common value on the "y"-axis,

$$y=[(b-a)/a][(k/R)-1]=100 \qquad (46)$$

For point P we have $a/2r=0.5$ or $r=a$ and have $S/a=29$; for point Q we have $a/2r=8$ or $r=(1/16)\,a$ and have $S/a=27$. For point P, the inset figure shows that for $r=a$ the drain will penetrate to the impermeable layer so D.F. theory should hold. To check this conclusion we take $b-a=0.1$ m, $a=1$ m ($b=1.1$ m) and from (46) we then find

$$[(0.1)/1][(k/R)-1]=100$$

$$\text{or } k/R=1001$$

(which might be for $k=5$ m/day and $R=0.5$ cm/day). D.F. theory, equation (3), now gives

$$S=[4(1001)(1.1^2-1^2)]^{1/2}=29 \text{ meters}$$

checking the value $S=29$ m of point P in the figure. For point Q, when $a=1$ m, we find $r=(1/16)a=(1/16)\,m$ or $2r=12.5$ cm. Thus, the drain size 12.5 cm (with center 1 meter above the impermeable layer) requires that the spacing be 29—27=2 meters closer than for ditches.

There is one situation when D.F. theory fails completely. It is for a in Figure 10 equal to ∞. Suppose we have in Figure 10, $b-a=0.6$ m, $a=\infty$, and $k/R=693$ and $2r=0.10$. These values (except $a=\infty$) are as in (44) and (45), but we cannot use Figure 10 to get the correct spacing. For $a=\infty$, Toksöz-Kirkham [1961, Fig. 2] give another chart from which we read (see the example of their inset figure) the value

$$S=308 \text{ meters}$$

D.F. theory, equation (3), gives for this case (as in vast areas of irrigated West Pakistan where impermeable layers are not found) the value

$$S=[4(k/R)(b-a)(b+a)]^{1/2} \qquad (47)$$

$$=[4(693)(0.1)\infty]^{1/2}=\text{infinity}$$

Our examples above have shown that D.F. theory gives too wide drain spacings, especially when S/a is not large (say >25). Guitjens and Luthin [1965, Table 1] found (in a different D.F. problem) that for S/a-values of about 10 or less, D.F. theory gave values of S/a that were larger than 50 per cent those found by experiment. Equation (47), when $S/a>25$, is a useful form. It shows that S must be quadrupled to double $(b-a)$, when k/R and $b+a$ are kept approximately constant. It shows that if R can be halved, as by not over-irrigating, S can be increased to 1.4145; it shows that if k can be doubled as by leaching out sodium, $b-a$ can be halved ; etc.

D.F. THEORY AND ANISOTROPY, ETC.

A D.F. soil is not an anisotropic soil. In a D.F. soil we find a different conductivity measurement, in the vertical direction, say, depending on whether we make the measurement in a "slot" or a "slab". In a true anisotropic soil, with vertical anisotropy, we would get the same value of conductivity regardless of where we make the measurement. A D.F. soil must be bounded at its bottom by a barrier. The barrier may be sloped (Schmid and Luthin, 1964 ; Guitjens and Luthin, 1966). In three-dimensional flow a D.F. soil will have vertical cylindrical slots. For flow to a well, the D.F. slots will be circular vertical cylinders. Our D.F. slots give exactness to the solution of a number of D.F. problems ; for example, seepage from a canal to a drainage ditch—Dupuit's parabolic flow problem, [Polubarinova-Kochina, 1962, p. 408].

POTENTIAL FLOW NETS OF FIGURES 8 AND 9

We said at the beginning of the section containing equation (43) that the "almost correct" flow nets of Figures 8 and 9 were

modifications of Kirkham's [1958] potential theory flow nets. For Figure 9 the modification amounts to extrapolating the exact flow net of an infinitesimally thin water table into the thin (2 ft. maximum height) arch region of Figure 9. For Figure 8 the modification was not as simple. It consisted of (*a*) re-solving the problem Kirkham's of [1958] Figure 3*c* to account for vertical-wall ditches now needed rather than for the sloping wall ditches of the earlier case and (*b*) extrapolating the flow net into the thin (1.395 ft. maximum height) arch region of Figure 8. The solution of the re-solved vertical ditch wall problem, not previously published, is given briefly as follows :

Kirkham's [1958] frictionless, infinitesimally thin, vertical, parallel, strips are imagined to exist in the water table arch region between $y=a$ and $y=b$ in Figure 4. With a, S, x and y as in Figure 4, and with R and k as defined above (1), and with a reference level for the hydraulic head taken at the barrier, $y=0$, we choose the hydraulic head (potential) function ϕ as

$$\phi=a+\sum_{m=1,2,\ldots}^{\infty}\frac{R}{k}\frac{S}{m\pi}A_m \sin\frac{m\pi x}{S}\frac{\cosh(m\pi y/S)}{\sinh(m\pi y/S)} \quad (48)$$

where the A_m are

$$A_m=(4/\pi)(1/m) \text{ for } m=1, 3, 5,.. \quad (49)$$

$$A_m=\text{zero for } m=0, 2, 4,.. \quad (50)$$

The ϕ of (48) satisfies Laplace's equation and gives $\phi=a$ at $x=0$ and $x=S$, as it should. And gives $\partial\phi/\partial y=0$ at $y=0$, as it should. And gives $\partial\phi/\partial y=R/k$ at $y=a$, as it should—seen as follows : From (48) we find, by differentiation

$$\phi=a+\sum_{m=1,2,\ldots}^{\infty}\frac{R}{k}\frac{S}{m\pi}A_m \sin\frac{m\pi x}{S}\frac{\cosh(m\pi y/S)}{\sinh(m\pi x/S)} \quad (48)$$

and putting $y=a$, and using then (49) and (50), the relations

$$\partial\phi/\partial y\ (R/k)\ \Sigma\ A_m \sin m\pi x/S$$
$$=(R/k)(4/\pi)[(1/1)\sin \pi x/S + (1/3)\sin 3\pi x/S+..]$$
$$=R/k \text{ because of Dwight [1947, formula 416.02 with } c=1]$$

The stream function ψ is now obtained from (48) by use of the Cauchy-Riemann conditions (see Kirkham, 1958) and is (we consider only the half-flow region, $0<x<S/2$, and put $\psi=0$ at $x=0$ and $\psi=RS/2$ at $x=S/2$ and drop a minus sign) given by

$$\psi=\frac{RS}{2}\left(1-\frac{8}{\pi^2}\ \Sigma\ \frac{1}{m^2}\cos\frac{m\pi x}{S}\frac{\sinh(m\pi y/S)}{\sinh(m\pi a/S)}\right), (m=1, 3..). \quad (51)$$

The equipotentials and streamlines were obtained from (50) and (51) by rewriting them as

ϕ per cent $=100\phi/a$, ψ per cent $=100\psi/(RS/2)$

To take account of the impedance of soil between Kirkham's strips, mentioned above (48), we must [Toksöz-Kirkham, 1961] multiply the right side by $(1-R/k)^{-1}$ which for our Figures 8 and 9 is essentially unity.

CONCLUSIONS

Some conclusions not given in the Abstract are : 1—D.F. theory gives too low a water table, that is, drain spacings must be closer than D.F. theory gives to establish a given water table height ; 2—D.F. theory gives a better approximation for flow into ditches than into tiles ; 3—D.F. theory may with little error be used to compute drain spacings if the ratio of water table height above a barrier to drain spacing will be greater than about twenty-five ; 4—D.F. theory fails completely (gives infinite drain spacings)

when the impermeable layer is at infinite depth ; 5—a D.F. soil is not an anisotropic soil in the conventional sense ; 6—equipotentials in D.F. theory are vertical ; 7—streamlines in D.F. theory are non-horizontal; 8—streamlines in a D.F. soil converge to a plane vertical or to a cylindrical vertical, outflow surface ; and 9—the equipotentials and streamlines in D.F. theory comprise a non-orthogonal flow net.

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Extract from The Lower Indus Report

By HUNTING TECHNICAL SERVICES AND SIR M. MACDONALD & PARTNERS

On 2nd October 1962, West Pakistan Water and Power Development Authority entered into an agreement with Hunting Technical Services and Sir M. MacDonald and Partners to investigate, plan, design and supervise the work for development of the Land and Water Resources of the area commanded by Sukkur, Guddu and Ghulam Mohammad Barrages in the former Province of Sind for the control of Water-logging and Salinity. The consultants have operated in the area since then and have issued reports of their investigations in 1966. The results of the major investigations are described in two volumes of the main report. Part I present the present situation and in Part II future development is explained. The full report contains 28 supporting report volumes, 68 supplements containing the basic data for the supporting report volumes and is accompanied by a Development Atlas of the regions.

The Development Plan involves an investment during the next 25 years of over Rs. 8000 million. A certain amount will be spent annually. A peak annual expenditure in 1975 is estimated to be nearly Rs. 500 million.

In this issue of the 'Engineering News' we have extracted brief information dealing with the present situation and the future development of Land and Water Resources only. The agricultural aspects, forestry and fisheries, agricultural services etc. will be presented in some subsequent issue of the journal.

The Sind

The former Province of Sind which is irrigated by the presently constructed three barrages, Guddu, Sukkur and Ghulam Mohammad covers an area of 23,000 sq. miles through which the Indus river flows like an open letter S. Even the name Sind has been derived from the original name of the Indus. The earliest records of the Civilisation on the sub-continent, as revealed from the ruins of Mohenjo Daro, represents the existence of flourishing agricultural community over 3 000 years ago. The area has always depended on the seasonal rise of the Indus. By the middle of the 19th century there were hundreds of small channels irrigating about half a million acres. From 1900 onward the Inundation Canals System steadily

improved, irrigating by 1921 over two million acres (see Fig. 1). In 1932 Sukkur Barrage was completed to divert the river into seven canals irrigating 7.5 million acres in the area. It was followed by Ghulam Mohammad Barrage and more recently the Guddu Barrage (see Fig. 2).

The Population

According to the census, in 1961 the population of the region was 6.42 million which was about 15% of the total population of 43 million people living in West Pakistan. In Table 1 below, the population of West Pakistan and the Lower Indus Region is exhibited along with the density of rural population in the Barrages command area (Table 2).

TABLE 1

Population of West Pakistan and Indus Region (1961 census)

	Population (1,000 persons)		
	Rural	Urban	Total
West Pakistan ..	33,226	9,654	42,880
Lower Indus Region	5,161	1,260	6,421
Region, as percentage of West Pakistan..	15.5	13.0	15.0

TABLE 2

Distribution and density of rural population, by barrage commands (1961)

Barrage Command	Total (1,000 persons)	Density (Number of persons per square mile).
Gudu ..	890	180
Sukkur ..	3,133	249
Ghulam Mohammad ..	656	124
Total ..	4,679	205

Irrigation and Agriculture

It is a common practice to designate the area lying in the Sind Province as the Southern Zone, whereas all the irrigated areas in the upper regions are called the Northern Zone. It may be seen from Table 3.

TABLE 3

Comparisons of the Northern and Southern Zones.

Commanded cultivable area (million acres)	Northern Zone	Southern Zone	Total
Perennial systems ..	13.6	7.8	21.4
Non-perennial systems ..	6.0	5.4	11.4
Total CCA (Million acres)	19.6	13.2	32.8
Areas cropped 1960-61 (million acres, cropping intensities are shown in brackets).			
Kharif 1960	8.0 (41%)	3.9 (29%)	11.9 (36%)
Rabi 1960-61	8.0 (41%)	3.7 (28%)	11.7 (36%)
Total crops grown (million acres)	16.0 (42%)	7.6 (57%)	23.6 (72%)
Major crops 1960-61 (million acres)			
Rice ..	1.0	1.4	2.4
Wheat ..	8.2	1.4	9.6
Cotton ..	2.4	1.0	3.4
Fodder ..	3.3	0.5	3.8

that in the Northern Zone out of 19.6 million acres of culturable commanded area, 13.6 million acres lie within the perennial system and less than 1/2 lie in the non-perennial system. In comparison, the Southern Zone having 13.2 million acres of C. C. A. the and perennial system exists on 7.8 million acres non-perennial system on 5.4 million acres.

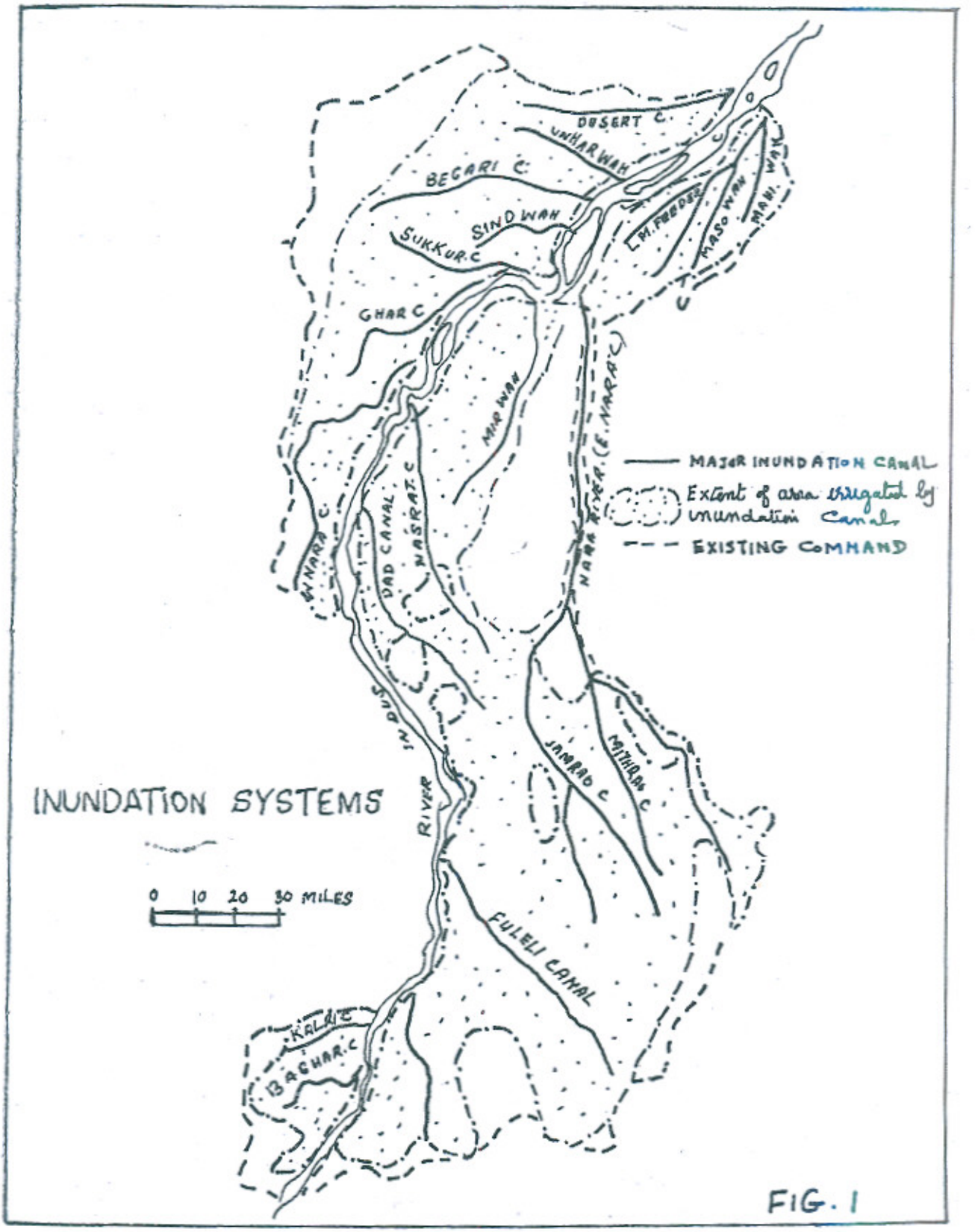
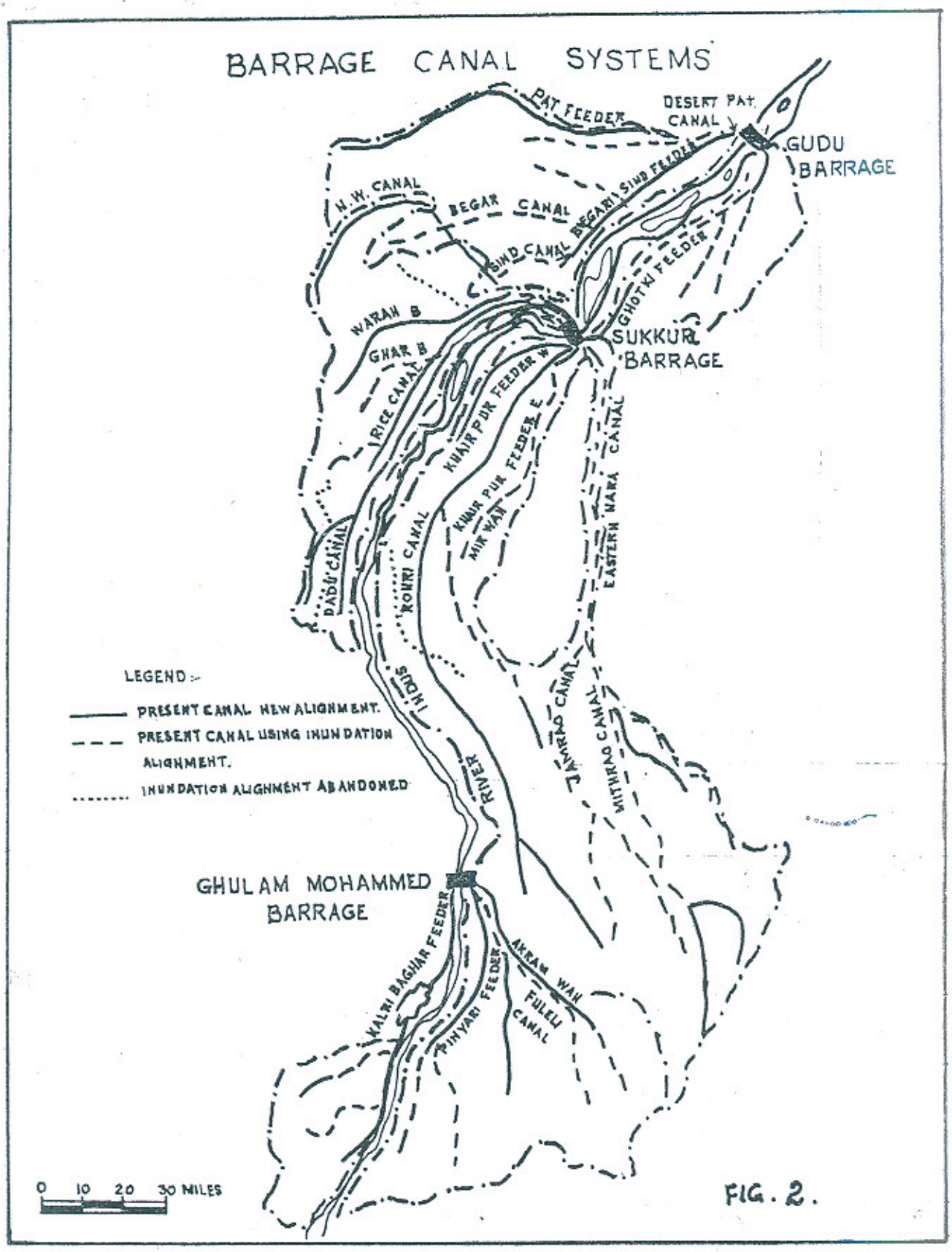

DESERT C.
UNHAR WAH
BEGARI C.
SIND WAH
SUKKUR C.
GHAR C
M. FEEDER
MASO WAH
MANI WAH
MAR WAH
NARA RIVER (E. NARA C.)
GWARO C.
DAD CANAL
NASRAT C.
INDUS RIVER
JAMRAO C.
MITHRAN C.
FULELI CANAL
KALRI C.
BAGHAR C.
MAJOR INUNDATION CANAL
Extent of area irrigated by inundation Canals
EXISTING COMMAND
INUNDATION SYSTEMS
0 10 20 30 MILES

FIG. 1


BARRAGE CANAL SYSTEMS
PAT FEEDER
DESERT PAT. CANAL
GUDU BARRAGE
N.W. CANAL
BEGAR CANAL
BEGARI SIND FEEDER
SIND CANAL
GHOTKI FEEDER
WARAH B
GHAR B
SUKKUR BARRAGE
RICE CANAL
KHAIR PUR FEEDER W
KHAIR PUR FEEDER E
EASTERN NARA CANAL
DADU CANAL
KOHRI CANAL
MIR WAH
LEGEND :-
PRESENT CANAL NEW ALIGNMENT.
PRESENT CANAL USING INUNDATION ALIGNMENT.
INUNDATION ALIGNMENT ABANDONED
INDUS RIVER
JAMRAO CANAL
MITHRAO CANAL
GHULAM MOHAMMED BARRAGE
KALRI BAGHAR FEEDER
PINYARI FEEDER
AKRAM WAH
FULELI CANAL
0 10 20 30 MILES
FIG. 2.

in Figure 3 perennial and non-perennial area within the 3 Barrages system together with cultivation intensity are shown. It may be noted that the cultivation intensity is the highest being 76% due to the perennial supplies available for the major area under the command of this Project. The cultivation intensity in Gudu and Ghulam Mohammad Barrage as shown in Table 4 is 47% and 43% only as the areas are generally non-perennial.

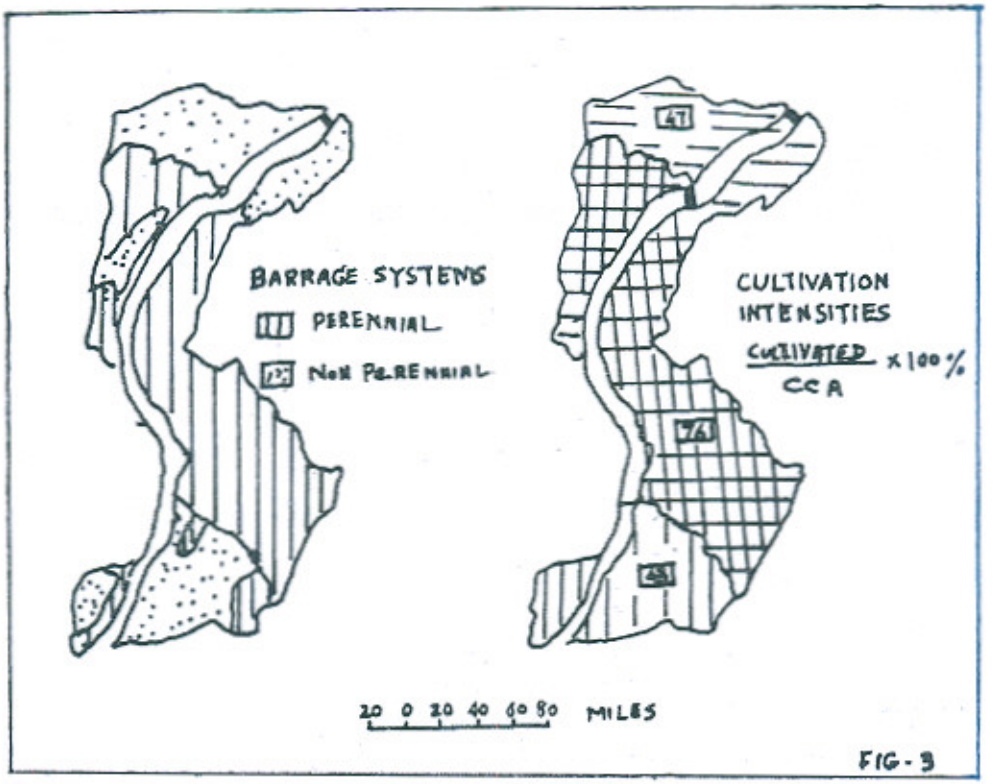


TABLE 4.—*Main statistics of the three barrage commands.*

	Gudu Command	Sukkur Command	Ghulam Mohd Command	Total
CCA (1,000 acres)				
Perennial ..	..	6,950	832	7,782
Non-parennial ..	2,802	520	2,092	5,414
Total ..	2,802	7,470	2,924	13,196
Cultivated area (1,000 acres) ..	1,310	5,671	1,258	8,239
Cultivation intensity (cultivated area—CCA) ..	47%	76%	43%	62%
Area cropped 1963-64 (1,000 acres):				
Rabi 1963-64 ..	643	2,991	240	3,874
Kharif 1964 ..	956	2,795	957	4,708
Total ..	1,599	5,786	1,197	8,582
Cropping intensity (1963-64):				
Cropped area—CCA ..	55%	77%	41%	65%
Farming intensity 1963-64 ..	122%	102%	95%	104%

Land Resources

Gudu lies at an elevation of 240. Sukkur Barrage elevation is 190 and that of Ghulam Mohammad Barrage about 70 ft. above sea level. The gross area under the command of various feeders canals is shown in Table 5,

TABLE 5

Gross areas of the main or feeder canals.

Main or feeder canal		gross area (1,000 acres)
GUDU BARRAGE		
Desert-Pat	..	1,061
Begari-Sind*	..	1,079
Ghotki*	..	960
Total Barrage Command	..	3,100
SUKKUR BARRAGE		
North-West	..	1,034
Rice	..	595
Dadu	..	567
Khairpur West	..	298
Khairpur East	..	541
Rohri	..	2,952
Nara	..	2,514
Total Barrage Command	..	8,501
GHULAM MOHAMMAD BARRAGE		
Kalri-Baghar	..	772
Pinyari	..	952
Fuleli	..	1,010
Akram Wah	..	582
Total Barrage Command	..	3,316
Total Barrage Commanded Area	..	14,917

*Includes the commands of small inundation canals.

so that out of total of 14.9 million acres, the canals of Gudu Barrage cover an area of 3.1 million acres, Sukkur Barrage canals 8.5 million acres and Ghulam Mohammad Barrage, 3.32 million acres. Majority of the soils fall within the range of meander flood plain, cover flood plain or levee deposits. The proportion of Pedimont plain is insignificant except in the area of pat feeder, Kirthar and Dadu regions. A small Tidal zone lies in the command of Kalri Baghar canals.

Soil Texture

The soils of this area are generally medium and fine, approaching very fine range. Sand and sandy loam are comparatively less being only 15%. The percentage of various texture of soil under the command of the three barrages is given in Table 6.

The nature of soil determines the available moisture and the infiltration of water from the surface. For a fine texture soil the plant has high order of wilting point moisture so that in spite of high order of field capacity, the available moisture is low. This statement is explained in Table 6 in which the moisture characteristics of the soil are explained. In Sind the mean daily temperatures are high resulting in a higher order of transpiration. This fact and the medium to fine texture of the soil needs more frequent surface watering.

As regards infiltration rate, it is high only in case of sand and loamy sand and decreases sharply with silty loam or silty clay etc. An idea of the infiltration rate can be had from Table 8. In the region there are certain canals which have extensive rice cultivation. These are, for instance, Gudu Barrage right bank or North-West canal, Nara Canal and several

TABLE 6

Part 2, Textures of surface soils by major commands percentage.

Command	S+LS	SL	VFSL	L	SIL	SICL	CL+SCL	SIC+SC
	coarse			Medium and fine				very fine
Gudu:								
Left Bank ..	7	4	6	5	29	35	9	5
Right Bank ..	7	5	1	14	27	28	10	8
Sukkur:								
Rohri ..	5	3	10	7	44	27	3	1
Nara ..	2	3	11	10	55	15	0	3
Khairpur ..	10	14	2	31	17	16	6	3
Right Bank ..	3	3	3	17	29	31	6	9
Ghulam Mohammad:								
Left Bank ..	6	9	5	26	18	26	3	7
Right Bank ..	6	3	5	15	35	19	5	12
Whole Area ..	5.1	4.9	6.1	14.2	34.6	25.0	4.8	5.4

S=sand: LS=Loamy sand: SL=Sandy Loam: VFSL=very fine sandy loam.
SIL=Silty loam: SICL=silty clay loam: SIC=silty clay loam.
CL=clay loam: SCL=sandy clay loam: SC=sandy clay.

TABLE 7

Moisture characteristics of the soils.

Texture	Porosity%	Sp. Gravity	Moisture content (%volume)			
			Field Capacity	Wilting Point	Available Moisture	Air Space
Sand ..	47.5	2.65	25.0	7.0	18.0	22.5
Sandy Loam ..	47.0	2.65	32.0	8.5	23.5	15.0
Loam ..	46.0	2.65	37.5	10.0	27.5	8.5
Silty Loam ..	45.0	2.65	38.5	12.0	26.5	6.5
Silty Clay Loam ..	43.0	2.70	41.0	17.5	23.5	2.0
Silty Clay ..	42.5	2.70	41.5	21.5	20.0	1.0

areas of Ghulam Mohammad Barrage on left and right banks canal. After the rice cultivation, high watertable falls down in many of the canals zone except Nara and the Rohri canals which thus needs quick application of drainage measures.

TABLE 8

Terminal infiltration rates (inches per hour)

Textural group	Max.	Min.	Median	Mean
L	1.75	0.25	0.75	0.85
M	1.05	0.00	0.20	0.29
H	1.00	0.00	0.06	0.13
V	0.06	0.01	0.02	0.02

L group =sands and loamy sand

M group =sandy loam, fine sandy loam, light loam and light silty loam.

H group =heavy loam, heavy silty loam, clay loam, sandy clay loam and silty clay loam.

V group =silty clay, sandy clay and clay.

Soil Salinity

The water of the Indus rarely possess more than 300 ppm of dissolved salt at Sukkur. Its sodium content is also very low. A comparison of the salt content of a few well-known rivers the waters of which are used for Irrigation, is shown in Table 9. The Indus possesses low salt and low order of sodium. The soil salinity in the region is more as a result of evaporation of the salt affected groundwater. Very extensive field surveys had been conducted to determine the salt affected region in the three-barrage command.

TABLE 9

Salt contents of river waters used for irrigation (1)

	Parts per million	
	Total Salinity	Sodium
Colorado (Arizona) ..	795	292
Gila (Arizona) ..	1023	664
Pecos (Texas) ..	6200	3080
White Nile (Khartoum) ..	174	71
Murray (Victoria, Australia)	96	28
Indus (Sukkur) ..	300	12

Figure 4 depicts some of the zones severely affected by salts. The regional distribution of moderately and severely salt affected dland is shown in Table 10.

Water Resources

Water resources available to Sind region are fixed more or less by the Sind-Punjab Agreement of 1945, according to which monthly discharge available at Sukkur and other Barrages are fixed. Sind is entitled to a share of 46.12 million acres feet of water. In Table 11 monthly flows as authorised or designed above the three barrages and that according to the Sind-Punjab Agreement are shown.

Apart from the share as fixed by the agreement, large volume of water goes waste into the sea during the summer. In Figure 5 is depicted the flow during different months in a year, a fraction of which is utilized. Evidently, storages in this region will im-

Regional distribution of moderately and severely salt affected land

Command	Percentage of gross area			
	Non-cultivable	Moderately salt affected	Severely salt affected	Unclassified (seasonal swamp)
Gudu:				
Desert Pat feeder ..	5	29	66	..
Begari-Sind feeder ..	6	54	40	..
Ghotki Feeder ..	15	53	32	..
Sukkur:				
North-West Canal ..	4	40	45	1
Dadu Canal ..	4	70	21	5
Khairpur Feeder West ..	5	79	16	..
Khairpur Feeder East ..	30	62	8	..
Rohri Canal ..	7	91	2	..
Eastern Nara Canal ..	5	71	23	1
Ghulam Mohammad Barrage:				
Kalri-Baghar Feeder ..	2	24	67	7
Pinyari Feeder ..	5	33	50	12
Fuleli Canal ..	3	41	49	7
Akram Wah ..	5	38	50	7

TABLE 11

Authorized or design supplies and 1964-diversion (map).

Month	Barrage						Total		Sind-Punjab Agreement
	Gudu		Sukkur		Ghulam Mohammad				
	a	d	a	d	a	d	a	d	
January			1.54	0.89	0.32	0.12	1.86	1.01	1.59
February			1.39	1.68	0.29	0.10	1.68	1.78	1.44
March			0.76	1.53	0.32	0.09	1.08	1.62	1.63
April ..	0.1	0.18	1.16	1.56	1.39	0.23	2.73	1.79	2.06
May ..	0.77	0.14	1.97	2.15	1.93	0.58	4.67	2.87	4.50
June ..	1.84	1.19	3.68	2.64	2.72	1.05	8.24	4.88	6.66
July ..	2.32	1.80	2.82	2.72	2.54	1.17	7.68	5.69	8.03
August ..	2.20	1.61	2.82	2.69	2.54	1.12	7.56	5.42	7.87
September ..	1.80	1.32	2.42	2.30	1.80	0.88	6.02	4.50	6.42
October ..	0.47	0.37	1.76	2.22	0.66	0.52	2.89	3.11	2.76
November			1.53	2.07	0.17	0.12	1.70	2.19	1.52
December			1.58	1.43	0.31	0.07	1.89	1.50	1.64

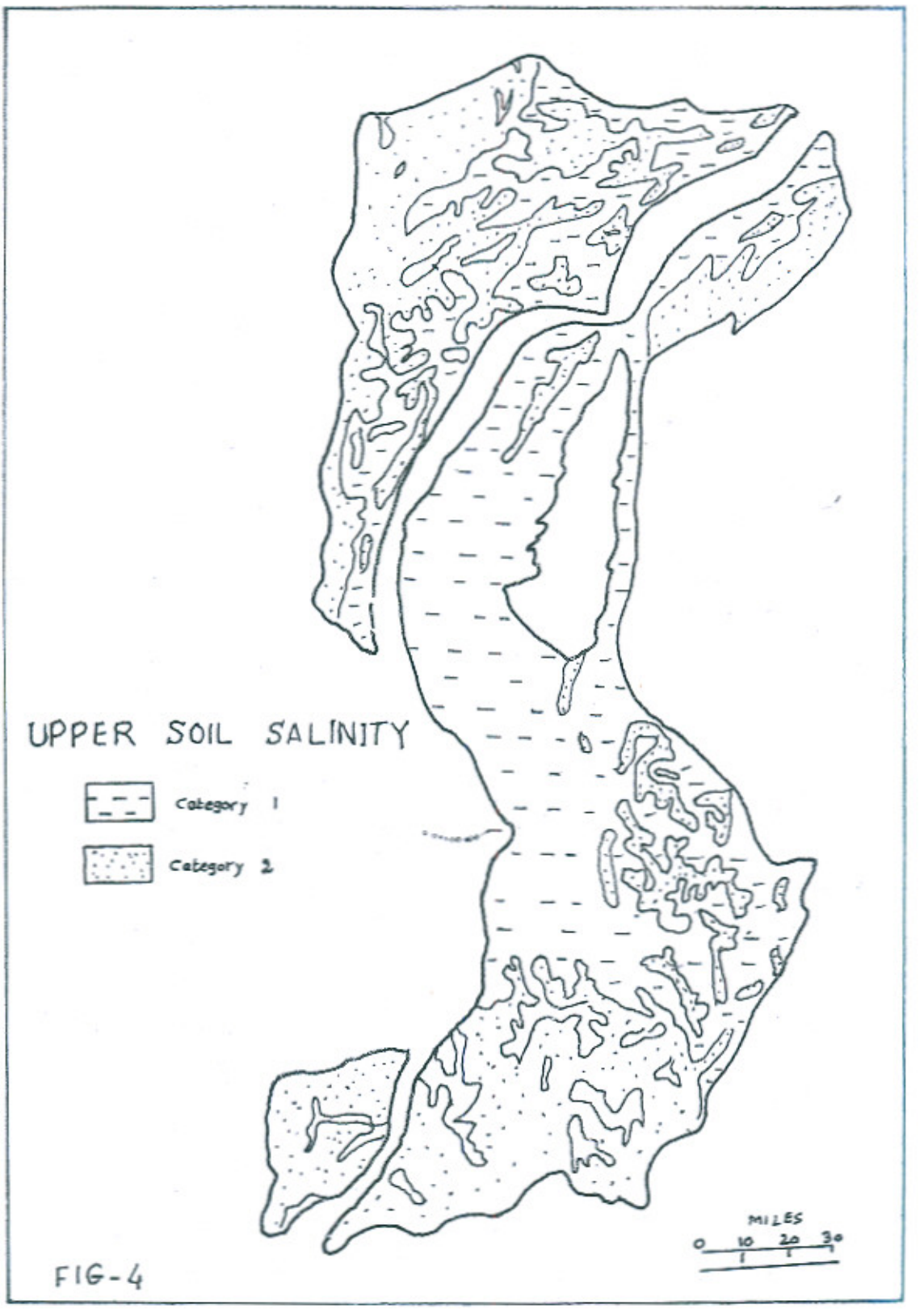
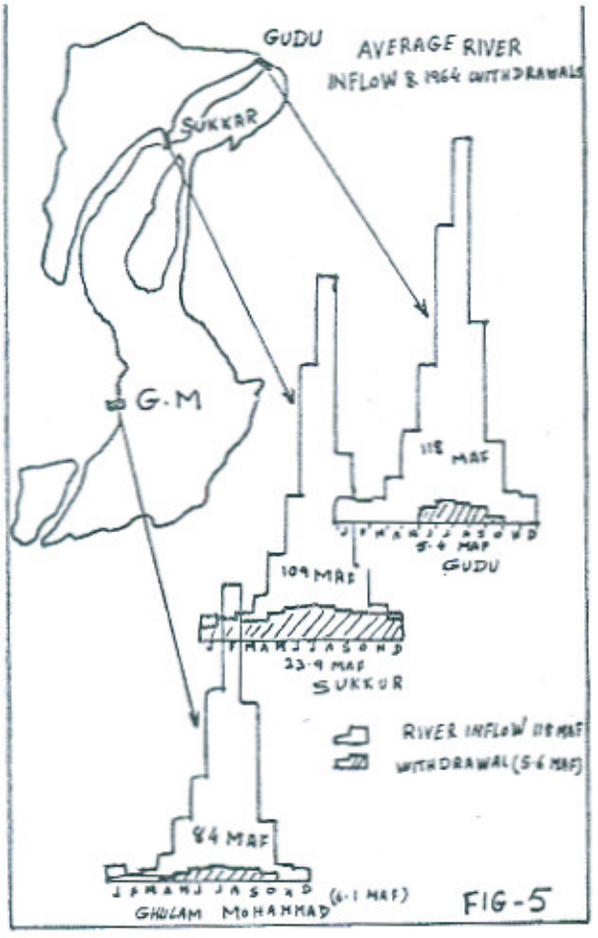
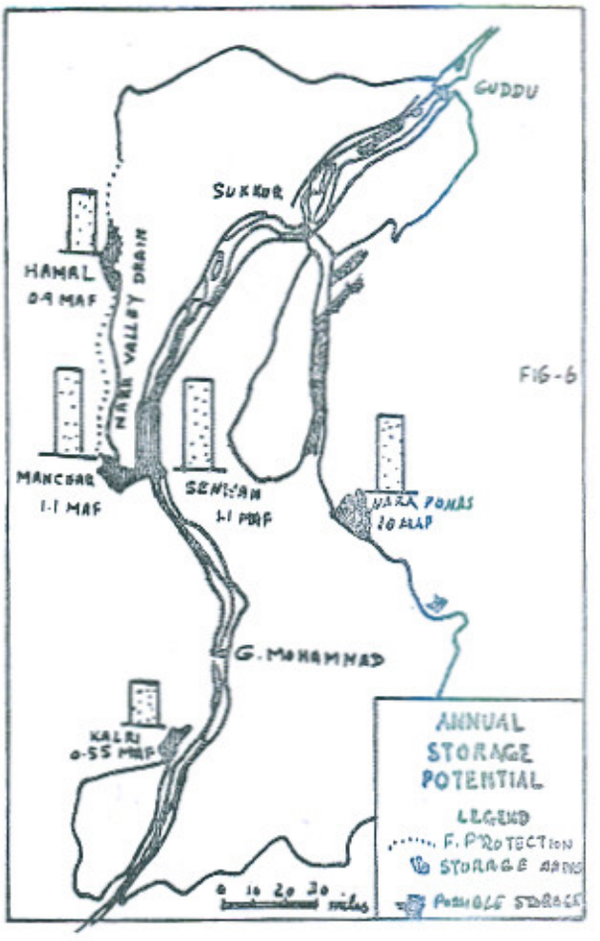


FIG-4



mediately benefit the development. Fortunately near the town of Schwan a storage site exists for retaining of the water. The stored water can also be diverted for accumulation into the Manchar Lake.

Referring Figure 6 it may be seen that there is a possibility of developing storages in Manchar Lake in the main river above Schwan and in Namal Lake and connecting it through the Nara Valley Drain to the Manchar Lake and developing some small storage on the Eastern Nara Canal. The storage of Kalari Lake can also continue to be used. Besides these resources of stored water there is a possibility to develop groundwater as some areas of the Sind along the Indus river possess zones of fresh water which can be pumped out for utilization. As a result of the investigation, the areas water under varying depths are shown in Table 12.



FUTURE DEVELOPMENT

The Second Part of the report consists of seven chapters. It contains the objective, the criteria for Land and Water Resources, and the Agricultural Development. The alternatives for Development and Plan of action are given in fourteen and fifteen chapters. The implementation of the proposals are given in the last chapter. The criteria for the use of land resources, its salinity, alkalinity and reclamation together with the criteria for the use of water resources are discussed at great length in the eleventh and twelfth chapters. Brief extracts from these two chapters are given before discussing the development alternatives and the plan.

TABLE 12

Regional distribution of groundwater of various salinities.

Command	Depth (feet)	Salinity (ppm) 0—750	750—1500	1500—2500	2500—4500	4500—	T
Gudu Left Bank ..	0—200	382	56	54	62	406	960
	0—300	319	53	51	83	454	960
	0—400	142	145	112	94	467	960
	0—500	70	136	106	72	576	960
Gudu Right Bank ..	0—200	329	104	137	257	1,313	2140
	0—300	252	163	91	181	1,453	2140
	0—400	86	273	69	212	1,500	2140
	0—500	61	112	229	177	1,561	2140
Sukkur Left Bank ..	0—200	1,143	446	235	355	4,126	6305
	0—300	809	525	153	261	4,557	6305
	0—400	361	234	545	327	4,838	6305
	0—500	253	138	278	507	5,129	6305
Sukkur Right Bank ..	0—200	164	236	115	161	1,520	2196
	0—300	147	141	82	192	1,634	2196
	0—400	100	149	82	180	1,685	2196
	0—500	44	115	104	174	1,759	2196
Ghulam Mohd Left Bank ..	..	..	...	..	...	2,544	2544
Ghulam Mohd Right Bank ..	..	..	...	...	...	772	772
Total ..	0—200	2,018	842	541	835	10,681	14917
	0—300	1,527	882	377	717	11,414	14917
	0—400	689	801	808	813	11,806	14917
	0—500	428	501	717	930	12,341	14917

CRITERIA FOR THE USE OF LAND RESOURCES

(*a*) Cultivated and Uncultivated Land

In Sind the cultivated land constitutes 62.5 per cent of the total CCA. The area is both perennial and non-perennial and its underground formations possess both the fresh and saline groundwater. The uncultivated land is either non-saline land, abandoned ; never cultivated or forest reserve. Its total constitute about 5.8 per cent. The uncultivated, saline land under the three divisions, constitute 29.3 per cent. The rest 2.4 per cent is covered by seasonal swamps. About 38 per cent of the land of the region is affected by salts. Its reclamation by leaching or by

addition of amendments shall have to be extensively practised to bring it under crop.

Reclamation Principle

Reclamation may be defined as the process of removing excess soluble salts or excess exchangeable sodium from soils in order that crops may be grown. The primary aim is to remove the excess soluble salts while at the same time maintaining the soil permeability. To do this, the exchangeable sodium percentage (ESP) of the soil must be controlled. With many soils an ESP of 15 to 20 is sufficient to bring about a deterioration in the soil physical properties, and especially a reduction in the infiltration rate. The risk of this occurring is greatest when the soluble salts have been reduced to comparatively low quantities ; if it occurs early in the leaching process, it makes the primary aim of removing salts impossible ; if it occurs after the removal of salts, the soil is left with poor physical properties and is only capable of limited crop production.

The usual method of reclaiming land is by the application of water to the affected soils, thus leaching out the salt. Adequate drainage is necessary to remove the saline sub-soil water and to keep the water-table low enough to prevent rapid resalinisation. Excessive amounts of exchangeable sodium are not so easily controlled by leaching alone and special practices, such as the use of gypsum or green manuring, are often necessary. Crops may be grown, and are indeed beneficial, during the leaching process. Such crops must be able to tolerate saline conditions and also prolonged submergence. Rice, once established, answers both requirements and can often be successfully grown under these circumstances. The rapid leaching of saline soils also removes plant nutrients, particularly nitrates, which are very soluble. A mineral fertilizer should be used to counter this deficiency.

Salinity and Alkalinity

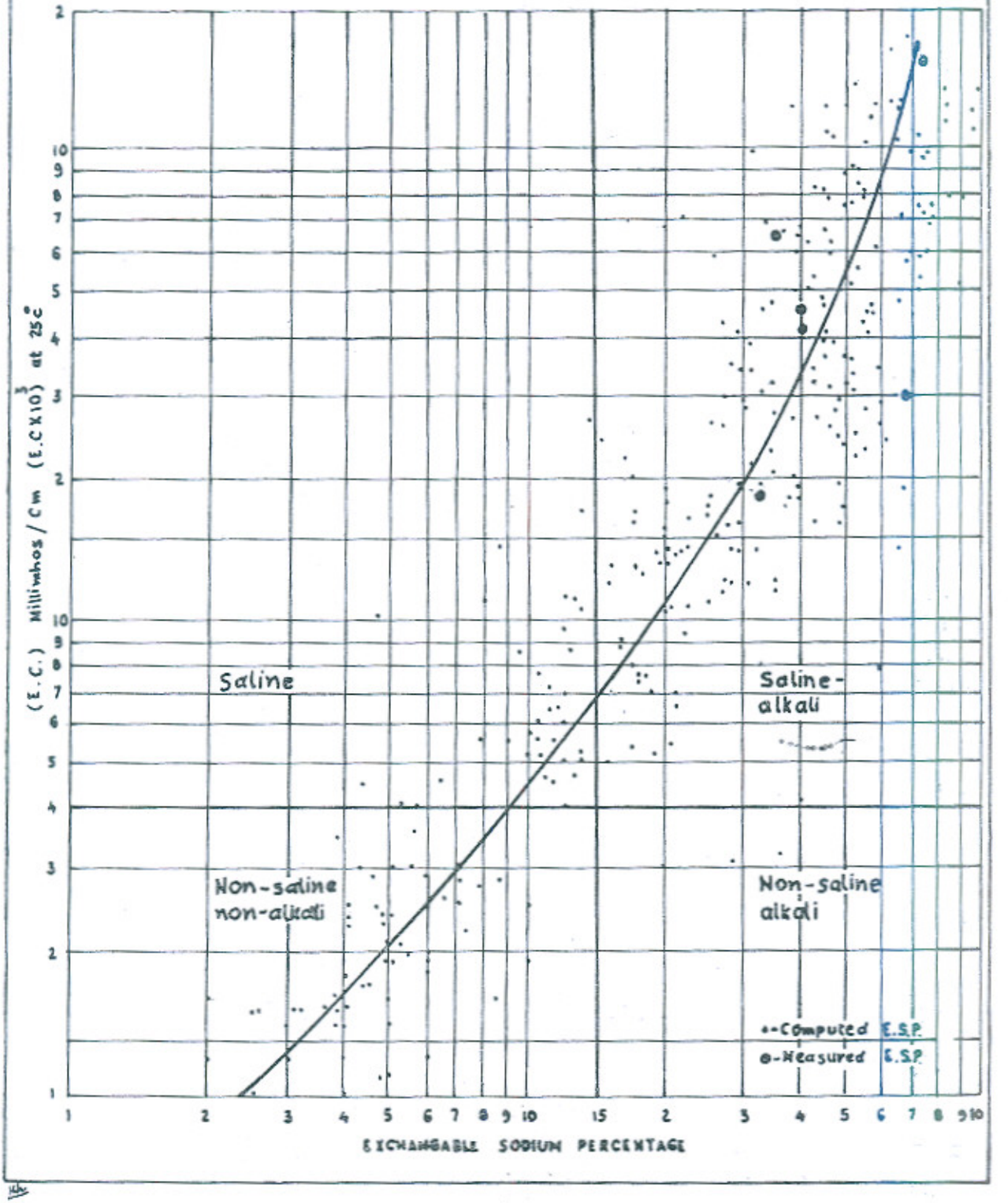
Salinity is measured by determining the electrical conductivity (EC) of a saturation extract of the soil. The soil is said to be saline if the EC exceeds four millimhos per centimetre, at which level crop yields begin to be depressed. This is a severe criterion and many crops can be grown when the EC is considerably higher than four. The regional distribution of saline soils is given in chapter 2, of the report, where this aspect is fully discussed.

An alkali soil is defined as one where the quantity of adsorbed sodium in the exchange complex exceeds 15 per cent of the total adsorbed cations. Most soils in the regions that are saline are also alkaline and they are termed saline-alkali soils. Figure 7 shows a plot of EC against ESP for a random selection of soil samples within the region. The limits of 4 for EC and 15 for ESP are also shown. It can be seen that while saline-alkali and saline non-alkali soils are common; non-saline alkali soils are rare. In fact this group forms less than one per cent of the soils in the region.

Saline soils that contain excessive quantities of exchangeable sodium may turn into non-saline alkali soils when leached with a consequent adverse effect upon the physical and chemical properties of the soil. Soluble salts exert a flocculating effect on soil particles and when they are removed dispersion may occur. The soils then become much less permeable to water and difficult to till. Strong alkalinity may develop because of the hydrolysis of exchangeable sodium. The sodium hydroxide thus formed will react with carbon dioxide to form first sodium bicarbonate and

FIG:-7

RELATIONSHIP BETWEEN ESP AND EC



the highly toxic sodium carbonate. This latter salt may also be formed by reduction of sulphate under natural waterlogged conditions. Biological reduction of sulphate to the sulphide, followed by hydrolysis, leads to the formation of sodium hydroxide and hydrogen sulphide. Sodium hydroxide reacts with carbon dioxide present and sodium carbonate may be ultimately formed.

Toxicity of salts

The rate of uptake of water by crop roots in response to the loss of water vapour in transpiration is controlled by the soil suction pressure which opposes the uptake. The osmotic pressure of the soil solution is regarded as an addition to the capillary component of the soil suction pressure. The sum of the soil-moisture tension and the osmotic pressure of the soil solution is termed the total soil moisture stress. The total soil moisture stress regulates the availability of water to growing plants. As the stress increases, water availability decreases. Therefore, the enhanced osmotic pressure of a saline soil solution has the effect of raising the wilting points of the soil and therefore, reducing the available moisture holding capacity. Plants also absorb ions in varying amounts. One particular ion therefore may accumulate in toxic quantities, another may be deficient to provide essential nutrition. Absorbed salts in toxic concentrations penetrate the plant cells, destroy the plasma and the cell membranes and so kill the plant.

The relative toxicity of salts in soils has been expressed by comparing identical weights of salts in identical quantities of solution. Table 13 shows the relative toxicities of various salts.

Sodium sulphate is generally considered as being the least toxic and its degree of toxicity is taken as unity, sodium carbonate, with a relative toxicity of eight, is the most toxic. Exchangeable sodium normally is not toxic unless the concentration is very high and most disorders may be attributed to the indirect effect of sodium on the soil physical properties or on the uptake of other essential elements.

TABLE 13

Relative toxicity of various salts

Salt	Relative toxicity
Sodium sulphate	1
Sodium bicarbonate	3
Magnesium sulphate	4
Magnesium chloride	5
Calcium chloride	5
Sodium chloride	6
Sodium carbonate	8

The leaching process

Salinity is a transitory soil characteristic and can be eradicated by leaching the soil with water. Large quantities of water are often necessary and the usual and most effective method is to pond water on the soil surface.

The concentration of different ions does not decrease proportionally during leaching. Because of their different mobilities and sizes and also because of exchange reactions, ions move down through the soil at different rates. Chlorides move through the soil at a faster rate than sulphates. Therefore, leaching operations usually leave the soil with a relatively higher percentage of sulphates.

In a soil-water system the adsorbed cations are in equilibrium with the cations in solution. The addition of more water to this system upsets the equilibrium and the adsorbed cations of lower valency tend to go into solution and are replaced by cations of a

some adsorbed sodium will go into solution and will be replaced by calcium. Boron is also adsorbed by the soil and gradually attains equilibrium with the boron in the applied irrigation water.

Criteria for the use of water resources

The first essential factor to note for establishing criteria for the use of water resources, is the water requirement for various crops which is estimated by referring to several meteorological parameters, an important of which is the free water surface evaporation, and the crop coefficient. Using these two factors, consumptive use of water for any crop is determined.

The amount of water consumed by a crop from its sowing to harvesting, is its consumptive use but when water is delivered to the field, some amount percolates deep into the ground and is not available to crop. Another percentage is wasted through breaches in field and channel bunds, so that the field efficiency lies between 74 to 92 per cent.

Now when the water is let out from an outlet into a water course, there are seepage losses of the order of 10 to 18 per cent and losses in the field channels, so that the farm efficiency is further reduced and lies between 61-83 per cent only.

On the bases of very careful experiments, Hunting found the following efficiencies for wheat and oil seeds.

TABLE 14

	Per cent.
(1) Field efficiency ..	74—92
(2) Losses in channels ..	18—10
(3) Distribution efficiency (100—(2)) ..	82—90
(4) Farm efficiency ((1)×(3)) ..	61—83

found as shown in Table 15.

Canal transit losses

Based upon the information of Farm efficiencies, estimate of canal discharge has to be made. Here an important factor is the seepage loss through transit.

The rate of seepage loss was actually determined for about 200 sites and the estimate of the orders given in Table 16, were obtained.

The average losses for canal were found to vary between 4 to 8 cusecs for unlined and 2 cusecs for lined canals.

Water-use efficiency

The total of field losses and transit losses amounts to about half of the water diverted at the barrage. Some part of this total loss is evaporated and is irretrievably lost; the remainder joins the groundwater and can be recovered by means of wells if the groundwater is fresh, but is totally lost if it is saline. In recirculating the water in the fresh groundwater areas, some is used by the crop, some lost due to evaporation and the rest rejoins the groundwater and the cycle begins again.

To demonstrate the advantage of developing fresh before saline-groundwater areas, the concept of water-use efficiency is helpful. It may be defined as the quantity of water used in consumptive use divided by the quantity diverted at the barrage. Owing to the recycling and hence the number of reuses of water in the fresh-groundwater areas the expression for water-use efficiency is somewhat complex. Details of the derivation of the expression shown on next page are to be found in supporting Report Volume 18, on Water Requirements.

TABLE 15

Command		Optimum application of water in range (inches)	Consumptive use (inches)	Farm efficiency per cent
Northern Rohri	..	30—34	16.5	49—55
Southern Rohri	..	30—34	16.3	49—55
Northern Nara	..	25—29	18.5	64—79
Southern Nara	..	20—24	18.5	77—92
Total of all Commands	..	30—34	17.0	50—57

TABLE 16

Column	1	2	3	4	5	6
	Canal	Location	Discharge (cusecs)	Seepage	Evapora-tion	Total
Sukkur Left Bank	Rohri	R. D. 180	12,000	5.5	0.3	5.8
Sukkur Left Bank	Nara	R. D. 146	9,000	4.1	0.3	4.4
Ghulam Moham-mad Left Bank.	Pinyari	R. D. 35	5,500	2.5	0.2	2.7
Sukkur Right Bank	North-West	R. D. 100	3,500	6.3	0.2	6.5
Sukkur Left Bank	Jamrao	R. D. 275	1,900	3.8	0.2	4.0
Sukkur Left Bank	Mithrao	R. D. 200	1,600	4.0	0.3	4.3
Sukkur Left Bank	Faiz Wah	R. D. 21	200	4.5	0.2	4.7
Sukkur Left Bank	Bhampar Dy	R. D. 0—0.2	120	0.1	0.3	2.4
Sukkur Left Bank	Chiho MR.	R. D. 1	35	4.7	0.2	4.9
Ghulam Moham-mad Left Bank.	Dodo MR.	R. D. 0—1.2	20	2.5	0.3	2.8
Sukkur Left Bank	Watercourse 2L (ex-Khadar Dy).	R. D. 0—0.5	2.5	4.2	0.3	4.5
Gudu Left Bank	Watercourse 17R (ex-Dingro Wah)	R. D. 0—0.5	1.5	8.2	0.3	8.5

Note.—R. D. is distance from head regulator in thousands feet.

$$\text{Water Use Efficiency} = \frac{100\,(1+Py+qz)}{(1+y+z)\,(1+y-Py)}$$

Where y = Loss between crop and watercourse head expressed as a proportion of the crop consumptive-use water requirements.

z = loss between watercourse head and barrage expressed as a proportion of the crop consumptive-use water requirements.

P = Proportion of y that is recoverable.

q = Proportion of z that is recoverable.

The following table shows the items in the water account leading to a water balance.

TABLE 17

Items in the water balance

Inflow	Outflow
Irrigation diversion	Crop use
	Non-crop use
Rainfall	Evaporation from bare soil
	Rainfall, run-off
	Rainfall stored in the soil and then evaporated.
	Direct evaporation from rainfall.
	Evaporation from canal water-surfaces.
	Drainable surplus.

For saline-groundwater zones p and q are zero and the expression reduced to :—

$$\frac{100}{1+y+z}$$

Typical values for y and z are 0.48 and 0.40, respectively. Hence in a saline groundwater zone:

$$\text{Water Use Efficiency} = \frac{100}{1.88} = 53\%$$

For a fresh-groundwater zone typical values for p and q are estimated to be 0.76 and 0.80.

Water Use Efficiency

$$= \frac{100\,(1+0.76\times0.48+0.8\times0.4)}{(1+0.48+0.4)\,(1+0.48-0.76\times0.48)} = 80\%$$

This means that 80 per cent of the water diverted at the barrage is eventually used beneficially in the fresh-groundwater zone, whereas only 53 per cent is so used in a typical saline groundwater area.

A complete appraisal of the criteria for water resources, depth to water table, drainage surplus, rainfall, run off, recharge, mining and skimming are points considered in the report.

Summary of criteria for the use of ground-water

The criteria in the previous sections are summarised below together with some further proposals for the practical use of groundwater.

(*i*) The total groundwater pumped must equal the total drainable surplus.

(*ii*) Fresh groundwater should be used as near as possible to the pumping well.

(*iii*) Pumping may be undertaken at any time during the year to meet or anticipate a shortage of surface supplies.

(*iv*) The longer the period over which pumping is done, the cheaper is the tubewell installation.

(*v*) Pumping should be as evenly distributed over the period as possible. High peaks in one particular month should be avoided, because this adds to the installed capacity and therefore, the cost of the tubewell field.

(*vi*) Water used directly for irrigation will

be satisfactory if the salinity is below 1,500 parts per million, and the SAR below 7.5.

(*vii*) Mixing will normally be continuous, that is, it will be mixed before applying to the land. However, in certain cases, where no winter surface water is supplied, discontinuous mixing will be considered. That is, groundwater may be applied directly in the winter at salinities higher than 1,200 parts per million and canal water only applied in the summer. Normally in areas where this practice may be considered rice will be the summer crop.

(*viii*) For broad planning purposes in calculating the available groundwater that can be used without mixing with canal water and in delineating the areas with usable groundwater a limit of 1,200 parts per million has been used.

(*ix*) The minimum exploitable depth of usable water for calculating groundwater availability has been taken as 300 feet.

The Development Plan

For Development, the whole area of the Sind region is divided into several development zones. These are shown in Figure 8. Each area will be developed to attain the intensity of irrigation as shown in Table 18. It may be noted that in some cases the order of intensity expected is 200% and generally it lies up to 150%.

As for the water availability, the ultimate pattern of development is discussed. It is proposed that there will be 4 storages in this region which will yield an annual flow of 3.1 million acres feet. These storages are as follows :—

	Stored	Available at canal head
	MAF	MAF
Manchar ..	1.33	1.80
Schwan headpond ..	1.00	
Chotiari ..	1.06	0.90
Kalri ..	0.58	0.40
	3.97	3.10

The total water from the surface resources constitutes 46.12 million acres feet. To this will be added 3.1 maf from storages and 3.3 maf from groundwater. The water plan by 1/2 month is explained in Figure 9. The availability of water from 3 sources at each command canal is clearly explained.

The Cost Estimate

The report contains detailed cost estimate for each Project and development plan.

The summary of the cost estimate is given in Table 19.

The cost of Irrigation and Drainage both capital and maintenance is put forth. The estimate cost runs into Rs. 8,357,115,000. The annual maintenance expenditure works out to be Rs. 77.016,000.

The cost estimate for electrification of all schemes is Rs. 437,834,000, that for roads is Rs. 14,288,1000. The foreign exchange component on capital cost on Irrigation and Drainage works will correspond to Rs. 4,600,530,000. Whereas the local currency will correspond to Rs. 3,756,585,000. The programme of construction starting from the year 1965 to 2000 years, is explained in Figure 10.

The proposed stages for the implementation of the plant, consist of Project Planning, detailed design and then construction. For operational, agricultural and other services will be established which will take over the completed work and operate the projects and do the monitoring.

TABLE 18

	Development unit		CCA for Develop-ment	Ultimate intensity		
				Rabi*	Kharif	Annual
G1	Gudu LB FGW	..	317	87*	73	160
G2	Gudu LB SGW	..	206	—	100	100
G3	Gudu RB FGW	..	349	87	73	160
G4	Gudu RB SGW		648	—	100	100
G5	Pat.	..	78	—	100	100
	Sub-total	..	1,598			
SR1	North-west FGW	..	155	87	73	160
SR2	North-west SGW	..	220	79	86	165
SR3	Kirthar	..	258	—	100	100
SR4	Rice	..	337	—	100	100
SR5	N. Dadu	..	118	87	73	162
SR6*a*	S. Dadu (W)	..	102	75	87	162
SR6*b*	S. Dadu (T)	..	174	75	87	162
	Sub-total	..	1,364			
SL1	W. Khairpur	..	252	87	73	160
SL2	E. Khairpr	..	124	79	86	165
SL3	S. Khairpur	..	206	75	87	162
SL4	N. Rohri FGW	..	573	87	71	158
SL5	N. Rohri SGW	..	502	75	87	162
SL6	Nara pumps	..	84	87	71	158
	Sub-total	..	1,741			
S1	S. Rohri FGW	..	475	80	65	145
S2*a*	S. Rohri SGW (W)	..	699	70	75	145
S2*b*	S. Rohri SGW (T)	..	188	70	75	145
S3*a*	W. Nara (W)	..	373	70	75	145
S3*b*	W. Nara (T)	..	343	70	75	145
S4*a*	E. Nara (W)	..	394	70	75	145
S4*b*	E. Nara (T)	..	234	70	75	145
S5	S. Nara	..	258	70	75	145
	Sub-total	..	2,964			

	Development unit		CCA for Development	Ultimate intensity		
				Rabi*	Kharif	Annual
GM1	G. M. RB (NP)	..	159	—	67	67
GM2	Ochito	..	69	100	100	200
GM3	Klari Pumps	..	46	100	100	200
GM4	G. M. LB (NP)	..	897	—	71	71
GM5	Gaja	..	62	90	95	195
GM6	E. Tando Bago	..	90	70	80	150
	Sub-total	..	1,323			

*Dubari and bosi acreages not shown. In assessing benefits these intensities are assumed to be 80% of the Kharif intensity.

Tubewell drainage, (W).

Tile drainage, (T).

Non-perennial, (NP).

Note.—For water requirement and benefit calculations all the ultimate intensities shown above have been reduced by 5%.

TABLE 19

Unit	Summary of irrigation and drainage capital costs for each development unit (1,000 Rs.)		Summary of annual irrigation and drainage costs for each development unit (1,000 Rs.)		Summary of capital costs of electrification and roads for each development unit (1,000 Rs.)	
	Total cost		Total cost		Total cost	
	Irrigation	Drainage	Irrigation	Drainage	Electrification	Roads
1	2	3	4	5	6	7
G1	91,081	—	14,547	—	18,050	52,700
G2	52,548	17,830	4,778	2,751	—	50,300
G3	95,119	3,022	17,261	367	23,450	27,500
G4	29,785	2,23,470	8,406	18,891	—	1,11,500
G5	28,836	22,587	2,804	2,676	—	11,300
Total	2,97,369	2,66,090	47,796	24,685	41,500	2,53,300

Unit	Summary of irrigation and drainage capital costs for each development unit (1,000 Rs.)		Summary of annual irrigation and drainage costs for each development unit (1,000 Rs.)		Summary of capital costs of electrification and roads for each development unit (1,000 Rs.)	
	Total cost		Total cost		Total cost	
	Irrigation	Drainage	Irrigation	Drainage	Electrification	Roads
1	2	3	4	5	6	7
SR1	88,039	—	12,103	—	13,090	15,200
SR2	35,321	1,84,792	3,507	23,388	22,350	56,400
SR3	1,54,928	85,099	10,931	6,961	43	38,400
SR4	17,918	1,08,280	3,560	9,281	43	50,400
SR5	91,244	2,486	10,906	301	11,480	7,700
SR6*a*	36,744	54,711	2,604	5,935	5,890	10,200
SR6*b*	69,699	2,70,249	4,849	19,850	12,730	16,300
Total	4,93,893	7,05,617	48,460	65,716	65,626	1,94,600
SL1	61,151	23,200	7,881	8,613	18.248	23,900
SL2	16,972	1,10,300	2,050	12,541	12,610	24,100
SL3	53,995	1,04,927	4,463	11,523	11,150	45,600
SL4	3,65,889	—	44,947	—	52,500	82,800
SL5	1,23,228	2,71,822	9,685	30,372	23,200	82,600
SL6	28,955	—	2,197	—	1,530	23,900
Total	6,50,190	5,10,249	71,223	63,049	1,19,238	2,82,900
S1	5,42,575	1,28,977	54,023	9,811	47,600	69,200
S2*a*	4,37,820	3,76,410	29,584	39,149	33,500	61,900
S2*b*	1,24,800	2,91,071	8,336	20,971	11,200	21,200
S3*a*	2,26,140	1,87,890	15,673	19,189	19,550	58,400
S3*b*	2,08,120	5,30,697	14,420	38,570	21,400	61,800
S4*a*	2,46,620	2,28,458	17,024	23,448	23,300	63,000
S4*b*	1,28,042	4,38,240	9,042	32,159	16,970	48,500
S5	1,42,930	4,92,528	9,880	34,920	15,880	24,230
Total	20,57,047	26,74,271	1,58,012	2,18,217	1,89,400	4,08,230
GM1	26,556	23,900	2,914	3,622	—	49,200
GM2	20,185	92,370	1,589	7,229	6,940	7,250
GM3	84,822	—	9,965	—	2,130	11,430
GM4	73,120	1,85,155	10,761	22,723	—	1,98,000
GM5	7,750	17,800	748	4,727	7,400	12,550
GM6	2,107	1,67,805	572	12,008	5,600	11,350
Total	2,14,540	4,87,030	26,549	50,309	22,070	2,89,780
Grand total	37,13,039	46,44,076	3,52,040	4,21,976	4,37,834	14,28,810

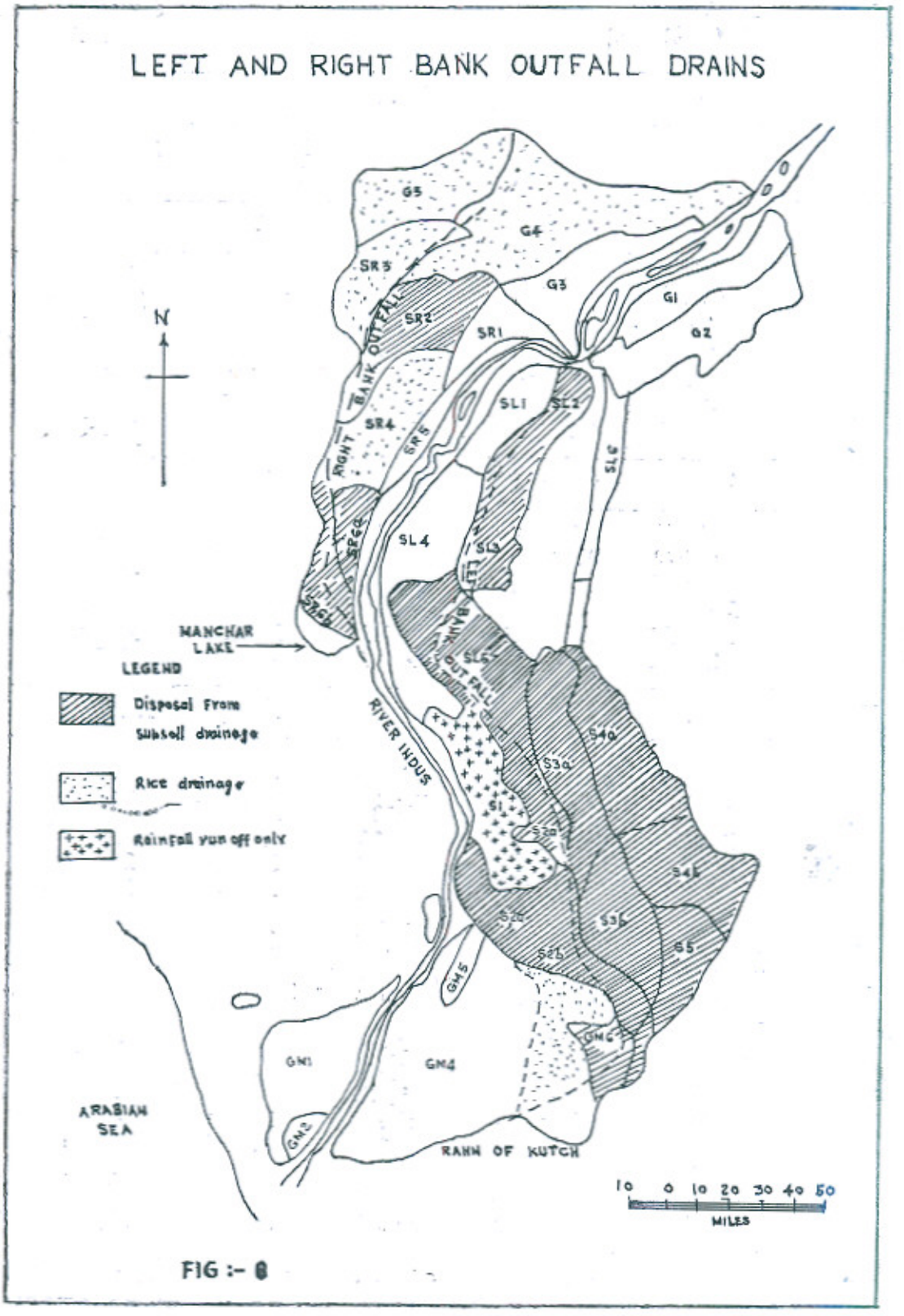

LEFT AND RIGHT BANK OUTFALL DRAINS
N
G5
G4
G3
G1
G2
SR3
SR2
SR1
RIGHT BANK OUTFALL
SR4
SR5
SR6
SL1
SL2
SL3
SL4
SL5
SL6
LEFT BANK OUTFALL
MANCHAR LAKE
LEGEND
Disposal From subsoil drainage
Rice drainage
Rainfall run off only
RIVER INDUS
S1
S2a
S2b
S3a
S3b
S4a
S4b
S5
GM1
GM2
GM3
GM4
GM5
GM6
ARABIAN SEA
RANN OF KUTCH
10 0 10 20 30 40 50
MILES

FIG :- 8

FIG:-9

THE WATER PLAN BY HALF MONTHS

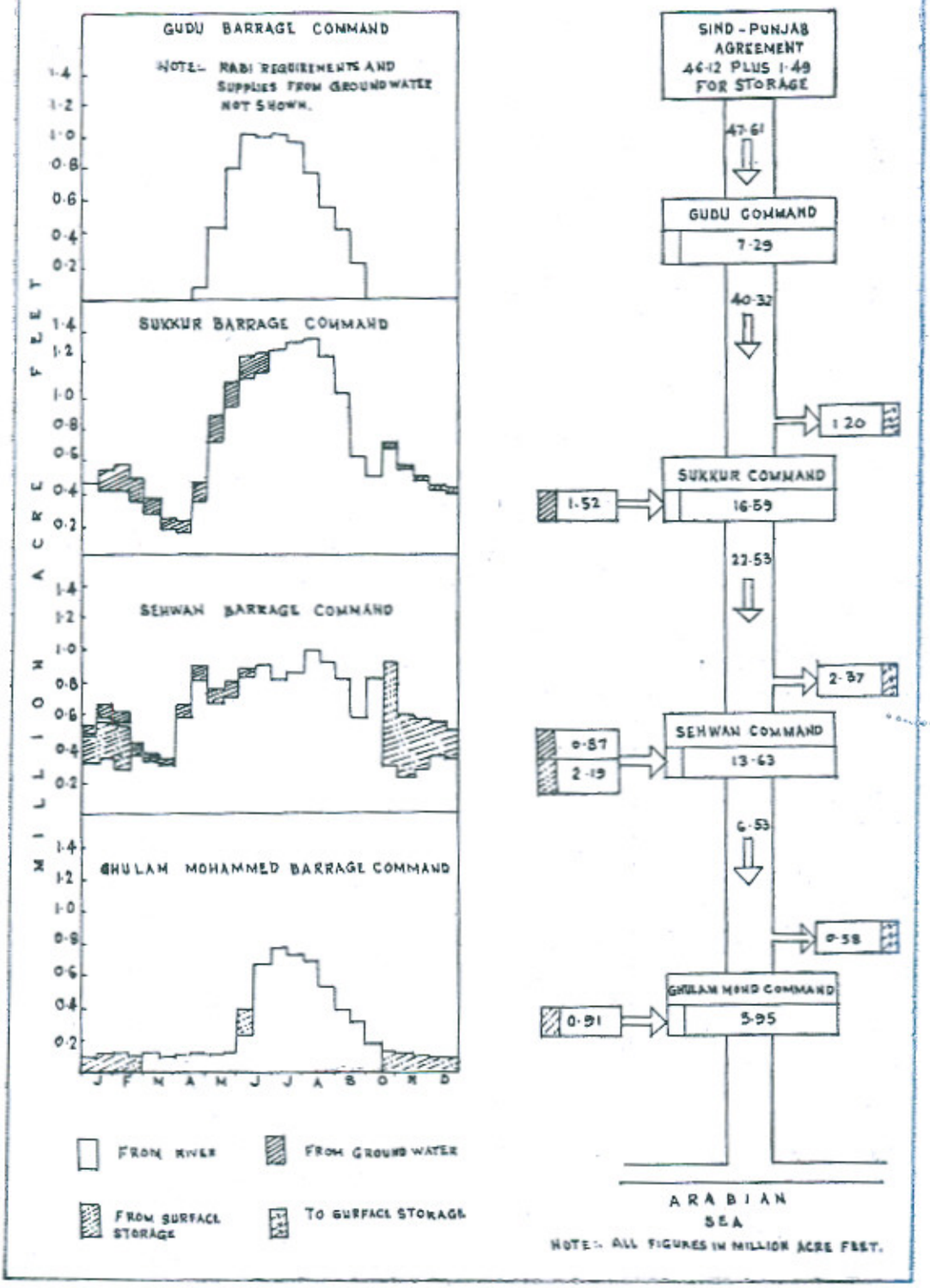
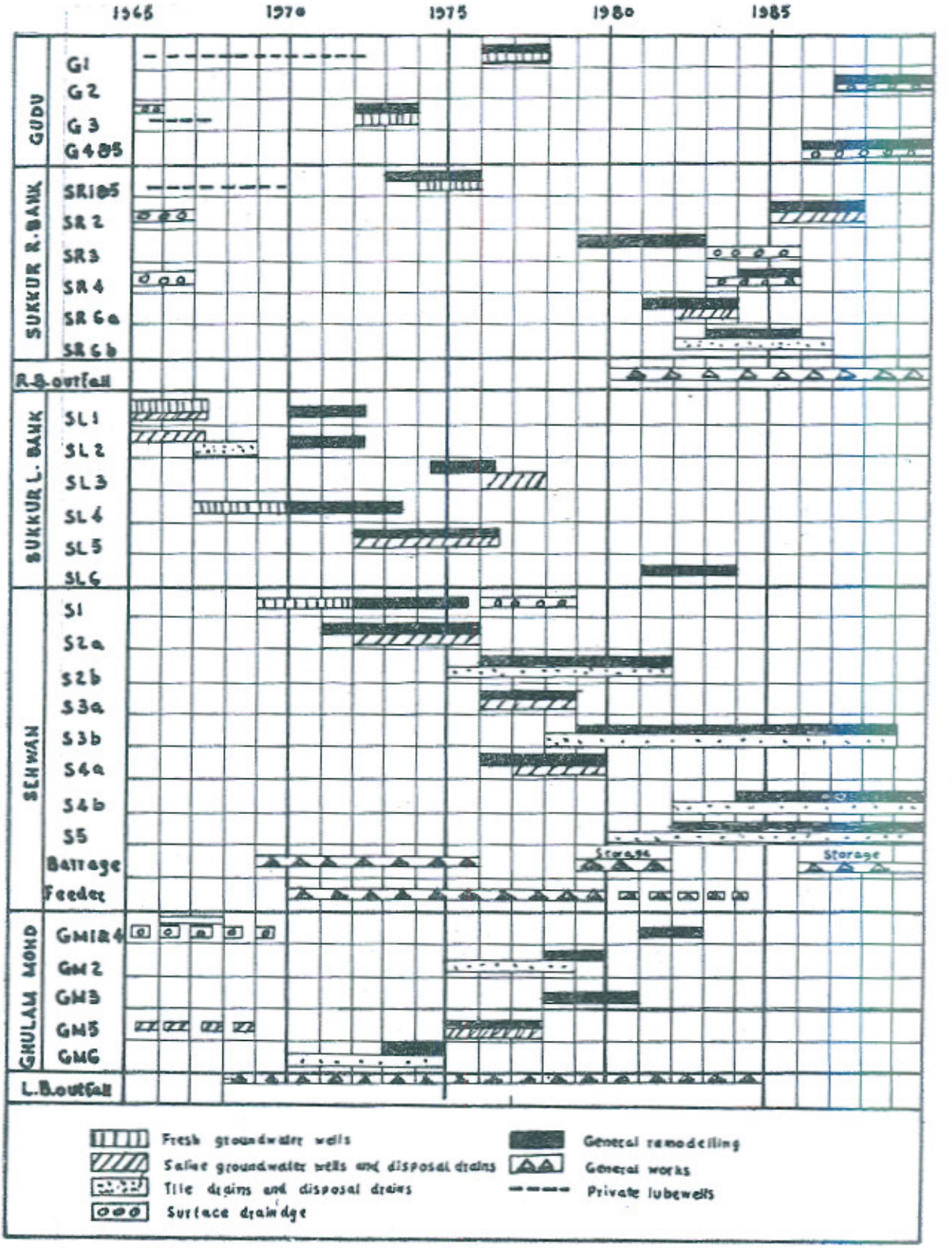


FIG. 10

PROGRAMME OF CONSTRUCTION



The planning and construction, which will be the responsibility of the Water and Power Development Authority (WAPDA) and for operation it is recommended that it should be the responsibility of the Agricultural Development Corporation (ADC). The Lower Indus Development Board, whose main function would be to determine policy and coordinate the work of WAPDA and ADC. It might be composed of as follows :—

1. Member, Board of Revenue, West Pakistan (*Chairman*),
2. the Chairman, WAPDA,
3. the Chairman, ADC,
4. the Secretary to Government of West Pakistan, Finance Department,
5. the Secretary to Government of West Pakistan, Agriculture Department,
6. the Secretary to Government of West Pakistan, Irrigation and Power Department,
7. the Secretary to Government of West Pakistan, Cooperation and Labour Department,
8. the Secretary to Government of West Pakistan, Basic Democracies and Local Government Department,
9. the Resident Member.

Mode of Working

The Chief Engineer would be appointed to take charge of all planning and construction and a Chief Project Director be appointed to take charge of the operation. As for the planning and construction it is probable that the large works will have to be carried out by foreign contractors after an international call for tenders.

To keep up with the schedule and to comply with the terms of some lending agencies project planning may have to be undertaken both departmentally and by consultants. Project planning carried out departmentally would include surface drainage, sections of the canal remodelling programme and other works which could be constructed by a Government Agency or a local contractor. Project planning for specialized works, such as barrages and tubewell schemes and for other works involving loans from abroad and foreign contractors, would require the assistance of consultants. It may well prove necessary to employ several consultants.

It is in the interests of the country that as much work as is feasible should be carried out departmentally or by local contractors. However the programme is too large and the time too short to avoid a large proportion of the work being allocated to foreign contractors. The subdivision between government agencies, local contractors and foreign contractors depends not only on the capacity of the first two but also on the sources of finance. Foreign aid is not normally provided for departmental work. Departmental work and local contracts can consist of small units but in order to generate interest among foreign contractors large units are necessary.

It is anticipated that later on in the 25-year programme less reliance will be placed on foreign consultants and contractors. This has particular significance for the tile-drainage works, initially foreign experts will be required for design and specialized contractors from abroad will be necessary for the first project and pilot schemes. When the specialized techniques have been adapted to the conditions of the region and mastered, this work could well be undertaken departmentally or by local contractors. It is expected that foreign contractors will form associations with local contractors and this will help in building up the capacity of the civil engineering industry of this country.

The report contains a most useful suggestion which needs urgent consideration of the people of this country.

"The Public and The Public Servant"

AN EXERCISE IN SELF CRITICISM

By
ABDUL LATIF MIRZA

A three-day seminar arranged by the Bureau of National Reconstruction of West Pakistan on the 'Public and the Public Servant' was a pleasant surprise as the plain speaking done by almost all the participants was not only unexpected but showed the basic soundness of the nation's thinking mechanism. There was no mincing of matters. The criticism was blunt, the analysis impartial and the remedies suggested were equally forth right and radical. It does not matter even if the recommendations meet the fate of Pay & Services Commission Report; what has been said has touched the sensitive spots and cannot be unsaid now.

The relationship of the Public and the Public Servant is a part of the attitude of public towards the statecraft practised at a given time which, in turn, is the integral component of the socio-economic structure and political status of the society. The Public Servant, in the ultimate analysis, is nothing except the instrument in the hand of State organs of power to implement the functions entrusted to the State. The formation of attitudes in this sphere cannot be separated from the attitude of public towards the State organs of power. In the days of imperial power and colonial subjugation, the Public Servant was a mere Government servant and functionary of a foreign power acting on the lines and in the interest of the colonial ruler. The interests of the public and the ruler were not identical. The Government servant was to function on the maxim that everything which was the public loss was of Government gain. The image of the Government servant was nothing separate than what was the image of the colonial Government itself in the eyes of the public. There was wide gulf in between the public and the State agency. The Government servant was not there to bridge this gulf but to be a partisan with the Government as against the public.

That the public took the Government servant as an organic part of the foreign colonial rule is evident from the mechanics of freedom movements in the country. The freedom fighters always selected Government servants for their expression of wrath and singled out the Government service for practising non-cooperation. Every one with

flame of freedom burning in his heart made it a positive part of his attitude to despise entry into Government service. In their heart of hearts the public respected, glorified, and made a hero of these people, who thus sacrificed their chances of pursuing wealth and comfortable career. This reflected the true evaluation of Government servant in the inner sensibilities of the public.

Now it is an objective law of nature that the manifest forms of a functional organ have to harmonize with the spirit of function. The organization and structure of services was designed to suit the colonial objectives. 'Ahlkars' were instruments of tyranny and suppression; mere soulless functionaries who have nothing in them to throb in unison with the public feelings. The steel frame was rigid enough, properly insulated and isolated from public opinion, with an inbuilt resistance to accept anything emanating from the people at large.

There came that great moment of history, when the morning breeze of 15th August 1947 blossomed the flowers of hopes and aspirations. It was the awakening of a nation—the nation as a whole—with its kith and kins, with its common man. It was perhaps for the first time in Muslim History that the change in political power was the outcome of the common man's struggle and determination and established in the name of masses at large. This time there came none on the galloping horses from across the mountains or fluttering its sails from beyond the sea shores, to change the ruling dynasty. This change was tremendous and under its impact the transformation of attitudes has to be revolutionary. This change at least for some time, developed an attitude in the public of owning policies of Government and be active participants in its execution. But unfortunated, we failed and failed gravely to bring in corresponding structural changes in the service organization to conform to this change of attitude. The Government servant was not changed to be the public servant. Wherever, the external forms of an organization do not conform to the internal substance, an imbalance resulting in a stoppage of progress and ultimate decay is inevitable. This is what resulted from this situation. The frame work of social attitude got badly distorted as the external forms of administration did not conform to the new substance and expectations generated by the advent of freedcm. It was a futile hope to expect that this distorted frame work operating in an imbalanced situation would smoothly move faster and faster on the path of happiness and cordial relationship.

Professor Ashfaq Ali Khan had a very charming and logical expression for this situation. He said, "Just as a fodder-cutting machine cannot start functioning, merely because of intention on the part of the operator, as a straw-binding machine, in the same way the administrative structure fashioned for imperial exploitation cannot, merely by a proclamation that independence has come, stop oppressing the people and start serving them. It can carry on some functions which were necessary then and are necessary now such as maintenance of law and order, transport services etc. But it cannot, all at once without a change in its component parts and their relations among themselves, start serving the people, giving them confidence, permitting them to use their energies to the utmost in constructive channels, valuing talent in place of abject submission, servitude and blind obedience, etc."

The criticism against the public servant for its corruption, red tapism, arrogance, indifference, etc. are all wellfounded and cannot be denied. The public indignation because of these cannot be ignored. But it must be realized that these are mere symptoms of a deeper malady. Short-time measures of quick relief in the isolated areas of these deficiencies cannot improve the situation permanently. In line with the aspirations and hopes kindled and generated by the freedom should have been the changes in the structure of administration. Unless form and substance is coherent, the imbalance and distortion is bound to result in halting the advancement. The basic problems are to be identified and solved. Some one, some where, some time, has to take a bold decision. Only then there can be any hope of a new era of relationship in the public and the public servant:—

1. There must be basic changes in our socio-economic structure. The organs of power have to function for realizing higher objectives for which this country was created. A dedication on the part of public servant to the ideals of equality and justice as enjoined by Islam have to be the starting point for such a change.
2. The public servant must have unshaken faith in the ultimate sovereignty of people. He must have confidence in the ultimate soundness of peoples free and unfettered judgement. The country has been created for fulfilment of higher ideals in accordance with the wishes of common man and his determination to realize those ideals.
3. The policy-making function must be taken away from the public servant and his role should remain confined to policy implementation. Policy formulation should be a sacred trust of the chosen representatives of the people. Through elected representatives the people should feel themselves identified with the policies and only then their participation with its implementation would be fuller. The public servant should be a mere instrument for policy implementation. He must obey the constitutionally and validly elected machinery in all dictates of policy formation. If ever he differs on honest and conscientious basis with the policy, framed by the chosen representatives of the people and he feels that this implementation is against his conscience, he may quit on moral grounds but constitutionally he must be bound to implement the policy laid down for him.
4. The closed system of service whereby a class of service has appropriated itself the entire right of initiating policies and controlling the sensitive spots of administration must give way to a system where merit, experience, ability, scholarship, devotion to idealogy and other qualities of heart and mind are made the basis of filling the posts. To make the administration of a developing society, the sanctuary of a group of people unifying themselves in a closed cadre is negation of talent and experience and causes that fundamental distortion which, as mentioned earlier, does not correspond to the substance brought in by freedom.

Proceedings of West Pakistan Engineering Congress

PAPER No. 372

Diversion of the River Jhelum at Mangla

By Mr. Mehtab Khan

One of the essential requirements towards the early and successful completion of the Mangla Dam Project was the timely and safe diversion of the mighty river Jhelum at a place about half mile upstream of the existing Upper Jhelum Canal Headworks.

The timely and safe diversion of the river Jhelum on the 16th September 1965, would go in the history of project as a great event, achieved under abnormal and emergent circumstances in the country.

The filling of the closure dyke was commended from the right bank side on the 8th September, 1965 when the discharge in the river was about 25,000 cusecs and the gap with this much flow was about 390 ft. On the 14th of September the tail race Coffer Dam was completed and the bulk head gate of tunnel No. 1 was raised. The river started flowing into the tail-race area through the gap, ever tapping partially the Fabre Dam. The discharge in the river on this date was about 19,300 cusecs. In the evening of 14th September, the bulk head gate of tunnel No. 2 was also opened, and on the next day all the five gates were raised, and the river flow passed through the five diversion tunnels. About 7,000 cusecs are still flowing in the old river bed while the remaining 12,000 cusecs pass through the tunnels. The complete closure was effected on 16th September.

In the paper, information about the pumps installed for dewatering and controlling of seepage flow is also given. All the advantages of closure at this period are discussed in the paper.

PAPER No. 373

Electric Traction on Pakistan Western Railway

By S. H. Nawab

Pakistan in 1947, inherited a railway route of 5,318 miles. By June 1965, Pakistan Western Railways had 5333.7 route miles which included 4,635 route miles of broad gauge and the rest was meter and narrow gauge. At that period it had 701 steam locomotives, 311 diesel locomotives, 38 diesel raii cars, 3,175 passenger coaches and 33,664 goods wagons. Pakistan imports a large quantity of oil for operating these

engines. If the traction is changed to electricity then much of the foreign exchange, spent on fuel supplies will decrease, and there will be a possibility to carry more passengers and freight due to the higher speed attainable by this means.

When it was decided to utilize electricity for traction, several experts from different countries were invited to advise Pakistan on the scheme. It has now been decided to implement this system of electric traction on Khanewal-Lahore Section in the first instance. The other lines considered suitable for this system of traction are : Lahore-Rawalpindi, Sibi-Quetta, Karachi-Kotri, and Karachi-Suburban Railways.

In the paper, the author has discussed the choice of system of voltage and currents used in various countries and their relative advantages.

The Electricity Department has agreed to supply power at the rate of 7 paisas per unit, up to 31st December, 1970 and thereafter at the rate of 6.5 paisas per unit. It is estimated that there will be an overall annual saving of Rs. 14.5 lakhs. In the Foreign Exchange Component alone there will be a saving of Rs. 4 lakhs annually. The decision to electrify the railways is therefore a correct one.

PAPER No. 374

Pumping installation for the Warsak Lift Irrigation Scheme

By Khan Sarwar Jan Khan

This project consists of a channel of 200 cusecs capacity, 37 miles long flowing along the slope of Khyber Hills at an elevation of 1,400 above the Mean Sea Level. The supply of this channel is drawn from the main gravity flow canal at R. D. 20,130. The canal takes off from the Warsak Dam. The capacity of the tunnel is 455 cusecs through the 17,000 ft. long tunnel on the right bank at R. D. 20,130, the canal bifurcates into a Right Bank Gravity canal of 255 cusecs, 45.2 miles irrigating 58 641 acres of which 33,000 acres are already under irrigation. The rest 200 cusecs flow through a feeder channel, 2,500 feet long into the sumps of the pumping station from, when the water is lifted by four Centrifugal Pumps, each of 50 cusecs capacity and of 1340 H. P. This canal is to command an area of 46,100 acres The overall cost of the lift canal including the cost of pumping is Rs. 3.7 crore. If the cost of the tunnel and the share cost of Warsak Dam is also included, the overall cost amounted to Rs. 8.03 crore.

The design of the pump house foundation presented some difficulty. The site had clay and silty soil on which the pump house was to be erected. It had a low bearing capacity and the foundation was expected to be subjected to complex stresses both direct and indirect. Very detailed anlaysis of foundation soil had thus to be carried out. The preliminary analysis was conducted in the Irrigation Research Institute which recommended an all safe bearing values of 1.1 ton/sq. ft. A filter below foundation was also recommended. In order to get the second opinion, advise of Messrs Harza Engineering Consultants, working with WAPD, was sought who conducted further detailed tests all of which are described in this paper.

The Company carried out several new bores, collected undisturbed samples, conducted shear tests under saturated conditions and ultimately came to the same conclusions that the bearing pressure recommended by the Irrigation Research Institute equal to 1.1 ton/sq. ft.

was safe. Harza's consultants also recommended that about 8.5 ft. thick loose silt or clay under the foundation may be replaced by compacted sand fill. It was done by means of vibratory compactors and compaction was done in layers of 4 inches to 6 inches. The order of compaction was to have a minimum density of 116 lbs. per cu. ft. The paper also describes the other components of this project such as the pump installation and their motor units, sluice valves, reflax valves, surge suppressors and all the other details of construction, conducted at site. Some details about the main transformers is also given.

The site was later on visited by the members of the Engineering Congress during their study tour.

PAPER No. 375

Remodelling Balloki Headworks

By Rana Mohammad Aslam Chohan

Balloki Headworks was constructed as a part of the Triple Canal Project in 1912-1916. It has now to cutter for a new link canal carrying a discharge of 18,500 cusecs. This resulted in heavy withdrawal which effected the approach conditions. Several attempts to correct the approach conditions did not yield a permanent remedy. The existing structure in fact was considered unreliable to pass the order of discharges particularly after the damages of previous floods. There were different proposals for remodelling the headworks. The final proposals approved for its improvement consisted of raising the pond level by one foot, and providing sheet pile cut-off on the upstream floor, raising the crest level by 2 feet, and such other works which are described in detail in the paper.

Before undertaking the construction many preliminaries had to be done which consisted of stock piling of materials, construction of railway track and buildings, providing electric power etc. The feeding of the L. B. D. Canal was also to be continued unobstructed. It was thus decided to undertake the work in two phases. In the first phase Bays No. 1 to 17 were set right and in the 2nd Phase construction was undertaken on Bays No. 16 to 35. In the paper details is given about the diversion bunds, arrangement for dewatering, installing of sheet piles etc. Similar work recorded for both the phases are described in the paper which is a good record of the work done on the remodelling carried on this Headworks.

PAPER No. 376

The Sunshade Table

By Ashfaq Hasan, M.Sc. Engg. (London), D. I. C. (London)

The author, Director of Research on Building Construction describe, a device called the Sunshade Table, by the use of which the apparent position of the sun is depicted on a table where orientation and shading devices of a building can be studied. The table is about $2\frac{1}{2}$ ft. square which can hold a model of about the same size in any orientation. The table is versatile, simple, cheap and can be conveniently used at any place to represent the sun of any place. Although principally meant for out-doors, it can be used indoors without any modification provided the source of light is strong and far enough. The apparatus is useful to the architects, engineers and the research, workers, it can also be used as a solar clock, if necessary.

PAPER No. 377

A Study of the Effect of Suspension Parameters of Ride Index of a Railway Vehicle and Results of Trials on the Pakistan Western Railway.

By M. Z. Mozaffar, P. R. S.

The paper describes the Railway journey comfort and riding characteristics of a Railway coaches. The suspension system which effects the riding characteristics on the track, is studied which was undertaken in collaboration with a German Firm. The whole mechanism of the suspension is described in the paper, together with the evaluation of the running qualities of the coaches. All the various phases of the experiments are described in the paper together with the apparatuses used to measure the vibrations. A special type of a computor was used in the tests. As a result of the studies it was found that an all coil spring bogie with suspension arrangement described as Proto-type A_2 and A_3 were most suitable for the track existing in this country. It was also noted that the condition of wheel tyres had a great influence on the riding quality of a coach. Use of head treated types were recommended. Instead of cost iron brake, composite brake shoes were recommended.

In these classes of bogies rubber fittings and shock absorbers will need close watch for their performance.

PAPER No. 378

Earthwork on Irrigation Works in the Land of the Indus

By Mazhar Ali

This paper is an attempt to trace a brief history of development of Irrigation Works in the former Sind Province, and to assess the growing earthwork needs. Potential of professional Manual labour and casual hari labour has been explored, and special features of the tract have been high-lighted. Role of machines and manual labour, and the shift towards mechanization has been studied. A strong case has been made for the optimum exploitation of indigenous labour force as a first preference.

It is concluded, after discussing the various pros and cons for utilizing manual labour against machinery that it is worthwhile to utilize the manual labour as much as possible in this country.

Large quantities of earthwork are required in Sind tract to keep complex system of irrigation channels and flood embankments operating at a high degree of efficiency. Occasionally new works also become necessary. This tract has no organised casual labour force and a limited professional labour strength. If the works are properly planned and phased and if proper authority, both financial and administrative, is delegated at all levels, it is possible to do away with machines almost completely for this region. The rate structure of machine works needs a critical appraisal. The dormant casual agriculturist labour offers a great challenge to the nation. The role of manual labour, professional and casual can be vastly improved by a more realistic look at the rate structure, delegation of proper authority, intensive planning, effective co-ordination between various field agencies and social reforms.

PAPER No. 379

The Need for a Sound Housing Policy in West Pakistan

By S. Sibt-i-Hassan

In this paper the housing needs for the country are described. It is putforth that the housing policy will not be successful

without assistance of Government. The form of assistances given in other countries such as USSR, Africa, Asia, America, U.A.R., are described. The Government assistance available in Pakistan is also discussed at a great length. The paper gives many interesting and useful suggestions with regards to the housing policy to be followed in West Pakistan.

PAPER No. 380

Determination of Firm Generating Capacity

By A. Rahimtoola

In the early stages of the development of the WAPDA Northern Grid Zone, the firm generating capacity was computed after subtracting the largest unit from the available generating capacity. With the subsequent addition of many large generators, the firm generating capacity has now been evaluated on a probability basis, keeping in view the past performance of generating units in the Grid System. The results have shown that 10 per cent of the total available capacity should be considered as Spinning Reserve and subtracted from the total generating capacity to arrive at the system firm capacity.

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THE SYMPOSIUM ON ENGINEERING RESEARCH

The subject of Symposium was "The Role of Engineering Research in Developing Economy of Pakistan". Ten contributions by various authors were presented. Brief synopses of these are also included in the volume.

PAPER No. 73

Importance of Nuclear Power Generation in the Developing Economy of Pakistan

By Masnoon S. Ahmed

Pakistan has a population of nearly 100 million people and is one of the countries of Asia where in a short span of eighteen years, since independence, economic development has been remarkable. Starting from a purely agricultural economy in 1947, Pakistan is emerging with a more balanced economy as a result of emphasis on the development of industries. Manufacturing now accounts for about 20 per cent of the gross national product and production in large-scale industries increased ten-fold from 1950 to 1963. The country is now in the period of rapid economic growth, typical of nations in the formative years of industrialization. In this area the annual per capita power consumption has risen from two kwhr in 1947 to forty kwhr in 1963. Unfortunately, the conventional sources of generation of power within the country, hydro and fossil fuels, are limited and will not meet the power demands of a growing economy on a long-term basis extending over the next 35 years. This paper presents a study of the economic feasibility of nuclear power in the three largest power demand areas of Pakistan.

East Pakistan

In East Pakistan it has been estimated that in 1966 there will be a deficiency of fifty-nine mw and about one hundred by 1970. It is estimated that in case of nuclear power plants installed in the area, the cost of generation will be 9.53 mills/kwhr against 11.94 mills/kwhr from an oil-fired plant (one mill. is 1/1000 S). East Pakistan area has been divided into two zones, so that the above estimate is for Eastern Zone whereas for Western Zone it is estimated that nuclear power will cost 9.53 mills/kwhr, and 12.32 mills/kwhr from an oil-fired plant. There is thus a considerable saving in the cost expenditure.

West Pakistan

As regards West Pakistan, the hydro-electrical potential of the Province are estimated to be ten thousand mw. Most of the sites, however, exist in the inaccessible hilly regions which would make the construction of dams extremely costly. Even if the whole of the hydro-potential is developed, it would leave a deficiency of about eight thousand mw, as it is estimated that during the next 40 years the requirements of power in this region will be eighteen thousand mw.

The deposits of natural gas discovered in West Pakistan are estimated at nine million cubic feet which in terms of heating value are equivalent to five hundred million tons of coal.

The oil production in West Pakistan is hardly equal to fifteen per cent of the present requirement. Similarly the coal deposits are estimated to be 165 million tons. These exist in hilly regions of Quetta and Kalat divisions. The coal contains sulphur, ash and volatile matter and is unsuitable for many purposes.

The estimate of power requirement showed a deficiency of 200 mw up till 1966. It is proposed to overcome by installing 200 mw gas fire thermal station in Lyallpur area near Chiniot. Between 1967 to 1968 Mangla is scheduled to be commissioned and the maximum power out of this dam is estimated at 300 mw. It is estimated that a nuclear power plant if installed in the area would produce power at 7.22 mills/kwhr as compared to 7.87 mills/kwhr from a gas-fired plant. It is estimated that by 1968 a generating deficiency of 150 mw will exist in West Pakistan.

Karachi

As regards Karachi, it is producing its requirement mainly from Sui Gas. It is estimated that the gas would start results would exhausting shortly after 1980. A survey has shown that by 1970 there will be a power deficiency of 66 mw. Thus an additional power requirement of 100 mw will become necessary. A power station of 100 mw in Karachi will cost 7.0 mills/kwhr. It is pointed out, the cost of nuclear fluid in the near future will come down as has happened during the last 5 years, when its cost had been reduced by 20%. Thus economically the feasibility of nuclear plant exists. The country will have reaped many other advantages with regard to radio isotopes for medicine and industry. These isotopes are by-product of any nuclear power plant.

PAPER No. 74

Nuclear Engineering Research for Development of Nuclear Power in Pakistan

By Mohammed Yusuf

It has been decided to build two nuclear power plants in Pakistan, one at Karachi in West Pakistan and the other at Rooppur in East Pakistan, as the first phase in the programme for development of nuclear power in the country. The Karachi Nuclear Power plant, presently under construction, will have a capacity of 137 mw (gross) and is of natural uranium and heavy water type. The capacity of the Rooppur Nuclear Power Plant will be about 140 mw (gross) and its construction is scheduled to start as soon as the necessary financing is arranged. The Rooppur reactor is also likely to be of heavy water and natural uranium type. It is believed that because of limited indigenous fuel resources, nuclear power has a bright future in Pakistan.

Plant location

Theoretically, it is possible to instal a nuclear power plant anywhere. But practi-

cally, the cost involved and the hazards associated with the location have to be considered first, to protect the surrounding population—man, animal and plant—it becomes necessary to introduce features in the plant what are known as engineered safeguards which may increase the cost of the plant beyond limits.

This paper deals with the equipment of Nuclear Energy for development of Nuclear Power. It discusses the Engineering Safeguards as well as the Improved Fuel Cycle. As regards the Heat Transfer and Fluid Dynamics, although the research is being carried out in all countries of the world but so far none has been able to understand the problem in a satisfactory manner and empirical relations have been evolved to predict performances.

The technique for fabrication of fuel elements using natural uranium is well known and can be done in Pakistan without much difficulty. It will be built with the introduction of the natural uranium nuclear power plant facilities for fuel elements in Pakistan. The reactor produces plutonium. It can be mixed with natural uranium and the enriched uranium can be used as fuel element. As regards the waste disposal, there are two methods generally in use. One is to dispose them in the underground and the other in deep sea. Both these require a thorough study before utilization.

PAPER No. 75

Role of Research in Railways of Developing Countries

By C. A. Vali

Engineering research consists of fundamental and applied research. Basic research concerns the universities, technical colleges and science academies. Applied research seeks to apply the result of the basic knowledge to a particular problem.

Research is an expensive undertaking. Britain is said to have spent $1775 million on research in 1961-62 which comes to thirty-one dollars per head. Besides the cost of research, it needs skilled personnels which in developing countries are still very small.

Pakistan Western Railway has invested as much capital as Rs. 165 crores. The railway has a dual role to play. As a public transport undertaking it is under statutory obligation to provide services which the community needs at a cost strictly controlled by the Government. As a commercial undertaking, it has to ensure a fair return on the capital invested. Organised research on most of the railways came into being only after the end of the Second World War. Railway Research, however, falls into two main processes, technical and non-technical. For the former an office for research and experiment was set up in 1949. The non-technical research includes market research, operational research and maintenance research. In the Western Railways there are four Directors dealing with:—

1. Technical Research.
2. Operational Research and Work Study.
3. Market Research.
4. General Economics Section and Planning Research.

PAPER No. 76

Development of Building Research in West Pakistan

By Mian M. Hanif

The research on building in this province started from 1961. The first problem to be

considered pertains to the expenditure on building. The Building Research Institute since it was established in May 1961, has devised new bricks having dimensions equal to $7\frac{5}{8}\times3\frac{5}{8}\times3\frac{5}{8}$. which with an addition of mortar comes to $8''\times4''\times4''$ Zed Tile made out of 1; 2; 4 concrete, 1 inch thick and $2\frac{1}{2}\times2\frac{1}{2}$ sq. ft. in dimension have proved the cheapest. Hollow Roofs have been developed which provide better living comforts. Polythene was introduced in Damp-Proof Course. Research has also been conducted on preparation of sunshade table. A model of building can be located on the table to study the sunshine and sunshades on the building at different latitudes. The Building Research Station is working on several other problems to improve building construction in the country. The Research Station collects research literature and also provides testing facilities.

PAPER No. 77

Role of Research in the Control and Use of Water

By Mushtaq Ahmad

In a developing country like Pakistan, the most basic problems facing the nation are the feeding of its teeming millions by improving and extending agricultural industry, by making best use of the water and land resources, development power resources to utilize them for industrial potential. The author has dwelt mainly on the scope of Irrigation Research and has started with the Organization of the Irrigation Research Institute which started to be realised, at least on papers, in 1915 and actually came into being in 1924. This institute has slowly developed during the last 40 years. The achievements of the Research Institute are innumerable; but the author refers to few ones such as, hydraulic structure on sand foundations, river training and control, design of alluvium channel, weir, silt excluders, falls, outlets and sediment investigations etc. The other contributions pertain to canal lining, water-logging and salinity, tubewell, dewatering of foundations, electrical analogy and resistivity and analysis of gauge discharge data. The author briefly enumerated the few problems in the field and control of water. He posed the following questions to be answered:—

(*i*) Have we got a programme of Research for augmenting precipitation and increasing supply of water from atmosphere?

(*ii*) Have we enough information for snow surveys, enough automatic rain gauge stations to make precipitation analysis and establish reliable rainfall run off relations for our river catchments and for drainage basins in the plains?

(*iii*) Do we know enough of the physical properties of ice, and ice-forming processes; to use ice as a Dam material?

(*iv*) Are our methods of water measurement not crude when compared to modern techniques of micro-measurements of electronic currents, can we yet measure seepage in a channel by measuring discharge at two places at a reasonable distance apart; for the order seepage?

(*v*) Can we measure the rate and direction of subsoil flow accurately in our aquifer?

(*vi*) Have we got a reliable means of cutting down evaporation loss under condition of wind and storm?

(*vii*) Can we effectively cut off seepage from any alluvial channel without closing it for a long time?

(*viii*) Have we got reliable apparatus for *in situ* determination of seepage in a flowing channel?

(*ix*) Can we measure scour depth under flood conditions near piers, dykes etc.?

(*x*) Have we got an apparatus to detect the position and size of a cavity under a weir?

(*xi*) Have we evolved an apparatus to measure the rate of bed load transport in an alluvial channel?

(*xii*) Can we estimate retrogression or degradation from the various factors affecting it?

(*xiii*) Does the damage to launching stone aprons of spurs, guide bank heads not suggest that our knowledge and practice needs further development?

(*xiv*) Have we obtained sediment discharge equations for stable channels taking all characteristics of sediment charge (*e.g.*, ratio of fine to coarse).

(*xv*) Can we rationally fix optimum waterway in a silt laden steam of variable hydrograph? What is most suitable discharge (keeping the duration in view) in relation to which the waterway should be fixed to minimise undesirable islands under a given approach?

(*xvi*) Do we have a design of a navigable channel vis-a-vis the variables entering the problem?

(*xvii*) Are we equipped to undertake analyses for scientific control, distribution and use of water in the Indus Basin comprising storage in reservoirs, used in power plants, routing the flow through channels, rivers and links, integrating its use with underground water, to arrange supplies at various points to meet the demands calculated on strict consumptive use?

(*xviii*) What is the optimum groundwater level for various crops in different soils for good plant growth?

(*xix*) For places where we cannot reduce salinity in the root zone, can salt tolerant plants be grown? Have we worked on the physiology of salt tolerance and do we understand clearly the reasons for difference in salt tolerance? Do we know which salt resistance plants can tolerate what range of concentration of salt at various stages of development?

(*xx*) Have we any work on cheap methods of desalinisation of water?

(*xxi*) Have we effective means of control and elimination of mass and weeds of different varieties usually met with in our country?

(*xxii*) Have we got a means of accurately estimating the storage capacity of an aquifer, field method for measuring moisture control, movement of water in unsaturated zone, etc.?

(*xxiii*) Have we accurately measured vertical permeability to distinguish from horizontal permeability and account for it in our flow problems?

(*xxxiv*) Have we instituted a scientific economic appraisal of irrigation water, taken from surface flow, or underground reservoir by means of different types of irrigation? What are relative costs of different types of drainage measures?

While discussing organizational applied research, the author stressed for a research policy and a research programme. Training of research workers and their services condition, basic and research financing and dissemination of research results. He gave instances of the facilities in other departments in comparison to those existing for the Research Institute. The paper contains several Organizational Charts.

PAPER No. 78

Hydraulic Research in West Pakistan

By Khalid Mahmood

The author divided his paper into seven parts. He stressed the importance of Hydraulic Research in irrigated agriculture and reviewed briefly the hydraulic research with regard to its mode and impact together with classification of the research problems. He put forth at length with regard to model studies as an important tool of a Hydraulic Research. Under this head he discussed the Hydraulic Similitude, Distorted Models, Dimensional Analysis and Model Verification etc. Under the head of Organisation of Hydraulic Research in West Pakistan the author gave a Historical Review of the Research Organization and its growth since independence. He discussed the growth of staff, number of model studies, submission of technical reports and the work load per worker. The difficulty of proper utilization of staff and attracting suitable talent together with financing, were discussed under problems financing hydraulic research in the country. Before giving the conclusions which are reproduced in this note, the author discussed the function of a Provincial Research Council, its constitution and functions. In conclusion, the author said that the present and future prosperity of West Pakistan depends on the successful maintenance of its existing irrigation system and on an increasing exploitation of its land and water resources. A successful irrigation system needs, among other things, adequate diversion of water supplies and their efficient conveyance. The gaps in the scientific knowledge, about the laws of hydraulic—especially the hydraulics of alluvial streams, call for an ever-growing research efforts in this field. The present status of hydraulic research in West Pakistan is modest and needs considerable expansion in the basic and applied fields.

The essential component of any research programme is the research worker. To accelerate the research activity in West Pakistan, prospects in this field have to be improved to attract suitable talent. In view of our limited economic and manpower resources, efforts in research can be made fruitful only if a systematic programme based on the considerations of research needs and priorities is pursued. The financing of research has always been a vexing problem. This can be solved by levying charges on the agencies utilising the results of hydraulic research.

The research needs of the two provinces of Pakistan are different and as such it is necessary to develop the hydraulic research in both the wings independently, with a general coordinating role vested in the newly created National Research Council. Within the provinces, Research Councils need to be set up on the lines of the existing National Council to boost up the research in hydraulics.

PAPER No. 79

Hydraulic Model Research for I. B. P.

By C. Van Beesten.

The Indus Basin Projects produced many problems to be solved in a short space of time. Facilities for Hydraulic Research existed in West Pakistan. The Irrigation Research Institute with Laboratories at Lahore and Nandipur could undertake a large programme of studies. It had a long experience on problems similar to be studied for Indus Basin Project. However, the facilities were considered inadequate with respect to instrumentation, number of ex-

perienced research workers, and all weather arrangements for the open air field station. An agreement was reached between the Irrigation Department, WAPDA for undertaking model studies in the Research Institute. The assistance of two expatriate was also provided. The main Project to be investigated dealt with the Mangla Dam Project and the new Barrages, *i.e.*, Sidhnai, Mailsi, Rasul, Qadirabad, Marala and Chashma. It has also to tackle some of the link problems. In the paper, detail of specific studies conducted for Mangla Dam and other Projects are mentioned. The list of studies conducted or underway is given at the end.

PAPER No. 80

Research on Water and Land for Survival

By Dr. Nazir Ahmad

The author at the outset pointed out that very few countries of the world are gifted with such vast natural resources of water and land as is West Pakistan. Diversion of about 84 million acres feet of water to 30 million acres of land has naturally created immense problems, the most devastating and menacing of all is the waterlogging and salinity. The Irrigation Research Institute has during its 40 years of existence devoted itself to understanding and solving many of the problems. One of the important means to quickly exploit the groundwater resources has been the tubewells. The Irrigation Research Institute started understanding the problems connected with the tubewells installation from 1936 onwards. Innumerable suggestions with regard to the installation of durable, long life, cheap tubewells, suitable for the conditions of West Pakistan, have been put forth from the Institute. The groundwater which is a precious mineral and has accumulated in the vast reservoir of the Indus formations during the last several centuries, is a gift of God which has been used since ages. It is only recently that with the development of the tubewell, its extensive exploitation has started and the understanding of the problems with regard to the sub-soil flow, accumulation of water in saline zones, creation of good water quality areas have been studied by the Research Institute.

The country has limited sources of water. It has to look to all sources of wastage. In this connection the Research Institute has worked out on the determination of the water lost from the soil, from free water surface and from crops and plants as a result of evaporation and transpiration and has been suggesting measures to save this water. In this connection the seepage estimation and the lining of canals has also been a subject of contribution from the Research Institute. The Institute could deliver much more useful information, had it been properly staffed and certain facilities of training had been created.

PAPER No. 81

Water Conservation Studies for West Pakistan

By Nazir Ahmad

West Pakistan surface water resources are limited to 140 maf. Out of this 83.5 maf. are being diverted to irrigation canals for crops production. The present estimate is that 36.4 maf. of this diversion seeps underground and 13.4 maf. are evaporated or wasted. This loss is about 60 per cent of the total diversion. Only 40 per cent of the water let into the canals is being used for the production of crops.

In this paper it is shown that at present there is no evidence about the deep percolation of 50,000 cusecs of seeping water.

On the other hand there are strong reasons to believe that this loss is being disposed of as evaporation from free water surface, evaporation from soil and excess evapo-transpiration by plants.

It is also shown that reducing free water surface evaporation and taking down the watertable to 15-20 ft. below surface, are measured by which a large component of loss by seepage and evaporation can be conserved and utilized. Although soil sealants, which can reduce percolation of earthen canals, are now giving promising results both with regard to reduction of seepage and cost, yet with the development of cheap tubewells, perhaps the reduction of seepage and consequent reduction of recharge of the aquifer may not now be permissible.

The author has summarised his main conclusions which are as under:—

1. At present (1966), 83.5 maf. of water is diverted into the irrigation canals of the country.

2. The transit losses which include seepage as well as evaporation and wastage, both from canal system and fields, as estimated by Kennedy, Benton, Revelle, Panel of Scientists and Harza, are shown in the form of a table, below.

According to Harza's latest estimate, 49.8 maf. of water being 58.5% of that let into the canals, is lost both as seepage and evaporation plus wastage.

3. Out of 49.8 maf. or about 68400 cusecs of losses, seepage is about 50,000 cusecs and the rest is evaporation and wastage.

4. There is yet little information about the disposal of 50,000 cusecs of seepage. The consideration of rise of groundwater levels, its salinity accumulation, existence of underground bed rocks and subterranean ridges in former Punjab, Sukkur and Kotri and the nature of the alluvium formation, all point to the fact that the disposal is not by deep underground flow but is due to other causes.

These are:

(*i*) the evaporation loss from free water surface.

(*ii*) evaporation loss from soil due to high watertable,

(*iii*) Evapo-transpiration loss by crops, weeds and trees,

Sources of loss	Kennedy		Benton		Harza		Revelle	
	%	Maf.	%	maf.	%	maf.	%	maf.
Canal system ..	47	39.2	42.7	35.6	..	..	..	..
Field ..	25	20.8	19.1	15.9	..	..	..	..
Seepage from C. system					42.6	36.4	29.7	25.4
Evaporation & wastage					15.6	13.4	14.65	12.5
Total ..	76	63.4	61.6	52.4	58.5	49.8	44.5	37.9

5. It is shown by actual figures that the above three items are the means for the disposal of not only a major component of the seepage but also of evaporation component as well.

6. It is shown that:—

(*a*) the use of evaporation reducing materials can save a certain portion of the water, being lost from free water surface.

(*b*) lowering the ground watertable to 15-20 ft. below surface will, reduce the evaporation and evapotranspiration loss from the soil and by plants etc.

7. Development of soil sealant is promising and will be a useful and cheap means to reduce percolation but it is yet a question whether in the face of development of cheap type of tubewells, it will at all be feasible to line the earthen canals and thus reduce recharge to the aquifer.

PAPER No. 82

Impact of Irrigation Research on the Developing Economy of West Pakistan

By Mohd Hussain and Nur-ud-Din Ahmed

In this paper the authors have enumerated the contributions of Land Reclamation Directorate to the solution of the problems of Soil and Water of the country. They have discussed at length, the results achieved by research. After establishing standards of deteriorated and reclaimed lands, the suitability of water for irrigation is discussed in terms of the latest conception and those of earlier periods. While discussing consumptive use of water, the anuthors have discussed at length, the Lysimeter methods for determining the Soil Moisture and other related problems. The effect of salinity on crop yield has been discussed. The main conclusions of the authors based upon long and continuous research work are:—

(*i*) that the existing water allowance for irrigated lands in the Indus plains is not adequate to meet the consumptive use and moisture requirement of crops;

(*ii*) that the problem of soil salinity has resulted from low water delta use for irrigation and improper levelling and the unscientific use of the available water supplies;

(*iii*) that for keeping the soil, free of excess of salts and to maintain the permanency of the irrigated agriculture, it is necessary that about 10-20% of water over and above the consumptive use requirements should be provided for soil leaching requirements.

(*iv*) that the existing water delta of 2'-3' which is used at present should be increased by about 100% for sustained agriculture and for keeping the soil free from harmful salts; and

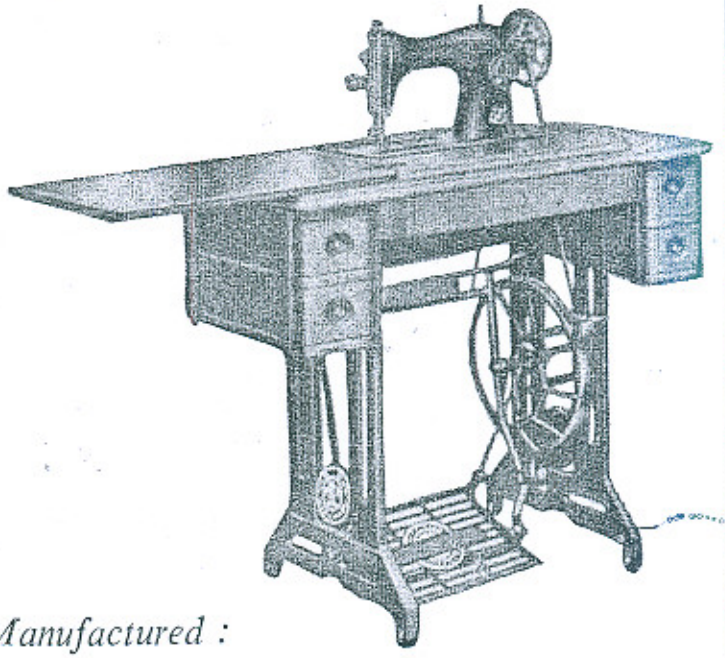
(*v*) that for proper crop production equal attention should be paid to efficient drainage system and the sub-soil water must be maintained below the root zone depth of the crops.

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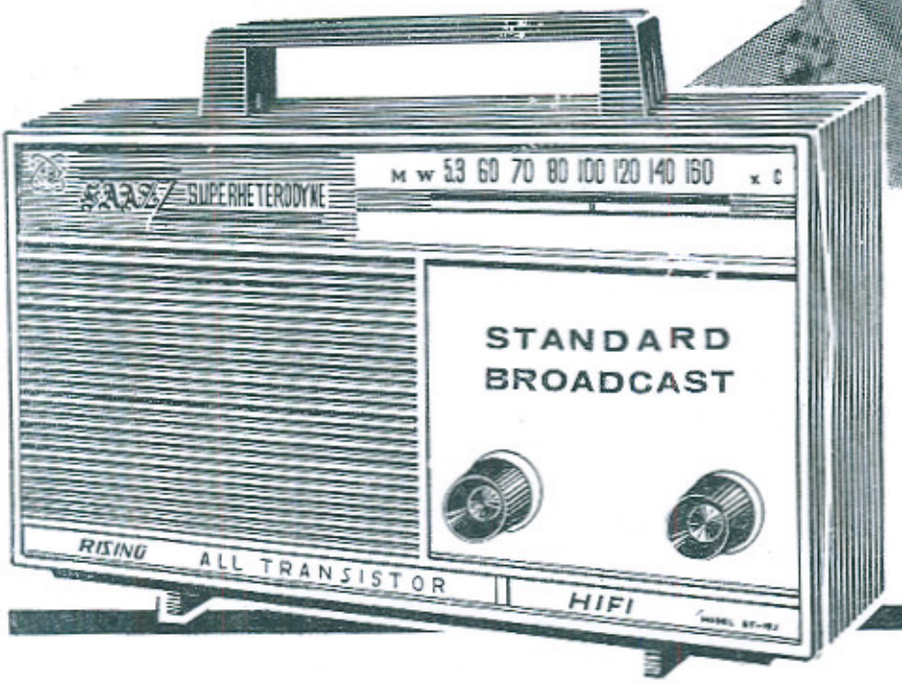
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