valley soils have a high potential for irrigation. The overall potential of this land for irrigation is therefore moderate. Less than half of the area is currently under irrigation. The major part is at present predominantly used for poor grazing and could be further developed by small-scale tubewell irrigation of the better soils which occupy approximately one-third of the total area. Crop yields are expected to be high. Adequate safeguards will be necessary to ensure that the sandy ridges are neither devegetated nor disturbed. The deep ground water is of good quality in most of this land and could be used for irrigation. This is not possible in parts of southern area because of poor quality ground water. Extension of canal irrigation is not recommended because of the predominantly sandy nature of the soils, long distances of distributaries required and the resultant high losses of water through seepage. Tubewells are needed in currently canal-irrigated areas to lower the water-table. This additional source of irrigation could be used for one cropping season and thus canal supplies could be limited to the other season. This would assist in lowering the water-table and the water thus saved could be used on better soils elsewhere. Present yields from the canal irrigated areas are moderate and could be increased by improved management. The remainder of the land that has moderate potential under irrigation suffers from a high water-table and the resultant surface salinity and alkali. Drainage is problematic due to the low-lying nature of the terrain. Investigations are required to ascertain if the drainage problems can be overcome before any large-scale reclamation measures are initiated. Part of this land is currently served by perennial canals and part is dry-farmed.

The extreme eastern subhumid part of Sialkot district has a *moderate economic potential under dry-farming*. Higher returns from this land could be obtained by application of balanced fertilizers, especially phosphates. In addition, modern management and emphasis on summer cropping by introduction of high-yielding varieties of millets and pulses would be beneficial.

Narrow belts of land along major rivers and hill-torrents have *moderate economic potential under flood-watering*. They are mainly used for wheat in winter and locally millets in summer. Due to the seasonal flooding hazard, large-scale improvement of this land is not feasible. Isolated high areas which are relatively free from the damaging floods could be irrigated by tubewells and used for general cropping.

Some areas in Thal consist of *land with a low to moderate overall economic potential for irrigation*, at present mainly used for poor grazing. Sandy ridges occupy fifty per cent of these areas and the better valley soils comprise twenty per cent of the land. Development by small-scale tubewell irrigation schemes could be initiated but the return would be low.

Small patches in the southern part of Thal comprise *land with a low overall economic potential for irrigation*. Currently the major part is canal irrigated and the remainder is used for poor grazing. Production from both uses of land is low due either to the sandy nature of the soils, or to the presence of dense saline-alkali soils. Additionally, the hazard of high water-table is present over most of the area. This land should not be considered for cultivation. In currently irrigated areas production could be increased by lowering the water-table and with modern management, but this effort is considered to be uneconomic. However, results from the economic appraisal are needed to confirm this assumption. Reclamation of the dense saline-alkali soils is not recommended until cheap supplies of gypsum and excess water (after the full requirements of the better soils have been satisfied) are available.

Locally patches of uneven and somewhat sandy soils occurring in a semiarid climate have *a low economic potential under dry-farming*. They are presently used for wheat, gram and mustard. Tubewells are being installed in areas where ground water is fit for irrigation. Under irrigation most of this land would have moderate to high potential for certain crops. With good management, vegetables and groundnuts would give high yields.

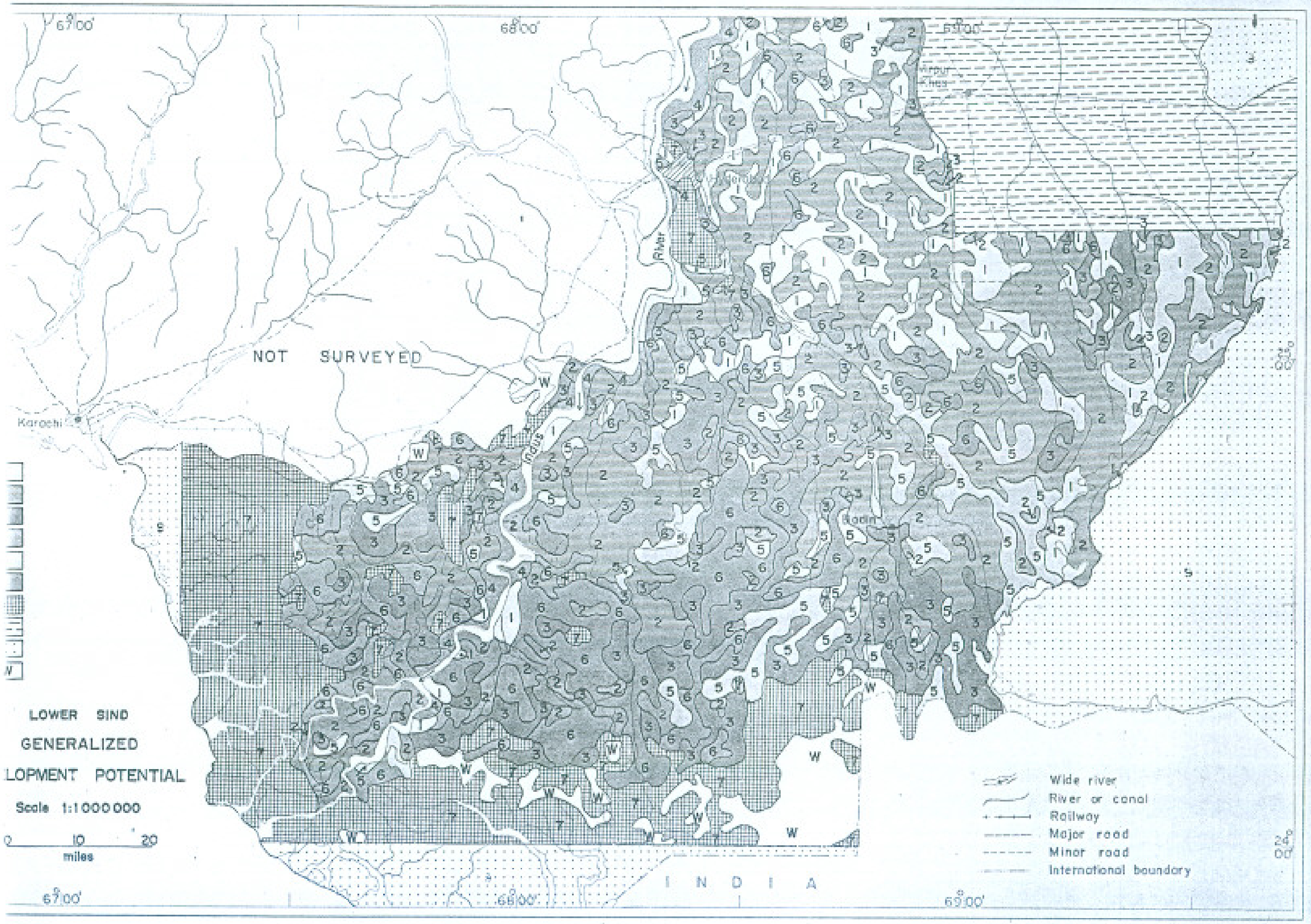
The southern part of Thal also contains *land with a low or no grazing potential with some moderate and poor irrigated land*. It is mainly used for grazing and its overall economic potential for this kind of use is low. The better soils, which are confined to the central parts of the valleys have moderate to high potential, and are irrigated only in small parts. The irrigation could be extended by small-scale tubewell schemes. The soils which occur at the margins of the valleys have low potential and should only be used for shrub planting for supplemental forage. The remainder of this land is unfit for cultivation but must be protected against wind erosion in order to safeguard the valley soils.

A considerable proportion of the entire area is covered by *land with a low economic potential for grazing*. A part of it is dense saline-alkali land. Because of its occurrence in semiarid climate it supports a sparse cover of grasses that are used for poor grazing. Reclamation of this land would entail prohibitively high expenditure on amendments, irrigation water and management. Such reclamation should not be considered until the water requirements of all the better land have been fully satisfied. The dense saline-alkali land could, however, be used for non-agricultural purposes like industry and housing. Also included in this category are patches of very sandy soils. The sandy areas could be used for poor grazing. Parts could be used for establishment of industry or for road-building or as a source of sand.

The dense, strongly saline and alkalisoils occurring in an arid climate constitute agriculturally *unproductive land*. These soils are devoid of any vegetation and are not economic to reclaim. They could best be used for non-agricultural purposes like establishment of industry or housing where possible. Active sand dunes and severely eroded land in arid climate are also included in this land class.

Land with some irrigation potential has only been delineated outside the areas where regular reconnaissance soil survey data are available, on the basis of exploratory survey or general information combined with earlier data (Fraser 1958). Most of this land is under irrigation and its potential for agricultural development ranges from very high to low. Some new irrigable land is also included in the area delineated.

Land without irrigation potential comprises mainly sandy desert, and some of the Salt Range and Salt Range piedmont. It is not practical to supply this land with irrigation water even if a small part of it would give moderate or high yields with irrigation.



NOT SURVEYED
Karachi
River
Indus
INDIA
67°00'
68°00'
69°00'
24°00'
LOWER SIND
GENERALIZED
LOPMENT POTENTIAL
Scale 1:1 000 000
0 10 20
miles
Wide river
River or canal
Railway
Major road
Minor road
International boundary

Lower Sind

In Lower Sind, the ground water is unusable almost throughout the area and canals would be the only source of irrigation supplies. Since water supplies are severely limited and even with full development not all the irrigable land would receive sufficient water, priority should be given to allocation of sufficient irrigation water for intensive cultivation on land with very high or high economic potential. Reclamation of uncultivated, saline areas with moderate potential should only be taken up with surplus-water after fully meeting the requirements of better land. Intensive irrigation development would also require provision of an efficient regional drainage system.

Ten mapping units are described below and delineated on map: agricultural development potential, Lower Sind.

In the following text, terms used for proportions of various kinds of land only indicate relative extent of different categories and of constituents within these categories. For specific areal extent of each kind of soil the summaries of development possibilities and the land capability mapping unit descriptions of the relevant soil survey reports should be referred to.

A considerable extent of the area comprises *land with a very high economic potential under irrigation*, which is highly suited to intensive irrigated cultivation, especially of high-value crops. It is mainly concentrated in the northern part. In the south its occurrence is only patchy, surrounded generally by land with a high economic potential. This land mostly lies at the tail end of the Sukkur Barrage command. It is being used for a variety of crops with perennial canal irrigation, but the present production is much below the optimum due to acute shortage of irrigation supplies and the traditional (poor) level of management. With adequate irrigation water throughout the year and modern management, including cultivation of improved crop varieties and balanced fertilization, total production from these soils could be doubled. A small area in the northern part has usable ground water to about 70 metres depth overlying saline water. If over-pumping is avoided, this water could supplement irrigation supplies through tubewell installation. Elsewhere, water shortage can only be met by increasing canal supplies.

Land with a high economic potential under irrigation constitutes a fair proportion of Lower Sind. Ground water is generally highly saline throughout this part. Most of this land comprises comparatively slowly permeable clayey soils under old irrigated cultivation. These soils have a minor problem of land preparation and a narrower range of suitable crops. Traditional management, inadequacy of irrigation water in the north and a seasonally high water-table in the south are the other limitations to agricultural production. With adequate irrigation supplies and modern management including use of improved tillage implements, proper water management to avoid over-irrigation and provision of field drains, this land would become highly to very highly productive. Emphasis should be on sugarcane or rice and wheat in the north and rice and clovers (a cash crop in this area) in the south. A minor part has silty soils with clayey surface having only a minor problem of land preparation. It could be used for very highly productive intensive cultivation with special care in land preparation preferably by use of improved tillage implements, sufficient irrigation water and a high level of management. Small areas of moderately deep silty soils over clayey or sandy materials are also included in this land. Irrigation practices need to be adapted to avoid temporary waterlogging of the soils over clayey substrata. These require frequent light irrigations. A minor extent of the land has strongly saline, gypsiferous silty soils which could be made highly productive by a few extra irrigations and subsequent intensive irrigated cultivation with modern management.

A large part of the area constitutes *land with a moderate economic potential for irrigation*. Most of it has permeable, gypsiferous, saline or saline-alkali soils, partly with a moderately high water-table. Due to good porosity and a stable subsoil structure, reclamation of these soils is relatively simple, provided sufficient water is available. With heavy irrigations in the initial stages, provision of proper drainage and rice cultivation for a few years, this land could be made capable of producing high yields of sugarcane or rice and a winter crop. A minor extent of this land comprises soils of basin depressions subject to seasonal ponding. Part of it is used for rice cultivation. It needs an efficient drainage system including interceptor drains to take care of irrigation run-off from the adjoining areas. This land could then become highly suitable for rice or sugarcane. Also included in this category are patches of non-saline somewhat sandy soils that would need frequent light irrigations for efficient water management and split applications of relatively high amounts of fertilizers to produce good yields of crops like gram and guara.

On either side of the Indus river there are narrow belts of *land with a moderate economic potential under flood-watering*. It is dominated by silty and clayey soils which are subject to deep flooding in summer. This land could produce at least one good crop per year with a high level of management including use of phosphate fertilizers and improved crop varieties. Areas adjacent to river channels could be provided with supplementary irrigation by lifting water with mobile pumps. Investigations are required to study the possibility of tubewell installation in relatively high areas in the north. Large-scale improvement of this land is not feasible.

The uncultivated southern part of the area contains a fair proportion of land with a moderate to low economic potential for irrigation. It consists of very silty soils which have a slow permeability and a high capillarity, causing rapid return of salts to the surface when left fallow. They usually remain wet even when the water-table is below 1.5 to 2 meters depth. Development of these soils should not be initiated before all the better land is fully developed, because their effective reclamation requires lowering of the water-table beyond three metres, which may not be economically feasible. Besides, they presently serve as 'dry drainage' areas for the adjoining irrigation land. Their reclamation would disturb the present balance between percolation on the irrigated parts and evaporation from these areas, necessitating provision of more drainage capacity.

A minor extent of the area is covered by *land with a low economic potential for irrigation*. It includes dense, saline or saline-alkali silty or clayey soils, and excessively-drained sandy soils, occurring as small islands surrounded by lands with economic potential under irrigation. They are too small to be shown at the scale of the accompanying map. These soils are considered unsuitable for irrigation development due to anticipated low returns. Part of the area is irrigated at present and part is scheduled to receive irrigation supplies in a few years. The most economic recommendation for the area would be to stop irrigation supplies; but this may not be socially acceptable for already irrigated areas. Further extension of irrigation should, however, not be taken up and any available water should be diverted for more intensive cultivation on land with very high or high economic potential. This land also includes seasonally-flooded sandy soils used for low-yielding arable cutivation with residual flood moisture.

Land with a poor grazing potential is fairly extensive and scattered all over the area. Most of it comprises saline, very silty deltaic soils and dense saline-alkali soils, both very difficult and uneconomic to reclaim. There are also some patches of permeable clayey soils that are uneconomic to develop due to their occurrence in small patches scattered in non-irrigable areas. A part consists of sandy soils: part saline, and part seasonally flooded by the river. The remainder comprises perennially wet soils involving prohibitively high expenditure for their drainage, and soils liable to burial by wind-blown sand. This land generally supports a sparse cover of natural scrub, providing rough grazing of poor quality. Unfavourable soil conditions preclude possibility of any agricultural development and it should continue to provide limited grazing. The non-flooded sandy part would be suitable for urban or industrial use.

A large area of Lower Sind consists of *agriculturally unproductive land*. Most of it is in the coastal belt comprising severely saline, wet soils subject to regular flooding by sea tides, coastal plays and tidal creeks and lakes. Other parts are areas of bare rock, open water or shifting sand dunes, and strongly saline or saline-alkali soils either with a high water-table or a dense subsoil. Due to extremely unfavourable soil conditions or the environment these areas are barren and generally not used. They do not have any scope for agricultural development, but could be used locally for non-agricultural purposes like salt production on the coastal land or quarrying of stones from the rocky areas. Large contiguous areas of the rock plain could also be used for siting of industry, housing or other structures.

Land with some irrigation potential has only been delineated outside the areas where regular reconnaissance soil survey data are available, on the basis of exploratory survey or general information combined with earlier data (Hunting Ltd. and Macdonald 1966/7 and Fraser 1958). Most of this land is under irrigation and its potential for agricultural development ranges from very high to low. Some non-irrigable land is also included in the areas delineated.

Land without irrigation potential comprises mainly arid sandy desert.

Acreage of canal commands by land Capability Subclass

Gross areas of canal commands by land capability subclasses, ground water zone and main climate are presented in the following tables. The information is based on the evaluation of findings of surveys completed up to December 1970. The data are tabulated by canal command to facilitate correlation with agricultural development possibilities appraised by other agencies. Detailed evaluations of development possibilities within each survey area are given in reconnaissance soil survey reports which have already been issued to Government and semi-Government agencies concerned with use of land, and which are available from the West Wing Directorate, Central Soil Research Institute (Soil Survey Project of Pakistan), Lahore.

The information presented in the tables will be expanded to other areas as more survey data become available. This basic information can be further interpreted for various uses. One example of such interpretation is a separate paper on economics of water use in the irrigated plains of West Pakistan (Ashraf, Brinkman and Rafiq 1971).

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Marala-Ravi Link	<1000	Sialkot	subhumid	145.1	25.5	—	—	20.1	—	25.1	—	—	—	2.0	1.5	—	—	31.8	8.9
B.R.B.D.	<1000	Sialkot	subhumid	191.9	11.5	—	—	76.8	0.6	56.2	—	—	1.2	0.3	6.3	—	—	3.9	6.6
	<1000	Sheikhupura	subhumid	335.4	30.1	—	—	7.5	—	107.1	10.6	—	—	—	53.0	—	—	—	—
Total				527.2	41.6	—	—	84.3	0.6	163.3	10.6	—	1.2	0.3	59.3	—	—	3.9	6.6
Upper Chenab	<1000	Gujranwala	subhumid	330.0	53.6	—	—	68.1	5.1	111.4	—	—	1.5	2.0	10.0	—	—	—	25.0
	<1000	Sheikhupura	main semiarid	481.9	60.0	—	—	17.1	4.7	182.4	21.4	—	—	2.1	51.6	—	—	—	—
Total				811.9	113.6	—	—	85.2	9.8	393.8	21.4	—	1.5	4.1	61.6	—	—	—	25.0
Lower Chenab	<1000	Gujranwala	main semiarid	248.7	85.0	—	—	34.2	9.7	12.8	1.3	—	0.6	26.2	16.7	—	—	0.2	2.2
	<1000	Sheikhupura	main semiarid	259.0	55.8	—	—	11.1	3.3	89.9	24.4	—	—	4.8	56.7	—	—	—	—
	<1000	Lyallpur	half main, half dry	722.9	452.4	—	11.4	19.4	21.4	78.4	—	—	—	—	35.2	—	—	—	—
	<1000	Jhang	semiarid	449.5	184.9	—	—	13.2	17.1	120.0	0.9	—	—	8.2	11.4	—	—	—	—
	1000-2000	Sheikhupura	main semiarid	295.2	102.7	—	—	12.2	1.8	40.3	30.3	—	—	7.5	51.4	—	—	—	—
	1000-2000	Lyallpur	half main, half dry	821.2	536.3	—	5.4	74.5	51.0	24.9	—	—	10.5	—	44.5	—	—	—	—
	1000-2000	Jhang	semiarid	65.8	22.2	7.9	—	1.1	3.3	10.9	0.1	—	—	1.5	3.4	—	—	—	—
	>2000	Sheikhupura	main semiarid	16 0	9,3	—	—	0.8	0.1	0.1	0.6	—	—	0.6	2.5	—	—	—	—
	>2000	Lyallpur	half main, half dry	709.6	496.9	8.8	6.7	46.5	67.4	17.4	—	—	4.1	—	18.2	—	—	—	—
	>2000	Jhang	semiarid	105.0	40.6	—	—	0.5	9.7	15.7	0.3	—	—	2.7	4.9	—	—	—	—
Total				3732.9	1986.2	16.7	23.5	213.6	184.9	410.4	58.0	—	15.2	51.5	245.0	—	—	0.2	2.2
Haveli	<1000	Jhang	main arid	98.4	30.4	—	—	2.3	1.6	19.4	—	—	—	0.9	16,1	—	—	—	—
	1000-2000	Jhang	main arid	27.0	11.9	—	—	1.6	0.7	6.2	—	—	—	0.4	1.8	—	—	—	—
	>2000	Jhang	main arid	71.3	21.7	—	—	12.6	2.4	15.4	0.3	—	—	1.4	3.4	—	—	—	—
Total				196.7	64.0	—	—	16.5	4.7	41.0	0.3	—	—	2.7	21.2	—	—	—	—

All figures in thousands of acres GR

Canal command	Ground water (ppm salts)	District	Main climate	Total area	irI	irIIe	irIIr	irIIw	irIIs (sandy)	irIIs (clayey)	irIIa	irIIIe	irIIIw	irIIIs	irIIIa	irIIIa (high WT)	dIIIe	dIIIw	d
Peshawar Vale																			
Upper Swat	<1000	Mardan	1/3 subhumid, 2/3 main semiarid	401.1	142.1	—	—	79.4	—	8.7	—	46.5	—	24.9	1.5	20.0	—	—	-
Lower Swat	<1000	Mardan	main semiarid	248.8	114.2	—	—	53.4	0.6	1.4	—	26.0	4.3	3.7	0.7	17.2	—	—	-
Kabul River	<1000	Peshawar	main semiarid	117.6	35.4	3.3	—	38.0	1.6	—	—	—	12.2	2.4	7.0	1.6	—	—	-
Warsak High Level	<1000	Peshawar	main semiarid	98.6	50.8	6.6	—	14.1	—	—	—	—	—	3.3	—	—	—	—	
Chaj Doab																			
Upper Jhelum	<1000	Gujrat	subhumid	584.9	265.0	—	—	—	—	201.1	—	—	—	5.2	0.8	—	—	4.7	1:
	1000-2000	Gujrat	subhumid	85.8	44.8	—	—	—	—	36.2	—	—	—	—	—	—	—	—	
	Total			670.7	309.8	—	—	—	—	237.3	—	—	—	5.2	0.8	—	—	4.7	15
Lower Jhelum	<1000	Gujrat	main semiarid	128.0	9.2	—	—	—	—	2.2	—	—	—	1.3	—	—	—	—	
	<1000	Sargodha	main semiarid	334.0	169.3	—	—	—	—	124.8	—	—	—	8.6	6.1	7.8	—	—	
	<1000	Jhang	dry semiarid	414.9	171.9	—	—	3.4	24.3	78.9	0.9	—	—	7.8	45.4	—	—	0.1	
	1000-2000	Sargodha	main semiarid	177.6	106.3	—	—	—	—	52.4	—	—	—	5.9	4.0	2.9	—	—	
	1000-2000	Jhang	dry semiarid	33.7	12.6	—	—	0.3	1.2	5.3	0.2	—	—	0.5	2.8	—	—	—	
	>2000	Sargodha	main semiarid	488.6	328.0	—	—	—	—	103.4	—	—	—	28.9	9.7	5.1	—	—	
	>2000	Jhang	dry semiarid	4.0	1.0	—	—	—	0.1	0.4	—	—	—	—	0.1	—	—	—	
	Total			1580.8	798.3	—	—	3.7	25.6	367.4	1.1	—	—	53.2	68.1	15.8	—	0.1	
Rechna Doab																			
Marala-Ravi Link	<1000	Sialkot	subhumid	145.1	25.5	—	—	20.1	—	25.1	—	—	—	2.0	1.5	—	—	31.8	
B.R.B.D.	<1000	Sialkot	subhumid	191.9	11.5	—	—	76.8	0.6	56.2	—	—	1.2	0.3	6.3	—	—	3.9	
	<1000	Sheikhupura	subhumid	335.4	30.1	—	—	7.5	—	107.1	10.6	—	—	—	53.0	—	—	—	
	Total			527.2	41.6	—	—	84.3	0.6	163.3	10.6	—	1.2	0.3	59.3	—	—	3.9	
Upper Chenab	<1000	Gujranwala	subhumid	330.0	53.6	—	—	68.1	5.1	111.4	—	—	1.5	2.0	10.0	—	—	—	
	<1000	Sheikhupura	main semiarid	481.9	60.0	—	—	17.1	4.7	182.4	21.4	—	—	2.1	51.6	—	—	—	

GROSS AREAS OF CANAL COMMANDS BY LAND CAPABILITY SUBCLASS, GROUND WATER ZONE AND MAIN CLIMATE

dIIIw	dIIIc	irIVs	irIVa	dIVe	dIVw	dIVs	dIVc	VIw	VIIe	VIIw	VIIs	VIIs (high WT)	VIIa	VIIc	VIIIe	VIIIw	VIIIs	VIIIs (high WT)	VIIIa	River-bed	Urban land	Misc.	NPC
—	—	2.1	—	—	—	33.0	—	—	19.2	—	4.9	—	—	—	—	—	14.0	—	—	—	—	—	—
—	—	0.4	—	—	—	14.6	—	—	9.6	—	0.4	—	—	—	0.4	—	1.5	—	—	—	—	—	—
—	—	0.3	—	—	—	0.7	—	11.4	0.3	—	0.3	—	—	—	2.9	—	0.1	—	—	—	—	—	—
—	—	—	—	—	—	9.3	—	0.3	1.2	—	6.6	—	—	—	2.8	—	2.5	—	—	—	—	—	—
4.7	15.2	23.2	41.9	—	—	9.2	—	—	18.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	4.4	—	—	—	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
.7	15.2	27.6	41.9	—	—	9.5	—	—	18.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	4.4	13.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
.1	—	—	2.7	0.1	—	18.0	—	—	1.3	—	27.9	—	23.1	5.3	—	—	—	—	1.6	—	—	2.2	—
—	—	2.0	4.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	0.1	—	—	3.0	—	—	0.2	—	2.6	—	1.0	1.0	—	—	—	—	—	—	—	2.9	—
—	—	7.4	6.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	0.6	—	—	—	—	0.2	—	—	0.2	—	—	—	—	—	—	—	1.3	—
.1	—	13.9	25.9	0.1	—	21.6	—	—	1.5	—	30.7	—	24.1	6.5	—	—	—	—	1.6	—	—	6.4	—
.8	8.9	—	2.6	—	—	25.7	—	—	—	—	—	—	1.9	—	—	—	—	—	—	—	—	—	—
.9	6.6	—	4.6	0.1	—	3.3	—	—	—	—	—	—	20.5	—	—	—	—	—	—	—			

	—	[illegible]	[illegible]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	0.1	—	—	3.0	—	—	0.2	—	2.6	—	1.0	1.0	—	—	—	—	—	—	—	2.9	—
—	—	7.4	6.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	0.6	—	—	—	—	0.2	—	—	0.2	—	—	—	—	—	—	—	1.3	—
0.1	—	13.9	25.9	0.1	—	21.6	—	—	1.5	—	30.7	—	24.1	6.5	—	—	—	—	1.6	—	—	6.4	—
1.8	8.9	—	2.6	—	—	25.7	—	—	—	—	—	—	1.9	—	—	—	—	—	—	—	—	—	—
3.9	6.6	—	4.6	0.1	—	3.3	—	—	—	—	—	—	20.5	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	0.1	0.8	—	—	—	2.2	—	123.7	—	—	—	—	—	—	—	—	0.2	—
3.9	6.6	—	4.6	0.1	—	3.4	0.8	—	—	—	2.2	—	144.2	—	—	—	—	—	—	—	—	0.2	—
—	25.0	—	4.9	0.8	—	—	—	—	—	—	—	—	28.8	—	—	—	—	—	—	—	—	—	18.9
—	—	—	—	—	—	—	5.0	—	—	—	1.1	—	135.7	—	—	—	—	—	—	—	—	0.8	—
—	25.0	—	4.9	0.8	—	—	5.0	—	—	—	1.1	—	164.5	—	—	—	—	—	—	—	—	0.8	18.9
0.2	2.2	—	2.8	—	—	0.2	16.3	—	—	—	—	—	41.2	—	—	1.5	—	—	—	—	—	—	—
—	—	—	—	—	—	0.6	10.1	—	—	—	—	—	41.3	—	—	—	—	—	—	—	—	1.0	—
—	—	—	26.1	—	—	—	—	—	—	—	3.0	—	2.5	—	—	—	36.0	—	—	36.2	0.7	—	—
—	—	0.2	1.2	—	—	18.0	5.1	—	6.6	—	27.5	—	13.8	4.7	—	—	6.3	—	2.5	—	—	7.6	—
—	—	—	—	—	—	0.3	4.6	—	—	—	—	—	42.4	—	—	—	—	—	—	—	—	1.6	—
—	—	—	5.8	—	—	—	—	—	—	—	3.5	—	53.8	—	—	—	0.1	—	—	—	2.0	—	—
—	—	—	0.3	—	—	2.2	0.3	—	0.3	—	9.2	—	4.3	—	—	—	4.1	—	0.9	—	—	1.6	—
—	—	—	—	—	—	—	—	—	—	—	—	—	1.9	—	—	—	—	—	—	—	—	0.2	—
—	—	—	4.2	—	—	—	—	—	—	—	—	—	5.4	—	—	—	23.3	—	—	—	10.6	—	—
—	—	—	0.2	—	—	4.8	—	—	1.0	—	10.7	—	8.6	1.3	—	—	1.5	—	2.4	—	—	0.1	—
0.2	2.2	0.2	40.6	—	—	26.1	34.4	—	7.9	—	53.9	—	215.2	6.0	—	1.5	71.2	—	5.8	36.2	13.3	12.1	—
—	—	—	1.0	0.2	—	1.1	—	—	—	—	1.1	—	8.8	—	—	—	—	—	10.3	—	—	5.3	—
—	—	—	0.1	—	—	0.1	—	—	—	—	0.9	—	3.1	—	—	—	—	—	—	—	—	0.1	—
—	—	—	0.5	0.7	—	1.5	—	—	0.2	—	4.5	—	6.8	0.1	—	—	—	—	—	—	—	—	—
—	—	—	1.6	0.9	—	2.6	—	—	0.2	—	6.6	—	18.7	0.1	—	—	—	—	10.3	—	—	5.4	—

Central Bari Doab	<1000	Lahore	main semiarid	212.2	128.1	—	—	24.1	9.6	7.0	3.8	—	5.1	1.1	2.1	—	—	—	—
	1000-2000	Lahore	main semiarid	203.9	151.3	—	—	13.3	3.4	12.7	3.2	—	4.1	2.2	2.6	—	—	—	—
	>2000	Lahore	main semiarid	266.5	244.6	—	—	—	14.2	1.0	1.5	—	—	—	—	—	—	—	—
Total				682.6	524.0	—	—	37.4	27.2	20.7	8.5	—	9.2	3.3	4.7	—	—	—	—
Lower Bari Doab	<1000	Lahore	main semiarid	26.0	9.8	—	—	—	2.1	6.4	0.1	—	—	—	4.9	—	—	—	—
	<1000	Sahiwal	dry semiarid	565.6	333.7	—	—	—	67.1	34.6	29.6	—	—	—	23.9	—	—	—	—
	<1000	Multan	main arid	558.9	163.3	—	—	—	—	115.5	17.9	—	—	2.4	126.9	—	—	—	—
	1000-2000	Sahiwal	dry semiarid	218.9	138.4	—	—	—	12.8	13.0	9.7	—	—	0.2	15.4	—	—	—	—
	1000-2000	Multan	main arid	71.7	29.0	—	—	—	—	10.5	1.3	—	—	—	11.9	—	—	—	—
	>2000	Sahiwal	dry semiarid	184.6	105.6	—	—	—	12.5	11.7	6.3	—	—	0.2	21.2	—	—	0.1	—
	>2000	Multan	main arid	85.1	27.6	—	—	—	—	27.8	—	—	—	—	23.7	—	—	—	—
Total				1710.8	807.4	—	—	—	94.5	219.5	65.9	—	—	2.8	227.9	—	—	0.1	—
Sidhnai	<1000	Multan	main arid	445.6	47.3	—	—	—	—	225.2	2.3	—	—	4.1	128.4	—	—	—	—
	1000-2000	Multan	main arid	40.6	4.3	—	—	—	—	26.3	—	—	—	—	7.2	—	—	—	—
	>2000	Multan	main arid	82.0	18.6	—	—	—	—	33.2	—	—	—	—	18.6	—	—	—	—
Total				568.2	70.2	—	—	—	—	284.7	2.3	—	—	4.1	154.2	—	—	—	—
Pakpattan	<1000	Sahiwal	dry semiarid	531.2	149.5	—	—	—	66.6	176.2	20.8	—	—	3.7	64.0	—	—	0.7	—
	<1000	Multan	main arid	494.6	159.3	—	6.2	—	2.6	160.7	8.9	—	—	—	123.8	—	—	—	—
	1000-2000	Sahiwal	dry semiarid	57.0	16.6	—	—	—	9.5	9.0	1.7	—	—	0.5	10.9	—	—	—	—
	1000-2000	Multan	main arid	107.3	44.5	—	0.1	—	—	22.4	4.8	—	—	—	16.7	—	—	—	—
	>2000	Sahiwal	dry semiarid	33.6	6.3	—	—	—	3.1	9.5	1.0	—	—	0.5	9.8	—	0.7	—	0.1
	>2000	Multan	main arid	210.6	70.2	—	0.4	—	—	53.0	6.3	—	—	—	32.3	—	—	—	—
Total				1434.3	446.4	—	6.7	—	81.8	430.8	43.5	—	—	4.7	257.5	—	0.7	0.7	0.1
Mailsi	<1000	Multan	main arid	410.5	151.2	—	4.0	—	—	125.2	13.0	—	—	—	83.5	—	—	—	—
	1000-2000	Multan	main arid	55.9	19.6	—	0.2	—	—	18.0	1.3	—	—	—	9.4	—	—	—	—
	>2000	Multan	main arid	254.5	81.7	—	0.2	—	—	41.7	6.4	—	—	—	36.7	—	—	—	—
Total				720.9	252.5	—	4.4	—	—	184.9	20.7	—	—	—	129.6	—	—	—	—

All figures in thousands of acres

GRC

Canal command	Ground water (ppm salts)	District	Main climate	Total area	irI	irIIe	irIIr	irIIw	irIIs (sandy)	irIIs (clayey)	irIIa	irIIIe	irIIIw	irIIIs	irIIIa	irIIIa (high WT)	dIIIe	dIIIw	dII
Bari Doab																			
Upper Dipalpur (above B.S. Link)	<1000	Lahore	main semiarid	303.9	90.2	—	—	—	89.0	47.8	17.9	—	—	5.6	21.5	—	—	—	—
	<1000	Sahiwal	dry semiarid	92.5	14.7	—	—	—	15.0	42.6	2.6	—	—	0.1	7.6	—	—	0.7	—
	1000-2000	Lahore	main semiarid	19.6	2.3	—	—	—	3.0	1.1	1.7	—	—	—	9.1	—	—	0.2	—
	>2000	Lahore	main semiarid	8.2	0.6	—	—	—	0.4	0.1	0.3	—	—	—	4.9	—	—	0.1	—
Total				424.2	107.8	—	—	—	107.4	91.6	22.5	—	—	5.7	43.1	—	—	1.0	—
Lower Dipalpur (below B.S. Link)	<1000	Sahiwal	dry semiarid	312.3	71.4	—	—	—	44.2	118.8	10.2	—	—	0.7	34.9	—	—	0.8	—
	1000-2000	Sahiwal	dry semiarid	239.6	53.8	—	—	—	25.7	99.7	8.7	—	—	0.8	21.5	—	—	0.4	—
	>2000	Sahiwal	dry semiarid	21.6	2.8	—	—	—	2.4	6.1	0.2	—	—	0.1	4.9	—	—	0.3	—
Total				573.5	128.0	—	—	—	72.3	224.6	19.1	—	—	1.6	61.3	—	—	1.5	—
Central Bari Doab	<1000	Lahore	main semiarid	212.2	128.1	—	—	24.1	9.6	7.0	3.8	—	5.1	1.1	2.1	—	—	—	—
	1000-2000	Lahore	main semiarid	203.9	151.3	—	—	13.3	3.4	12.7	3.2	—	4.1	2.2	2.6	—	—	—	—
	>2000	Lahore	main semiarid	266.5	244.6	—	—	—	14.2	1.0	1.5	—	—	—	—	—	—	—	—
Total				682.6	524.0	—	—	37.4	27.2	20.7	8.5	—	9.2	3.3	4.7	—	—	—	—
Lower Bari Doab	<1000	Lahore	main semiarid	26.0	9.8	—	—	—	2.1	6.4	0.1	—	—	—	4.9	—	—	—	—
	<1000	Sahiwal	dry semiarid	565.6	333.7	—	—	—	67.1	34.6	29.6	—	—	—	23.9	—	—	—	—
	<1000	Multan	main arid	558.9	163.3	—	—	—	—	115.5	17.9	—	—	2.4	126.9	—	—	—	—
	1000-2000	Sahiwal	dry semiarid	218.9	138.4	—	—	—	12.8	13.0	9.7	—	—	0.2	15.4	—	—	—	—
	1000-2000	Multan	main arid	71.7	29.0	—	—	—	—	10.5	1.3	—	—	—	11.9	—	—	—	—
	>2000	Sahiwal	dry semiarid	184.6	105.6	—	—	—	12.5	11.7	6.3	—	—	0.2	21.2	—	—	0.1	—
	>2000	Multan	main arid	85.1	27.6	—	—	—	—	27.8	—	—	—	—	23.7	—	—	—	—
Total				1710.8	807.4	—	—	—	94.5	219.5	65.9	—	—	2.8	227.9	—	—	0.1	—
Sidhnai	<1000	Multan	main arid	445.6	47.3	—	—	—	—	225.2	2.3	—	—	4.1	128.4	—			

GROSS AREAS OF CANAL COMMANDS BY LAND CAPABILITY SUBCLASS, GROUND WATER ZONE AND MAIN CLIMATE

dIIIw	dIIIc	irIVs	irIVa	dIVe	dIVw	dIVs	dIVc	VIw	VIIe	VIIw	VIIs	VIIs (high WT)	VIIa	VIIc	VIIIe	VIIIw	VIIIs	VIIIs (high WT)	VIIIa	River-bed	Urban land	Misc.	NPC
—	—	—	—	—	0.6	—	—	—	—	0.5	30.8	—	—	—	—	—	—	—	—	—	—	—	—
0.7	—	3.0	—	—	—	0.2	—	—	—	0.1	5.1	0.1	—	—	—	—	0.4	—	0.4	—	—	—	—
0.2	—	—	—	—	—	—	—	—	0.1	0.9	1.3	—	—	—	—	—	—	—	—	—	—	—	—
0.1	—	—	—	—	—	—	—	—	—	1.3	0.3	—	—	—	—	—	—	—	—	—	—	—	—
,0	—	3.0	—	—	0.6	0.2	—	—	0.1	2.8	37.5	0.1	—	—	—	—	0.4	—	0.4	—	—	—	—
,8	—	6.2	—	—	—	0.3	—	—	—	—	14.3	3.7	—	—	—	—	0.2	—	6.6	—	—	—	—
4	—	3.6	—	—	—	1.0	—	—	—	—	19.3	3.2	—	—	—	—	0.8	—	0.9	—	—	—	—
3	—	0.3	—	—	—	0.1	—	—	—	—	2.1	0.7	—	—	—	—	0.1	—	1.5	—	—	—	—
5	—	10.1	—	—	—	1.4	—	—	—	—	35.7	7.6	—	—	—	—	1.1	—	9.0	—	—	—	—
	—	—	—	—	—	—	3.7	—	0.6	0.9	0.1	—	26.1	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	0.1	0.1	—	—	10.9	—	—	—	—	—	—	—	—	—	0.1
	—	—	—	—	—	—	—	—	0.1	0.1	—	—	5.0	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	3.7	—	0.8	1.1	0.1	—	42.0	—	—	—	—	—	—	—	—	—	0.1
	—	—	—	—	—	—	—	—	0.3	—	—	—	2.5	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	7.0	—	—	—	16.6	—	5.1	—	47.1	—	0.6	—	—
	—	—	—	—	—	—	—	—	1.6	—	15.6	—	—	—	42.0	—	—	—	71.4	—	2.2	—	—
	—	0.5	—	—	—	0.1	—	—	—	—	3.7	1.9	—	—	6.3	—	0.6	3.2	10.4	—	2.5	—	—
	—	—	—	—	—	—	—	—	0.4	—	—	—	—	—	9.5	—							
	—	1.4	—	—	—	[illegible]																	

																—	1.1	—	9.0	—	—	—	—
—	—	—	—	—	—	—	3.7	—	0.6	0.9	0.1	—	26.1	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	0.1	0.1	—	—	10.9	—	—	—	—	—	—	—	—	—	0.1
—	—	—	—	—	—	—	—	—	0.1	0.1	—	—	5.0	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	3.7	—	0.8	1.1	0.1	—	42.0	—	—	—	—	—	—	—	—	—	0.1
—	—	—	—	—	—	—	—	—	0.3	—	—	—	2.5	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	7.0	—	—	—	16.6	—	5.1	—	47.1	—	0.6	—	—
—	—	—	—	—	—	—	—	—	1.6	—	15.6	—	—	—	42.0	—	—	—	71.4	—	2.2	—	—
—	—	0.5	—	—	—	0.1	—	—	—	—	3.7	1.9	—	—	6.3	—	0.6	3.2	10.4	—	2.5	—	—
—	—	—	—	—	—	—	—	—	0.4	—	—	—	—	—	9.5	—	—	—	6.6	—	0.1	—	—
.1	—	1.4	—	—	—	0.3	—	—	—	—	5.2	2.0	1.8	—	13.8	—	0.5	0.3	1.7	—	—	—	—
—	—	—	—	—	—	—	—	—	0.1	—	1.2	—	—	—	3.2	—	—	—	1.3	—	0.1	—	—
1	—	1.9	—	—	—	0.4	—	—	2.4	—	35.2	4.0	4.3	—	91.4	—	6.2	3.5	138.5	—	5.5	—	—
—	—	—	—	—	—	—	—	—	0.2	—	2.0	—	—	—	4.0	—	—	—	32.0	—	0.2	—	—
—	—	—	—	—	—	—	—	—	—	—	0.4	—	—	—	0.5	—	—	—	1.9	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	1.8	—	—	—	3.3	—	—	—	6.4	—	—	—	—
—	—	—	—	—	—	—	—	—	0.2	—	4.2	—	—	—	7.8	—	—	—	40.3	—	0.2	—	—
	—	3.3	—	—	—	0.6	—	—	—	—	24.6	12.5	—	—	—	—	1.2	—	7.0	—	—	0.6	—
	—	—	—	—	—	—	—	—	3.5	—	11.6	—	—	—	9.5	—	3.5	—	5.0	—	—	—	—
	—	0.7	—	—	—	0.2	—	—	—	—	3.8	2.3	—	—	—	—	1.4	—	0.5	—	—	—	—
	—	—	—	—	—	—	—	—	0.6	—	2.1	—	—	—	6.6	—	2.1	—	7.5	—	—	—	—
	0.1	—	—	—	—	—	—	—	—	—	1.5	1.0	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	2.7	—	4.9	—	—	—	10.9	—	2.9	—	26.9	—	—	—	—
	0.1	4.0	—	—	—	0.8	—	—	6.8	—	48.5	15.8	—	—	27.0	—	11.1	—	46.9	—	—	0.6	—
	—	—	—	—	—	—	—	—	2.2	—	9.7	—	—	—	7.3	—	5.5	—	8.8	—	—	—	—
	—	—	—	—	—	—	—	—	0.8	—	1.5	—	—	—	2.9	—	0.2	—	2.1	—	—	—	—
	—	—	—	—	—	—	—	—	3.7	—	9.4	—	—	—	14.9	—	1.7	—	58.1	—	—	—	—
	—	—	—	—	—	—	—	—	6.7	—	20.6	—	—	—	25.1	—	7.4	—	69.0	—	—	—	—

All figures in thousands of acres

Canal command	Ground water (ppm Salts)	District	Main climate	Total area	irI	irIIw	irIIs (sandy)	irIIs (clayey)	irIIa	irIIIw	irIIIs	irIIIa	irIII: (high W
Lower Indus													
Khairpur Feeder West	less than 750	Khairpur	main arid	107.5	11.5	0.1	—	60.0	0.1	0.1	2.1	25.8	—
	750—1200	Khairpur	main arid	17.2	0.6	—	—	7.7	—	—	—	6.9	—
	1200—2500	Khairpur	main arid	51.4	4.4	0.1	—	27.5	0.1	—	0.3	14.7	—
	2500—4500	Khairpur	main arid	34.7	4.8	0.5	—	14.0	0.4	—	0.2	10.4	—
	more than 4500	Khairpur	main arid	79.6	8.8	0.6	—	29.4	0.8	0.1	0.5	22.5	—
Khairpur Feeder East	1200—2500	Khairpur	main arid	0.4	—	—	—	0.3	—	—	—	0.1	—
	2500—4500	Khairpur	main arid	58.6	0.6	6.2	—	7.0	—	25.3	1.1	5.5	—
	more than 4500	Khairpur	main arid	416.5	55.8	4.6	—	158.9	3.7	0.2	4.1	53.9	—
Pinyari Feeder	more than 4500	Hyderabad	frost-free arid	4.9	2.4	—	0.2	1.2	0.3	—	0.3	0.4	—
	more than 4500	Thatta East	coastal arid	1271.2	111.3	—	—	495.3	—	—	90.8	12.9	—
Lined Channel (Tando Bago)	more than 4500	Badin	coastal arid	409.0	26.3	—	—	86.8	0.2	14.8	—	203.2	—
Lined Channel (Gaja)		Hyderabad	frost-free arid	2.2	1.2	—	0.1	0.7	1.1	—	0.1	—	—
Fuleli Canal	more than 4500	Hyderabad	frost-free arid	9.6	2.2	—	0.2	1.0	1.5	—	0.6	3.2	—
	more than 4500	Hyderabad	coastal arid	924.6	70.3	—	—	390.4	—	20.7	87.2	174.8	—
Ghotki Feeder	less than 1200	Ghotki	main arid	340.0	62.8	—	6.3	149.2	5.2	—	17.4	53.6	—
	1200—2500	Ghotki	main arid	41.1	9.1	—	1.9	10.7	1.2	—	3.2	9.6	—
	more than 2500	Ghotki	main arid	568.8	82.5	—	5.7	131.0	29.9	—	42.1	129.2	—
Thal Doab Muzaffar Garh Canal	less than 1000	Muzaffargarh	main arid	617.1	50.8	—	2.4	124.3	1.8	—	26.4	37.9	46.0
	1000—2000	Muzaffargarh	main arid	148.7	2.2	—	10.5	4.1	1.4	—	2.1	2.2	2.5
	more than 2000	Muzaffargarh	main arid	196.3	5.1	—	3.4	11.7	5.1	—	1.2	2.9	1.0
Rangpur Canal	less than 1000	Muzaffargarh	main arid	312.8	56.7	2.2	4.0	83.1	3.0	—	1.5	59.4	—
	1000—2000	Muzaffargarh	main arid	19.8	.5	—	—	7.5	—	—	—	4.0	—
	more than 2000	Muzaffargarh	main arid	15.3	.3	—	—	5.1	—	—	—	1.9	—

GROSS AREAS OF CANAL COMMANDS BY LAND CAPABILITY SUBCLASS, GROUND WATER ZONE AND MAIN CLIMATE.

√w	irIVs	irIVx	irIVa	dIVs	dIVc	VIw	VIIe	VIIw	VIIs	VIIs (high WT)	VIIx	VIIa	VIIc	VIIIc	VIIIw	VIIIs	VIIIa	VIIIc	Misc
1	0.7	—	1.8	—	—	0.1	—	—	0.3	0.1	0.3	0.8	—	0.5	0.3	—	—	1.7	—
3	0.1	—	0.4	—	—	—	—	—	—	—	—	0.6	—	0.1	0.2	—	—	0.1	—
6	0.3	—	0.9	—	—	0.1	—	—	0.1	—	0.1	0.6	—	0.2	0.4	—	—	0.7	—
5	0.3	—	1.8	—	—	—	—	—	0.1	—	0.1	1.3	—	0.2	0.2	—	—	0.8	—
8	0.5	—	1.2	—	—	0.2	—	0.2	0.2	0.1	0.2	9.5	—	0.4	1.9	—	—	1.5	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0	—	—	0.5	—	—	0.2	—	0.2	—	—	—	1.5	—	0.2	0.9	—	1.2	0.3	—
8	3.7	—	1.3	—	—	1.5	—	1.4	3.6	0.6	1.5	11.8	—	56.8	12.4	0.6	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	0.3	—	—	—	—	—	31.2	—	—	181.8	—	—	—	—	347.4	—	—
—	—	—	—	—	—	—	—	0.1	7.6	—	—	56.5	—	—	7.0	—	6.3	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	0.2	—	—	—	—	—	0.1	—	0.3	—	—	0.1	10.2	—	26.3	—	—
—	—	—	1.7	—	—	—	—	0.2	14.0	—	—	128.6	—	—	—	—	—	—	—
—	9.0	—	12.3	—	—	—	—	—	—	—	—	—	—	1.9	0.5	—	19.2	1.7	—
—	—	—	1.9	—	—	—	—	—	—	—	—	—	—	0.3	—	—	2.7	0.3	—
—	—	1.8	17.1	—	—	—	—	—	—	—	—	—	—	—	—	—	14.8	16.0	—
0	40.0	—	14.0	0.9	6.3	—	—	—	117.3	24.6	—	59.9	4.5	47.3	0.2	—	4.4	—	—
—	17.0	4.3	3.1		9.3	—	—	—	42.5	0.1	—	8.3	5.7	31.8	—	—	1.5	—	—
—	17.2	—	1.6	3.7	20.1	1.0	—	—	78.7	—	—	2.5	15.2	23.0	0.3	—	2.7	—	—
—	0.7	—	2.6	9.9	—	—	9.9	—	25.7	19.1	2.4	40.1	1.3	—	0.2	0.5	—	—	2.4
—	—	—	—	—	—	—	—	—	0.5	—	—	7.3	—	—	0.4	—	—	—	—
—	—	—	—	—	—	—	—	—	0.3	—	—	7.2	—	—	—	—	—	—	—

I. A. S. Bokhari

The Cigre Conference 1970

By
I. A. S. BOKHARI*

CIGRE is the abbreviation in French for the International Conference on Large High Tension Electric Systems. CIGRE is an important International Association of power system engineers, drawn from Government Departments; Scientific, Technical, Educational and Research Organisations; Industrial and Commercial undertakings etc., throughout the world.

In accordance with its Statutes, the objective of CIGRE is to facilitate the interchange of technical knowledge and data amongst various countries in the field of electricity generation and transmission. Its field of activity covers in particular the following :

(*a*) Electrical aspects of electricity generation;

(*b*) The construction and operation of the sub-stations and transformer stations and their associated equipment ;

(*c*) The construction, insulation and operation of high voltage electrical lines ;

(*d*) The Inter-connection of systems, the operation and protection of inter-connected systems.

The constituent bodies of CIGRE are :

Administrative Bodies

The Council;

The Executive Committee;

National Committees approved by the Council;

The permanent Central Office located at Paris.

Technical Bodies

The Technical Committee;

The Study Committees.

Regular Sessions of Conference take place every two years.

**Managing Director (Power) Water and Power Development Authority, Lahore.*

The 1970 Session of CIGRE was held as usual in Paris. It was attended by 2050 delegates from about 55 countries and international organisations, and the Session lasted from August 24 to September 2. I had the pleasure to lead the Pakistani delegation to this biennial Session. The delegation included Mr. Imtiaz Ali Qazilbash, Director Telecommunications of the Power Wing of Water and Power Development Authority. The Conference was also attended by Ch. A. Hamid, retired General Manager (Power), WAPDA, and Mr. S. A. Siddiqui of Imperial Electric Company from Pakistan.

The participation of Pakistani Engineers in CIGRE Conference was certainly a great experience and an extremely useful one. The subject of Power System Engineering had been allotted to 14 Groups. For each Group a discussion meeting was held to discuss the papers presented in its special field and to exchange knowledge on the problems in this field in the various countries and their solutions. The standard of these meetings was very high as the people who took part in the discussions were all experts in their special fields.

There were four Group Sessions held every day, two in the morning and two in the afternoon, and it was seldom that the proceedings finished before 7 o'clock in the evening. The interest shown by engineers was immense and therefore the attendance was very good and in spite of the fact that the UNESCO Building in Paris, the venue of the Conference, has large conference halls, most of the time they remained full. Each group meeting started with its Special Reporter presenting a special report giving a preliminary study of the papers presented pointing out the questions to be discussed in the light of the Preferential Subjects for the Session.

Whereas the subjects of the various groups, the preferential subjects taken up by them, the study of various problems and their solutions discussed in the respective group meetings will become the subject of a report being prepared for publication by Mr. Imtiaz Ali Qazilbash, I will only mention a few of the subjects discussed, which were found to be more closely connected with our work and our problems in WAPDA, West Pakistan.

Transmission Lines

Some new methods were discussed in CIGRE to increase transmission capacity outside the conventional methods. A 132 kV double circuit line has been converted into a double circuit 330 kV line by installing a new type of rigid insulator arms on the existing towers in Australia. In Canada they have substantially increased the capacity of a 220 kV line by resagging it to increase the ground clearance and thereby enabling it to be operated at higher temperatures.

These operations were furthermore done under live-line conditions. This saved a great deal of money which would have had to be spent to build new lines. It is internationally accepted now that older lines can be economically rehabilitated to meet new loading conditions and to this we shall have to give serious thought in Pakistan. Live-line maintenance and modifications have also found general acceptance.

In transmission lines besides the design overloads it is now being accepted that excessive power can be carried for certain limited periods on transmission lines up to say an excess of 76 per cent for 10 per cent of the time.

Mr. Imtiaz Ali Qazilbash, Pakistani delegate to the C.I.G.R.E. Conference, Paris speaking to the participants

The experience of other countries on their 765 kV systems was reported and discussion took place on what the ultimate transmission voltages could be.

Pollution

A great deal of work has been and is being done internationally on pollution problems. We have been having difficulties on the Karachi-Hyderabad transmission line, and more recently around Lahore, due to insulator pollution and therefore this aspect has assumed some importance for us.

Transformers

In transformers, as indeed in all equipment, great stress was laid in utilizing equipment to their maximum capabilities so as to get the all possible economies. Transformers are sometimes used on the thermal overload criterion and not on current ratings.

Sub-Stations

In sub-stations the use of SF6 as a means of insulation for high voltage installations is today being given great importance in the advanced countries of the world. Because of the limitation of the space in congested localities metal-clad very high voltage sub-stations which are totally enclosed, are being installed.

Simplified designs of sub-stations was another interesting subject. In the USSR they have installed dozens of sub-stations at 110 and 220 kV without circuit breakers on the high voltage side. Instead they use switch isolators.

In switching equipment, importance was given to problems connected with transient switching voltages, synthetic testing of circuit breakers and switching phenomena in high voltage d.c. systems.

Large Turbo-Alternators

On large turbo-alternators, the temperature rise of the rotor appears to constitute a hurdle and the internal cooling by gas is being continuously improved by the manufacturers. Liquid cooling is also being used.

Although most of the time was spent in the discussion meetings at the CIGRE Session and this kept everybody very busy, yet a couple of visits were also arranged to works such as Research Centres and a Nuclear power station. A number of receptions were also arranged by CIGRE as well as some French organisations.

There is no doubt that the CIGRE Conference is a most useful forum for the electrical engineers and it offers an excellent opportunity to gather knowledge and information about the latest development in power system engineering. I hope it will be possible in future for greater number of our engineers to participate in the Sessions and ctivities of CIGRE.

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Selection of Standard Sand for Pakistan

By MOHAMMAD TAHIR* *and*
IRSHAD AHMAD**

Irrigation Research Institute in June 1966 started collection of the information for selecting standard sand for use in testing the cement specimens. In this paper the results of sand collected from four sites in West Pakistan are put forth. It is found that sand deposit in Thano Bula Khan about 40 miles from Karachi is quite suitable for selection as a standard sand. The sand from Mari Indus can also be selected as a standard provided it is subjected to an acid treatment to remove the excess of carbonates. In this paper the details of test are given, on the basis of which the Karachi sand is recommended for selection as a standard sand.

INTRODUCTION

All cement manufacturing concerns, testing laboratories and other research organizations are required to test the quality of cement produced in the country or used by them. Cement factories in particular have to conduct daily tests on the quality of cement under production.

Very commonly, cubes of cement sand and occasionally briquettes are made in a given ratio of cement and a standard sand. For a proper type of cement under production the cubes or briquettes should have a specified strength after a given period of curing. Besides these tests, sometimes other tests on cement, which also require the use of standard sand, are made.

In all these tests, sand of specified qualities is used. It is a standard sand. But in Pakistan so far no sand has been specified as standard, therefore all institutions and factories import their requirements from England where sand obtained from Leighton Buzzard is selected as standard. The import not only involves foreign exchange but Pakistan has to depend upon a foreign stuff although sands of the specified range are available in the country.

All cement producing countries of the world have selected such sand as standard as is available in their countries. In America, Ottawa sand is used for the same purposes. In England, Leighton Buzzard sand is the standard. In India sand obtained from deposits near Madras is selected as standard.

In this study it has also been tried to put forth the results of research conducted by the Institute to find a deposit from which West Pakistan standard sand can be obtained.

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Requirement of standard sand in the country

During the year 1966, a circular was issued to all organizations interested in the use of standard sand. Enquiries were made about the type of sand they use for their tests, their yearly import, cost and such other connected questions.

It was found that about 500 tons of Leighton Buzzard sand was needed in West Pakistan each year, by cement producing factories and other agencies. It is anticipated that the demand for standard sand will continue to increase in the future. The selection of standard sand for Pakistan was thus considered very necessary. This paper gives the results of investigations conducted to select a standard sand for Pakistan.

Specification for a standard sand

The selection of a standard sand is based upon two main qualities :

(*i*) A given specified size.

(*ii*) Absence of acid reactive materials like carbonates etc.

The standards for Leighton Buzzard sand are that the sand shall be obtained from Leighton Buzzard. It shall be of white variety and shall pass through 18 mesh B. S. Sieve (opening 0.853 mm) and not more than 10 percent by weight shall pass a 25 mesh B. S. Sieve (opening 0.599 mm). When this sand will be treated with hot dilute or concentrated hydrochloric acid its loss in weight shall not be more than 0.25 percent. It means that the standard sand of Leighton Buzzard has more or less one grade lying between 0.853 mm and 0.599 mm. It possess very low percentage of acid reactive materials like carbonates.

The American ASTM standard sand is a natural Silica sand from Ottawa. It too has the same specifications with regard to grades. The sizes of sieves specified are No. 20 which corresponds to B. S. No. 18 sieve and No. 30 corresponding to B. S. No. 25 sieve.

While selecting the standard, it is stated that the natural silica sand from Ottawa will be graded and shall be considered standard when not more than 15 grams *i.e.*, 15 percent are retained on 20 mesh (0.853 mm) and not more than 5 percent pass No. 30 (599 mm) sieve after 5 minutes of continuous sieving.

Sand deposits in West Pakistan

In all the constructions carried out in this country sands available from natural resources have been utilized. In 1952-55 the Building and Road Research Laboratory and the Irrigation Research Institute conducted a survey of the available sands from various sites. Their physical characteristics such as grading, presence of inorganic and organic impurities; Fineness Modulus etc., were determined. These surveys were, however, not conducted from the point of view of determining a standard sand. For all ordinary unimportant work, sand available close to the work has been utilized, but for all quality works sand deposits of Daudkhel, Lawrencepur and Harrow river have been utilized. The grades from these sands are fairly coarse.

In the Southern Region, sands of Nullahs have been utilized. These are predominantly calcarious *i.e.*, containing excessive amount of lime. In this study we have concentrated on sand deposits found near Karachi, in Daudkhel (Mari Indus), Lawrencepur and in the bed of Harrow River. There may be other sites yet unknown where perhaps sand of a still better standard quality might be available, but our present study has shown that we have deposits from where standard sand can be collected.

ocations and occurrence of sands investigated in Karachi sand

A superior quality of white sand is found in the districts of Thatta and Dadu near Karachi, especially in Jangshahi and Thano Bula Khan area. The deposits of Thano Bula Khan are the best and the largest found until now in Pakistan and these occur in the Unt Palank Range, which is 40 miles away from Karachi. In Fig. 1 the site of these deposits is shown.

An unmetalled track connects Karachi with Thano Bula Khan and the south extremity of Unt Palank Range runs at about two miles from this road while the place of the main deposits at which the sand is mined is at about 5 miles from the road.

The sand occurs in Gaj Rocks of the Lower Miocene Series of the Tertiary system. It is light brown in appearance (white or colourless particles predominate).

At present this sand is being mainly exploited by Glass industry which is interested only in finer content of the sand while the coarser one is rejected. The rejected portion in fact contains a very high percentage of standard sand particles.

It is mined mainly by manual labour. At present transport facilities are good owing to the increasing interest in this sand by the Glass industry and the construction of Karachi-Hyderabad Super Highway which passes through this area. The lease of these sand deposits is being claimed by Pir Ghulam Rasool, a landlord of Thano Bula Khan.

Mari Indus sand

A good quality coarse grade sand of mixed black and white variety is found in the Salt Range hills around Mari Indus town. The sand deposits are scattered, some contain coarse sand while the other fine one. The most promising sand site is at a distance of about two miles south of the old Mari village, four and five miles to the eastern side of the Daud Khel-Kalabagh Road and Mari Indus Railway station respectively.

The hills are covered with yellow and reddish yellow coloured material and these contain deposits of cobbles, gravels, sand and silt. The sand occurs in the form of layers and pockets, formed as a result of prehistoric depositions and erosion etc. Many pockets contain high percentage of standard size particles. The sand mainly contains silica particles. It also contains particles of magnetite, limestone and flakes of mica etc.

It is mainly mined by manual labour and it is carried down and hauled at the foot of the hill from where it is collected by different agencies for their respective uses. As the deposits are very near the road and the railway station and, moreover, the manual labour is cheap and easily available at the site, so the standard sand can be obtained very economically.

Some persons of the old Mari village claim the right of the exploitation of these sand deposits.

The survey report shows very huge deposits of the promising sands. Their location is roughly depicted in map No. 2.

Lawrencepur sand

The Lawrencepur sand deposits are very large and contain an economical percentage of standard sand grades. The deposits are 208 miles away from Lahore on the G. T. Road and are only a few furlongs away from the main road. The rail facility is also

MAP
SHOWING LOCATION OF
KARACHI SAND DEPOSITS

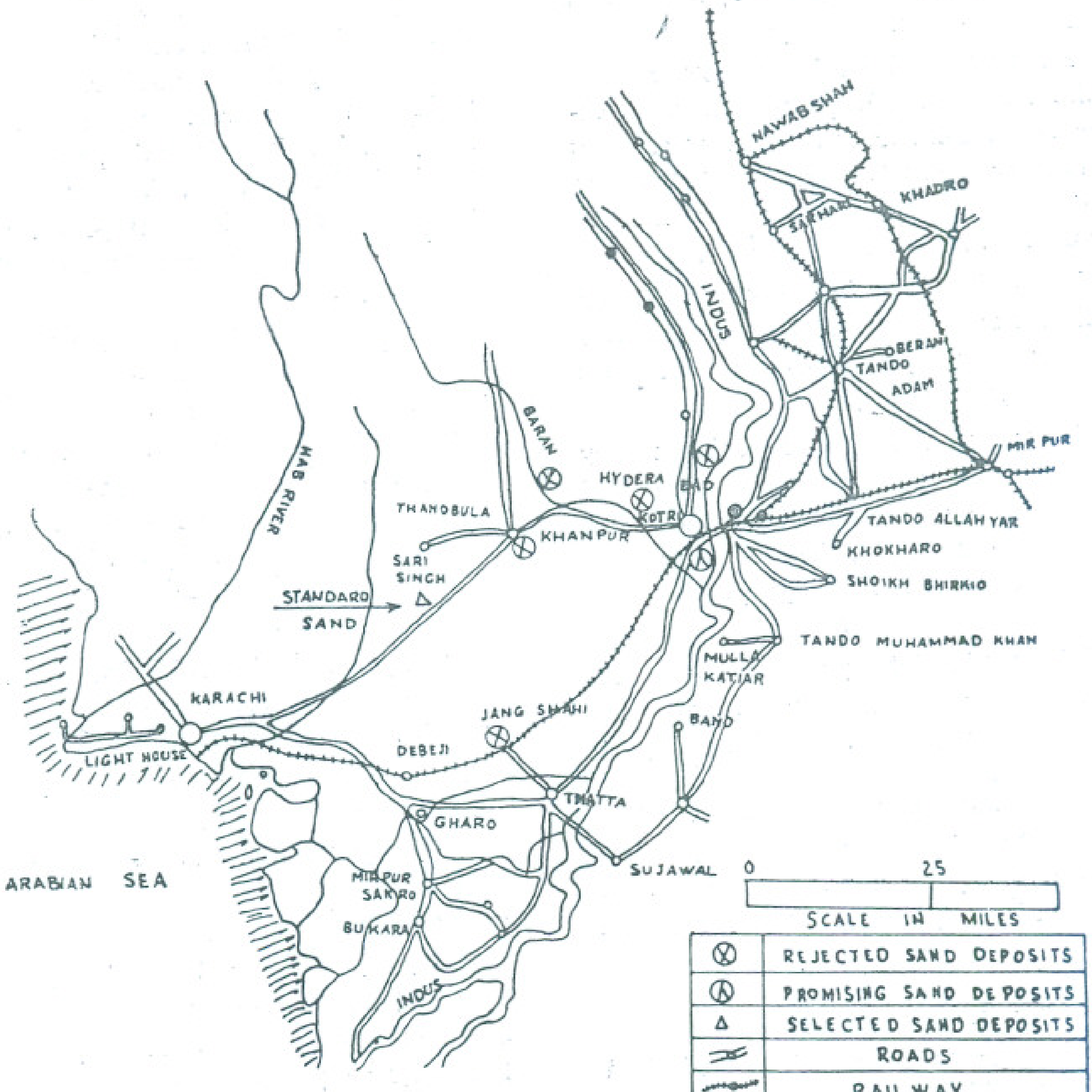

Fig. 1.

MAP SHOWING LOCATION OF
MARI INDUS, LAWRENCE PUR, &
HARROW SAND DEPOSITS.

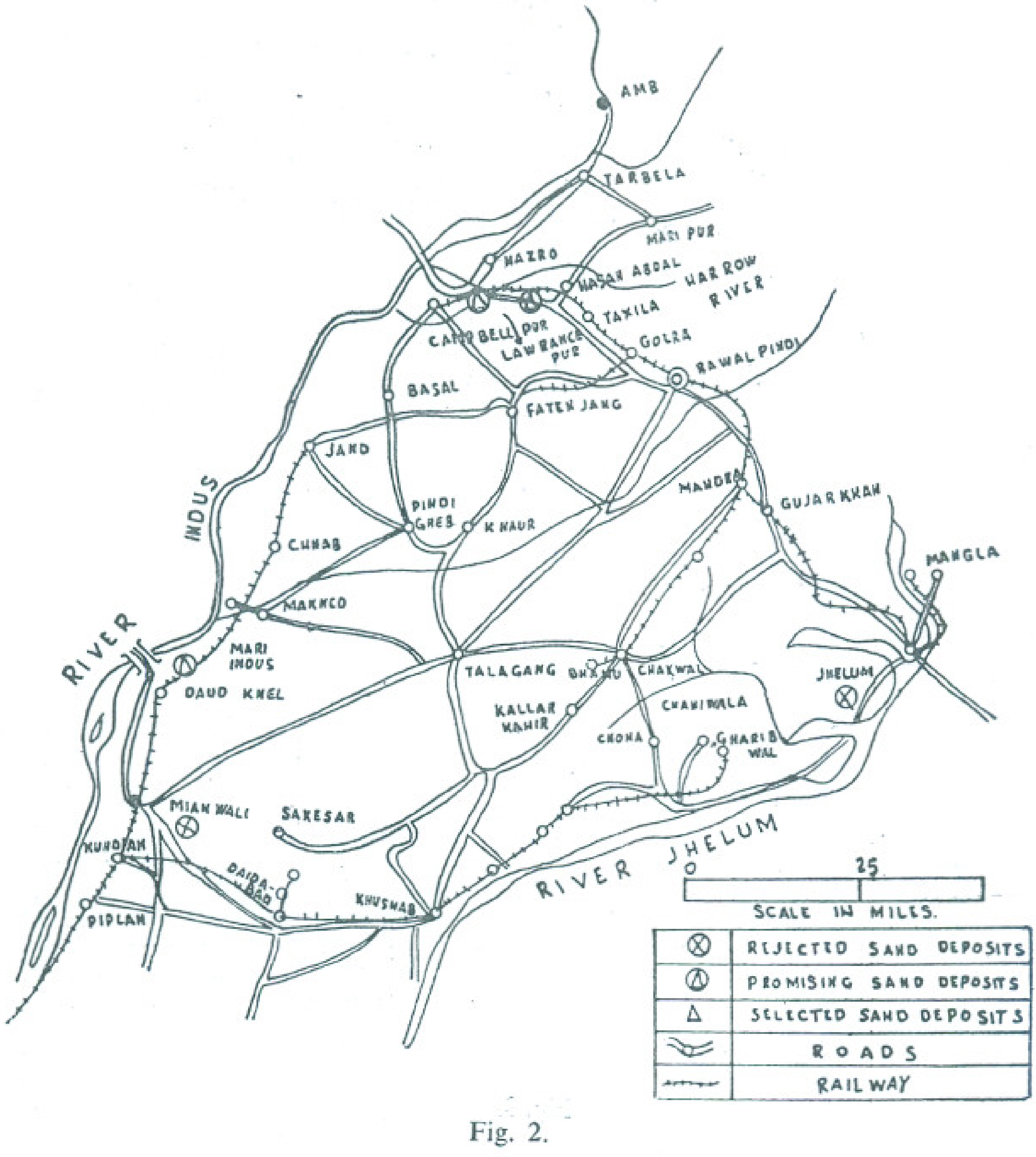

Fig. 2.

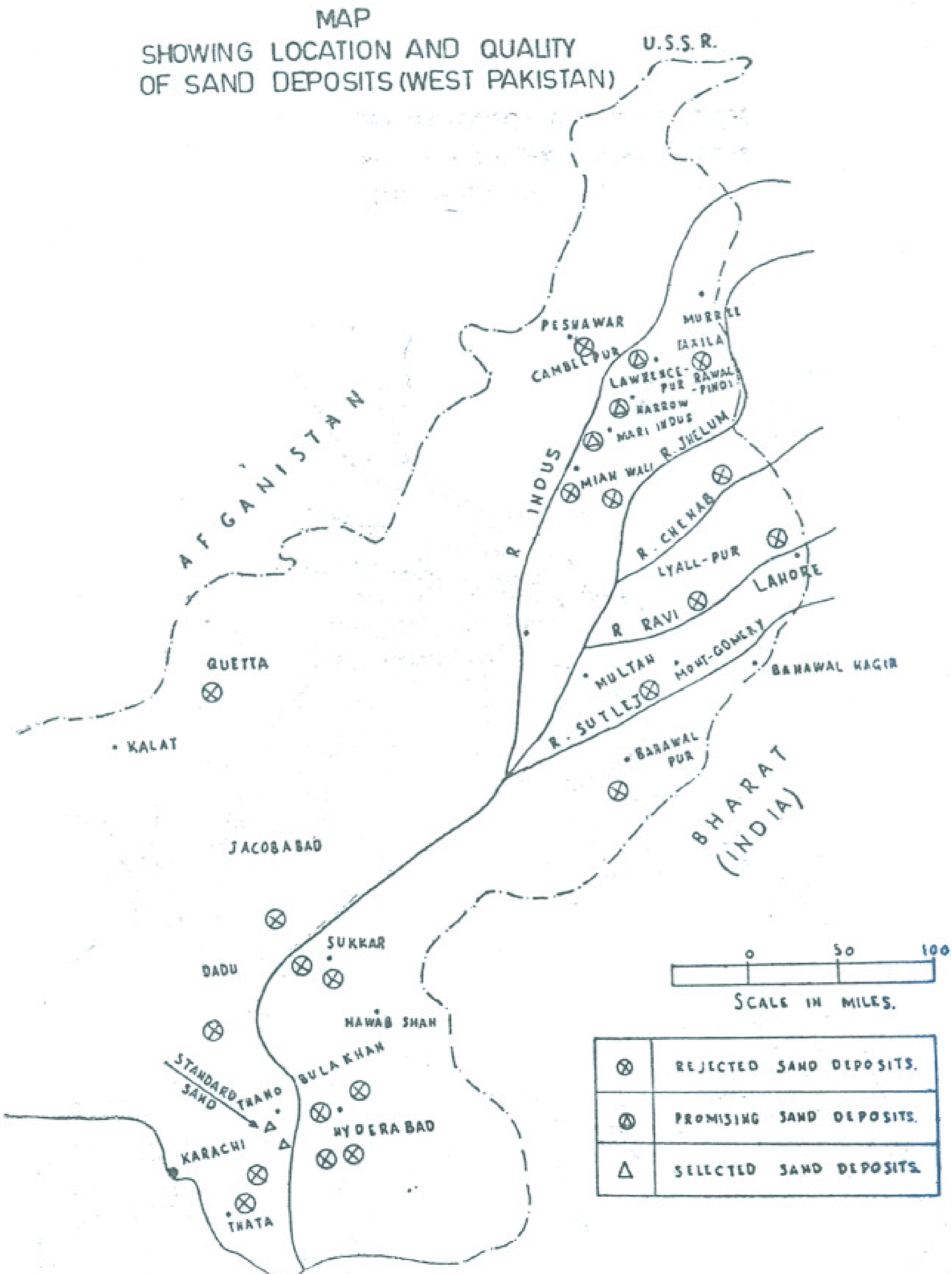
MAP
SHOWING LOCATION AND QUALITY
OF SAND DEPOSITS (WEST PAKISTAN)
U.S.S.R.
AFGANISTAN
PESHAWAR
MURREE
TAXILA
CAMBLEPUR
LAWRENCE-PUR
RAWAL-PINDI
HARROW
MARI INDUS
R. JHELUM
MIAN WALI
R. INDUS
R. CHENAB
LYALL-PUR
LAHORE
R. RAVI
MULTAN
MONT-GOMERY
BAHAWAL NAGIR
R. SUTLEJ
BAHAWAL PUR
QUETTA
KALAT
JACOBABAD
BHARAT (INDIA)
SUKKAR
DADU
NAWAB SHAH
STANDARD SAND
THANO
BULA KHAN
HYDERABAD
KARACHI
THATA
0
50
100
SCALE IN MILES.
REJECTED SAND DEPOSITS.
PROMISING SAND DEPOSITS.
SELECTED SAND DEPOSITS.

Fig. 3.

available and sand is already being transported.

These sand deposits occur in layers of variable but appreciable thickness. The uppermost layer is mainly soil, followed by medium sand. These overlie a fairly coarse sand grade. The sand contains predominantly grey particles with some flakes of mica.

Harrow sand

A fairly good quality of sand is found at new and old beds of Harrow river. The sand is available in a huge quantity. It contains an appreciable amount of standard sand grades. Its colour is grey and contains some flakes of mica as well. These deposits are near the road and railway and are also being utilized. All the prospective sites of these sands are shown in Fig. 3.

Sieve analysis of sand from various sites

In Table I sieve analysis of 12 different specimens of sand is put forth. Four specimens of sand were collected from Karachi. The same number was obtained from Daud Khel and two specimens each from Lawrencepur and Harrow river. On the basis of this analysis another was Table No. II was prepared to determine the percentage of particles retained on 25 mesh and passing 18 mesh. This grade of sand is classified as the standard. The specimen of Karachi sand gave about 8% of the particles of standard size. Daud Khel sand gave about 25% of standard sand. The Lawrencepur and Harrow sand yield less percentage of standard sand as compared to Daud Khel which from the gradation point of view is better than the Karachi specimen.

TABLE I

Sieve analysis of sands

Samples		% Pass B.S.S.							Fineness modulus
		4	7	14	25	52	100	200	
Karachi sand									
1	A	100	99.65	97.48	85.54	63.84	7.61	6.31	1.46
2	B	100	99.84	98.63	91.25	42.50	9.72	8.22	1.38
3	C	100	99.73	97.55	88.79	65.14	11.52	9.42	1.37
4	D	100	99.79	97.88	89.96	63.31	10.43	9.52	1.39
Mari Indus sand									
5	E	100	99.01	96.46	50.67	14.74	5.63	2.11	2.33
6	F	100	99.60	98.24	60.76	21.35	8.28	3.97	2.12
7	G	98.48	97.26	94.56	59.00	20.14	6.04	2.59	2.24
8	H	98.80	97.86	95.87	56.15	18.93	6.70	2.75	2.25
Lawrancepur sand									
9	I	99.9	99.5	93.8	69.9	21.70	4.3	2.1	2.109
10	J	99.9	99.5	95.1	69.5	20.10	4.0	1.9	2.119
Harrow sand									
11	K	100	99.7	95.2	79.5	28.70	5.2	2.0	1.918
12	L	100	99.8	96.8	79.0	28.80	6.0	1.8	1.895

Chemical analysis of sand

In Table III, chemical analysis of sand collected from these four sites is put forth. The Karachi sand contains about 98 percent particles of Silica sand followed by about 90 percent from Daud Khel, Lawrencepur and Harrow river. The total soluble salts in all these specimens are quite low. The carbonates appear as traces in Karachi sand and about 2.5 percent in the rest three sands.

The losses of weights of various sand samples on extraction with hot hydrochloric acid were determined following B. S. specification No. 12 of 1956 for standard sand as given in Appendix A. The results obtained are put forth in Table IV and these showed that the loss of weight with acid of Karachi sand was lower than even the specified limit of 0.25% thereby proving it to be good quality sand while the other three sands gave higher losses than the prescribed limit and evidently this is a serious defect which makes them unsuitable.

Improving the quality of Mari Indus sand

Availability of low percentage of particles of a particular grade is not a serious defect but the presence of excess of carbonates makes a specimen unsuitable. It is thus concluded that Karachi sand is the best sand found out. It will need only sieving and washing. Daud Khel sand can also be made a standard sand after treatment with hydrochloric acid to remove the carbonates etc. Acid treatment procedure is given in Appendix B. In Table IV the results are put forth after treatment of this sand with hydrochloric acid.

The acid treatment of the sand brought down its acid reactive content (*i.e.*, carbonates etc.) less than 2 percent but it was still higher than the prescribed limit. It can, however, be brought down to the specified limit of 0.25 percent but the treatment will be rather costly.

CONCLUSIONS

Investigations have been carried out to determine a standard sand for testing of cement out of the deposits available in West Pakistan. The basis of selection of a standard sand are that :

(*i*) *a.* It should be Silica sand preferably white or colourless.

b. Its grades should be those corresponding to passing 18 mesh and not more than 10% passing through 25 mesh sieve.

c. Its loss of weight after treatment with hot hydrochloric acid should be less than 0.25%.

The study has shown that fairly extensive deposits of white silica sand corresponding to the above stated specifications are available in Thano Bula Khan about 40 miles from Karachi. This sand is used in Glass Industry which rejects the coarser grades and which are suitable for selection as standard.

(*ii*) Our investigations on the possibility to determine any alternative site have shown that sand deposits at Mari Indus are the next best. This natural sand contains particles of which about 18% are retained on 18 mesh sieve and about 25% are retained on 25 mesh sieve. These deposits thus contain a greater volume of standard sand grades.

Its main defect is that it contains high percentage of carbonates which do not permit its use for selection as a standard sand. These carbonates and soluble salts can, however, be removed by treatment with hot hydrochloric acid. It will thus involve another chemical process before this sand can be selected as a Pakistan standard sand.

TABLE II

Sieve analysis, according to B. S. specifications, 12, 1958 for finding out standard sand content.

S. No.	Samples	Retained on 18 mesh %	Retained on 25 mesh%	Passed through 25 mesh%
	Karachi			
1	A	4.94	9.51	85.55
2	B	3.63	5.12	91.25
3	C	4.11	7.12	88.77
4	D	3.52	6.52	88.96
	Mari Indus sand			
5	E	18.75	30.51	56.71
6	F	18.04	21.22	60.74
7	G	18.83	22.20	58.97
8	H	16.96	26.92	56.12
	Lawrencepur sand			
9	I	9.26	20.90	69.84
10	J	9.68	50.82	69.50
	Harrow sand			
81	K	5.50	15.00	79.50
12	L	5.29	15.71	79.00

TABLE III

Chemical composition(%) of various sands.

Samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	CO_3	Organic impurity	T.S.*
Karachi sand								
A	97.99	0.91	00.72	00.01	Traces	Traces	Nil	00.09
B	98.50	0.70	0.50	00.03	00.01	do.	Nil	00.07
C	96.97	0.25	1.60	00.04	00.02	do	Nil	00.11
D	98.70	0.50	00.65	Traces	Traces	do	Nil	00.09
Mari Indus sand								
E	90.91	2.75	1.99	2.18	0.125	2.61	Nil	00.17
F	89.93	3.01	2.22	2.42	0.215	2.55	Nil	00.15
G	93.12	2.28	1.85	1.31	0.105	1.66	Nill	00.11
H	91.46	2.21	1.60	1.57	0.989	1.40	Nil	00.12
Lawrencepur sand								
I	90.20	2.25	2.80	2.60	0.13	2.65	Traces	0.07
J	90.10	2.12	2.60	2.75	0.12	2.83	do	0.05
Harrow sand								
K	89.60	2.45	2.96	2.77	.017	3.02	do	0.08
L	89.21	2.73	2.99	2.60	0.19	2.84	do	0.09

*T.S.=Total salts solution; determined by conductivity method.

TABLE IV

Loss of weight of various sand samples on extraction with hot hydrochloric acid according to B. S. specifications 12, 1956.

	Loss of Wt. (%) of various samples			
	A	B	C	D
Karachi sand				
Original sand ..	0.52	0.49	0.78	0.41
Standard sand (unwashed) ..	0.19	0.18	0.25	0.16
Standard sand (washed) ..	0.17	0.17	0.22	0.15
Acid treated standard sand ..	0.11	0.10	0.15	0.09
Mari Indus Sand	E	F	G	H
Original sand ..	8.65	7.45	6.42	6.99
Standard sand (unwashed) ..	7.85	6.43	6.99	6.21
Standard sand (washed) ..	7.76	6.36	5.91	6.17
Acid treated standard sand ..	2.25	1.90	.55	1.71
Hot acid treated standard sand ..	1.75	1.52	1.21	1.25
Lawrencepur sand	I	J		
Original sand ..	9.60	8.88		
Standard sand (unwashed) ..	8.21	7.90		
Standard sand (washed) ..	8.05	7.78		
Acid treated standard sand ..	1.81	1.75		
Hot acid treated standard sand	1.25	1.22		
Harrow sand	K	L		
Original sand ..	10.80	10.40		
Standard sand (unwashed) ..	9.32	9.22		
Standard sand (washed) ..	9.21	9.09		
Acid-treated standard sand ..	2.23	2.19		
Hot acid-treated standard sand	1.39	1.28		

It is suggested to select the sand of Thano Bula Khan as standard. Some Government control will be necessary. The sand will be sieved at the site, washed with water and then packed properly to meet the requirements of various cement Industries and other Organisations. In our study this sand has been found to be the best one so far encountered and can be adopted as Pakistan standard sand.

It may be noted that by introducing standard sand of Pakistan for various cement tests, slight alterations will be found necessary in the already accepted cement tests based upon specifications with foreign sands.

This selection of standard sand has been made on the basis of gradation and the loss of weight on extraction with hydrochloric acid. These two properties are mainly the criteria for selecting a standard sand. The strength characteristics both compressive and tensile of this sand when used with cement produced by various factories located at various sites still remain to be investigated. It is also proposed that more sites in West Pakistan will be explored to find any better variety. There are frequent enquiries from various factories and Institutions which are keen to know the availability of standard sand as presently there is considerable difficulty to import sand from abroad.

Hence Karachi sand is recommended to be selected as Pakistan standard sand.

ACKNOWLEDGEMENT

This study is a result of active co-operation of several persons concerned with the Soil Mechanics and Materials testing laboratories of the Research Institute. The authors are particularly grateful to G. F. Zafar in charge of these laboratories for his keen interest in the progress of work. We are also thankful to M/s Riaz-ul-Amin, Ali Mohammad, S. R. As. and Azhar Ali Inayat, R. A. for their help in carrying out the laboratory experiments and M/s. S. D. Pervez and A. D. Firdausi for their assistance in the relevant field work.

APPENDIX A

Loss of weight of a sand on extraction with hot hydrochloric acid (B. S. specification 12, 1956).

Procedure

Dry the sand at 100°C for 1 hour. Weigh out 2 gm. in a porcelain dish. Add 20 cc of hydrochloric acid of specific gravity 1. 16 and 20 cc of distilled water. Heat on a water bath for one hour, filter, wash well with hot water, dry and ignite in a covered crucible.

APPENDIX B

Removal of carbonate of Mari Indus sand

Calcium carbonate can be easily and completely removed by treating it with hydrochloric acid. The chemical reaction involved being

$$2HCl + CaCO_3 = CaCl_2 + CO_2 + H_2O \quad \text{——(I)}$$

(73 g) (100 g) (111 g) (44 g) (18 g)

Theoretically 73 gms of Hydrochloric acid are required to remove 100 gms of calcium carbonate, but practically slightly more quantity of the acid is required for the completion of the above reaction in a reasonable time.

Acid treatment procedure

To get rid of carbonate content of Mari Indus sand, perform the following two simple steps.

1st step

Take a weighed quantity of Mari Indus sand of a grading specified for standard sand in a suitable acid proof container. Then take a quantity of 25-30% commercial hydrochloric acid of about one-fourth the weight of the sand (or the quantity calculated from the equation (I) and put it into the sand. Add some water to the acid sand mixture to slow down the reaction. The reaction starts with the evolution of carbon dioxide gas and when it ceases the reaction is complete. Stir the mixture to complete the reaction quickly and confirm the completion of the reaction as well as the excess of the acid with blue litmus paper, pH paper or by dropping some more acid on to the mixture.

2nd step

Remove the unreacted acid and then wash the sand four or five times with tap water, or till the removal of last traces of the acid, conforming it with a blue litmus paper or pH paper etc. Dry the sand. The treated Mari Indus sand free of carbonates is the standard sand if it is again sieved from 18 and 25 mesh sieves, the exact grade of standard sand will be obtained.

The procedure of acid treatment suggested for Mari Indus sand will also prove equally good for Lawrencepur and Harrow sands.

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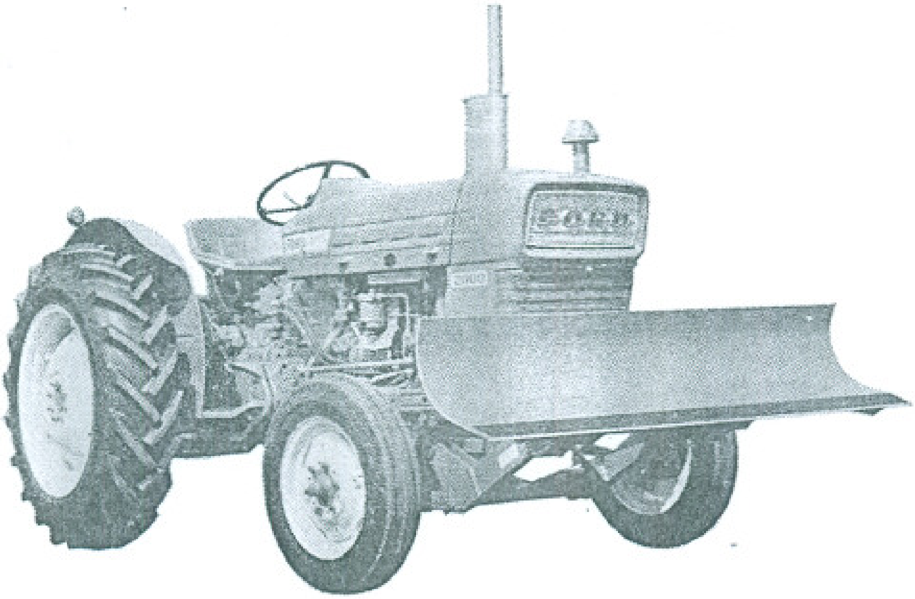

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FROM TELLUS TO TELLUROMETER

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Introductory-Primitive Land Surveying

Land surveying is one of those branches of engineering that have gone through centuries of haphazard experimentation and development before reaching the present-day rigorous standards. In fact the history of land surveying is as old as the history of mankind and it is difficult to accredit a region or a nation with the first efforts to measure land. According to Encyclopaedia Britannica "it is very probable, that surveying had its origin in ancient Egypt"—the land of the Pyramids. This however cannot be claimed with certainty.

The primitive people carried topographical knowledge in their heads making mental maps of their private little worlds which centred around their caves and hunting grounds. Archeologists maintain that the Neolithic man was able to make rough maps of tribal and property boundaries. Even today one finds that Polynesians, Eskimos or Bedouins, people with primitive ways of life, who have to travel far and wide, have a remarkable natural talent for drawing sketches of their territories using wood or bone or just putting together shells and sticks.

The Greeks and the Romans had a particularly commendable knowledge of Civil Engineering. They shared with many early civilized peoples: Egyptians, Babylonians, Chinese, Aztecs, and Peruvians of the Inca Empire the ability to plan and build temples, cities (for which they made excellent sanitary arrangements), canals and roads. They could carry out cadastral surveys and record property boundaries for purposes of taxation, etc. They could make topographical maps for military use. Land surveying was already established as a necessary though limited governmental activity. Right here in Pakistan, the ruins of Moenjodaro are a witness to the proficiency of the surveyors and engineers living here many thousands of years ago.

Some Early Maps

One of the earliest known efforts to measure large tracts of land was carried out during the reign of Roman Emperor Augustus. Marcus Agrippa, one of his generals, prepared

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a map of the Roman Empire on Royal command. Using some sort of a plane table a survey of over five thousand miles of paved highways was carried out which served as a framework for the grand map. It took 20 years to complete and at the end a large master map engraved on marble was erected on a wall near the Roman Forum. Copies of this map were made on papyrus rolls and distributed among civil and military administrators. The result, however, was highly inaccurate in many ways. No regard was paid to the relative dimensions of the major features although the distances along the highways were fairly accurately marked.

Ptolemy produced a similar distorted map that was considered the last word in world maps for several centuries, but his map was based more on myth and travellers' tales than on any serious measurements.

The Chinese are said to have had a knowledge of some sort of a magnetic compass as long ago as 1600 B.C. and maps are known to have been made in China and Japan around 1 A.D., depicting their own countries and the world known to them. But again these maps were not free from the mythical elements.

Surveying in the Middle Ages

Compass was a powerful tool for surveying. It is claimed that around 1300 A.D. Italians made a lot of sea charts using compass. By 1450 the Arabs were quite familiar with the use of compass and many coastal maps were prepared by them of the countries they traded with.

The regional maps of the Middle Ages were drawn from route surveys or eye-sketches supplemented by linear measurement and they had considerable angular as well as linear distortions. In the first half of the 16th century geometrical methods of survey with more precise instruments for observations of angles by geographers of Germany and Netherlands were introduced. The principle of triangulation was described by Munser in 1528 and by Firsius in 1533 enabling large areas to be measured more rapidly as well as more accurately. Many European countries were first mapped during this century.

Topographic mapping of Europe that had started in the 16th century, gained new momentum for military needs such as aiming field guns, finding cover or moving men and materials. Napoleon was aware of the military implications of accurate cartography and it flourished under his patronage.

In the 17th century regular explorations were being carried out to find out what lay beyond the known world and many of the earlier myths were being shattered.

Progress during the last two centuries

Measuring and mapping as we know it, has been going on for many centuries now. Over this period some parts of the earth have been measured and remeasured with ever increasing accuracy and others have not been measured at all. In fact a very small part of the earth (about 2% of the land area) is mapped accurately at a scale of 1 : 25000 and less than 25% has reconnaissance maps at 1 : 250,000. The demands of accuracy for present-day mapping are high and the speed of operation is becoming more vital every day.

Until recently the surveyor has been restricted by lack of adequate equipment and means of transportation in underdeveloped areas, although remarkable accuracies were achieved in the work that was carried out. Even today charts originally made by

Captain Cooke are in use and much of the details go back to the work done in eighteen hundreds.

The first systematic survey of united India was carried out by the British and it is a tribute to the proficiency of their surveyors that in Pakistan, the bench marks laid down in those days still serve as primary reference points.

Before the 19th century, surveys were occasional and maps known by the names of the surveyors. Then for obvious reasons survey organizations were set up at governmental levels to carry out surveying and mapping continuously.

Basically, surveying involves three fundamental measurements:

Vertical Distances or Levels.
Horizontal Distances.
Angles or Directions.

By the early part of this century, optical instruments for measuring angles and transferring levels or measuring vertical distances reached an extremely high standard of accuracy and performance, thus meeting two of the three basic requirements of a surveyor adequately.

Telescope, which was invented by Galileo in 1608, was primarly used for astronomical work for almost 200 years and was useful in fixing georaphical positions etc. In the 18th century it was widely introduced to surveying and navigational instruments, increasing their accuracy and efficiency. In this century, surveys were carried out and maps were prepared to do work never before dreamed of.

The development of angle measuring instruments was linked up with the man's struggle to master the difficulties of circular dividing. It is claimed that the first machine for automatic divisions of circles for surveying instruments was invented by Edward Troughton of England in 1793.

In 1851 Photogrametry or picture meauring was initiated by Laussedat of France. Later, E. Deville, a Canadian, did practical work using phototheodolites on ground. Then during World War I, practical Aerial Photography opened up new vistas. Aerial photography and photogrametry augmented but in no way eliminated ground surveying which was necessary for control or for laying out or constructing projects. It was also necessary for smaller surveys at low cost and for land with thick vegetation. Photogrametry, however, minimized the more costly phase of conventional surveys by ground instruments. The design and construction and measuring accuracy of levelling instruments and theodolites continued to improve.

Advances in optical glass working coupled with successful photographic reproduction of carefully prepared and highly accurate master circles on glass discs ushered in the era of optical theodolites which could measure angles to within fractions of a second of arc. Parallel successes were achieved with levelling instruments, but the third requirement, that of measuring horizontal distances, still demanded carrying of chains, bands and tapes over difficult terrain and where the ground was inaccessible laborious indirect methods were employed.

Distance Measuring Techniques

The distance between two points in surveying is understood to mean the horizontal distance. Any slope distance is reduced to the horizontal and in geodetic work it is further reduced to sea level. The means of measuring these distances can be direct or indirect.

The common methods of direct measurement are pace, chain, metallic tape, and steel tape. (Another possible method is by counting the number of revolutions of a wheel of known circumference, but it is difficult to keep the wheel exactly along a predetermined path and there is possible slipping so the results are only approximate). Pacing, using an average pace of 25"-30" (to be ascertined by travelling a known distance several times) may give an accuracy of 1/100 or 1/200.

Engineer's, Surveyor's or Gunther's chains soon gave way to tape and taping although the former are still used in our country. Metallic tapes may give an accuracy of 1/500—1/700. Ordinary steel tapes will be accurate to 1/1000—1/5000 but under carefully controlled conditions this figure may be between 1/10,000—1/30,000.

At one time rigid bars were used for base line measurement but they are now obsolete.

About 1883, Professor Jaderin of Stockholm devised the method of measuring a base by means of wires stretched between tripods. He made use of two wires of steel and brass thus forming a bi-metallic thermometer.

The two-wire method was not entirely satisfactory for temperature measurements and researches were made to find an alloy with a negligible coefficient of expansion.

In 1896 Dr. Guillaume discovered the alloy 36% Ni, 64% Steel which had a coefficient of expansion of the order of 0.0000005/F° as against 0.00000625/F° of steel. This was named Invar (from invariable).

From that time till the early 1950's all important bases have been measured using Invar tapes or bands. Using Invar tapes hung in catenary taking careful precautions to allow for standardization temperature, slope, tension, sag and alignment etc. accuracies of 1/50,000 to 1/1000,000 are possible. The method however is long and laborious.

Indirect methods largely fall into two categories optical and electronic. Optical methods make use of intercepts and solutions of acute angled traingles depending for accuracy on precise knowledge of a small distance. The common methods are Stadia, Subtense Bar and Range Finder. Subtense bars have been used for base line measurements but the accuracies are not sufficient for present-day standards.

The Age of Electronics

In 1880, Hertz had produced radio waves and shown that they could be deflected by metallic objects. A German Engineer, Hulsmeyer developed a simple radio echo device (for which he got patents in 1904), for location of ships on the high seas, but no one seemed to be interested in the gadget at that time.

Sound waves which had been previously used for estimating distances were developed into a system for surveying positions of enemy guns during the 1914-18 War but sound ranging on ground was too much at the mercy of atmospheric changes and the results were uncertain and approximate.

Development of Radio detecting and ranging (RADAR) in the 30's opened up new possibilities. It was developed independently in U.S.A. Germany, U.K. and France. By early 1940 the invention of multicavity magnetron made the microwave radiation possible. The name RADAR was coined by the U.S. Navy in 1942 and it was universally accepted.

Two types of radars were developed. First there was the continuous wave type which used interference or doppler techniques and secondly, there was the pulse radar which sent out a pulse of energy and waited for echos before sending out another pulse.

Soon after the war introduction of several electronic instruments on land, on the high seas and in the air revolutionized the entire concept of distance measurement for surveyors.

Today one hears of many strange names like Shoran, Hiran, Rana and Lorac, Rayadist, Terrafix, Decca Chain, E.P.I., Makeometer, Decometer, Geodimeter, Electrotape, Tellurometer and so on. The Shoran system was employed in Canada soon after the war. It determines range from travel time of radio signals. An aeroplane with Shoran transmitter-receiver and indicator units aboard, flies across the line, about midway between two ground stations equipped with Shoran transponders, recording simultaneous readings. Several corrections are necessary, as for any other electronic method, before a result is obtained, but first order accuracies are possible. In the early 50's E. Bergstran in Sewden developed the Geodimeter. Th's instrument uses modulate light waves with reflectors at the remote stations. With Geodimeter 4 using mercury lamps at night, lines of 15-25 Km can be measured. During daylight, the range is restricted to 15 meters—4 Km, but very high accuracies are possible. In 1956 T. L. Wadley in S. Africa came up with Tellurometer. For medium ranges up to 20 or 30 miles, Tellurometer using modulated microwaves has a distinct advantage. More recently, 1960 onwards the invention of laser (using pencil thin coherent light waves) beams is bringing up new range finders. Solid lasers have been in use for some years for ranging and radar. Using Q switched pulses with a typical band width of 10-8 seconds, range determination to a few cm is possible.

The single frequency 6328 A° Helium Neon laser has been used for very precise measurement of distances of the order of several metres. For longer paths refractive index differences make the use of interference techniques impractical. Over ranges greater than a few metres, modulated beams not necessarily single frequency, are being used and accuracies of a few parts per million are being achieved.

All these modern developments have made the surveyor's dream of measuring large tracts of land with extreme accuracy and at great speed a reality and the future holds a still greater promise.

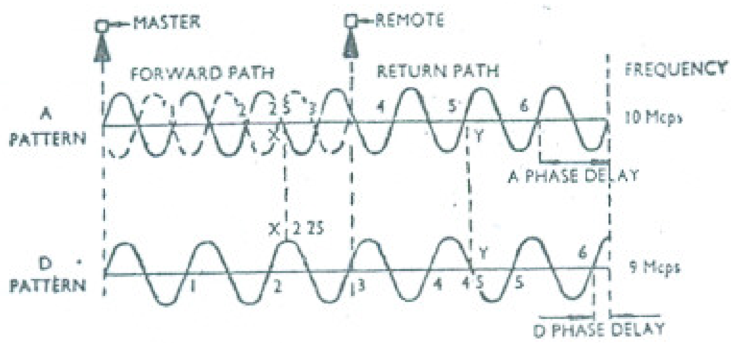
How a Tellurometer Works

The Tellurometer uses modulated microwaves which travel between two instruments, a master and a remote, used in conjunction. The first sends out modulated signals which are in effect radiated back and received again by the first. The phase difference between the emitted and received signals at the master station is a measure of the range.

The range is determined as an unknown number of wave lengths plus a known fraction of a wave length (the observed phase difference) if the velocity of electromagnetic waves has been established.

By emitting a series of signals and comparing the phase differences between the emitted and received signals the number of complete wavelengths can be determined to any required limit. To borrow an example from "Sandover and Bill":

"Let it be supposed that ten wavelengths of signal A, with a phase difference A, are equal to nine wavelengths of signal D with a phase difference D.



PHASE DELAY DIAGRAM

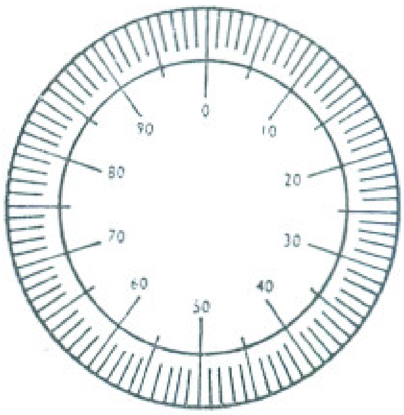
Then each numerical value of A-D defines a length within limits corresponding to the linear distance of ten wavelengths of signal A or nine of signal D. If now a third signal C is used, such that 9.9 wavelengths correspond to 10 wavelengths of signal A. then A-C defines a distance within limits ten times as large as those relative to signals A and D. This could of course be extended indefinitely, the intermediate signals being required as a check on the accuracy of the measurements obtained when the difference in the two wavelengths is least".

One Tellurometer instrument (MRA2) used a carrier microwave frequency of 3000 Mc/s and four different modulating radio signals at 10 Mc/s, 9.99 Mc/s, 9.9 Mc/s and 9 Mc/s. These signals gave four different wave patterns respectively referred to as A, B, C and D. The master and remote stations were linked by a built in radio telephone system and on instructions from the master operator the remote operator switched on the different wave patterns in turn while phase delay readings A, B, C and D were recorded at the master station.

The A readings used a 10 Mc/s signal which had a wavelength of approximately 30 metres and considering the two-way journey of the signal, this could give the distance between the two stations to within 15 metres.

It was so arranged that A-D varied such that it was zero for every ten wavelengths of signal A and nine wave lengths of signal D. (which was approximately equivalent to 300 metres). Therefore signals A and D could give the distance to the nearest 150 metres. Similarly A-C and A-B determined the distance to the nearest 1500 metres and 15,000 metres respectively. For measurements of longer distances it was necessary to know the distance approximately to within 15,000 metres or about 10 miles.

In the original Tellurometers the phase-delay was measured in milli-micro-seconds. It was shown as a break in a circular trace

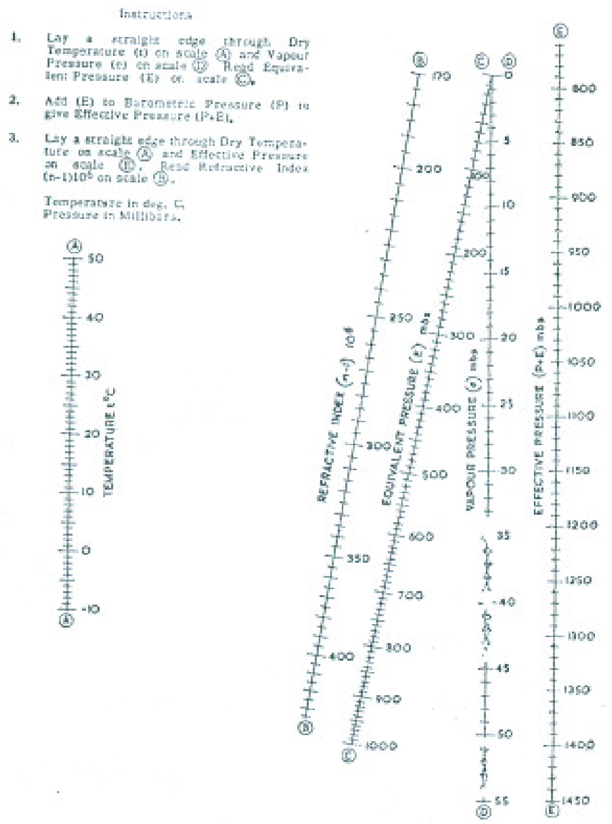


.Cathode ray tube display

on the screen of a cathode ray-tube. The circle was divided into 100 parts, each part corresponding to one milli-micro-second. Accurate estimation to a quarter of this was possible.

To find the distance from this, velocity of radio waves was determined for field conditions. In other words, the velocity of radio waves in vacuum (latest figure is 299792.5 km/s) had to be corrected for refractive index of the atmosphere between the two instruments. This in turn was determined from measurements of temperature pressure and humidity at the two stations.

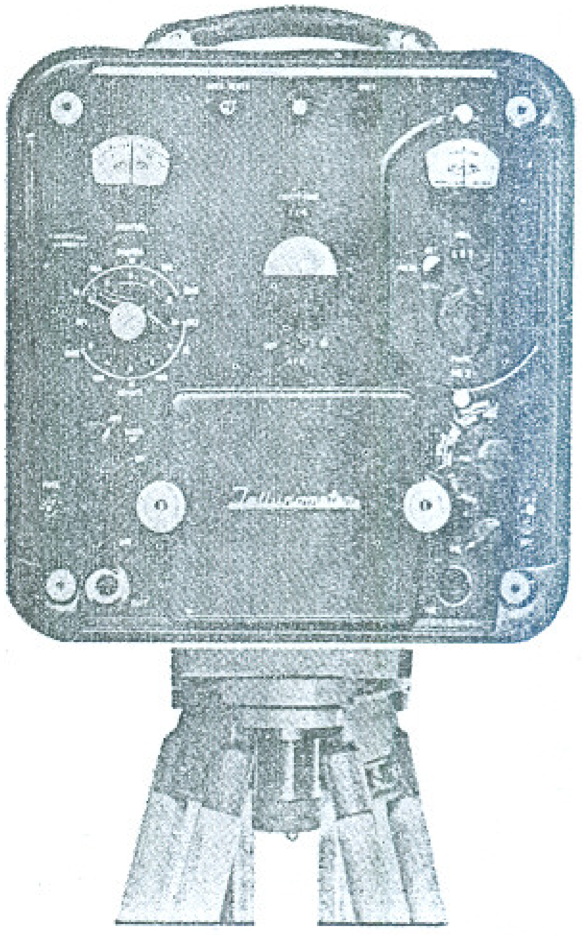
The refractive index could be calculated using certain formulae, tables of coefficients nomographs such as the one reproduced below.



Nomograph for measuring refractive index of radio waves

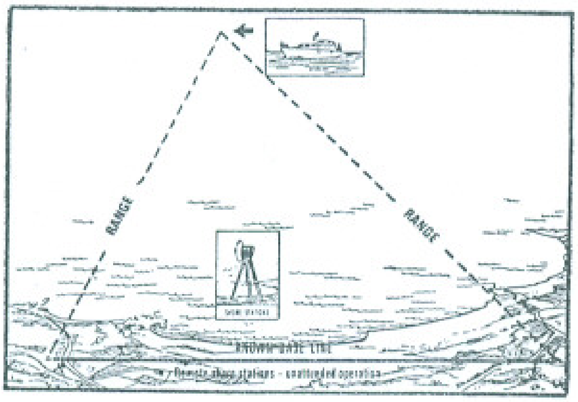
Since its invention in 1956 Tellurometer went through many a useful development and in the process brought about a revolution in surveying.

The latest instruments make use of standard refractive index and give a direct "read-out" of the range in metres. Instruments are now available in different accuracies and ranges for specific uses and single measurements of 50 metres to 50 kilometers or beyond are possible. Using very narrow beam widths and suitable carrier and modulating frequencies, accuracies of ± 3 m.m. ± 3 PPM. are claimed. A survey of Pakistan team under U.N. Development Fund has been using Tellurometer MRA 3 instruments in East Pakistan for some primary work.



Tellurometer MRA 3

After the success of the ground instrument, a second instrument, Tellurometer Hydrodist 'MRB-2' was introduced which could operate on the sea and, as a less accurate instrument, on land. It also eliminated the conversion from milli-micro-seconds to distance and gave the range directly in metres. While 'MRA-2' was used for traversing, trilateration, and base line measurement or control, the Hydrodist was widely employed for hydrographic surveys, off-shore construction work, off-shore drilling and pipeline laying, dredging, operational trials of ships etc., besides distance measurement on land.



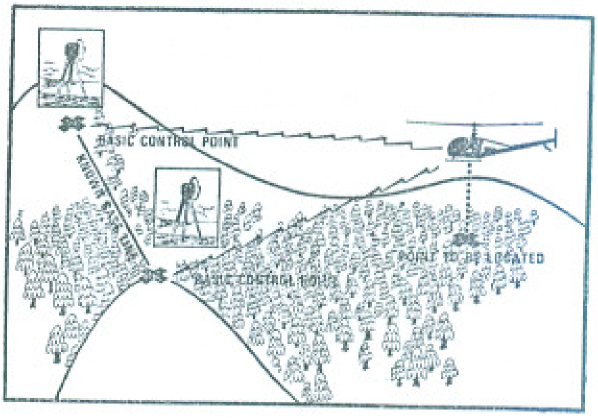
Hydrographic Surveys

Air-Borne Control

In America, using Hydrodist in conjunction with a helicopter, the Air-Borne Control Survey System (or the ABC System) was developed to augment aerial photography for preparation of maps.

To map a given area, certain control points are established by conventional ground instruments. The area is now Aerially photographed. Then ABC system is used to determine hundreds of supplemental control points.

A helicopter pilot, equipped basically with a Hydrodist, a Hoversight, a Height Indicator and a High Intensity Rotating Beacon flies to the point that has to be established with respect to the known control



Air-Borne Control

points. He marks the ground below by dropping a 'point bomb' and brings his machine to hover precisely over the mark. At this point ground parties take theodolite readings on the beacon in turn and also measure range with the Hydrodist. The pilot records atmospheric data and his height etc. He then moves to a second point and the whole procedure is repeated.

Finally the ABC readings go through a complicated routine of computer work, plotting, re-plotting and checking before a map is made. The accuracies are more than sufficient for 1 : 24,000 scale mapping. As for speed, the Bureau of Land Management in Alaska is reported to have covered 50 square miles a day using ABC as against 6 square miles with conventional methods. It is an interesting comparison with the efforts of Marcus Agrippa for the Roman Emperor Augustus.

The Twentieth Century Moves on

From the times of ancient worship of Tellus Mater, (the Greco-Roman goddess of earth who supposedly brought fertility to the land by receiving and flourishing the sown seed) to the present age of Tellurometers, computers and space travel, the civilized Tellurians have come a very long way.

With the passage of time the pace of progress has gained staggering momentum. The twentieth century has brought about more material progress in every field of technology than the entire remaining history of mankind and we still have a third of the way to go.

Tellurometers, with all their sophistications are certainly not the last word in distance measuring. Already there are many strong rivals in the field, each with its own relative merits or demerits. Elaborate computerised equipment is available that will give the distance between two stations at the flick of a switch. Infra-red photography and lasers (with their remarkably narrow beam widths) have opened up fantastic new avenues.

Man-made satellites are going around the world for the last several years carrying out measurements that have given an entirely new dimension to land measurement and mapping. Man himself has landed on the moon more than once and this heavenly body is being mapped with unbelievable accuracy.

What would be the shape of things to come towards the end of this century? It would be wise not to make a guess.

As for land surveying perhaps the space surveyors of tomorrow will look at the work done in our times in the same light as we look back on the crude efforts of the primitive folk.

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Lasers, Electronics World Aug. 1965 by Warren Groner.

Electronic Principles of the Tellurometer T. L. Wadley, Transactions of the S. A. Institute of Electrical Engineers, May 1958.

A short range highly accurate electro optical distance measuring equipment, H. D. Hotscher, National Institute for Telecommunications Research C.S.I.R.

Precise Tellurometer Surveying, Major A. G. Bromford Empire Survey Review No. 117 and 118, 1961, Vol. XV.

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First Order Traversing with the Tellurometer, G. J. Humphries and H. H. Brazier, Empire Survey Review Vol. XIV, Nos. 105, 106, 107 and 109.

Measurement of Distance by Radio Waves and its Application to Survey Problemes. J. A. Sandover and Comd. R. Bill.

Proceedings of the Institute of Civil Engineers, Vol. 24 Jan. 1963. (Paper No. 6643).

Discussion on Paper No. 6643 Proc. Instu. Civ. Engrs. 27, pp. 822-83, April 1964.

Engineering Abstracts

FLOW MEASUREMENT

The Use of Probes Derived from the Pitot Tube for Pipe Flow Measurement

(Utilisation des cannes derivees du tube de Pitot pour l'etude des debits dans les conduites). By P. Mathivet. La Houille Blanche (France), No. 5, 1969, pp. 493-498 (French text, English summary and abstract).

The author states the problem as having to determine a simple instrument capable of being introduced without difficulty and at little cost at any point in the pipes constituting the Paris Prefecture's water distribution loop system. His choice fell on a cylindrical tube derived from the Pitot tube, featuring two dynamic pressure tappings and no static pressure hole in order to increase the differential pressure.

On calibrating this probe in an infinite medium in the French Navy's hull testing tank, it was found that the conventional formula $Q=K\ D^2\ H\alpha$ relating discharge to average velocity Vm gave two values of the exponent α, both of which were close to $\frac{1}{2}$ and that the discontinuity invariably occurred at a velocity in the neighbourhood of 1 m/s.

The author decided that the velocity should always be measured in the centre V_0 in order to reduce the margin of uncertainty to a minimum. He made measurements on a large number of pipes with widely varying velocity distribution curves in order to determine the maximum probable variation range of coefficient v-mean velocity÷central velocity. He was then able to plot a graph consisting of a family of straight lines on a double logarithmic scale, the spacing of which was related to pipe diameter by a parabolic law.

The author then goes on to show successive applications of the probe in the Paris Prefecture's water distribution system, including one probe permanently installed in a 1.5 m diameter pipe; Finally, he argues in favour of the use of these probes for investigation and supervisory purposes—and not as precision insturments as a means of establishing basic requirements for operation ensuring optimum running economy, combined with satisfactory service to the consumer.

In the work described more than one thousand tests were run, from which the author determined curves for Q in terms of H, the characteristic feture of which is the same type of discontinuity as that associated with aerofoil lift curves, and equivalent coefficients to the calibration coefficients for Venturi tubes, so as to enable permanent discharge measurement, recording or totalising. About 3-4 per cent accuracy was achieved, which was more than adequate for the types of measurement to be carried out. Several models were built for pipe diameters ranging from 100 mm to 1500 mm.

CHEMICAL ANALYSIS

Automatic Analysis of High-purity Waters

J. A. Tetlow. Effluent Water Treat. J., 8 : 79 (1968). Because of the high pressures and temps used in present day boilers, ultrapure H_2O must be used. Impurities must, in many cases be of the order of thousandths of mg/l. One-line samp and analyzing should be used to follow quality of the boiler feed H_2O. This has advantage over discrete sampling in givin continuous record, and the results are obtain in a much shorter period of time. Ca should be taken to get a representati sample. Analaysis can be done by sever phys, chem, or elec. methods. Gases can b swept out of solution, and then measured O by its ability to oxidize and, therefore change a solution conductivity, and CO_2 by its capacity to change the pH. They can be measured down to concentration of 0.0005 and 0.02 mg/l, respectively. Na can be monitored by an electrode system which is specific for it. Many of the heavy metals can be measured by colorimetric means by using flowthrough cuvettes and proportioned pumps to supply a continuous and precise amount of reagents.

NEWS AND NOTES

The Aswan High Dam

Aswan, Egypt's capital of the South, celebrated on January 15, the two most important events in the country's recent history: the birth of late President Nasser in 1918 and completion of Aswan High Dam, Nasser's most important scheme for regenerating Egypt.

The Aswan High Dam, started in January 1960, carries through the work of the first Aswan Dam built by the British at the beginning of this century. To-day 80 million cubic meters of water are stored in the vast Lake. Egypt needs 20 billion to fill this year's Irrigation requirements. Full storage capacity is 160 billion cubic meters. This level may never reach, if the yearly Nile floods are normal. But reserves will always be sufficient to ensure that Egypt does not know the anguish of waiting for possible disaster from too high or too low floods.

Cash Investment in the Project is equivalent to about £400 million. Loans from Soviet Union totalled £113 million. The dam is 364 feet High and spread over in 480 kilometers, which was completed by 37,000 Egyptians and Russian technicians, who worked day and night for ten years to complete this project. There are twelve big turbine units for electric generation of about 1000 Megawatts.

In Harnessing the Nile's impetuous behaviour, the dam has deprived the river of much of its beauty and robbed Egypt of the silt deposit it received each year at flood time. But in its mature role, the river is adding the rich, green beauty of new crop lands to the sands of Nile Valley. Hydro-electric power is turning the wheels of Egypts expanding industry and bringing light, clean water, and a better way of life to towns and villages.

Paharpur Canal Commissioned, Regular Supplies to Dera Ismail Khan Ensured

On the 1st February 1971, Paharpur Canal was commissioned through the newly constructed head regulator on the right bank of Chashma Barrage. To connect the old canal with the barrage a new three mile feeder was completed. This feeder channelizes supplies to the old Paharpur Canal. As a result of its commissioning it would be possible to ensure supplies to the lands in D. I. Khan Irrigated areas. In the past the supplies to the canal depended on the discharge level in the river, because there was no weir or barrage to control the supplies. The canal was closed in January, 1971 and the old canal upstream of the point, where the feeder joins this canal had been plugged in order to stop supplies from the old head regulator.

Euphrates Dam in Syria

The dam is being built with the assistance of Soviet Union. Tabka, site of construction of the dam, has been developed.

Biggest in the Country, the Project is expected to make a tremendous contribution to the development of the economy. More than 600 Engineer, Technicians from Russia are working with about 7000 Syrians. The Power station on Euphrates will have a capacity of 800,000 K. W. First stage of the station will generate 100 per cent more electricity than the total now produced in Syria. First three generators of 100,000 K. W. each are to be commissioned in 1973, while remaining five in the subsequent years.

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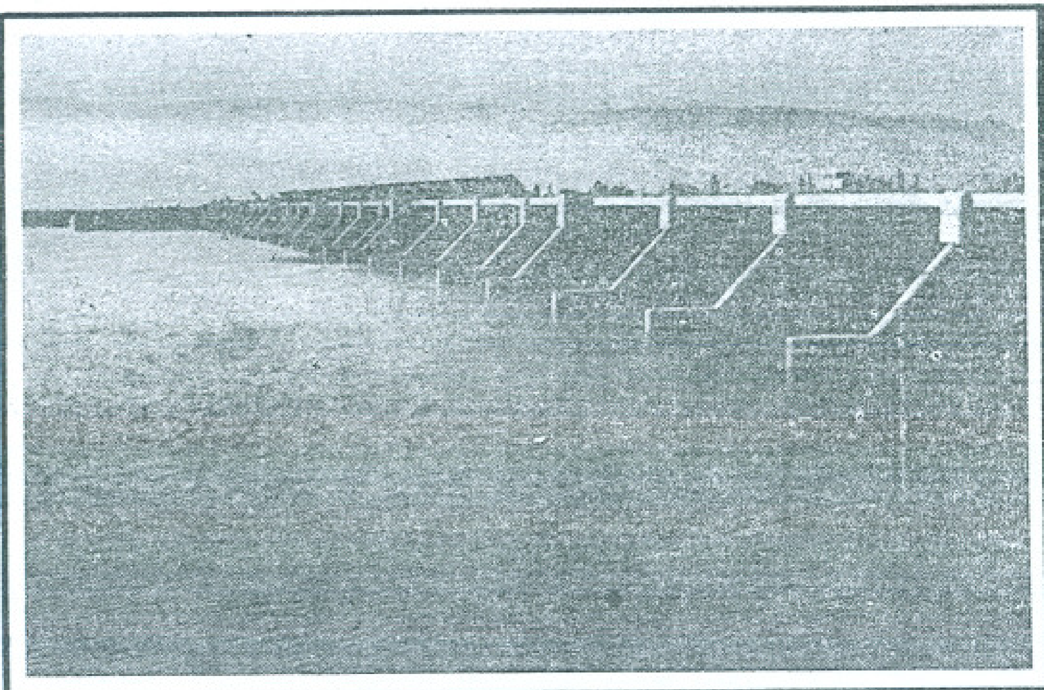

A view of the Chasma Barrage.

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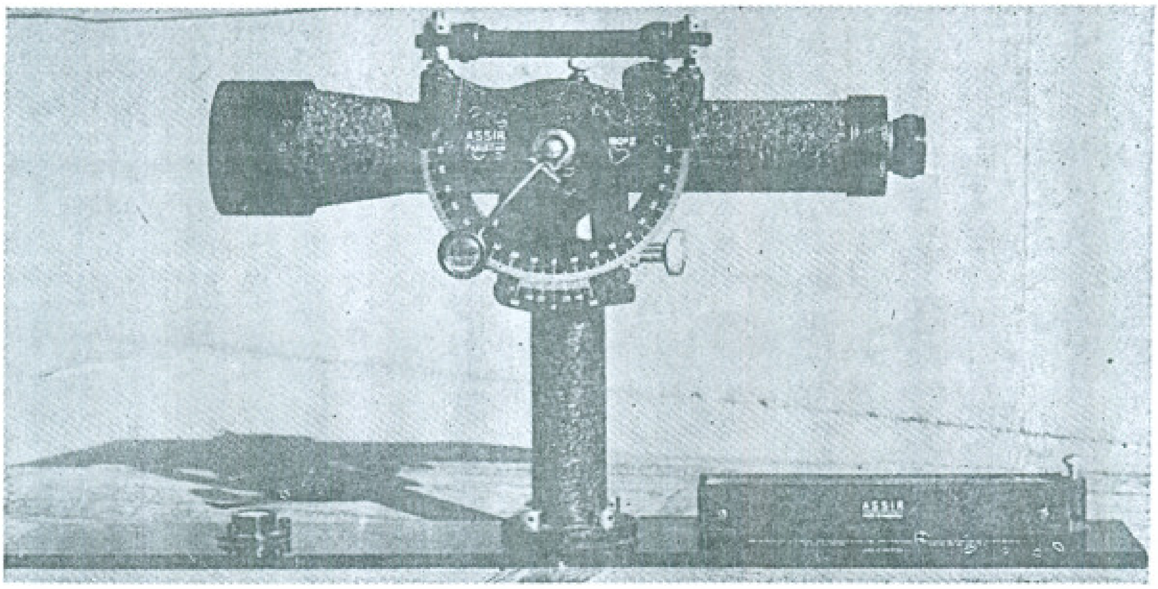

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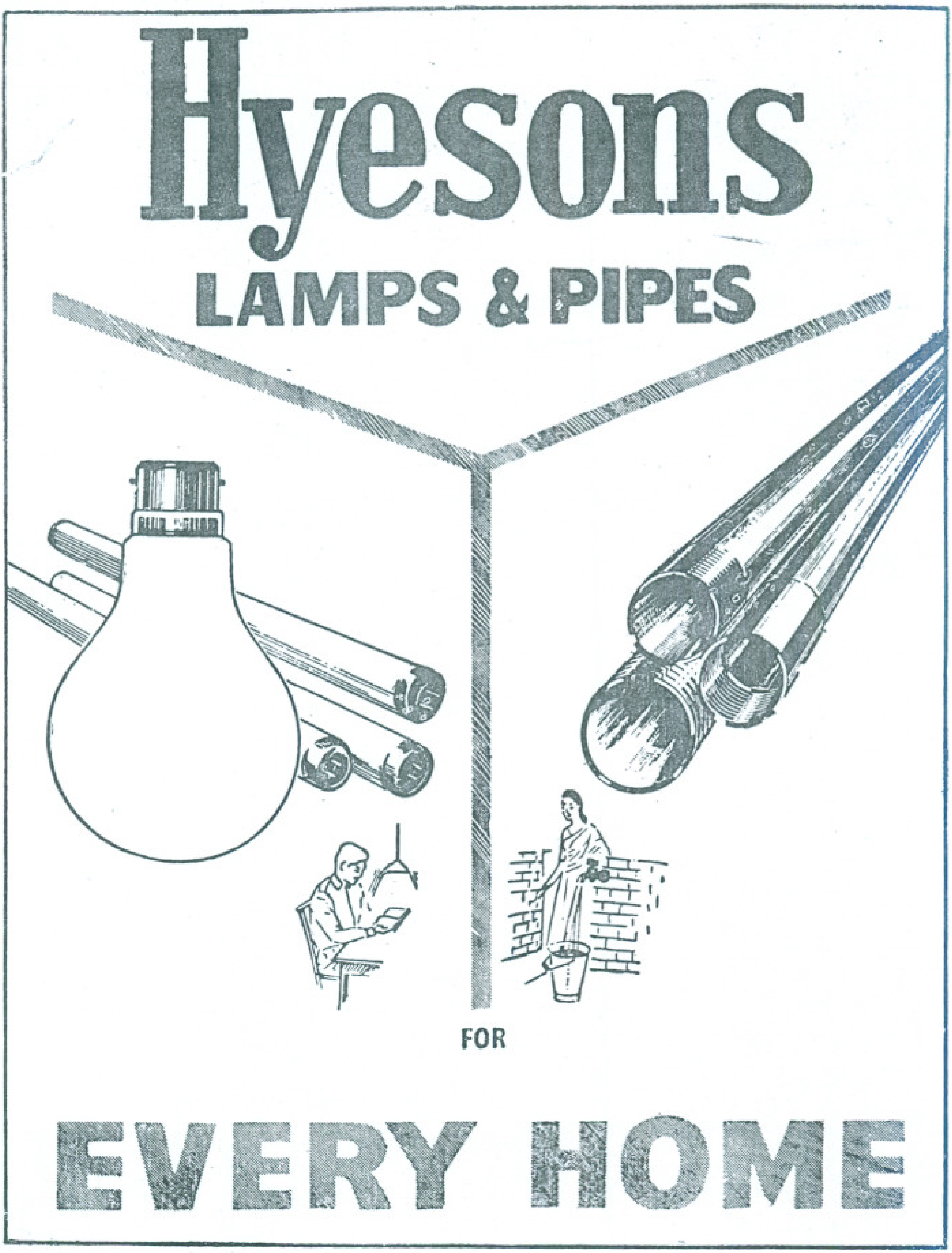
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