF)	Case 2 Area (acres)	Case 2 W.R 1/ (MAF)	Case 3 Area (acres)	Case 3 W.R 1/ (MAF)	Case 4 Area (acres)	Case 4 W.R 1/ (MAF)
New Water Requirement									
Kharif Crop									
Sorghum	23.17	55,100	0.107	42,800	0.083	55,100	0.107	42,800	0.083
Rice	41.95	122,400	0.428	104,000	0.365	122,400	0.428	104,000	0.365
Oilseed	16.00	85,600	0.115	73,500	0.098	85,600	0.115	73,500	0.098
Mungbean	20.58	18,400	0.032	18,400	0.032	18,400	0.032	18,400	0.032
Soybeans	23.74	55,100	0.109	42,800	0.085	55,100	0.109	42,800	0.085
Sugarcane	68.97	30,600	0.176	24,500	0.140	30,600	0.176	24,500	0.140
Sub-total		367,200	0.967	306,000	0.803	367,200	0.967	306,000	0.803
Rabi Crop									
Wheat	13.16	330,500	0.349	275,400	0.301	208,100	0.228	208,100	0.228
Oilseed	9.39	122,400	0.095	104,000	0.082	79,600	0.062	79,600	0.062
Pulses	16.11	79,500	0.103	67,400	0.090	49,000	0.066	49,000	0.066
Fodder	13.84	49,000	0.055	42,800	0.049	30,600	0.035	30,600	0.035
Sub-total		581,400	0.602	489,600	0.552	367,200	0.391	367,200	0.391
Total		948,600	1.569	795,600	1.325	734,400	1.358	673,200	1.194
Water Requirement at Outlet									
Kharif Crop			1.422		1.180		1.422		1.180
Rabi Crop			0.885]2.307		0.813]1.993		0.575]1.997		0.575]1.755
Drinking Water			0.036		0.033		0.036		0.033
Total			2.343		2.026		2.033		1.788
Water Requirement at the Guddu Barrage									
Kharif Crop			2.069		1.714		2.069		1.714
Rabi Crop			1.292]3.361		1.115]2.829		0.837]2.906		0.837]2.551
Drinking Water			0.053		0.048		0.053		0.048
Total			3.414		2.877		2.959		2.599

Note: 1/ W.R means Water Requirements.

According to the proposed cropping pattern for each case, the total water requirements were calculated on 10-day basis as shown in Table IV.2-1. (For detail see Tables IV.2-15 to IV.2-18 of Appendix IV.2-1)

In estimating the total water requirements, the following irrigation efficiencies are adopted:

Conveyance efficiency 68.9%
Field canal and application efficiency 72%

For the conveyance efficiency, canal losses such as seepage loss, evaporation loss, operation loss, etc. of Desert-Pat Feeder Canal, the Pat Feeder Canal, distributaries and minor canals are considered. For the field canals and application efficiency, the canal losses of water courses and application loss of rice and upland crops are considered. Based on the above criteria, the Project efficiency is estimated to be 49.6 per cent.

Water Allowance

The calculation of total water requirements on 10-day basis indicates that the peak demand period will take place in the last ten days of September in any cases. The peak demand water allowance, which is the water amount to be delivered to the farmers at outlets, is calculated by cases as tabulated below:

Peak Demand Water Allowance

Case	Peak Demand Water Allowance per 1,000 Acres
Case-1	9.23 cusec
Case-2	7.54 cusec
Case-3	9.23 cusec
Case-4	7.54 cusec

Annual Water Requirement

From the above computation, annual water requirements in each case were calculated as shown in Table IV.2-1 and briefly tabulated below:

Annual Water Requirements

(Unit: M.A.F)

Description	Case-1	Case-2	Case-3	Case-4
Water requirement at the Guddu				
Kharif Crop	2.069	1.714	2.069	1.714
Rabi Crop	1.292	1.115	0.837	0.837
Drinking Water 1/	0.053	0.048	0.053	0.048
Total	3.414	2.877	2.959	2.599
Water requirement at Outlet				
Kharif Crop	1.422	1.180	1.422	1.180
Rabi Crop	0.885	0.813	0.575	0.575
Drinking Water 1/	0.036	0.033	0.036	0.033
Total	2.343	2.026	2.033	1.788

Note: 1/ For drinking water, see Section IV.2-7 "Drinking Water Plan"

b) Designed Discharge of Canals

1) Conveyance Canal

The conveyance canal consists of Desert-Pat Feeder Canal, the Pat Feeder Canal, distributaries, and minor canals, and conveyance efficiency was determined as 68.9 per cent, namely, canal losses at 31.1 per cent. For the design of canals, the following conveyance efficiency of each canal is assumed and the unit designed discharge of each canal was calculated taking into consideration the canal length, discharge and size as tabulated below:

Conveyance Losses and Unit Designed Discharge

Name of Canal	Conveyance Efficiency	Conveyance Losses	Unit Designed Per 1,000 Acres Case 1,3	Case 2,4
Desert-Pat Feeder Canal and the Pat Feeder Canal	85%	15%	13.40	10.95
Distributaries	90%	10%	11.39	9.31
Minor Canals	90%	10%	10.26	8.38

Note: Total conveyance efficiency is calculated as follows:

$$\frac{85}{100} \times \frac{90}{100} \times \frac{90}{100} \times 100 = 68.85\% = 68.9\%$$

2) Water Courses

Water courses consist of the main water course, internal water course and link water course. Each water course covers the following areas:

Main water course ..... Chak (average of 350 ac)
Internal water course .. Irrigation rotation area (average of 80 ac)
Link water course ..... Irrigation block (average of 16 ac)

Irrigation rotation will be made within an irrigation rotation area; accordingly, the designed discharge of main water course can be calculated with the unit designed discharge, and that of other water courses will be calculated with the peak water demand in rotation irrigation.

Link Water Course

According to the proposed cropping pattern, the peak water demand will occur at the land soaking and land preparation time for rice when rice is planted in 60 per cent of an irrigation rotation area. The amount is water quantity necessary for land soaking, land preparation, and for first-day irrigation of rice.

In land preparation and land soaking for rice, one time ploughing and two times harrowing will be made in a plot. The land preparation and land soaking for the whole Project Area is expected to be completed in 40-day period. The rotation of water supply for the land preparation and land soaking of rice will be made within an irrigation block served by a link water course. Then, the designed discharge of a link water course is determined based on the following figures:

- One rotation area: 16 acres
- Land preparation period for one rotation area: 40 days
  - Land preparation & soaking: 10.0 inch
  - First irrigation : 2.8 inch
- Efficiency: 76%

Consequently, the design discharge of a link water course is calculated at 0.283 cusecs* (8.0 lit/sec), which is equivalent to 0.0177 cusecs/acres (1.2 lit/sec/ha) inclusive losses.

Internal Water Course

Supply of water from an internal water course to link water courses is planned to be made simultaneously. Therefore, the designed discharge of an internal water course will be three times that of a link water course plus conveyance losses of the interval water course, namely, 0.90 cusecs (25.5 lit/s).

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* (12.8 inch - 12 x 43,560 sq.ft x 16 acres)/(40 days x 86,400 sec x 0.76) = 0.283 cusecs

Main Water Course

The chak, which is served by a main water course, is not a rotational unit, so that the designed discharge of a main water course can be determined based on the peak demand water allowance inclusive of its conveyance losses, which is equivalent to 9.23 cusecs per 1,000 acres.

IV.2.4. Canal Plan

1) Alignment of Irrigation Network

The existing irrigation system of the Pat Feeder Canal Project is composed of Desert Pat Feeder Canal, Pat Feeder Canal and 13 distributaries. The alignment of these main canals and distributaries would be maintained, and for effective water management and reduction of water losses in the water courses, minor canals should be constructed from distributaries to decrease the length of the main courses.

In general, an intensity of main and lateral/secondary canals in an irrigation system is discussed as a length of canals per unit irrigable area ranging from 10 ft to 20 ft per acre. In contrast, the existing Pat Feeder Canal System has a canal intensity of 2.9 ft per acre, resulting from a large chak and long main water course.

To carry out proper water management, the size of a chak should be maintained at reasonable magnitude, and the minor canal of 4,080,000 ft in total length or a canal density of 6.7 ft per acre is proposed.

It is proposed to extend the Pat Feeder Canal by 12.5 miles (20.1 kms) and to newly construct two distributaries, Qabula and Murad, for irrigation of an extension area of 146,000 acres in the downstream of the Project Area.

2) Minor Canal

The head of a water course is generally located at the immediately upstream of the fall together with some of the other water courses. Therefore, several water courses run in parallel with each other. These water courses are mostly of irregular shape and route, resulting in much water losses and difficulties in operation and maintenance.

Some parts of water courses would be substituted by the proposed minor canal and integrated to improve the size of chaks and the alignment of water courses.

3) Turnout and Check Structure

Diversion works from a main canal to distributaries will be provided with gate to control the flow of water. To easily operate the diversion works with gate, a check gate is installed at cross regulators of main canals to keep a sufficient water level.

A constant head orifice turnout (double gated turnout) is used for diversion works from a distributary to minor canals to measure and control the flow of water. To keep a sufficient water level in the distributaries for diverting the water flow during low water flow, the falls and bridges would be provided with stop-log by improving the said structure.

4) Hydraulic Dimension of Canals

a) Selection of Formula for Hydraulic Design of Canals

It is important for hydraulic design of canals to select a formula to determine the depth, bed width, side slope and longitudinal slope of canals. Generally speaking, Manning Formula is well known. However, in Pakistan, Lacey's Formula is commonly used

for the design of unlined earth canals. A study on the formula for canal velocity is made based on a calibration result of canals by current meter during the field survey.

Manning Formula

$$V = (1.486/n).R^{3/2}.S^{1/2}$$

where V: Mean velocity in ft/sec
R: Hydraulic mean depth in ft
S: Slope of canals
n: Coefficient of roughness

Lacey's Formula

$$V = (1.3458/Na).R^{3/4}.S^{1/2}$$

where Na: $0.0225\ f^{1/4}$
f: Lacey's silt factor = $1.75\ m^{1/2}$
m: Mean diameter of silt in millimeter
= 10 per cent of the mean diameter of silt particles in the river water

The calibration of canal by current meter has revealed that the coefficient of roughness(n) of Manning Formula ranges from 0.0201 to 0.0209 assuming m = 0.17 to 0.23 mm and f = 0.8 (0.72 to 0.86). Therefore, Lacey's Formula can be applied to the hydraulic design of canals n = 0.020 approximates to the result of caliblation(See Appendix).

Since RD 109 to 145 and RD 418 to 505 of the Pat Feeder Canal are uniform and regular in canal shape without weed growing, the coefficient of roughness was empirically determined at 0.020. Prof. Ven Te Chow discusses on the coefficient of roughness in his book of

"Open Channel Hydraulics" as 0.018 at minimum and 0.022 on an average. Therefore, n = 0.020 is quite reasonable. On the other hand, according to the USBR criteria, the coefficient of roughness of canals of this kind is n = 0.025 in case of a discharge less than 100 cusec and n = 0.0225 or 0.020 in case of a discharge over 100 cusec. This is because the value of "n" commonly decreases when the canal discharge increases.

Though the discharge of Pat Feeder Canal ranges from 11,000 cusec to 2,000 cusec, n = 0.020 in Manning Formula can be applied, and that leads to the same result of calculation by Lacey's Formula, which is very commonly used in Pakistan. Therefore Lacey's Formula is used for hydraulic design of canals in the Project.

In case of brick lined canals, Manning Formula is applied with the coefficient of roughness n = 0.015.

b) Permissible Velocity of Canal

Canals in the Project Area are unlined earth canals and the Indus water being diverted to the canals contains much suspended load. These unlined canals should have an appropriate flow to protect the canal prisms from scouring and deposition of silt. The maximum permissible velocity to prevent scouring or the minimum permissible velocity to prevent silt deposition depend upon the soil characteristics to cause sediment in water and natural factors, but general limits can be set down from experience.

Mr. R.G. Kennedy, Executive Engineer of Punjab Irrigation Office, published his work in 1895 that non-silting and non-scouring velocity Vo is given by:

$$Vo = 0.84\ D^{0.64}$$

where Vo: critical velocity for non-silting and non-scouring in ft/sec
D: depth of canal in ft/sec

According to "Open Channel Hydraulics" of Prof. Ven Te Chow, the maximum permissible velocity of canals applicable to the Project is as follows:

Fine Sand and Sandy Loam	2.5 ft/sec
Silty Loam	3.0 ft/sec
Hard Loam	3.5 ft/sec

c) Side Slope of Canals

Considering the general conception on design of canals in "Open Channel Hydraulics" and "Design Standard of USBR", the side slopes of 1:1 and 2:1 are applied for silty loam and hard loam, and sandy loam, respectively, for the design of unlined earth canals.

d) Freeboard

The freeboard of a canal is usually designed by empirical manner. Although the freeboard is affected by the canal size inflow of flood into the canal and movement of water surface, etc., the freeboard equivalent to 5 to 30 per cent of the depth of the canal is generally used. On the other hand, the range of the freeboard is considered as one foot for small-size canals and four feet for large-size canals with 3,000 cusec or above.

Taking into consideration the safe of both canal dikes, the originally designed freeboad of three feet for main canals and two feet for distributaries are applied in the Project.

e) Berm

A service road or an operation and maintenance road with a top width of 25 feet and the shoulder of three feet is designed for the left bank of the main canals while a berm with a top width of 20 feet and a top elevation by six feet higher than FSL is designed for the right bank of the main canal.

For distributaries, a berm with a top width of 20 feet is designed for the left bank and the berm at the right bank will have a top width of six feet.

f) Canal Losses

Conveyance loss and other losses of the main canals, distributaries, and minor canals were estimated at 15 per cent, 10 per cent and 10 per cent, respectively, and the conveyance efficiency throughout the system was calculated at 68.9 per cent. The above-mentioned canal losses include seepage loss, evaporation loss, operation loss and so on.

IV.2.5. Drainage Plan

a) Drainage of Flood from Hilly Land

Since the Pat Feeder Canal crosses Kachhi plain from east to west, flood water from the hilly land located at the northern Kachhi plain has attacked this canal. For the prevention of the Canal from flood damages and the consideration of flood management, the following four methods would be considered;

i) To construct cross drains under the canal to introduce flood into the Project Area;

ii) To construct the drain inlet to introduce flood water into the Pat Feeder Canal;

iii) To reinforce the right bank of the Pat Feeder Canal to stand against future floods and to flow down flood water to the lower basin;

iv) To store flood water in the hilly side.

The following shows the advantage and disadvantage of each method mentioned above.

i) Method to construct the cross drain,

advantage:

This is the most common method of flood protection, and highly reliable.

disadvantage:

The Pat Feeder Canal being about 350 feet wide on an average, it is difficult to construct the cross drain without temporarily stopping the canal flow.

ii) Method to construct the drain inlet.

advantage:

It is easy to construct the drain inlet.

disadvantage:

A drain inlet of a very big capacity is required to meet the peak flood. Furthermore, it is necessary to give the Pat Feeder Canal a large capacity to meet both the irrigation requirements and floods, resulting in difficulty in gate operation for the cross regulator and head regulator.

iii) Method to reinforce the right bank of the Pat Feeder Canal

advantage:

The construction by this method is easy because the bank can be reinforced with excavated materials in the widening of the canal.

disadvantage:

Since flood water will be conveyed toward the down-stream of the Pat Feeder Canal, the flood damage might be concentrated to the commandable area of Murad distributary.

iv) Method to store flood water in hilly side

advantage:

The construction of structures such as dam, conveyance canal, etc. for this purpose can be carried out independently outside the Project Area.

disadvantage:

It takes a long time to construct those structures.

Taking into the consideration the construction cost, construction period, construction method, etc., of each method, the method iii) is recommended for the purpose.

On the other hand, the flood protection of the Pat Feeder and Kirthar Canal (Baluchistan Portion) has been studied by the National Engineering Service (Pakistan) (NESPAK), as summarized below;

i) Major works by raising and strengthening of the right bank of the Pat Feeder Canal in the length of 149,000 feet.

ii) Minor works by raising, strengthening and restoring the existing right bank of the Pat Feeder Canal to designed section. The length of the bank necessitating such works is 153,000 feet.

iii) Construction of a canal along the right bank of the Pat Feeder Canal in the length of 78,000 feet.

iv) Construction of flood regulating and dispersing structures

v) Incidental works for the above.

More detailed discussion is given in Appendix IV.2-4

According to the proposed cross section of the Pat Feeder Canal, the right bank of the canal is three feet higher than the left bank in elevation. And the following parts of the right bank of canal is designed to be additionally banked up to the designed elevation.

From R.D 201 to R.D 246 ..... 6 feet
From R.D 368 to R.D 372 ..... 5 feet

In addition, the excavated materials from the Pat Feeder Canal shall not be used for the embankment of the canal but spoiled at the right side of the bank of the canal. In this manner, the NESPAK's recommendations of i) and ii) can be realized.

In NESPAK's study, the extention of the Pat Feeder Canal is not taken into account and the flood is planned to be led to the Qabula

Nallah and Bagh River. However, it is planned in the Project that the Pat Feeder Canal will be extended to R.D 624, crossing the Qabula Nallah; consequently, flood will be separated at Qabula; a part will be released to the Bagh River after flowing down along the right bank of the Pat Feeder Canal, and the other will flow to the downstream of the Qabula through the proposed cross drain under the Pat Feeder Canal. And the designed discharge of the proposed cross drain was estimated at 10,000 cusecs by dividing the design discharge to the flood protection bund(FP Bund) of Kirthar Canal calculated by NESPAK by the catchment area.

b) Drainage from Fields

(1) Drainage Quantity to Drainage Canals

In planning the field drainage, the seasonal fluctuation of groundwater in water balance was estimated with the following formula:

$$H = xf + fk + fn - Z - W - Y$$

where
- H: seasonal fluctuation of groundwater
- xf: seepage of precipitation
- fk: seepage from canals
- fn: seepage from irrigation
- Z: evaporation from non-cultivation field
- W: outflow of groundwater from the Project Area
- Y: drainage water amount from groundwater to drainage canals

In estimating the seasonal fluctuation of groundwater by the above formula, the following assumptions were made:

- The seasonal fluctuation is estimated on monthly basis.

- A precipitation of less than two inches per month is not considered to affect the groundwater since such precipitation will be lost in evaporation or as surface runoff

- Seepage from canals such as the Pat Feeder, distributaries, and other minor canals will be gathered by deep drains, so that the seapage is not considered effective.

- Seepage from irrigation is considered to be equivalent to an estimated delivery amount at an outlet minus drinking water and crop water requirements.

- About five per cent of the irrigation water for rice is wasted as surface flow.

- Evaporation from uncultivated fields (fallow) is estimated at 15 per cent of an observed evaporation by pan-evaporation.

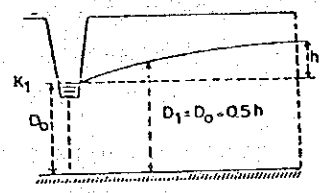
- The outflow of groundwater from the Project Area can be estimated by the Darcy's law, and the coefficient of water permeability is assumed to be 1.5 feet/day (0.4 m/day) on an average since soils in the Area are of silty clay loam.

According to the calculation by the above formula, in the case that drainage water amount to drainage canal is considered by 0.001 inches/day for the overall Project Area, commonly the ground-water table recovery to the initial level will take one year. However, for the land of cropping type C, drainage amount to the drainage canal was estimated at 0.032 inches/day.

(2) Interval between Open Drains

In determining the interval between open drains, the Erust's formula is used as follows:

$$h = q \cdot L^2 / 8 \cdot k \cdot D_1 + (q \cdot L / \pi \cdot K) \cdot \ln(D_0 / u)$$



in which;

L : interval of open drains in meters

q : drain discharge expressed in meters per day (m/day)

K : hydraulic conductivity of the layer in m/day (0.46 m/day)

h : the height of the water table above the drain level in drains in meter (0.5 m)

$\ln(D_0/u)/\pi \cdot K$ = Rr: radial resistance (1.4)

As a results of the calculation, the following interval between open drains is obtained:

Drain Discharge	Drain Spacing
0.001 inches/day (0.000025 m/day)	2,760 feet (842 m)
0.032 inches/day (0.0008 m/day)	459 feet (140 m)

(3) Drainage Plan

From the above study, the following drainage plan is recommended: