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No. 7

THE ISLAMIC REPUBLIC OF PAKISTAN
CAPITAL DEVELOPMENT AUTHORITY

THE REGIONAL STUDY
FOR
WATER RESOURCES DEVELOPMENT POTENTIAL
FOR
THE METROPOLITAN AREA
OF
ISLAMABAD-RAWALPINDI

EXECUTIVE SUMMARY

FEBRUARY 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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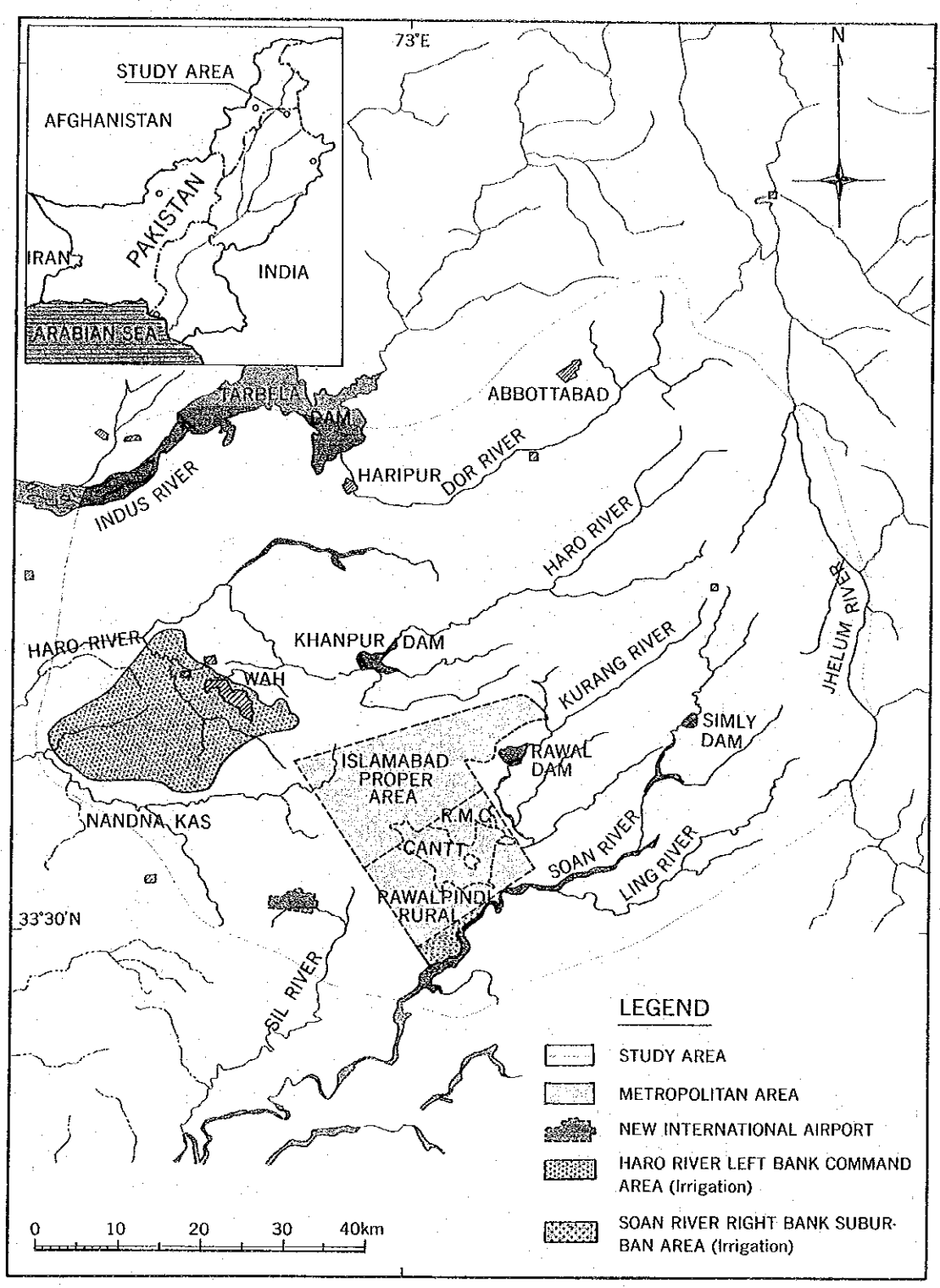
LOCATION MAP OF STUDY AREA



GENERAL MAP OF WATER RESOURCES DEVELOPMENT SCHEME

NORTH WEST FRONTIER PROVINCE

5,000m 0 5 10 15km

Miles 5 4 3 2 1 0 5 10Miles

LEGEND

- Province Boundary
- Study Area
- Catchment Area
- Existing Dam
- Main City
- Local Town
- Main Road
- Railway
- River
- Proposed Dam
- Proposed Diversion Dam
- Hightening of Existing Dam
- Pump Station
- Canal
- Pipeline
- Tunnel
- Treatment Plant
- Tubewell
- Metropolitan Area
- Proposed New International Airport
- Haro River Left Bank Command Area
- Soan River Right Bank Suburban Area
- Haro River Right Bank Command Area (Existing)

Abbottabad
D-1
Rajoia
Havelian
Dor River
Haripur
DW-1
D-2
H-4
Murree
Jw-1
Jp-1
Haro R
Dam
Wah
Haro River
Kcp-1
Kcp-2
Kc-1
Kc-2
Kc-6
Nilan Kas
Islamabad
Kurang River
Dam
Simly Dam
Gumreh Kas
Attock
Rawa
Nandna Kas
Np-1
Shatian Dam
Fatehjang
Malal Kas
Cherah
S-1
M-1
Pind Daro
Sc-1
Rawal Dam
KL-1
Soan River
Kahuta
Lc-1
Lp-
L-1
Sw-3
Sip-1
SL-1
SLc-1
Chahan
SLp-1
Sil River
Soan River
Jhelum River
Mangla Dam
PUNJAB PROVINCE

72°00' 15' 30' 45' 73°00' 15' 30' 45'
34°00'
45'
30'
33°15'

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1. GENERAL

1. GENERAL

101. The Report

The contents of the report consist of Executive Summary, Main Report and Appendix. The report was compiled based on the field survey, analysis and review of data/information collected, careful study in Pakistan and Japan including a series of discussion meetings between the governmental officials concerned and the study team, and the interim report which has been submitted to the government of Pakistan in July 1987.

102. Beneficiary Area and Study Area

The study area of the master plan is divided into two categories, i.e. the water supply beneficiary area and the water resources development potential area. The former consists of Islamabad and Rawalpindi urban areas in the metropolis, irrigation areas covered by the Left Bank of Haro river of about 16,000 ha and close vicinity of the metropolitan area with about 1,000 ha excluding the area commanded by the Master Plan Study for the Integrated Rural Development Project, and the proposed international airport area. The latter covers vicinity of the metropolitan area as the area for water resources development potential evaluation including the water supply beneficiary areas mentioned above.

103. Establishment of the Coordination Committee

Since the study ranges over a fairly large area, it is closely related to water supply beneficiaries, its implementation agencies and the government authorities concerned with the water resources development project, such as the federal government, the provincial government, governmental factories, corporation agencies and city water supply authorities.

The Coordination Committee and Technical Working Committee, therefore, are essential for the study team to coordinate their interwoven relations and encourage them to carry out the study smoothly. Accordingly, these committees were established and empowered in accordance with expected targets.

2. REGIONAL STUDY AREA

2. REGIONAL STUDY AREA

201. Location

This study concerns with water resource development in response to future water demand in and around the capital district. The area constituting the object area of the study is centered around Islamabad and Rawalpindi and extends to the main Indus river and the Jhelum river. The principal rivers of the study area; namely, the Dor river, the Haro river, and the upper reach of the Soan river are located in the tableland area and the alluvial plateau of northern Pakistan.

202. Topography

The study area can be divided into two geomorphological units. One is the eastern mountainous area consisting of the Margala Hills, Murree Mountains and Hazara Mountains. The other is the western plain area named "Potwar Plateau".

In the mountainous area, steep mountain ranges (highest summit some 9,000 ft.) run in a SW-NE direction. The river system shows a dendritic pattern elongating in the same direction.

Potwar Plateau's particular composition is of low lying hills tending to be in a WSW-ENE direction and the surrounding alluvial plain. In the western part of Potwar Plateau severe soil erosion is taking place, and highly dissected plain with deep gullies showing the features of so-called "bad land topography" is spreading over a wide area.

203. Geology

The main part of the Dor river basin is composed of slate, sandstone and conglomerate with intercalation of limestone. They are relatively hard and compact.

The central part of the study area is mainly composed of limestone and occasionally intercalate sandstone and shale layers. The limestone is highly corroded along the bedding planes and cracks and many cavities have been formed in the main Haro river basin.

The alternation of sandstone and shale which exist on the Soan river basin are generally weak, highly weathered and not able to endure erosion well. Among them, the shale is highly sheared and has turned into very weak red clay.

The Quaternary system which is widely distributed on the Potwar Plateau is composed of silt, sand, gravel and boulders. The major aquifers in the study area are interlayered in this deposit.

204. Climate

There are rainy seasons in both summer and winter. The precipitation ranges from 700 mm in the alluvial plain to 1,750 mm in the Murree hill region. 60 percent of the annual precipitation is concentrated in the monsoon season from July to September so there is polarization within the year itself. The yearly precipitation for the capital district is around 1,100 mm.

The annual mean temperature for the capital area is 21.5°C. The monthly mean temperature is highest in June, 31.6°C and the lowest mean temperature is for January, 10.0°C at the capital.

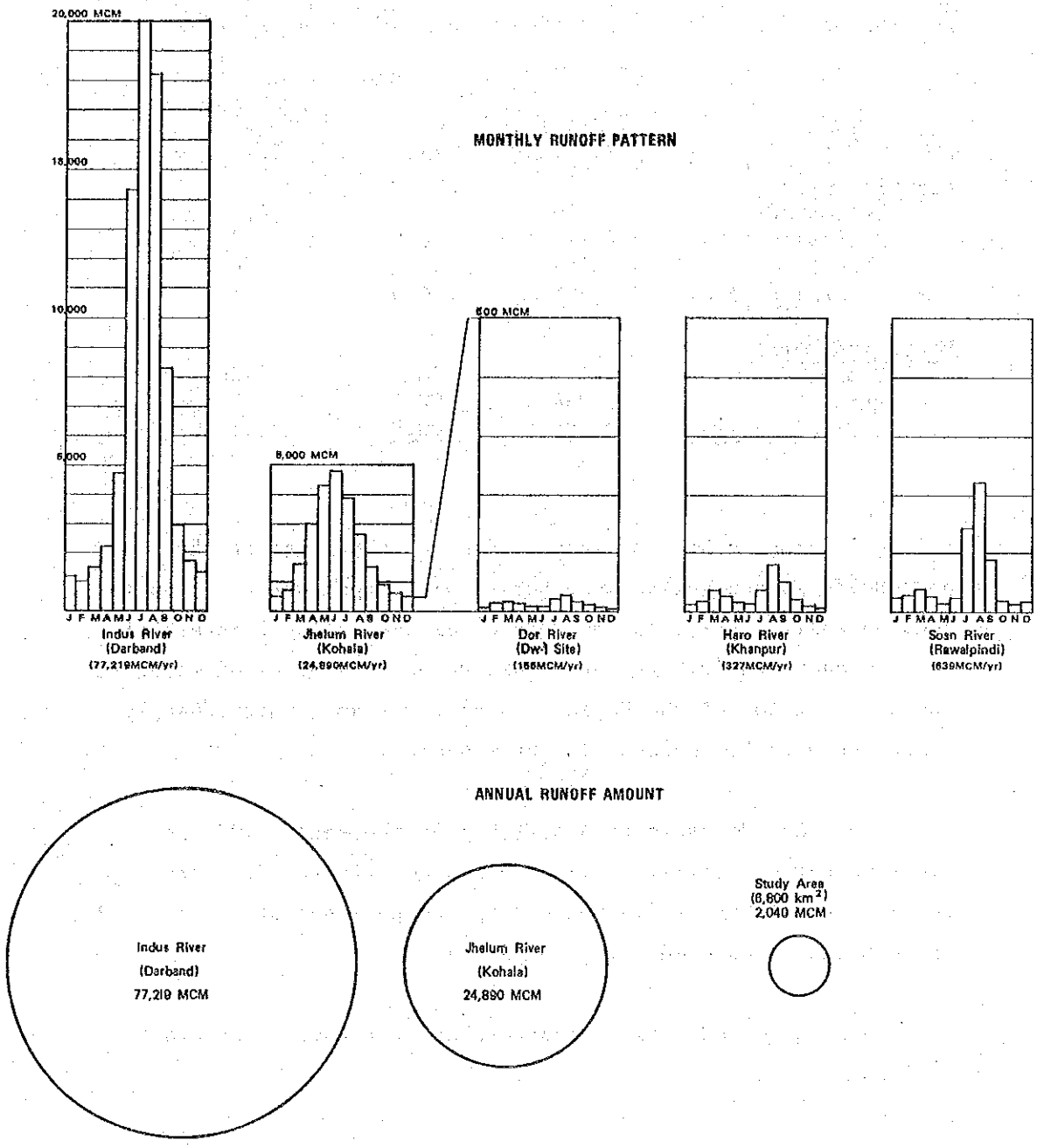
205. River Runoff

As may be seen in Figure II-1, the runoff of the rivers reaches its peak in the summer period. The runoff of large rivers such as the Indus and the Jhelum is mainly snowmelt. The runoff of the rivers in the study area is mainly rainfall. Because of this, the runoff pattern of the rivers within the study area has two wet seasons - one peaking in March and one peaking in August.

However, the amount of runoff in March is less than half of that in August.

The total annual runoff for surface flow over the entire 6,800 km^2 of the study area is estimated at approximately 2,000 MCM.

Figure II-1. Comparison of Runoff Pattern and Amount in Major Rivers



206. Socio-Economy

The Project Region incorporates administratively three different units, i.e., Islamabad District which is under direct jurisdiction of the Federal Government, Rawalpindi District and Attock District, both of which are under jurisdiction of the Provincial Government of the Punjab.

According to Population Census 1981, distribution of population of the three Districts is summarized as follows:

Item	Population (thousand)	Share (%)	Annual Growth Rate (%)
District-wise			
Islamabad	340	9.4	4.3
Rawalpindi	2,121	58.9	2.3
Attock	1,144	31.7	1.8
Total or Ave.	3,605	100.0	2.3
Urban and Rural			
Urban	1,371	38.0	4.3
Rural	2,234	62.0	1.3
Total or Ave.	3,605	100.0	2.3

According to Housing Census 1980, 25.4 percent of the households in the Region were served with piped water, which is considerably higher than the Provincial and national levels of 14.0 percent and 20.3 percent. Diffusion rate of piped water in the urban sector of the Region was 62.1 percent, which sharply contrasts with 5.0 percent in rural sector.

The gross domestic product (GDP) of the Region 1981 is estimated at Rs. 11,241 million, which constitutes 7.2 percent of the Provincial GDP or 4.5 percent of the national GDP. Out of it, urban sector accounted for 48.3 percent.

Summarized industrial structure and per capita GDP are as follows:

Industrial Structure and Per Capita GDP in Project Region, 1981

(Unit: percent)

Item	Total	Urban	Rural	Province	Pakistan
1. Industrial Structure					
1) Social & Personal Services Group	29.4	36.5	22.6	10.7	16.4
2) Agriculture, Forestry, Hunting & Fishing Group	16.7	1.6	30.8	26.7	29.0
3) Wholesale & Retail Trade Group	15.2	18.4	12.2	18.5	16.4
4) Manufacturing Group	12.0	13.3	10.8	24.3	16.5
5) Other Groups	26.7	30.2	23.6	19.8	21.7
6) Total	100.0	100.0	100.0	100.0	100.0
2. Per Capita GDP (Rs.)	3,117	3,961	2,600	3,281	2,939

3. PRESENT CONDITIONS OF WATER RESOURCES DEVELOPMENT

3. PRESENT CONDITIONS OF WATER RESOURCES DEVELOPMENT

301. Present Urban Water Supply

a) Islamabad

The average daily water supply and the rated capacity of water supply facilities in 1986 were 200,800 cu.m (44.2 million gallons) and 225,100 cu.m (49.6 million gallons), respectively, as shown below.

Daily Water Production in 1986
(Islamabad Proper)

(Unit: MLD (MGD))

Name of Source	Average Daily Production	Production Capacity
Simly-Filtration Plant	95.0 (20.9)	109.1 (24.0)
Kurange H.W	-	11.3 (2.5)
Shahdara H.W	3.3 (0.7)	11.3 (2.5)
Nurpur H.W	3.2 (0.7)	3.2 (0.7)
Saidpur H.W	3.6 (0.8)	3.6 (0.8)
Golf Course H.W (New)	12.3 (2.7)	12.3 (2.7)
Golf Course H.W (Old)	10.0 (2.2)	10.0 (2.2)
G-10 H.W	9.1 (2.0)	11.3 (2.5)
Tube Wells in National Park Area	34.0 (7.5)	34.0 (7.5)
Tube Wells in Sectoral Area	30.3 (6.7)	30.3 (6.7)
Total	200.8 (44.2)	236.4 (49.6)
Per Capita	707 litres	

b) Rawalpindi Urban Area

The arranged daily water supply and the rated capacity of facilities were 178,300 cu.m and 192,200 cu.m, respectively, in 1986, as shown hereunder.

Daily Water Production in 1986
(Rawalpindi Urban)

(Unit: MLD (MGD))

Name of Source	Average Daily Production	Production Capacity
Rawal Lake Filtration Plant	87.1 (18.0)	95.6 (21.0)
Sohan Camp Tube Wells	11.3 (2.5)	11.3 (2.5)
PHED Tube Wells	17.8 (3.9)	17.8 (3.9)
RMC Tube Wells	47.1 (10.4)	47.1 (10.4)
CB Tube Wells	19.3 (4.2)	19.3 (4.2)
MES (Army) Tube Wells	1.1 (0.2)	1.1 (0.2)
Total	178.3 (39.2)	192.2 (45.2)
Per Capita	263 litres	

302. Command Area of Irrigation

The proposed irrigable areas are located in the Potwar plateau in the northern Punjab, which have a characteristic of Barani (rainfed) agriculture. Cropping intensity and yield in the area are fairly lower than the national averages due to the fact that farming is dependent upon physical factors of climate and soil.

Furthermore, such social infrastructure as road, electricity, communication, health and educational institutions are so poorly arranged that the living conditions of farmers are extremely backward.

The Haro river left bank command area covers 16,100 ha in irrigable area and 31,500 ha in total area including Wah and Taxila cantonments, Wah industrial area and 37 villages.

The Soan river right bank suburban area is situated in the suburbs of Rawalpindi on the right bank of the Soan river covering 3,000 ha in total area and 900 ha in irrigable area.

303. Developed Water Resources in Study Area

a) Storage Dams

Existing storage dams in the study area are considerably many, i.e., two large dams, three medium dams and six small dams. Authorities of these dams are WAPDA, CDA and SDO. WAPDA has concerned itself directly or indirectly to all of these dams at the stages of investigation, design and implementation. The following are features of existing major storage dams.

Name	Catchment Area (km^2)	Annual Runoff (MCM)	Live Storage (MCM)	L.W.L (m)(MSL)
Tarbela	168,400	75,200	11,600	396.2
Mangla	33,300	28,400	6,586	317.0
Rawal	275	104	53	520.6
Simly	153	141	25	680.6
Khanpur	778	327	113	579.7

b) Rivers and Streams

According to the result of the field survey and information collected from the authorities concerned, characteristics of major diversion water from the Dor, Haro and Soan rivers are as follows:

River	Purpose	Beneficiary or Production
Dor	Irrigation	3,825 ha
Haro (Jhablat)	Irrigation	570 "
Soan	Urban Water	15.1 MCM/annum

c) Groundwater

In Islamabad and Rawalpindi area, more than 150 tubewells have been constructed. Among them around 20 percent of total tubewells are regularly in rest for the maintenance. Annual discharge amount by the tubewells is about 59 MCM in the capital area.

On the other hand, in Wah and Taxila area, more than 50 tubewells are working and around 21 MCM/year has been exploited by

the tubewells. The tubewells in this area are operated by many authorities which are HMC, HFF, HRF, PHED and so on.

304. Implementation and Operation/Maintenance Agency

The entire urban water supply facilities in Islamabad such as treatment plant, conduction main, service reservoirs and distribution pipe networks are constructed, operated and maintained by CDA. Such high-level engineering as dam design and construction is committed to WAPDA.

Urban water supply to Rawalpindi is maintained by PHED. In Rawalpindi RMC, MES and CB receive benefit from water supply. Ground water development is being done by PHED or other beneficiaries and tube wells constructed by the provincial government are maintained by RMC. Rawal dam, the major water resource in the area, is maintained by SDO under the Irrigation and Power Department due to the fact that original purpose of the Rawal dam was irrigation.

305. Finance and Water Tariff Systems

As summarized in the table below, financial situation of water supply organizations of twin cities is not in a good shape.

Financial Situation of Metropolitan Water Supply Organizations, 1985-86

Item	CDA	RMC	MES & CB
1. Profit & Loss (Rs. Million)			
1) O/M Cost			
a) Pay & Allowance of Establishment	13.86 (16.5%)	1.30 (9.9%)	2.96 (14.5%)
b) Electricity Charges	34.29 (40.8%)	7.55 (57.5%)	7.35 (35.9%)
c) Store/Materials	11.03 (13.1%)	0.65 (4.9%)	5.48 (26.8%)
d) Depreciation	21.48 (25.5%)	1.64 (12.5%)	2.11 (10.3%)
e) Others	3.44 (4.1%)	2.00 (15.2%)	2.55 (12.5%)
f) Total	84.10 (100.0%)	13.14 (100.0%)	20.45 (100.0%)
2) Water Charges Receipt	11.62	4.85	3.28
2. Unit Cost of Water, Rs./1,000 lit. (Rs./1,000 gal.)			
1) Production Cost	1.64 (7.45)	0.50 (2.29)	1.05 (3.33)
2) Recovery of Production Cost	0.23 (1.03)	0.19 (0.85)	0.17 (0.76)

At present, average income and water demand per month of a Metropolitan household are estimated at Rs. 2,713 and 32.54 m^3, respectively. Consequently, average water payment per month of a household works out at Rs. 33 under the above tabulated water cost, corresponding to 1.2 percent of its income.

World Bank considers it all right when water payment is kept within 5 percent of household income. It would be preferable if it could be contained within 3 percent.

It is clear from the above that domestic (and, therefore, all) users have enough means to get water supply authorities financially stand on their own feet. The existing situation where the authorities are subsidized extensively is given rise to by the interactions of various factors centering on the existing water tariff systems.

Water tariff systems of Metropolitan area consists of quantity rate systems and flat rate systems. Flat rate systems impose fixed monthly or yearly charges on individual users on the basis of plot size, dimensions of dwellings/buildings, diameters of pipes, etc.

On the other hand, quantity rate systems are also practised in a few areas of Islamabad (18%), RMC (2%) and MES (40%). The quantity rates applied to respective consumers are summarized as follows:

Quantity Rate Systems in Metropolitan Areas, 1987

(Unit: Rs./1,000 lit. (Rs./1,000 gal.)

Administrative Organ	Domestic/Public Users	Commercial/Industrial Users
CDA	0.79 (3.60)	1.32 (6.00)
RMC	Discontinued	1.10 (5.00)
MES	0.88 (4.00)	1.32 (6.00)
CB	Discontinued	Discontinued

4. WATER DEMAND PROJECTION

4. WATER DEMAND PROJECTION

401. Population Forecast and Served Population

The population forecast of a city should be made as accurate as possible in formulating an urban water plan. However, the future population could be affected by various factors including future development process of the relevant cities as well as surrounding areas, and it is difficult to discuss future population unconditionally.

Projection of population and served population can be summarized as follows:

Future Service Ratio and Population Served

Sub-areas	Item	1987	2000	2010	2030
Islamabad Proper(I)	Population	284	621	760	1,006
	Service Ratio	100	100	100	100
	Population Served	284	621	760	1,006
Rawalpindi					
CANTT	Population	409	616	782	1,100
	Service Ratio	67.5	80	85	95
	Population Served	276	492	664	1,045
RMC	Population	536	711	849	1,050
	Service Ratio	75	87.5	92	100
	Population Served	402	622	781	1,050
Sub-total	Population	945	1,327	1,631	2,150
	Population Served	678	1,114	1,445	2,095
	(Service Ratio)	(71.7)	(83.9)	(88.6)	(97.4)
Rural	Population	91	122	146	196
	Service Ratio	25	30	45	85
	Population Served	22	36	65	166
Total (II)	Population	1,036	1,449	1,777	2,346
	Population Served	700	1,150	1,510	2,261
	(Service Ratio)	(68.5)	(79.4)	(85)	(96.4)
Grand Total (I)+(II)	Population	1,320	2,070	2,537	3,352
	Population Served	984	1,771	2,270	3,267

Note: Population..... 1,000 persons
Service Ratio.. Percent

402. Demand for Urban Water

Urban water is basically classified into domestic, public, commercial and industrial water. Wastage and leakage shall be included in the water demand. In an area like Rawalpindi CANTT, water use for military service should be taken into account in addition to the above categories of water uses.

Urban water demand in the future could be defined as the sum of the net total demand for water by these consumers plus leakage and wastage. The net total demand for water is estimated from the present water use by consumers in each category in consideration of the future development plan, population increase and other data. Leakage and wastage from the water supply system are estimated from the present quantities and prospective reduction by improvement of the supply system in the future.

The projected water demands for each area are tabulated in Table IV-1 in the succeeding page.

Table IV-1. Summary of Projected Daily Demand

(Units: Water Demand ... MLD (MGD)
per Capita ..... LCD (GCD)

	1987	2000	2010	2030
Islamabad Proper Area:				
Water Demand				
Average Daily Demand	200.8 (44.2)	362.7 (79.7)	433.0 (95.3)	563.0 (123.8)
Maximum Daily Demand	251.0 (55.2)	453.4 (99.7)	541.3 (119.1)	703.8 (154.8)
Per Capita Daily Demand				
Domestic Use	222 (49)	236 (52)	245 (54)	257 (56)
Total	707 (155)	584 (128)	570 (125)	560 (123)
Rawalpindi Urban:				
Water Demand				
Average Daily Demand	178.3 (39.2)	370.9 (81.5)	547.8 (120.5)	924.2 (203.3)
Maximum Daily Demand	222.9 (49.0)	463.6 (102.0)	684.8 (150.6)	1,155.3 (254.1)
Per Capita Daily Demand				
Domestic Use	118 (26)	151 (33)	177 (39)	227 (50)
Total	263 (58)	33 (73)	379 (83)	441 (97)

	1987		2000		2010		2030	
	West Area	East Area	West Area	East Area	West Area	East Area	West Area	East Area
Rawalpindi Rural Area:								
Water Demand								
Average Daily Demand	0.3	0.5	2.9	6.6	6.0	14.3	17.9	47.0
			(0.6)	(1.5)	(1.3)	(3.1)	(3.9)	(10.3)
	0.8		9.5		20.3		64.9	
			(1.6)		(4.4)		(14.2)	
Maximum Daily Demand					7.5	17.9	22.4	58.8
					(1.6)	(3.9)	(4.9)	(12.9)
					25.4		81.2	
					(5.5)		(17.8)	
Per Capita Daily Demand								
Domestic Area			150 (33)		177 (39)		227 (50)	
Total			264 (58)		312 (69)		391 (86)	

403. Irrigation and Water Requirement

Estimate of irrigable area was carried out on the basis of the present land use, field survey and consideration of Barani development plan. The proposed areas of the Haro River Left Bank Area and Soan River Right Bank Suburban Area are 16,100 ha and 900 ha, respectively.

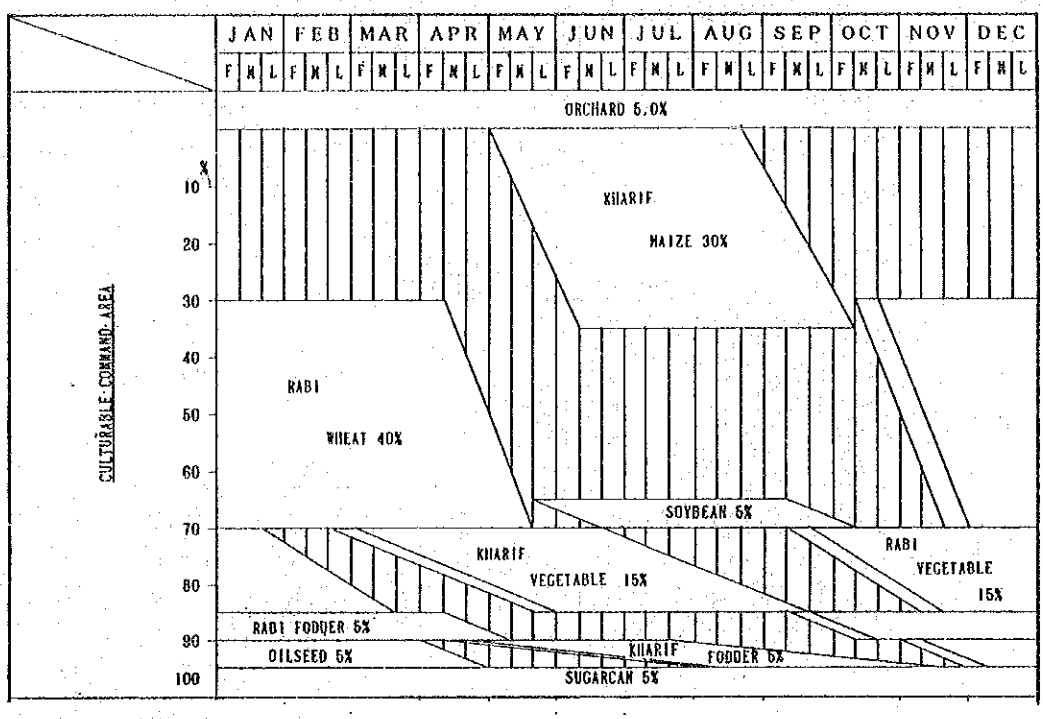
Crops to be introduced are selected on the basis of the present cropping pattern, soil, farmers' demand, national policy for agriculture and the Barani area development plan.

The unit irrigation water requirements after considering irrigation method, effective rainfall, soil moisture holding capacity and irrigation efficiency are summarized as follows:

Cropping Intensity (%)	Irrigation Water Requirement (MCM/1,000 ha/Year)	
	(1) 1/	(2) 2/
110	4.772	5.619
120	5.094	6.014
130	5.570	6.545
140	6.045	7.077

Note: 1/ ... Average irrigation water requirement in 35 years from 1952 to 1986.

2/ ... Irrigation water requirement in drought years appearing once in a ten-year period.



404. Airport Water

The new airport will be located by 25 km southwest of Islamabad city center, about 15 km east of Fatehjang town and about 18 km south of Sang Jani railway station. The present airport will be reserved for the exclusive use of PAF. The total area is about 1,060 ha, and the land acquisition has been made by CAA. The airport will have a runway of 3,800 x 45 m. In the south of this runway, a land will be reserved for construction of a future second runway and an industrial area of 120 ha.

The water requirement by the new international airport is about 0.5 MGD (2,300 cmd) in the target year 2000 tentatively. This value came from the new airport master plan report which was issued by CAA. Since this projection is only to meet the new airport facilities requirement, the total average daily demand up to the target year 2030 approved by the Coordination Committee is 1.5 MGD (6,800 cmd), including the requirement of airport facilities and relative industry/commerce. The total average daily demand in 2010 is tentatively determined at 1.0 MGD (4,600 cmd).

405. Summary of Water Demand

Water demand as direct targets of the study is summarized below, and the total water demand including indirect targets are shown in Table VII-3.

Summary of Water Demand

(Unit: MCM/Year)

- Urban Water

Sub-Area	1987	2010	2030
° Islamabad Proper Area	73.3	165.9	215.8
° Rawalpindi RMC	37.2	109.0	171.1
CANTT	27.8	101.0	183.1
Rural Area	0.3	7.7	24.9
Sub-total	65.3	217.7	379.1
Total	138.6	383.6	594.9

- Irrigation Water

	2000	2010	2030
° Haro River Left Bank Command Area	70.8	88.1	102.3
Small Lift Irrigation Scheme	(11.6)	(11.6)	(11.6)
° Soan River right Bank Suburban Area	6.4	6.4	6.4
Total	88.8	106.1	120.3

	2000	2010	2030
- International Airport Water	0.8	1.7	2.5

5. METEOROLOGICAL AND HYDROLOGICAL ANALYSIS

5. METEOROLOGICAL AND HYDROLOGICAL ANALYSIS

501. Precipitation

Annual mean rainfall for each river basin has been estimated by Thiessen method: the highest is 1,413 mm in the Soan river basin and the lowest is 837 mm in the Nandna Kas basin. Mean annual rainfall for the whole study area is estimated at around 1,000 mm.

Mean Annual Rainfall of River Basins

River Basin	Annual Mean Rainfall (mm)	Point	Catchment Area (sq.km)	Remarks
Dor River	1,269	Dw-1 Site	517.7	
Haro River	1,403	Khanpur Dam	778.0	
Kurang River	1,309	Soan Junction	580.3	
Soan River	1,413	Sw-1 Site	487.9	except the Kurang, the Ling
Ling River	1,129	Soan Junction	404.6	
Bauhti Nala	(820)	Bauhti Village	12.8	
Jhablat Kas	857	Hassan Abdal SGS	248.6	
Nandna Kas	837	N-1 Site	462.0	
Lei Nala	(820)	Soan Junction	211.2	
Sil River	1,009	SL-1 Site	237.6	
Whole Study Basin	(1,000)		6,800	

502. River Runoff Analysis

The annual runoff at the key sites from 1960 to 1980 is tabulated in Table V-1.

As seen in the above table, the rivers in the study area generally have a large fluctuation of annual runoff amount by year. On the other hand, the fluctuation of that of the gigantic rivers like the Indus and the Jhelum is relatively small. In the study area, only the Jhablat Kas has a steady flow with less fluctuation due to abundant outflow of groundwater in its basin.

Runoff analysis at prospective development sites were carried out by adopting tank model method, and the results are summarised in Table V-2.

Table V-1. Annual Runoff at Key Sites

River	Site	Drainage Area (sq.km)	Annual Runoff (MCM) Mean	Max.	Min.	Runoff Height (mm) Mean	Max.	Min.	Ratio to Mean Max.	Min.
Dor	Dw-1	517.7	155	240	112	299	464	216	1.55	0.72
Haro	Khanpur	778.0	327	629	127	420	808	163	1.92	0.39
Soan	Cherah	326.3	175	361	51.7	536	1,106	158	2.06	0.30
	Rawalpindi	1,684	639	1,301	291	379	773	173	2.04	0.46
Kurang	Rawal Dam	275.1	(100	191	56	364	694	204	1.90	0.56)*5
Ling	Kahuta	145.0	74.6	154	31.3	514	1,062	216	2.06	0.42
Jhablat	Hassan Abdal*1	248.6	170	187	152	686	752	611	1.10	0.89
Sil	Chahan	241.0	50.3	99.5	20.0	209	413	83	1.98	0.40
Indus	Darband*2	166,019	76,700	101,600	64,400	462	612	389	1.32	0.84
	Tarbela Dam*3	168,350	69,200	84,500	57,400	411	502	341	1.22	0.83
Jhelum	Kohala*4	24,890	24,900	34,500	13,000	1,000	1,386	522	1.39	0.52

Note) *1: September 1961 - June '65 *2: 1961 - April 1974

*3: October 1973 - September 1986 *4: 1965 - 1980 ..... 1960 - 1980 other than *1 - *4

*5: Data Source: Upper Kurang Study

Table V-2. Runoff Analysis at the Prospective Development Sites

River	Development Site	Catchment Area (km^2)	Runoff Analysis	Annual Average Runoff (MCM)	Annual Average Height (mm)
Dor	D-1	292.3	Tank model at Khanpur Station	96.24	329
	Dw-1	517.7	- ditto -	154.72	299
Haro	H-4	498.5	Multiplied Khanpur runoff by catchment area ratio	209.50	420
	Khanpur Dam*	778.0	Applied Khanpur runoff	326.95	420
Nandna Kas					
	Shahpur Dam*	203.9	Multiplied Chahan runoff by catchment area ratio	42.54	209
	N-1	462.0	- ditto -	96.35	209
Soan					
	Simly Dam*	152.8	Multiplied Cherah runoff by catchment area ratio, and adding CDA intake after 1969 (Same procedure as Khanpur Conduction F/S)	83.45	546
	S-1	341.1	Multiplied Cherah runoff by catchment area ratio	182.85	536
	Sw-1	1,472.8	Multiplied Rawalpindi runoff by catchment area ratio	558.70	379
Kurang	KL-1	283.7**	Using three tank models at Khanpur, Cherah and Chahan, and applying C.A.4.0, 157.7, 122.0km^2 considering geological formation.	102.66	362
Malal Kas					
	M-1	82.8	Applying tank model at Cherah and Kahuta	38.03	459
Ling	L-1	285.0	Multiplied Kahuta runoff by catchment area ratio, then adjusted the runoff by reduction of runoff coefficient estimated by tank model	107.10	376
Sil	SL-1	237.6	Multiplied Chahan runoff by catchment area ratio	49.57	209

Note * ... Existing Dam, ** ... excluding the catchment area of the Rawal dam

6. EVALUATION OF WATER RESOURCES DEVELOPMENT POTENTIAL

6. EVALUATION OF WATER RESOURCES DEVELOPMENT POTENTIAL

601. Basic Concept of the Water Resources Development

With the exception of points which have been developed and/or schemed already, economical and steady water resources shall be studied and selected over the whole study area. Those evaluations shall be based on comprehensive consideration of both of natural and social conditions and, especially on a ratio of development cost to water production developed.

Any previous precedence on the selection between surface water development and groundwater development will not be taken. For the final selection, the above "unit water cost" will be also referred to.

In principle, water resources to be developed will be connected to the nearest users. And yet, the above "unit water (conveyance) cost" has still priority over the actual distance between two points.

For a trans-basins or trans-provinces scheme, and/or a scheme in which various water rights are involved, the final adoption (*1) will be left to the authorities concerned and then, in this study, only a technical proposal will be submitted.

(Note *1): Schemes in such situations are the Dor Conduction (Transbasins) Scheme and the Upper Kurang River Development Scheme.

In a surface water development, either to simply take or store water will be decided by runoff condition of the stream.

In case of the storage dam, the location and dam type will be assumed first and, based on size-cost curve and water balance simulations study, the dam size will be optimized and finally the amount of water production by the dam will be settled.

In case of other development forms, size of the facility will correspond to the reasonable maximum potential of water resources computed on collected hydrological data.

Water resources potential will be computed in trials of water balance with applied runoff data and projected water demand. The projected water demand consists of not only the principal water usage but also the reasonable release downstream. Even though there is no evident water right downstream, in general, some amount of released water will be considered for uncertain use. It will be named as "Minimum Regulated River Flow" in the study.

602. Basic Criteria for the Evaluation of Development Potential

The development potential of the surface water has been evaluated under the following criteria:

- Evaluated using runoff data for 21 years from 1960 to 1980.
- Minimum regulated river flow (MRRF) to be released for downstream water rights. (MRRF = 355 days flow).
- Safe water utilization ratio has been set to allow the water shortage once in 10 years. Water shortages of less than 5% of demand are not considered as water shortage.
- Water loss is considered only for evaporation, and not for seepage taking the MRRF into account.
- Demand for urban water and irrigation water is considered under the following fluctuation on average:

Monthly Fluctuation of Urban Water Demand

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
0.80	0.85	0.90	1.00	1.15	1.25	1.05	1.00	1.05	1.05	1.00	0.90	1.00

Monthly Fluctuation of Irrigation Water Requirement

(Unit: MCM/1,000 ha)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
0.349	0.401	0.579	0.611	0.757	0.961	0.456	0.285	0.474	0.478	0.477	0.330	6.158

603. Comprehensive Evaluation of Development Potential

The development potential of the surface water has been computed by computer simulation at various potential sites and the results are illustrated in Figure VI-1. The figure shows the relation between the firm water resources and the size of live storage capacity of dams. Using this relation, the optimum development size has been selected by the study on unit water cost. Table VI-1 shows the summary of the potential development on optimum development and, the table reveals the following:

- Total live storage capacity of dams (including Khanpur dam) will be 573 MCM, and in this case, average utility ratio will be 1.89 to the total inflow of 1,085 MCM.
- Total net available water resources are estimated at 482 MCM, and development ratio at 0.444 to the total inflow of 1,085 MCM.
- Total MRRF will be 133 MCM, which will be 12.3 percent of the total inflow of 1,085 MCM.
- The total of the net available water resources development and the MRRF will be 614 MCM, and that is 56.6 percent of the total inflow of 1,085 MCM.

In the study of unit water cost, the following sites are excluded from the selected potential development site.

N-1 dam: due to submergence of the irrigation area of the Shahpur dam.

Upper Simly dam (Chaniot): due to extremely high unit water cost.

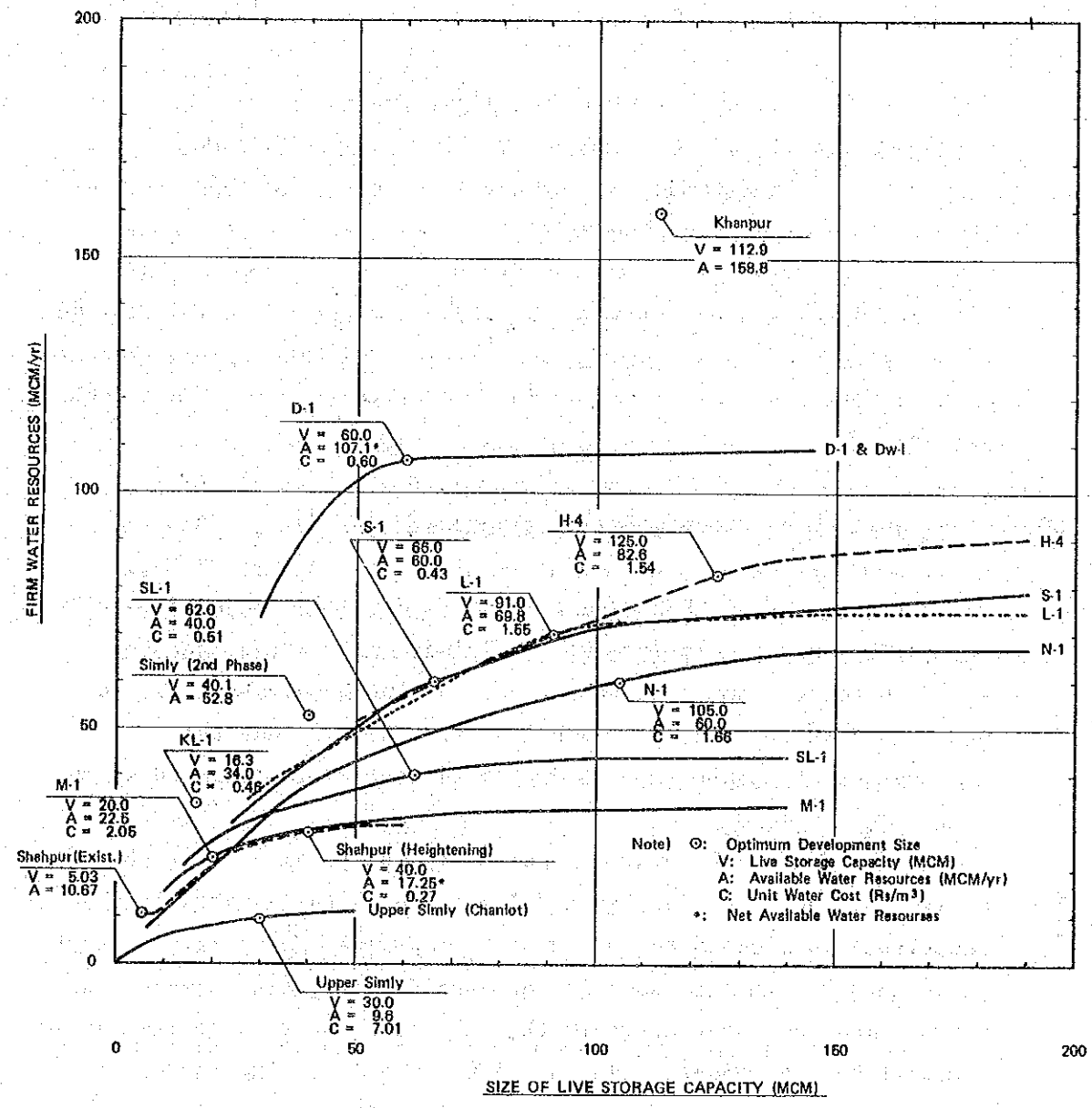
M-1 dam: due to technical difficulties.

Sw-1 diversion dam: due to hydrological reasons.

Table VI-1. Potential Water Resources in the Study Area

Development Site	D.A. (km^2)	(1) Ave. Annual Runoff (MCM/yr)	(2) Live Storage (MCM)	Utility Ratio (1)/(2)	(3) Potential Water Resources (MCM/yr)	(4) Water Resources developed by Existing Facil. (MCM/yr)	(5) Net Water Resources Development (3) - (4) (MCM/yr)	Development Ratio (5)/(1)	Evp. Loss (MCM/yr)	M.R.R.F. (MCM/yr)	Spill (MCM/yr)	Years in Shortage
Dor River												
D-1	292.3	96.2	60.0	1.60		0						
Dw-1	517.7	58.5	0	-		0				32.5	10.9	
Sub-Total	517.7	154.7	60.0	-	107.1	0	107.1	0.692	1.6	32.5	10.9	1966, 70
Haro River												
H-4	498.5	209.5	125.0	1.68		0						
Khanpur Dam	778.0	117.5	112.9	1.04		158.8				49.5	36.6	
Total	778.0	327.0	237.9	1.37	241.4	158.8	82.6	0.253	5.3	49.5	36.6	1970, 75
Dor-Haro Link (Conduction Capacity 5.0 cu.m/sec.)												
H-4		209.5	125.0	1.68		0						
Khanpur Dam		228.2	112.9	2.02		158.8				49.5		
Total		437.2	237.9	1.84	348.5	158.8	189.7	0.434	5.3	49.5	40.4	1970, 75
Shahpur Dam	203.9	42.5	40.0	1.06	27.92	10.67	17.25	0.406	6.6	2.2	5.9	1973, 75
Jw-1	248.6	170.4	0	-	101.80	31.0	70.8	0.415	-	22.7	45.9	
Sub-Total	1230.5	539.9	277.9	1.94	371.12	200.47	170.65	0.316	11.9	74.4	88.4	1970,73,75
Soan River												
S-1	341.1	130.9	66.0	1.98	60.0	0	60.0	0.458	4.5	11.4	55.0	1970, 75
L-1	285.0	107.1	91.0	1.18	69.8	0	69.8	0.652	5.5	9.5	22.3	1970, 75
KL-1	283.7	102.7	16.3	6.30	34.0	0	34.0	0.331	6.8	2.3	59.6	1962, 74
SL-1	237.6	50.1	62.0	0.81	40.0	0	40.0	0.798	4.4	2.6	3.1	1962, 75
Sub-Total	1147.4	390.8	235.3	1.66	203.8	0	203.8	0.521	21.2	25.8	140.0	1962,70,74,75
Total	2895.6	1085.4	573.2	1.89	682.02	200.47	481.55	0.444	34.7	132.7	239.3	1962,70,73,74,75

Figure VI-1. Relation between the Firm Water Resources and the Size of Live Storage Capacity



604. Basic Concept of Groundwater Development

There are two conceptions for the groundwater development scheme. One is to use the groundwater under stable conditions over a year's time. The other is to use only in the drought year.

For a stable utilization, the discharge to be used in a year should be restricted to an amount within the annual amount recharged to the groundwater basins. Otherwise, many detrimental effects including ground subsidence will arise.

For an emergency utilization in the drought year, a discharge may be permitted to exceed the annual recharge amount. The amount of utilization can be recharged in several years after the drought year.

605. Availability of Groundwater Development

Groundwater of 26 MCM/year might be developed at the least in the capital area including the Rawalpindi rural area. But the actual potential for groundwater development should be assessed based on further studies. Such studies would include the measurement of long-term groundwater table fluctuations and so on.

According to the hydrological analysis the amount for the entire catchment area of Wah and Taxila which infiltrates to the subsurface is assumed to be around 210 MCM/year and a large amount of the infiltration flows into the groundwater basin as recharge. Hydrological analysis suggests that the effluent flow to the rivers (Jhablat Kas and Bauhti Nala) was 160 MCM/year during the period from 1961 to 1965. This means that around 80 percent of the annual amount of groundwater recharge was flowing out to the other basins in the form of surface runoff.