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THE ISLAMIC REPUBLIC OF PAKISTAN
CAPITAL DEVELOPMENT AUTHORITY

FINAL REPORT
FOR
FEASIBILITY STUDY ON THE CONDUCTION OF WATER FROM KHANPUR TO ISLAMABAD/RAWALPINDI

MAIN REPORT

MARCH 1985

THE JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Islamic Republic of Pakistan, the Japanese Government decided to conduct a feasibility study on the Conduction of Water from Khanpur to Islamabad and Rawalpindi, and entrusted the survey to the Japan International Cooperation Agency. The J.I.C.A. sent to Pakistan a survey team headed by Mr. Satoshi Kadowaki from July 6, 1984 to December 9, 1984.

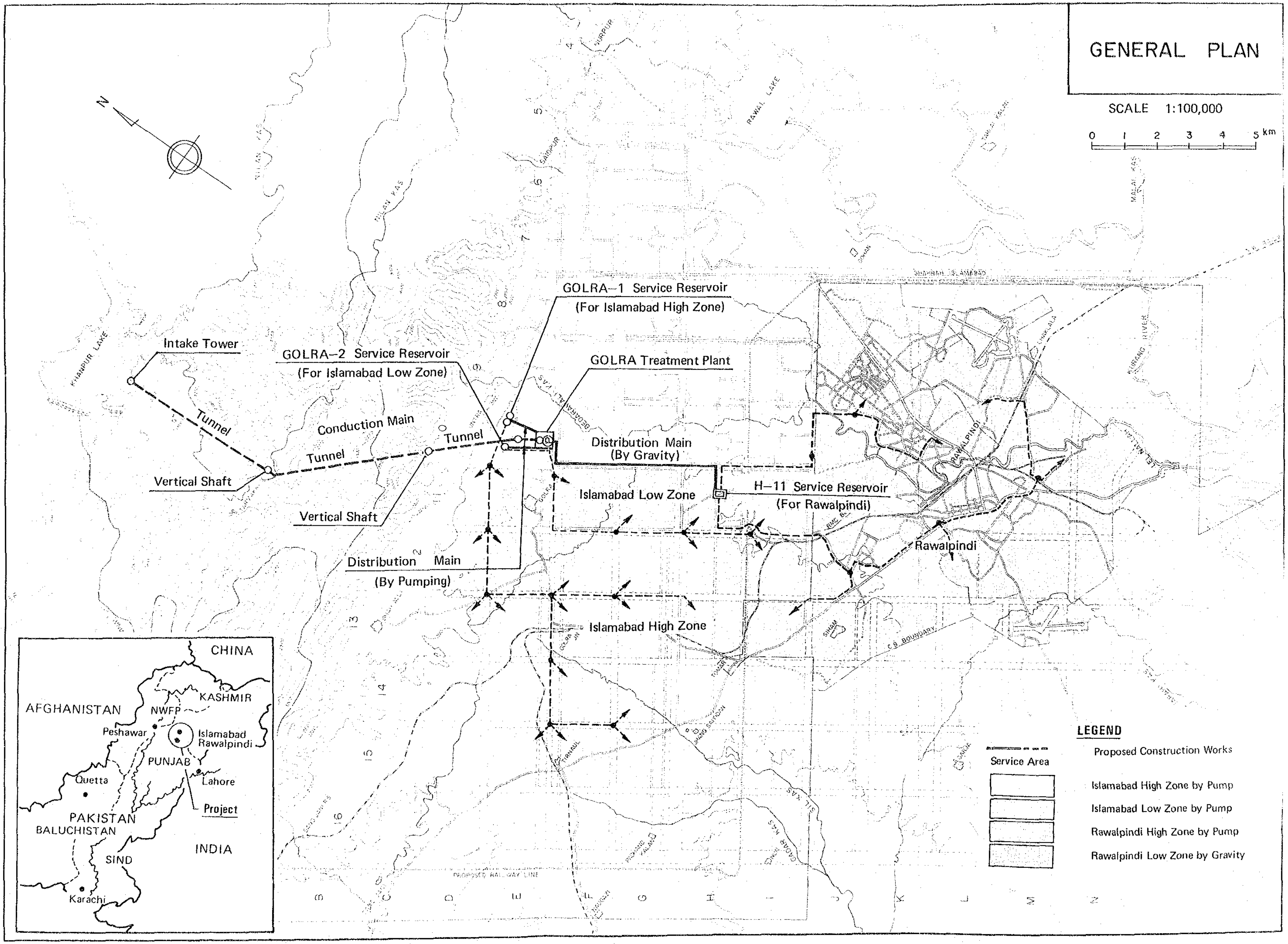
The team exchanged views on the Project with the officials concerned of the Government of Pakistan and conducted a field survey in the Metropolitan area. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

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

March, 1985

Keisuke Arita
President
The Japan International Cooperation Agency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Tunnel
Vertical Shaft
Conduction Main
Tunnel
Vertical Shaft
GOLRA-2 Service Reservoir
(For Islamabad Low Zone)
GOLRA-1 Service Reservoir
(For Islamabad High Zone)
GOLRA Treatment Plant
Distribution Main
(By Gravity)
Distribution Main
(By Pumping)
Islamabad Low Zone
Islamabad High Zone
H-11 Service Reservoir
(For Rawalpindi)
Rawalpindi
CHINA
AFGHANISTAN
KASHMIR
NWFP
Peshawar
Islamabad
Rawalpindi
PUNJAB
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ABBREVIATIONS

1. Organization

ACE	:	Associated Consulting Engineers Ltd.
AESL	:	Associated Engineering Services Ltd.
CB	:	Cantonment Board
CDA	:	Capital Development Authority
FAO	:	Food and Agricultural Organization of the United Nations
JICA	:	The Japan International Cooperation Agency
MES	:	Military Engineering Service
NESPAK	:	National Engineering Services (Pakistan) Ltd.
PAF	:	Pakistan Air Force
PHED	:	Public Health and Engineering Department
PIDC	:	Pakistan Industrial Development Corporation
POF	:	Pakistan Ordnance Factory
RMC	:	Rawalpindi Municipal Corporation
SDO	:	Small Dams Organization
TECSULT	:	TECSULT International Limited
WAPDA	:	Water and Power Development Authority
WHO	:	World Health Organization

2. Units

AF	:	acre feet
cfs	:	cubic feet per second
cm	:	centimeters
cu.m	:	cubic meters
cu.m/d	:	cubic meters per day
cu.m/sec	:	cubic meters per second
cusec	:	cubic feet per second
ft	:	feet
gal (gal.)	:	imperial gallons
ha	:	hectares
hr.	:	hours
kg	:	kilogrammes

km	:	kilometers
lit.	:	liters (litres)
m	:	meters (metres)
MCM	:	million cubic meters
mg/d	:	million gallons per day
MGD	:	million gallons per day
min	:	minutes
MLD	:	million liters per day
mm	:	milimeters
ppm	:	parts per millions
Re.	:	rupee
Rs.	:	rupees
sec.	:	seconds
sq.	:	square
sq.m	:	square meters
Yd	:	yards

3. Others

B/C	:	benefit cost ratio
D.F.	:	discount factor
EIRR	:	economic internal rate of return
GDP	:	Gross Domestic Product
IRR	:	internal rate of return
LBC	:	Left Bank Canal
O/M	:	operations and maintenance
P.C.I.	:	Planning Commission I Pro Forma
RBC	:	Right Bank Canal
SWHP	:	Surface Water Hydrology Project

CURRENCY EQUIVALENTS

US$ 1.0 = Rs. 14.1 = 245

Rs. 1.0 = US$0.071 = 17.4

(as of Aug. 1, 1984)

CONVERSION FACTORS

Length

1 inch	= 25.4 mm	1 mm	= 0.0394 inch
1 foot = 12 inches	= 0.305 m	1 m	= 3.28 feet
1 yard = 3 feet	= 0.914 m		= 1.09 yard
1 statute mile	= 1.61 km	1 km	= 0.621 mile

Area

1 in^2	= 6.45 cm^2	1 cm^2	= 0.155 in^2
1 ft^2	= 0.0929 m^2	1 m^2	= 10.8 ft^2
1 yd^2	= 0.836 m^2		= 1.20 yd^2
1 acre	= 0.405 ha	1 ha	= 2.47 acres
1 sq. stat. mile	= 2.59 km^2	1 km^2	= 0.386 sq.stat. miles

Volume

1 in^3	= 16.4 cm^3	1 cm^3	= 0.0610 in^3
1 ft^3	= 0.0283 m^3	1 m^3	= 35.3 ft^3
	= 28.3 litre	1 litre	= 0.0353 ft
1 gallon (imp)	= 4.55 litre		= 0.220 gallon (imp)
1 acre-foot	= 0.123 ha-m	1 ha-m	= 8.11 acre-feet
	= 0.00234 MCM	1 MCM	= 811 acre-feet

Weight

1 lb = 16 oz	= 0.454 kg	1 kg	= 2.20 lb
1 cwt = 112 lb	= 50.8 kg		= 0.0197 cwt
1 long ton (2240 lb)	= 1.02 metric ton		= 0.000984 long ton
1 cotton bale	= 178 kg		= 0.00562 cotton bale

Capacity and Velocity

1 cusec	= 0.0283	cu.m/sec	1 cu.m/sec	= 35.3	cusec
1 MGD	= 4.55	MLD	1 MLD	= 0.220	MGD
1 Knot	= 1.85	km/hr	1 m/sec	= 3.28	ft/sec
1 foot/sec	= 0.305	m/sec		= 197	ft/min
1 foot/min	= 0.508	cm/sec	1 km/hr	= 0.541	knot
1 mile/min	= 1.61	km/min		= 0.621	mile/hr

Temperature

°F = 1.8°C + 32

°C = (°F-32) x 5/9

Pressure

1 atmosphers	= 76.0 cm Hg	1 inch H20	= 2.49 mbar
1 bar	= 1.013 atm	1 mbar	= 0.750 mm Hg
1 inch Hg	= 0.0334 atm	1 lb/in^2	= 51.7 mm Hg

CHAPTER I. INTRODUCTION

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1.1. Authorization and Report

The FINAL REPORT is prepared in accordance with the implementing arrangement for the feasibility study on the Conduction of Water from Khanpur to Islamabad and Rawalpindi in the Islamic Republic of Pakistan agreed upon between the Government of Pakistan and the Government of Japan dated December 14, 1983.

The contents of the report consist of Executive Summary, Main Report and Appendixes. The report was compiled based on the field survey, review of data, information and existing reports related to the Project, careful study and series of discussion meeting between the governmental authorities concerned of Pakistan and the study team, and interim report which has been submitted to the Government of Pakistan dated November 3, 1984.

1.2. Scope of the Study

The scope of study in accordance with the implementing arrangement is summarized as follows:

1) The study area will cover Khanpur reservoir including drainage area, water conduction routes from Khanpur Reservoir to Islamabad/Rawalpindi up to H.I. Principal road, inclusive of raw water reservoir, water treatment plant, pumping station and service reservoirs,

2) To collect and review the relevant existing maps, data, information and the study reports related to the water conveyance system in the study area for the project formulation,

3) To review the future water demand which will be projected by the year 2000 and conduct the water balance computation on the basis of water from the Khanpur Reservoir in consideration of the water demand for industrial area and farm land irrigation,

4) To conduct survey in respect of topography, foundation geology, hydrogeology, water quality or any other information, if necessary,

5) To study the alternative plans for water conveyance systems including outlet works, pumping station, tunnelling, open channels, main pipeline, raw water reservoir, treatment works and service reservoirs based on topographical and geological conditions, water demand studies and economic assessments so as to obtain most adequate concepts and least cost water conveyance system for project formulation,

6) To prepare layout plans and preliminary designs for the selected water conveyance system and related structures based on the comparative study mentioned above,

7) To prepare implementation programmes of the project including construction plan and project organization, and cost estimate in consideration of foreign and local currency components,

8) To carry out studies on organization and method of the post project operation and maintenance inclusive of estimate of operation and maintenance cost, and

9) To evaluate the cost and benefits of the Project including economic and financial analysis, and sensitivity analysis.

1.3. Background of the Project

The metropolitan area, the twin cities of Islamabad and Rawalpindi is situated at north-eastern corner in the north of Punjab Province. The construction of the new capital of the country was started in 1961 in accordance with a policy formulated by the Federal Government in 1958 and it was transferred from Karachi to Islamabad in 1968-69.

These circumstances have given a substantial stimulus to the development of the old city, Rawalpindi, which is very close to Islamabad, and growth in all parts of Rawalpindi city has been accelerated since the early 1960's.

Present population in Islamabad and Rawalpindi is 0.200 and 0.835 million, respectively. It is projected that ultimate population of the twin cities in the year 2030 will reach 1.00 million for Islamabad and 1.70 million for Rawalpindi.

The Khanpur Dam which was constructed on Haro river by WAPDA has been projected to supply 33 MGD of water to Islamabad and 69 MGD to Rawalpindi.

Numbers of studies have been carried out for conduction of water from Nicholson Monument, the terminal point of the Left Bank Canal, to Islamabad/Rawalpindi as well as for direct withdrawal from the reservoir and conduction through tunnels to the twin cities. A final plan, however, has not been so far adopted and the most economical alternative has been still under contemplation.

In response to the request of the Government of the Islamic Republic of Pakistan, the Government of Japan dispatched the preliminary survey team headed by Mr. Takeshi KOBAYASHI to Pakistan from December 4th to 15th, 1983, through the Japan International Cooperation Agency (hereinafter referred to as JICA), and carried out the preliminary survey on the Conduction of Water from Khanpur to Islamabad/Rawalpindi (hereinafter referred to as the Project) in close cooperation with the Pakistan authorities concerned.

As the result of the preliminary survey, the Government of Japan has decided to undertake the Feasibility Study on the Project in accordance with Laws and Regulations in force in Japan.

The JICA, the official agency responsible for the implementation of the technical cooperation programmes of the Government of Japan, carried out the feasibility study from July 1984 to February 1985 in close cooperation with the Capital Development Authority (hereinafter referred to as CDA) and the authorities concerned of the Government of Pakistan. Furthermore, the JICA conducted training and technology transfer to the counterpart personnel appointed by the Government of Pakistan in the course of the study.

1.4. Assignment and Counterpart

The member of the advisory committee and study team and counterpart personnel contacted for the feasibility study on the project are listed up as follows:

A. Advisory committee

Chairman	KOBAYASHI, Takeshi	Director, Planning Division, Japan Sewerage Project Corporation
Water Demand & Supply	TSUNEMATSU, Hiroshi	Expert Officer, Water Administration Division, Hokkaido Development Agency
Facilities	YANAGISAWA, Hiroyuki	Director, Survey and Design Division, 2nd Saitama Gouguchi Construction Office, Water Resources Development Public Corporation
Conduction	TAKEMURA, Tomoyoshi	Director, Survey and Design Division, Maruyama Dam Survey Office, Chubu Regional Construction Bureau, Ministry of Construction
Water Treatment	IWAHORI, Haruo	Expert in Sanitary Engineering Institute for International Cooperation, Japan International Cooperation Agency

B. Study team

KADOWAKI Satoshi	:	Team Leader
ISHIBASHI Naomichi	:	Project Economist
KIMURA Yoshiaki	:	Hydrologist
KOSAKA Kazuhisa	:	Water Supply Planner

SUGIYAMA Shigeru	:	Geologist
KONISHI Sumio	:	Canal Engineer
ASADA Hideki	:	Water Treatment Engineer
MORI Tatsuhiko	:	Facility Designer
OHTA Kunio	:	Construction Planning and Cost Estimate

C. Officials and personnel contacted

Jan Nadir Khan	:	Chairman, CDA
Mohammad Anwar	:	Member (Planning), CDA
Iqbal Nawaz Khan	:	Inspector of Works, CDA
A.R. Javaid	:	Deputy Director General (Services), CDA
A.Q. Nomani	:	Director, Water and Sewerage (Maintenance), CDA
M.K. Pasha	:	Director, Planning, CDA
Mohammad Habibullah	:	Director, Water and Sewerage (Development), CDA
Anjum Malik	:	Director, Structure, CDA
Fateh Mohammad	:	Deputy Director, CDA
C. Ghulam Mohammad	:	Deputy Director, CDA
Akhtar Zeb	:	Deputy Director, CDA
Fida Hussain	:	Deputy Director, CDA
M.A. Mohammad Azam	:	Senior Geologist, CDA
Mohammad Aslam	:	Scientific Officer, CDA
Masihullah Khan	:	Chief Engineer, PHED, Lahore
M. Saeed Mehtab Butt	:	Project Director, Rawalpindi Water Supply and Sewerage, PHED
Ch. M. Asghar	:	Deputy Director, PHED

Sh. Ghulam Hussain	:	Mayor, Rawalpindi
Abdul Sattar Malik	:	Municipal Engineer, RMC
Tariq Iqbal Khan	:	Municipal Engineer, RMC
Makhdum Jamil Ahmad	:	Commander, MES (Army)
Iqbal Hussain	:	Deputy Commander, MES (Army)
Fazal Amin	:	Senior Engineer, Cantonment
N.C. Syed	:	Member (Water), WAPDA
M.A. Qureshi	:	Chief Engineer, CDO(W), WAPDA
Altafur Rehman	:	Chief Engineer, DMO, WAPDA
Saleem Warshi	:	Project Director, Surface Water Hydrology, WAPDA
M. Ishaq Shinwari	:	Project Director, Khanpur Dam, WAPDA

CHAPTER II. PROJECT AREA

CHAPTER II. PROJECT AREA

2.1. Location

The Project Area, the twin cities of Islamabad and Rawalpindi, is situated in the north-eastern corner of the Potwar Plateau in the north of Punjab Province in the north latitude between 33°29' and 33°48', and the east longitude between 72°49' and 73°23'.

The area lies on the gentle undulating slope from the base of the Margala hills which are made up of marine limestone of Eocene age. Owing to the deposition of the alluvium, there has been rapid erosion in the area, largely brought about by the activities of man. Combination of soft, easily eroded rocks, intense cultivation, grading and wood cutting along with intense rates of precipitation is rapidly changing a gently sloping plain into a deeply dissected area of badland topography.

2.2. Physical Features

2.2.1. Climate

Being located at the southern foot of the Murree and Margala hills, the Capital Area is under relatively pleasant climate with cold winters and hot summers. There are two rainy periods a year; the summer monsoon originated from the East and winter rains caused by western disturbances.

The cold season, from December to March, is characterized by fine weather, low humidity and large diurnal range of temperature. Western disturbances in this season accordingly cause fairly widespread rains, but the amount of rainfall is not large as compared to that received during the monsoon period. These western disturbances are extra-tropical in nature and have at times well marked warm and cold fronts associated with them, and the higher peaks of the Margala hills receive light snow in some years.

The months April to June are characterized by extreme continentality with hot and dry climates. In March and April weather becomes progressively warmer and drier. May and June are usually the hottest and dusty with the maximum temperatures rising up to 45°C, and relative humidity during these two months falls below 50% as a daily average.

The southwest monsoon reaches the Area towards the beginning of July and establishes there by the middle of the month. The strength of the monsoon currents increases from June to July, it remains steady and begins retreating toward the end of August, but occasionally it continues active even in September when some of the highest floods in rivers have been recorded. A series of tropical depressions bring heavy rainfalls in the catchment of rivers causing high floods in them.

Beginning from the middle of September, October and early November are the transitory period and the most pleasant months with weather becoming increasingly cool with much sunshine. December becomes again cold with occasional rainfalls.

The annual rainfall ranges remarkably from season to season and from year to year amounting to 1,100 mm as an average in the past 30 years, of which about 60% concentrates during the monsoon season from July to September. The daily mean temperature varies from 32°C in June to 10°C in January with annual average of 21.5°C at Rawalpindi. Major climatic elements, in terms of monthly averages observed at Rawalpindi, are summarized in Table II-1.

TABLE II-1 CLIMATIC ELEMENTS OBSERVED AT RAWALPINDI

Climatic Element	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Precipitation (1954 - 1983)													
Average (mm)	67.9	65.1	80.7	62.1	39.5	52.7	245.1	298.8	108.4	30.6	21.1	30.1	1,102.2
Maximum (1981)	159.8	73.4	176.5	131.6	109.6	19.4	580.2	338.3	131.3	10.0	5.0	0.0	1,735.1
Minimum (1964)	143.3	13.7	20.6	43.9	45.7	24.6	263.7	91.9	47.0	0.0	1.8	12.4	708.7
Temperature (1954 - 1983)													
Average (°C)	10.0	12.3	17.1	22.7	27.6	31.6	30.0	28.8	27.4	22.7	16.5	11.6	21.5
Dew-point	2.0	4.1	7.5	10.3	11.2	14.8	21.5	22.3	18.8	11.5	5.6	2.6	11.0
Relative Humidity (1954 - 1983)													
Average (%)	71.4	698.8	65.3	54.2	41.5	41.5	65.8	74.8	69.5	63.2	66.3	70.7	62.8
Actual Sunshine Hours (1957 - 1983)													
Average (hrs)	6.3	6.8	6.8	8.5	10.0	10.3	8.6	8.5	8.6	9.0	8.2	6.7	8.2
Pan-Evaporation (1966 - 1973)													
Average (mm)	61.0	82.6	152.4	208.8	309.1	347.7	268.7	208.8	171.2	139.7	85.9	58.9	2,093.7

2.2.2. Topography and Geology

From the topographic and geological point of view, Islamabad/Rawalpindi area is divided into three zones, namely Margala hills, the foot zone of Murree hills and the flat zone.

Margala range of hills is composed of rather steep mountains spread easterly and westerly in the north of Islamabad/Rawalpindi area with an elevation ranging from 600 m to 1,200 m (2,000 - 4,000 ft). In the middle of the hills, Haro river traverses westwards. Geology of the Margala hills consists mainly of limestones with alternating marl and shale beds belonging to Jurassic to Eocene age. The start are tightly folded and faulted resulting in complicated geological structures such as an overturned fold. As a whole the main geological structures stretch in the direction from east to west, or northeast to southwest, following the axis of hill range and it is appeared that the strata dip overturned southwards. The Margala Fault run along the south front of Margala hills, bounding two geological units, marine sediments before Miocene age and non-marine sediments belonging to Miocene age. Several faults which run in parallel with Margala Fault have been observed in the range.

The foot zone of Murree hills is occupied mostly by the National Park Area with an elevation ranging from 540 m to 900 m (1,800 - 3,000 ft) forming steep and irregular valleys eroded by the Soan and Kurang rivers, which flow southeastwards, and intervening ridges. Geology of this zone is characterized by non-marine sandstone and mudstone of Miocene to Pleistocene age, and most part of the zone except the area along Soan river is composed of Miocene Strata which is called Murree Formation.

The flat zone expands over the Sectoral Area of Islamabad and Rawalpindi City, and in its most part consists of rolling table land sloping southwards with an elevation ranging from 480 m to 600 m

(1,600 - 2,000 ft). The main geological units comprise Pleistocene to Recent unconsolidated sediments which consist of alternating beds of clay and gravel. The most clay is silty clay and considered to be reworked loess. The gravel layers embrace an available amount of groundwater. After eroding the upper layers of bedrock materials, river has cut the underlying foundation to a depth exceeding 200 m (650 ft) and old valleys thus formed are subsequently filled with alluvial deposits of unconsolidated sediments. In this zone, outcrops of sandstone and mudstone are exposed at places and some old high terraces are observed on the foot of Margala hills.

In addition, of the three dams under consideration, the Khanpur dam and its catchment area are situated in Margala hills where limestone dominates, while both the Rawal and Simly dams with their catchments are located in the area where Miocene sandstone and mudstone are predominant.

2.3. City Development and Socio-Economic Condition

2.3.1. City Development

A. Islamabad

It was in June 1959, that shifting of the Federal Capital of Pakistan from Karachi to the Potwar area near Rawalpindi was decided by the Central Government. The construction of the new Capital Islamabad commenced in October 1961.

The new sovereign state of Pakistan came into being on August 14, 1947. The Central Government of the new state was hurriedly shifted from Delhi to Karachi. It was, however, a temporary arrangement to establish a bridgehead. Successive Governments gave their thoughts to the question of Capital building. On the recommendation of a high-powered Commission, the Government decided in favor of the Potwar area and made a public announcement to this effect in June 1959.

The Capital, given the status of an independent district, is spread over an area of 906.5 sq.km and comprises Islamabad Proper, Islamabad Park and Islamabad rural area.

In accordance with the CDA plan, construction work of major buildings in administrative area and public building area such as the Presidency, Parliament Building, Ministry of Foreign Affairs, Government Hostel, State Bank of Pakistan and National Broadcasting House are almost completed. Residential area up to series 8 is almost completed and series 9 and 10 are now in progress. Special institutional and light industrial areas of series 8 and 9 are in progress. The sectoral areas from series 11 are projected to be developed from 1984 on the basis of the CDA 15 Years Development Programme.

B. Rawalpindi

Rawalpindi is the headquarters of the Rawalpindi District. It is divided into two parts, namely, municipal corporation area and cantonment area by the Pakistan Railways' line and the sluggish stream Lei Nallah. Rawalpindi Municipal Corporation was formed in 1867 and Rawalpindi Cantonment was established after the defeat of the Sikhs by the British, and subsequently it remained as the headquarters of the Northern Command of British Army.

In August 1947 when Pakistan emerged as an independent country, Rawalpindi also gained special significance. A shift of the British Army's headquarters into the General Headquarters of the Pakistan Army brought the increase in military personnel and more economic activity, and immigration from India also brought a large number of people into the city though Hindus and Sikhs emigrated.

The city undertook national importance in 1959, when shifting of the Federal Capital of Pakistan near Rawalpindi was decided. The construction of the Capital started in 1961 and it was actually shifted in 1968. In the intervening time from 1959 up to 1968, Rawalpindi remained as the interim capital of Pakistan. These brought substantial incentive into the development of Rawalpindi and growth in all parts of the city has accelerated since the early 1960's. Development of the twin cities of Islamabad and Rawalpindi has now reached the point where the urban areas merge together in places.

2.3.2. Household Income and Social and Economic Conditions

A. Household Income

According to house visit inquiry surveys which were conducted by the Study Team in July to August in 1984, the household income is on the average Rs. 1,890 per month in the project areas encompassing both Islamabad and Rawalpindi. Area-wise, it is Rs. 2,937 in Islamabad, Rs. 1,495 in Rawalpindi City and Rs. 1,977 in Rawalpindi Cantonment.

In terms of income brackets, the households whose monthly income is less than Rs. 500, Rs. 500 to Rs. 999, Rs. 1,000 to Rs. 1,999, Rs. 2,000 to Rs. 2,999, Rs. 3,000 to Rs. 3,999, Rs. 4,000 to Rs. 4,999 and Rs. 5,000 or more occupy 4%, 22%, 38%, 18% 10%, 4% and 4% of the total respectively. It means that 78% of households fall under the income range of Rs. 1,000 to Rs. 3,999.

B. Social and Economic Conditions

The urban water from the Khanpur reservoir will be conveyed to the twin cities of Islamabad and Rawalpindi. The population of both cities was approximately one million in 1981 according to the census reports. The figure precludes rural population living within the boundaries of two cities. (Moreover, it might be reminded that in case of Islamabad the population that will be served with piped water does not cover the whole urban population as defined in the report.)

The labor force counted 274,489, of which 40.5% was comprised of government employees, 28.0% of self-employed people and 26.3% of non-governmental employees. In Islamabad government employees occupied the majority (58.8%) of labor force. The ratio of labor force to population was 27.5%, which is almost equal to both the averages of the Province of the Punjab in which the cities are located and the whole nation. Unemployment rate was 4.3%, which is a little higher than the provincial and national averages (3.2 and 3.1%). The reason is a steep rate of unemployment (9.0%) in Islamabad.

This fact combined with the comparatively low employment ratio (25.6%) testifies to an acute employment situation in Islamabad.

Population of the cities constitutes 2.1% of the provincial population, whereas its share in the national population is 1.2%. Urban population wise, it occupies 7.7% and 4.2% of the provincial and national totals respectively. Comparative ratios of labor force in the cities vis-a-vis provincial and national levels turn out to be almost the same with the above.

Salient features in the employment and industrial structures of the cities are a low share of the agriculture, forestry, hunting and fishing division on one hand, and a high share of community, social and personal services division on the other. It attests to the "metropolitan" and "political" characteristics of the twin cities. The gross value added in 1981 works out to Rs. 4,553.9 million, which occupies 1.8% of the GDP in the same year. Per capita gross product of the cities is calculated at Rs. 4,558, which is by 53 percent higher than the national average (Rs. 2,979). Table II-2 presents population and labor force in the twin cities in 1981.

2.3.3. Population

A. Islamabad

The total population of Islamabad urban and rural areas in March 1981 was 340,286 as compared to 234,813 in September 1972, as shown in Table A.I-2 of Appendix A. The urban area comprises Islamabad Proper area (220 sq.km) and a part of Islamabad Park (91 sq.km) including many villages in both the areas.

As for the population of the Islamabad Proper area in the study, the population in 1972 and 1981 was 73,598 and 143,902 respectively. The population increased by 95.5% in the 1972-81 period as shown in Table II-3. This was due to the expansion of the Proper area and migration from the other districts with the construction of the new Capital. The population in 1984 was estimated at 205,723 based on the past census data as described in 3.1.2. Population Projection.

TABLE II-2 POPULATION AND LABOR FORCE IN THE TWIN CITIES IN 1981

Items	Rawalpindi Urban	Islamabad Urban	Total
1. Population	794,843	204,364	999,207
2. Labor Force	222,085 (100.0%)	52,404 (100.0%)	274,489 (100.0%)
1) Self Employed	67,394 (30.3%)	9,368 (17.9%)	76,762 (28.0%)
2) Employee (Govt.)	81,979 (36.9%)	29,238 (55.8%)	111,217 (40.5%)
3) Employee(Non-Govt.)	60,309 (27.2%)	11,916 (22.7%)	72,225 (26.3%)
4) Employer	7,928 (3.6%)	1,222 (2.3%)	9,150 (3.3%)
5) Unpaid Family Helper	4,475 (2.0%)	660 (1.3%)	5,135 (1.9%)
3. Employment Ratio	27.9%	25.6%	27.5%
4. Unemployment Rate	3.2%	9.0%	4.3%

Items	Rawalpindi/ Islamabad A	Province of the Punjab B	Pakistan C	Ratio D = A/B	Ratio E = A/C
1. Population	999,207	47,292,000	84,253,000	2.1%	1.2%
2. Labor Force	274,489	13,147,000	23,254,000	2.1%	1.2%
3. Employment Ratio	27.5%	27.8%	27.6%	-	-
4. Unemployment Rate	4.3%	3.2%	3.1%	-	-

Sources: 1981 Census Report of Rawalpindi, 1981 Census Report of Islamabad and Pakistan Economic Survey 1983-84.

TABLE II-3 HISTORICAL POPULATION GROWTH IN ISLAMABAD PROPER AREA

Year	Population	Percentage Increase (%)	Annual Growth Rate (%)
1972	73,598	-	-
1981	143,902	95.5	7.73
1984	205,723	43.0	12.65

The above population in 1972 and 1981 are adjusted from the original figures in the Population Census reducing population of many villages in the Proper areas and a part of Islamabad Park as described in Appendix A.

B. Rawalpindi

Population census data of Rawalpindi, consisting of the Rawalpindi Municipal Corporation and Rawalpindi Cantonment, are available from 1901 up to 1981, as presented in Table II-4. Except for the initial setback from 1901 to 1911 when the city lost population due to the spread of plague, population had been growing steadily. The decade of 1961-72 recorded much more population growths which was because of Rawalpindi's recognition as an important administration and commercial center of the region, shifting of the Federal Capital next to Rawalpindi and the interim capital in the intervening time from 1959 to 1968. The population in 1984 was estimated at 888,182 based on the past census data as described in 3.1.2. Population Projection.

TABLE II-4 HISTORICAL POPULATION GROWTH IN RAWALPINDI

Year	Population	Percentage Increase (%)	Annual Growth Rate (%)
1901	87,638		
1911	86,483	-1.4	-0.14
1921	101,142	17.0	1.58
1931	119,284	17.9	1.66
1941	185,042	55.1	4.49
1951	237,219	28.2	2.52
1961	340,175	43.4	3.67
1972	598,023	75.8	5.26
1981	794,843	32.9	3.21
1984	888,182	11.7	3.77

2.4. Water Resources of the Existing Water Supply Systems

Major water sources undertaking at present and near future supply of water requested in the cities of Islamabad and Rawalpindi are surface water drained by the Haro, Kurang and Soan rivers. Supported by the storage function of the Khanpur, Rawal and Simly reservoirs, these rivers would contribute towards the existing achievement of perennial water supply accounting for 60% and 80% of the total requirements respectively for Islamabad and Rawalpindi for drinking and domestic uses, while surface water from small streams would cover 20% of total demand for Islamabad, and groundwater including springs would account for the remaining 20% for both the cities.

2.4.1. Storage Dams

A. Khanpur Dam

The Haro river, originating from the Murree and Margala hills and joining a number of affluents, traverses the hill range westwards, and flows into the Khanpur reservoir. The dam is located in Haripur Tehsil of Abbottabad District across the Haro river approximately 14.5 km (9 miles) upstream from Taxila-Haripur Road and downstream of confluence of river with its tributary of Nilan Kas in the vicinity of Khanpur Village.

Originally the Khanpur Dam Project was approved in 1963 envisaging construction of 41.8 m (137 ft) high earth-fill dam and a canal system to irrigate 31,150 ha (77,000 acres) of agricultural land situated both on the left and right bank of the river including some area on the eastern side of the Margala range of hills, and the construction work was started in the beginning of 1967. Due to growing need for municipal and industrial water supply in the terrain, irrigation water in the vicinity of twin city of Islamabad and Rawalpindi, heavy industrial complexes at Taxila and Wah, the

Project was revised in 1973 converting the primary objective of the scheme from irrigation to water supply. Consequently, the Khanpur Reservoir was designed with the raising of dam height to 50.9 m (167 ft), which is the maximum allowable from technical, geographic and geologic point of view, to supply 33.0 MGD of water to Islamabad and 69.37 MGD of water to Rawalpindi for domestic purposes, 28.5 MGD to the various industries at Wah and Taxila, and irrigation water for 14,770 ha (36,470 acres) of culturable command area on both the Left and Right Bank Canal. The projected requirements and yield from the reservoir, communicated by all beneficiaries on the request of the Expert Committee met on 20th October, 1972 at WAPDA House, Lahore and estimated on the basis of a long period of recorded rainfalls collected at Murree and Rawalpindi, are reported in P.C. I (1976) Proforma as under:

PROJECTED REQUIREMENT AND YIELD FOR YEAR 2000 AD

Beneficiary	Requirement MGD (MCM/yr)	Yield (MCM/yr)
Rawalpindi Town	69.37 (114.9)	
POF (Wah)	15.00 (24.8)	
PIDC (Taxila)	13.50 (22.5)	
CDA (Islamabad)	33.00 (54.6)	
Right Bank Canal	34.72 (57.7)	
Left Bank Canal	20.44 (33.9)	
Total	186.03 (308.4)	308.4 (250,000 AF)

It is pointed out that the hydrological investigations examined in P.C. I Proforma (2nd revised, 1976 May) were based on the average annual amounts of inflow and demand. Since the average inflow involves flood runoff which is unavoidable to be spilled out, the Project, in consequence, allows frequent occasions of shortage of water of more than once in 2 years. Reservoir specifications are presented in Table II-5.

TABLE II-5 RESERVOIR SPECIFICATIONS (EXISTING)

Item		Khanpur	Rawal	Simply
River		Haro	Kurang	Soan
Type of Dam		Earthfill	Gravity partly arched	Rockfill
Catchment Area	(sq.km)	778	275	153
	(sq.mile)	300	106	59
Elevation (ft)				
Full Water		1982	1752	2295
Dead Water		1902	1722	2229
Effective Depth		80	30	66
Storage Capacity				
Maximum Storage	(MCM)	130.75	58.59	35.40
	(AF)	106,000	47,500	28,700
Dead Storage	(MCM)	18.50	14.93	10.79
	(AF)	15,000	12,100	8,750
Effective Storage	(MCM)	112.25	43.66	24.61
	(AF)	91,000	35,400	19,950
Annual Inflow				
Average Inflow	(MCM/yr)	327.0	92.4	87.1
	(AF/yr)	265,000	75,000	71,000
Maximum Inflow	(MCM/yr)	629.4	177.9	175.6
Minimum Inflow	(MCM/yr)	126.9	35.9	26.9
Water Demand				
Average Demand	(MCM/yr)	305.6	48.8	41.8
- Islamabad	(MGD)	33.0	-	24.0
- Rawalpindi	(MGD)	69.37	21.0	-
- Wah and Taxila	(MGD)	28.5	-	-
- Irrigation	(MCM/yr)	88.2	-	-
	(Ha)	14,770	-	-
Shortage (MCM/yr)				
Maximum Shortage		163.4	-	11.5
Minimum Shortage		-	-	-
Spillage (MCM/yr)				
Average Spillage		41.1	34.6	37.8
Maximum Spillage		219.7	101.4	114.6
Minimum Spillage		-	-	-
Parameters by Mean Value				
Demand/Inflow		0.93	0.53	0.48
Spillage/Inflow		0.13	0.37	0.43
Shortage/Demand		0.16	-	0.02

B. Rawal Dam

The Kurang river rises from the Margala range of hills, flows southwestwards across the land of mostly flat and rising gradually on all sides except a low ridge on the northwesterly flank where a saddle embankment was constructed to contain the storage area, and joins the Soan river at the point near from the city of Rawalpindi. The Rawal dam is sited across the Kurang river near Village Rawal, at a distance of about 14.5 km (9 miles) from Rawalpindi town along Pindi-Murree Road.

The Kurang River has been the source of domestic water supply for Rawalpindi since 1880, in which some seepage wells were constructed just upstream of the present Rawal dam site, on the right bank of the river. The Rawal Dam Project was conceived to meet chronic shortage of water supply having been experienced in Rawalpindi and Cantonment, and was formally inaugurated by the President of Pakistan on 17th May, 1962. In the original plan of the dam, the reservoir was proposed so as to provide 28.0 MGD of water to Rawalpindi and Cantonment, but the Project was revised due to the drought during the years 1972-73 with the conclusion that the supply of water be reduced to 21.0 MGD and the filtration plant was completed in 1979 with design capacity of 21.0 MGD.

The Rawal Lake formed by the dam spreads over an area of 780 ha (3 sq.miles) and with 3.0 m (10 ft) high gates installed on the top of the spillway crest has a gross storage capacity of 58.6 MCM (47,500 acres ft) out of which 46.9 MCM or 38,000 acre-ft is provided at present as the net live storage. The annual inflow into the reservoir is estimated, on the basis of specific runoffs observed at Khanpur on the Haro river, to be about 92.4 MCM or 75,000 acre ft, and from this figure, the annual usable yield from the reservoir would be more than that at present utilized. Reservoir specifications are presented also in Table II-5.

C. Simly Dam

The Simly dam is located at a distance 38.6 km (24 miles) northeast of Islamabad and at the place a small village Simly was originally situated on the right bank of the Soan river. The Simly Dam Project is recognized as an essential constituent of bulk water supply scheme for Islamabad. The reservoir stores not only the perennial low flows but also a considerable parts of flood water of the Soan river. Water released from the reservoir is conveyed to Islamabad through twin conduction main pipes after treatment and the reservoir is expected to provide 24.0 MGD of water for drinking and domestic uses to the Federal Capital of Islamabad.

In the original design, it has been mentioned that the normal conservation level of the reservoir will be raised from 2,295 ft to 2,315 ft level in order to increase the live storage of the reservoir after about 21 years of operation when almost all of the dead storage is lost due to sediment deposit. This will be done by providing three 7.62 m (25 ft) high gates, and may result in an additional live storage of 11.8 MCM (9,600 acre ft) obtainable. It has become realized that the installation of gates can be advantageously progressed in near future to raise the conservation level to 2,315 ft thereby increasing live storage by 11.8 MCM resulting in gain of a substantial safe yield from the catchment.

2.4.2. Rivers and Streams

Besides storage dams, seven head works have been planned and constructed at the foot of the Margala hills as well as in the vicinity of the Capital area receiving surface water from streams and supplying treated water to Islamabad. The Saidpur and Nurpur Head Works commenced supplying water in 1963, following the progress of the Islamabad new city development project started in 1960. The Kurang, Old Golf Course, Shahdara and G-10 Head Works were constructed successively during the years 1966 to 1970. In addition, to cope with the chronic shortage of water supply, New Golf Course Head Works was further expanded to receive water from the Rawal Lake for the interim period. According to the data on production of water prepared by CDA for the period of 11 years from 1974 up to 1984, seasonal fluctuation of water production is appeared small throughout a year.

EXISTING HEAD WORKS

Head Works	Water Source	Intake Capacity		Actual 1/ Production	
		(MLD)	(MGD)	(MLD)	(MGD)
Kurang	Kurang River	10.9	(2.4)	-	(-) 2/
Shahdara	Shahdara River	7.7	(1.7)	5.5	1.2
Nurpur	Nurpur Shahan N.	3.2	(0.7)	2.7	0.6
Saidpur	Saidpur Kas	3.6	(0.8)	2.7	0.6
Golf Course (Old)	Ojhr N.	10.0	(2.2)	10.0	2.2
-do- (New)	Rawal Lake	12.3	(2.7)	10.0	2.2
G-10	Bedarawali Kas	9.1	(2.0)	8.6	1.9
Total		56.8	(12.5)	39.5	(8.7)

Notes: 1/ Average in the last 11 years (1974 - 1984)

2/ Not in operation since 1983.

2.4.3. Groundwater

The number and yield of the existing groundwater intake facilities in Islamabad and Rawalpindi as of August 1984 are tabulated as under. With exception of a few dug wells, majority of facilities are of tube wells and their locations, dimensions and yield are investigated in detail. Tube wells are distributed mostly in the development areas of Islamabad and Rawalpindi, and in the National Park area along the Kurang river downstream of Rawal lake.

PRESENT GROUNDWATER PRODUCTION

Operating Agency	Water Source	No. of Wells	Production (MLD)	MGD
(Islamabad)				
CDA	National Park Area	19*	29.6	(6.5)
	Old Golf Course	3*	3.2	(0.7)
	New Golf Course	3	3.6	(0.8)
	Sectoral Area	35*	17.3	(3.8)
	Sub-Total	60*	53.7	(11.8)
(Rawalpindi)				
RMC		38	27.3	(6.0)
PHED	Sohan Camp	6	15.9	(3.5)
	Others	11	20.5	(4.5)
CB	CB	7	11.4	(2.5)
	MES (ARMY)	3	3.2	(0.7)
	MES (PAF)	3	3.2	(0.7)
	Sub-Total	68	81.5	(17.9)
Total		128	135.2	(29.7)

Note: *... Abandoned wells and long resting wells are not counted.

Location, dimension and yield of the existing wells for public water supply in the twin cities of Islamabad and Rawalpindi are given respectively in an appended map, Table A.II-45, Tables A.II-46 and A.II-47, in Appendix A.

2.5. Water Production and Demand

2.5.1. Islamabad

A. Water Production

Islamabad water supply system produces water at nine water sources. The average day production and production capacity as of 1984 are 142.0 MLD (31.2 MGD) and 147.4 MLD (32.4 MGD) respectively, as shown in Table II-6. All head works and tube wells are now in full operation.

TABLE II-6 DAILY WATER PRODUCTION IN 1984

Unit: MLD (MGD)

Name of Source	Average Production	Production Capacity
Simly Filtration Plant	49.1 (10.8)	54.6 (12.0)
Kurang H.W.	-	9.1 (2.0) 1/
Shahdara H.W.	7.7 (1.7)	7.7 (1.7)
Nurpur H.W.	3.2 (0.7)	3.2 (0.7)
Saidpur H.W.	3.7 (0.8)	3.7 (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)	9.1 (2.0)
Tube Wells in National Park Area	29.6 (6.5)	29.6 (6.5)
Tube Wells in Sectoral Area	17.3 (3.8)	17.3 (3.8)
Total	142.0 (31.2)	147.4 (32.4)

Source: CDA

Note: 1/ : Not in operation since 1983 for the preparation of the future expansion.

H.W.: Head Works

B. Water Demand

Water produced at nine sources is consumed in the Proper area up to sectoral series 10 and a part of I-11 excluding Golra and Nurpur Shahan, as shown in Figure III-3. Due to the limited water production and considerable amount of leakage and wastage of the system, water shortage often occurs especially in May and June resulting in intermittent supply in some sectoral area.

Present water consumption of Islamabad is calculated using the above production and estimated population served. The gross per capita consumption is very high as about 730 lit. (160 gal). This high consumption level will be derived from the high level of living, large amount of consumption by non-domestic users and large amount of leakage and wastage. The present consumption of each category is estimated as shown below (refer to Appendix A):

WATER CONSUMPTION IN 1984

Domestic Use	37.9 MLD (8.3 MGD)
Public Use	33.1 MLD (7.3 MGD)
Commercial/Industrial Use	23.7 MLD (5.2 MGD)
Leakage/Wastage	47.3 MLD (10.4 MGD)
Total	142.0 MLD (31.2 MGD)

2.5.2. Rawalpindi

A. Water Production

The existing water supply system of Rawalpindi produces water at seven sources. The average production and production capacity are 172.4 MLD (37.9 MGD) and 186.6 MLD (41.0 MGD) respectively, as shown in Table II-7. Tube wells are actually forced to reduce their operation time into 8-16 hours due to drawdown of groundwater table in summer season.

TABLE II-7 DAILY WATER PRODUCTION IN 1984

Unit: MLD (MGD)

Name of Source	Average Production	Production Capacity
Rawal Lake Filtration Plant	91.0 (20.0)	95.6 (21.0)
Sohan Camp Tube Wells	15.9 (3.5)	17.8 (3.9)
PHED Tube Wells	20.5 (4.5)	22.8 (5.0)
RMC Tube Wells	27.3 (6.0)	30.5 (6.7)
CB Tube Wells	11.3 (2.5)	12.7 (2.8)
MES (Army) Tube Wells	3.2 (0.7)	3.6 (0.8)
MES (PAF) Tube Wells	3.2 (0.7)	3.6 (0.8)
Total	172.4 (37.9)	186.6 (41.0)

Source: PHED, RMC and MES

B. Water Consumption

Water produced at seven sources is consumed in the Municipal corporation and Cantonment areas, as shown in Figure III-3. Distribution pipelines of Rawalpindi are generally old and corroded considerably according to the ADB report. The capacity of the distribution pipes is therefore, presumed to be decreased to some extent. Leakage and wastage of the system are assumed to share a large portion of a total consumption. Presently, Rawalpindi water supply system is operated under the condition of intermittent supply. Deterioration of water supply level is observed in some areas, resulting from the shortage of supply capacity and insufficient distribution system.

Present water consumption data of various consumers are not available due to unmetered connections and flat rate system of water tariff. From the present water production of 172.4 MLD (37.9 MGD), gross per capita consumption is calculated at about 280 liter (61 gal). According to the sample survey on domestic consumption, the average per capita consumption was about 80 liter which seems lower than the potential demand. The present water consumption of each category is estimated as shown below:

WATER CONSUMPTION 1984

Domestic Use	49.8 MLD (10.9 MGD)
Public Use	16.5 MLD (3.6 MGD)
Commercial/Industrial Use	28.6 MLD (6.3 MGD)
Military Use	15.9 MLD (3.5 MGD)
Leakage/Wastage	61.6 MLD (13.6 MGD)
Total	172.4 MLD (37.9 MGD)

2.6. Existing Water Supply System

2.6.1. Intake and Conduction Main

A. Intake of Khanpur Reservoir

Intake facility of water to be diverted from Khanpur Reservoir has been constructed at and under the right bank saddle embankment of the Dam. Design diversion capacity of the intake is approximately 15.6 cu.m/sec with conduit elevation of 580.11 m (RL 1,902 ft) at the inlet. Diameter of the conduit is about 2.0 m (6.5 ft) with RCC structures.

B. Left Bank Canal

The Left Bank Canal has been completed stretching over 19 km (11.8 miles) as the conduction main of Khanpur Project between the dam site and near Nicholson Monument. Water derived from the dam at the irrigation outlet structure flows through 80 m long Main Canal and 65 m long head regulator into the Left Bank Canal.

The Left Bank Canal was constructed by WAPDA during years from 1973 to 1978 to convey Khanpur water for water supply to both the cities of Islamabad and Rawalpindi, for industrial water supply to POF (Wah) and PIDC (Taxila) and for irrigation to agricultural land extending on the left bank of the Haro river. Irrigation water is diverted from the canal between the points 0.0 km and 8.8 km, and the canal section downward is allocated for municipal and industrial waters allowing water diversion for PIDC at the point of 15.6 km. Downstream portions of the canal are assigned only for water supply.

Design capacity of the canal varies from 12.5 to 7.9 cu.m/sec (440 to 278 cusec). Since the canal passes undulating terrain of northwest foot of the Margala range of hills, many appurtenant structures such as tunnels, syphons and aqueducts are accompanied, and the canal is lined with concrete block on its all faces for about 80% of total length. The majority of canal portions is situated on the rock foundation with fine limestone and alternations of limestone and shale or marl. However, sedimentary loam has been found at the limited portions near the beginning point of the Left Bank Canal, outlet of the Mohra Muradu Tunnel and inlet of Margala Tunnel.

It is investigated that the Canal has been designed employing design procedures prepared for irrigation purposes, consists of many deep-cut portions without protection works of side slopes allowing sediment inflows during heavy rains, and that operation and maintenance works are laborious. In addition, subsidence of canal bed due to piping of seepage water along a cross-drainage and traces of overflow at just upstream of a cross-regulator were inspected during field investigations.

C. Conduction Main to Islamabad

Major Conduction Mains to Islamabad are briefly explained as follows:

a. Simly Conduction Main

This is to convey treated water at the Simly Filtration Plant to the service reservoir located in Sector F-5 of Islamabad, and the major dimensions are as under;

Length	:	L = 27.75 km (91,000 ft)
Pipe	:	PRCC with steel core, 900 mm (36") Dia.
Discharge	:	Q = 0.632 cu.m/sec (12.0 MGD)

Elevation :

Simly Clear Water Res.	HWL	669.8 m (2,196 ft)
	LWL	666.4 m (2,185 ft)
Islamabad Service Res.	HWL	619.2 m (2,030 ft)
	LWL	613.1 m (2,010 ft)

Two conduction lines of 900 mm diameter have already been completed and at present one line is being operated, as the first phase of the scheme, to convey 12 MGD of water. The other line is expected to be ready soon as the second phase to make fully yield of 24 MGD of Simly dam available.

b. <u>Conduction Line from National Park Area</u>

Waters produced from tube wells in the National Park Area are gathered in the Central Sump and then conveyed to the Rawal Sump by means of pumping up. Water is boosted at Rawal Sump and sent to the service reservoirs situated at F-5 and north of F-6.

Length	:	Central Sump to Rawal Sump, L = 4 km
		Rawal Sump to F-6 Service Reservoir, L = 10 km
Pipe	:	PRCC with steel core, Dia. 500 mm (21") x 2 lines
Discharge	:	Q = 0.37 cu.m/sec (7 MGD)

However, some of tube wells are not in operation, and actual discharge at present is reported as about 0.34 cu.m/sec (6.5 MGD).

c. <u>Other Conduction Lines</u>

The majority of conduction mains are provided with PRCC pipes with steel core of diameters 450 mm to 225 mm (18" to 9"), with exception of 18" mild steel pipe which forms a part of conduction line from the Golf Course Head Works.

D. Conduction Main to Rawalpindi

Water, treated at the Rawal Filtration Plant and from tube wells in the National Park Area, is conveyed to RMC and CB through RC pipes of 1,350 mm (54") diameter. The conduction main branches off, before it reaches distribution block of RMC, in two directions for RMC and CB, and then water is conveyed through respective lines of 900 mm (36") RC pipes.

2.6.2. Water Treatment Plant and Service Reservoir

A. Water Treatment Plant

a. Islamabad

There are eight treatment plants including one filtration plant and seven head works out of which one plant is now suspending operation for further expansion of the facilities. The summary of the treatment plants of Islamabad is presented in Table II-8 indicating water sources, production capacities, year of construction, etc.

Simly Filtration Plant

The Simly Filtration Plant, located near by the Simly dam, takes raw water directly from the reservoir through ø900 mm transmission mains (two lines). The production capacity of the plant is 24 MGD and the major facilities are distribution wells, flocculation and sedimentation basins, rapid sand filters. The details of the plant facilities is presented in Table II-9. Raw water quality shows higher values than normal in pH, total solids, hardness and alkalinity. Such high alkalinity of water is considered to be caused by the geological conditions as limestone strata of mountains extend behind the reservoir. According to CDA, turbidity of raw water ranges 50 to 200 units (JTU). Treated water quality obtained from CDA shows normal turbidity, odor, colour, etc., indicating that purification works are carried out smoothly and satisfactorily.

Head Works

Head works take raw water from surface water or river-bed water of various streams originated from the Margala range except those at Golf Course Head Works for which raw water are taken from tube wells and Rawal Lake. A total production capacity of the head works is 12.1 MGD. Major facilities of the head works are sedimentation basins and slow sand filters.

b. Rawalpindi

Rawal Lake Filtration Plant is only the treatment plant of Rawalpindi. The plant, located near by Rawal dam, takes water from the lake through open canal with the length of about 600 m. The production capacity of the plant is 21 MGD and the major facilities of the plant are similar to the Simly plant. The details of the facilities is also presented in Table II-9.

As for the current practice of chemical application, solid Alum and liquid chlorine or bleaching powder are used for coagulant purpose and for disinfection in every treatment plant in both cities.

The prices of solid Alum and liquid chlorine in the project area are Rs. 2,600 to 3,400 per metric ton and Rs. 2,800 to 3,400 per 900 kg, respectively. Those chemicals are locally produced within Pakistan and are available from Karachi and Lahore.

Laboratory is provided in Simly and Rawal Lake filtration plants, in which raw water and treated water are analyzed and their data are registered. In addition, CDA has a laboratory at the sewerage plant in Sector I-9.

Table II-8 EXISTING WATER TREATMENT PLANTS IN ISLAMABAD/RAWALPINDI

Water Treatment Plant	Water Source	Production Capacity (mg/d)	Year of Construction	Treatment Process	Operated By	Expansion Programe
Islamabad						
1. Simly Filtration Plant	Simly Reservoir	12	1969	Sedimentation & rapid sand filtration	CDA	12 mg/d, by 1984 24 mg/d, within 5 years
2. Korang Head Works	Riverbed Water	2.0 (Not in operation)	1966	Sedimentation & slow sand filtration	CDA	2 mg/d, by 1986
3. Shaldara Head Works	Surface water from stream	1.7	1967	Sedimentation & slow sand filtration	CDA	
4. Norpur Head Works	Riverbed water	0.7	1963	Sedimentation & slow sand filtration	CDA	
5. Saidpur Head Works	Riverbed water	0.8	1963	Sedimentation & slow sand filtration	CDA	
6. Golf Course Head Works (New)	3 tube wells & Rawal Lake	2.7		Sedimentation & slow sand filtration	CDA	
7. Golf Course Head Works (Old)	3 tube wells & surface water from stream	2.2	1966	Sedimentation & slow sand filtration	CDA	
8. G-10 Head Works	Surface water from stream	2.0	1970	Sedimentation & slow sand filtration	CDA	2 mg/d, by 1986
Rawalpindi						
9. Rawal Lake Filtration Plant	Rawal Lake	21	1963-14 mg/d 1979- 7 mg/d	Sedimentation & rapid sand filtration	PHED	7 mg/d, by 1986

TABLE II-9 PLANT FACILITY

Item	Simly Filtration plant	Rawal Lake Filtration plant
Capacity	24 mgd (109,100 m^3/d)	21 mgd (95,500 m^3/d)
Flocculation time	20 min	12 min
Sedimentation time	3 hrs	1.5 hrs
Filtration rate	120 $m^3/m^2/d$	140 $m^3/m^2/d$
Coagulant used	Alum	Alum
Sterilizing agent	Chlorine	Chlorine
Backwash system	Compressed air + water	Compressed air + water
No. of clarifiers	4 (6 mgd each)	3 (7 mgd each)
No. of filter beds	12 units	12 units
Filter Bed area	76 m^2	69 m^2

B. Service Reservoir

Service reservoirs are categorized into two types; namely elevated reservoir and ground reservoir. Elevated reservoirs are of small scale and those recently constructed are, mostly, of reinforced concrete, excluding some of old type which are made of brick masonry or steel. Although most of service reservoirs in Islamabad are of gravity flow type providing large capacities, those in Rawalpindi are of small capacity and considerable number of direct pumping distribution systems are found.

Scales and dimensions of major service reservoirs are as tabulated below;

ISLAMABAD

Name of S.R.	Capacity cu.m		Hour	Production cu.m/H		Structure	Source
F-5	31,800)	54,500	15.1	2,275)	3,602	RC	Simly T.P.
F-6	22,700)			1,327)		RC	N.P.A T/W
Shahdara	4,500		14.0	322		RC	H.W.
Saidpur	4,500		30.0	152		RC	H.W.
G-10	9,100		24.0	379		RC	Surface W.
Golf Course (New)	6,600		12.9	512		RC	T/W & Rawal Lake

RAWALPINDI

Name	Suction cu.m	Pool Hour	Service Reservoir cu.m	Service Reservoir Hour	Discharge cu.m/H	Structure
Water Works No.1	11,370	2.8	1,140	0.3	4,079	RC
Water Works No.2	11,370	2.8	1,140	0.3	4,079	RC
AMC Centre	900	0.4	2,270	1.1	2,030	RC
Westridge	450	0.6	7,670	9.4	816	RC, BM
Chaklala Road	2,730	3.4	-	-	816	RC
Topi Pump Station	11,820	2.9	18,460	4.5	4,091	RC, BM

Note: RC: Rainforced Concrete
BM: Brick Masonry
T.P. : Treatment Plant
N.P.A: National Park Area
T/W : Tubewell
H.W. : Head work

2.6.3. Distribution Network

In Islamabad distribution networks of pipeline have been systemized for each sector. Bounded by main roads, such systems are formed also in Rawalpindi. Criteria prepared for design of distribution system are as follows;

Islamabad

Demand	:	Average 100 gallon/day per capita	
		Maximum Hourly factor: 2.0	
		Fire Demand: 60 gallon/min/sector	
Terminal Pressure:		House:	14 m (50 - 40 ft)
		Main Pipe:	40 m (130 - 120 ft)
Velocity Formula:		Hazen-Williams Formula (c=100)	
Hydraulic Gradient:		0.002 as average	

Rawalpindi (PHED)

Demand	:	Average 37.5 gallon/day per capita	
		peak Hourly Factor: 2.5(*)	
Terminal Pressure:		House:	9 m (30 ft)
		Main Pipe: 30 m (100 - 90 ft)	
Hydraulic Gradient:		Distribution System	0.002
		Rising Main	0.005

Pipe materials in use are PRCC, AC, PVC, G.I and C.I, and diameter of pipe ranges between 75 mm (3") and 450 mm (18") in Islamabad, and 35 mm (1.5") and 650 mm (27") in Rawalpindi.

Remark: (*) This standard is being applied to various sizes of distribution system concerned within Punjab Province, controlled by PHED. In general, the larger is the delivery the smaller the peak hourly factor and so, the peak hourly factor to be adopted for Rawalpindi may be smaller than 2.5 when the scale of water supply system is considered.

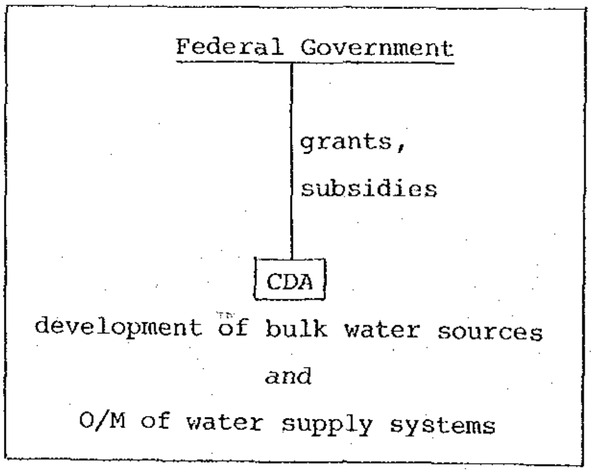
2.7. Operation and Maintenance

In Islamabad operation and maintenance of water supply systems are performed by CDA, which at the same time executes the development of bulk water sources. In Rawalpindi, RMC (Rawalpindi Municipal Corporation) is in charge of the operation and maintenance of water supply systems for the city areas under its jurisdiction, while MES (Military Engineering Service) and CB (Cantonment Board) are in charge of the operation/maintenance for the cantonment areas under their jurisdiction. PHED (Public Health Engineering Department) of the Government of the Punjab is responsible for the development of bulk water sources in Rawalpindi. After they are developed, they are handed over to RMC and MES & CB.

There are two MES's: One is under the control of the Army, and the other the PAF (Pakistan Air Force).

2.7.1. Islamabad

The supply of water in the Capital of Pakistan is under the responsibility of CDA. The population served with piped water in Islamabad is now estimated at 195,000. Water sources are nine in number, of which the largest one is the Simly Dam reservoir, providing 35% of the total production of water. Though most



of water sources have been developed from surface water, some of them are tube wells, taking water from underground. Per day production of water is 142.0 million litres (31.2 million gallons), which divided by population is rendered to 728 litres (160 gallons), of which the portion for domestic use is estimated at 194 litres (43 gallons).

As is described in 2.8, the existing financial status of CDA water supply service is not self-supporting, and the losses are made up by the subsidies from the central government. The development of water sources by CDA is also funded from the resources of the central government in the form of grants.

The organization directly responsible for the operation and maintenance of water supply is composed of Chairman, Member Engineering & Director General Works, Deputy Director General Services and Director Water and Sewerage Maintenance.

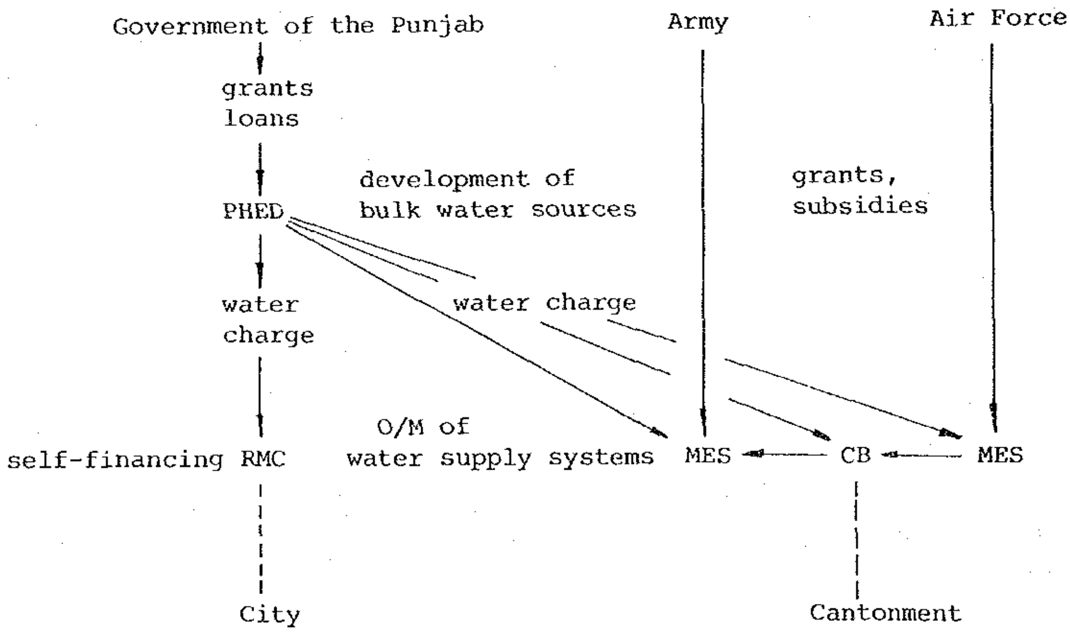
ORGANIZATION
OF CDA WATER SUPPLY SERVICE

- Chairman
  - Member Engineering & Director General Work
    - Deputy Director General Services
      - Director Water & Sewerage Maintenance
        - Deputy Director Distribution
        - Deputy Director Bulk Water
        - Deputy Director Tube Well
        - Deputy Director Water Meter
  - Member Planning
  - Member Finance
  - Member Administration

Under Director Water and Sewerage Maintenance regular personnel numbering more than one thousand are daily working for the maintenance and running of the dam, the filtration plant, head works, tube wells, service reservoirs, pipe lines and others.

2.7.2. Rawalpindi

Maintenance and operation of water supply facilities in the city and cantonment areas are under the responsibilities of RMC and MES & CB respectively. The population served with piped water in Rawalpindi is now estimated at 622,000. Water sources are seven in number, of which the largest one is the Rawal reservoir, providing 53% of the total production of water.



Three seventh of the water produced in the Rawal Lake Filtration Plant is supplied to the city and the remainder to the cantonment. Tube wells produce 43% of the total volume of water supplied in Rawalpindi.

Per day production of water is 172 million litres (37.9 million gallons), which divided by population is rendered to 277 litres (61 gallons), of which the portion for domestic use is estimated at 79 litres (17 gallons).

As is described in 2.8, the existing financial positions of the water supply services by RMC, MES and CB are not self-supporting. RMC leads others in financial records though it is in the red. The losses are covered interdepartmentally within the Corporation. RMC, also, takes charge of the development of small water sources using its own funds. The financial losses in MES and CB are subsidized by the Army (or Air Force). Also the funds for the development of small water sources are granted by the military authorities.

The development of bulk water sources for the Rawalpindi areas is taken charge of by PHED. After they are developed, they are handed over to the maintenance authorities. The latter pay charges to the former for the supply of raw water. The PHED funds are granted or loaned by the Government of the Punjab.

ORGANIZATION

OF WATER SUPPLY SERVICE IN RAWALPINDI

RMC

- Mayor
  - Chief Corporation Officer
    - Taxation Officer
    - Municipal Medical Officer
    - Account Officer
    - Municipal Engineer Buildings & Roads
    - Municipal Engineer Water Works
      - Assistant Municipal Engineer Water Works
      - Assistant Municipal Engineer Water Supply & Sewerage
      - Fire Superintendent

CB

- President Cantonment Board
  - Cantonment Executive Officer
    - Sanitation Branch
    - Revenue Branch
    - Works Branch
      - Senior Cantonment Engineer
        - Cantonment Engineer Building
        - Assistant Engineer Water & Sewerage
        - Cantonment Engineer Road
        - Cantonment Engineer Project

PHED

Project Director

- Deputy Director Sewerage
- Quality Surveyor
- Deputy Director Water Supply
- Hydro-Logist

The organization directly responsible for the operation and maintenance of water supply systems in RMC is composed of Mayor and Municipal Engineer Water Works. Under Municipal Engineer Water Works regular personnel numbering 315 are daily in touch with the procedure and problems in connection with the running of water supply facilities.

The organization of MES has been not disclosed to the JICA Study Team because of the reason that it belongs to the military secret. However, CB is a civil body, where the organization directly responsible for the operation and maintenance of water supply systems is composed of President, Executive Officer, Senior Cantonment Engineer Works and Assistant Engineer Water & Sewerage. Under Senior Cantonment Engineer Works regular personnel numbering 254 are working for the management and control of water supply systems in CB. PHED, Rawalpindi is headed by Project Director, under whom there are eight direct subordinates, of which Deputy Director Water Supply is directly in charge of water supply.

2.8. Water Tariff System and Finance

The present water supply systems in the twin cities have inherent factors which tend to disrupt the efforts towards financial self-support in the water supply service of the organizations concerned. They are listed below:

1. Intermittent supply of water
2. Prevalence of unmetered connections
3. Losses of water through leakage/wastage
4. Predominance of flat rate tariff system

All the above factors interrelate with each other, creating a vicious circle situation.

The existing flat rate tariff system must be totally abolished and a system where people are charged in accordance with the volume of water consumed has to be thoroughly and strictly applied if the water supply service is to be financially on a sound basis. Because, so long as a flat rate system exists, human nature being what it is, wastage of the precious resources can never be stopped, resulting in the failure in the recovery of the costs invested and expended on water. However, so long as unmetered connections are prevalent, the complete application of the system in which charges are levied in accordance with the volumes consumed is out of the question. But, so long as intermittent supply of water persists, metering gauge cannot function properly, thereby making the notion of all metered connections impracticable. If 24 hours a day supply of water is to be realized, the existing enormous losses of water through system leakage must be reduced to the minimum. To minimize the extensive system leakage, abundant investment funds are a primary requisite. However, usable financial resources can never be available in abundance unless water supply service organizations are financially viable.

In spite of the existing state of affairs described above, the people concerned are not inclined to take positive attitude and actions to remedy and rectify the situation.[1/] A CDA official in a report "Supply Costs, Water Supply System of Islamabad" writes, "Water, ..., is not a commodity like one resulting from economic activity; it is a basic necessity of life and economic law of supply and demand may apply to it, if at all it does, it an extremely limited sense".

He continues, "Under such circumstances, the water charges cannot be fixed always to match the actual costs; being essential for human life, the price structure of water is also dependent upon the paying capacity of consumers". Thus, as will be described below, the circumstances persist where the costs expended on the construction and operation/maintenance of water supply facilities are not fully or only nominally recovered.

Note: 1/ Behind it there is a pious faith founded on Islam, which is that sun, air and water are directly sent from God to be shared free among men.

2.8.1. Water Tariff System

A. Islamabad

The water tariff system of CDA is based on the two sub-systems. One is applied to the consumers with metered connections and the other to those with unmetered connections.

The consumers are divided into domestic/public and commercial/industrial users.

A domestic or public user with a metered connection shall pay Rs. 0.66 (Rs. 3) per 1,000 litres (gallons) of water consumed. Whereas, a commercial or industrial user shall pay Rs. 1.10 (Rs. 5) per 1,000 litres (gallons).

A flat rate system is applied to domestic/public and commercial/industrial users with unmetered connections. It is said that they constitute about two thirds of the served population. Flat rates are on a monthly basis and differ according to the categories of users and the categories and sizes of houses and buildings.

Domestic/public users are treated favourably in comparison with commercial/industrial users in the existing water tariff system. Behind it there may lie a notion that water should be provided to them at a less price possible because they are not engaged in economic activities.

Due to the flat rate system which is applied to the majority of users, people may tend to be careless and wasteful in using water.

B. Rawalpindi

Basically a water tariff system in Rawalpindi is the same with that in Islamabad in that it consists of a variable rate sub-system and a fixed rate sub-system.

Three separate tariff systems are now in force in the city: RMC, MES and CB systems are independently applied to the respective citizens.

Under the RMC system, a domestic/public user with a metered connection shall pay Rs. 0.55 (Rs. 2.5) per 1,000 litres (gallons) of water consumed. Whereas, a commercial/industrial user with a metered connection shall pay Rs. 1.10 (Rs. 5) per 1,000 litres (gallons). Actually, there is at present no metered domestic or public user in RMC. That is to say, all domestic/public users are unmetered. To them as well as to unmetered commercial/industrial users, a flat rate system is applied. Flat rates are on an annual basis and differ according to the categories of users and the categories and sizes of houses and buildings.

Under the MES system, those users belonging to the army with metered connections shall pay Rs. 0.264 (Rs. 1.20) per 1,000 litres (gallons) of water consumed. Metered citizens and public institutions not belonging to the army shall pay Rs. 0.88 (Rs. 4) per 1,000 litres (gallons). Likewise, metered commercial/industrial establishments shall pay Rs. 1.32 (Rs. 6) per 1,000 litres (gallons).

Monthly flat rates are applied to the unmetered users. They differ in accordance with the categories and sizes of houses and buildings.

Under the CB system, domestic/public users with metered connections shall pay Rs. 0.88 (Rs. 4) per 1,000 litres (gallons) of water consumed. Whereas, metered commercial/industrial users shall pay Rs. 1.32 (Rs. 6) per 1,000 litres (gallons).

Monthly flat rates are applied to the unmetered users. They differ in accordance with the categories and sizes of houses and buildings.

The existing water tariff system has an inherent weakness in that it permits consumption of an unlimited volume of water in as much as the user pays a fixed charge under a flat rate sub-system. At the same time, collection of water bills tends to be not thorough and complete; In CDA the collection rate is 73.7%, and in the Cantonment (MES + CB) it is only 16.6%.[1/]

However, it might be added that under the present tariff systems, metered users are victimized at the hand of unmetered majority, and unless this situation is rectified the increase in metered population, which is a step towards a sound management of water supply service can hardly be expected and realized.

Note: 1/ At the root of all these things may lie the Islamic concept on water.

2.8.2. Finance

In CDA the recovery rate of the water cost is only 14%. In RMC is reaches the height of 59%. However, in the Cantonment (MES + CB) the rate goes down to as low as 9.4%. These figures evince the financial status of water supply service in the twin cities. The losses are made up by subsidies. As mentioned already, this state of affairs reflects the mentality of the officials concerned in which water is regarded as a divine gift.

An official of CDA previously cited writes, "The subsidy, ... is not free of cost. It shifts the burden of additional costs from the limited group of direct beneficiaries-the consumers-to a far larger group comprising a district, a province or the whole country ... " This way financial losses are transferred and justified.

In calculating the operation and maintenance costs two alternations have been made to serve our purpose on the cost data provided by the Pakistani side:

1. Depreciation costs have been added for CDA. For Rawalpindi, raw water charges have been deducted because they do not reflect the capital costs properly, and in their stead depreciation/amortization costs have been introduced.

2. Some costs originally included in the O/M costs list have been excluded because they actually belong to capital costs, and they are added to the latter.

A. Islamabad

Total costs incurred for the operation and maintenance of water supply systems amount to Rs. 64.05 million in 1983-84, of which the electricity charges account for 40.8%, depreciation 30.2% and personnel costs 17.5%. Depreciation costs are high because the

Simly dam reservoir, a filtration plant and conduction facilities costing Rs. 700.02 million in total have been recently completed. Most of electricity charges derive from the pumping of water.

In contrast to the costs of the order of two digits million rupees, revenues come to Rs. 9.09 million, which constitutes only 14.2% of the costs. In terms of the unitary cost of water, the cost is calculated at Rs. 1.54 (Rs. 7.03) per 1,000 litres (gallons), whereas the actual recovery of cost is only Rs. 0.22 (Rs. 1.00). If a complete collection of water bills (collection rate is now 73.7%) is presupposed, the recovery works out to Rs. 0.29 (Rs. 1.33) per 1,000 litres (gallons). But it makes little difference.

To recover the costs fully, the authority will have to double the rates for metered consumers and at the same time multiply the rates for unmetered consumers by several times.

B. Rawalpindi

Total costs incurred for the operation and maintenance of the water supply systems under the jurisdiction of RMC amount to Rs. 10.70 million in 1983-84, of which electricity charges and other contingencies account for 36.0%, personnel costs 33.4% and depreciation and amortization 22.0%.

RMC is making greater efforts aiming at the self-support of its water supply service. The water charges receipt amounting to Rs. 6.33 million as against Rs. 10.70 million of costs must be appreciated. In terms of the unitary cost of water, the cost is calculated at Rs. 0.45 (Rs. 2.03) per 1,000 litres (gallons), whereas actual recovery of cost is Rs. 0.26 (Rs. 1.20).

If the authority doubles the flat rates now applied to unmetered consumers (in doing so only can metered consumers stand on an equal footing), a full financial viability can be achieved.

Finance of water supply service by MES and CB has been merged for convenience's sake.

Total costs incurred for the operation and maintenance of the water supply systems under the jurisdiction of MES and CB amount to Rs. 10.89 million in 1983-84, of which personnel costs account for 33.7%, electricity charges 32.5% and depreciation and amortization 16.3%.

In contrast to the costs of more than one crore rupees, revenues comes to Rs. 1.03 million, which constitutes only 9.5% of the costs. In terms of the unitary cost of water, the cost is calculated at Rs. 0.56 (Rs. 2.55) per 1,000 litres (gallons), whereas the actual recovery of cost is only Rs. 0.05 (Rs. 0.24). However, if a complete collection of water bills (collection rate is now 16.6%) is presupposed, the recovery works out to 0.32 (Rs. 1.46) per 1,000 litres (gallons).

To recover the cost fully what the authority has to do first of all is the strict observance of full collection of water bills, and secondly those flat rates now applied to unmetered consumers must be doubled.

TABLE II-10(1) EXISTING WATER TARIFF SYSTEMS(1)

C.D.A.

1. Supply of Water Through Metered System
   1) Domestic Rs.0.66/000 l (Rs.3/000 gal.)
   2) Commercial/Industrial Rs.1.10/000 l (Rs.5/000 gal.)

2. Supply of Water Through Unmetered System
   1) Residential
      (1) Government Quarters

Types	Flat Rate (per month)
A-Type	Rs.7
B-Type	Rs.7
C-Type	Rs.7
D-Type	Rs.10
E-Type	Rs.13
F-Type	Rs.17
G-Type	Rs.22
H-Type	Rs.26
I-Type	Rs.30

      (2) Private Consumers

Plot Sizes	Flat Rate (per month)
Less than 209 m^2 (Less Than 250 Yd^2)	Rs.15
209 to 417 m^2 (250 to 499 Yd^2)	Rs.18
418 to 835 m^2 (500 to 999 Yd^2)	Rs.22
836 to 1,002 m^2 (1,000 to 1,199 Yd^2)	Rs.30
1,003 to 1,253 m^2 (1,200 to 1,499 Yd^2)	Rs.40
1,254 to 1,671 m^2 (1,500 to 1,999 Yd^2)	Rs.50
1,672 and above m^2 (2,000 and above Yd^2)	Rs.60

   2) Public and Commercial/Industrial: Different according to the categories and sizes of establishments/institutions.

Source: CDA

R.M.C.

1. Supply of Water Through Metered System
   1) Domestic Rs.0.55/000 l (Rs.2.5/000 gal.)
   2) Commercial/Industrial Rs.1.10/000 l (Rs.5/000 gal.)

2. Supply of Water Through Unmetered System
   1) Domestic

Sizes of Ferrule	Flat Rate (per Annum)
a. 1/2" Ferrule	Rs.150
b. 3/4" Ferrule	Rs.300
c. 1" Ferrule	Rs.700
d. 1-1/2" Ferrule	Rs.1,600

   2) Commercial/Industrial

   Different according to the categories and sizes of establishments/institutions.

Sources: RMC

TABLE II-10(2) EXISTING WATER TARIFF SYSTEMS(2)

M.E.S.

1. Supply of Water Through Metered System

1)	Army	Rs.0.264/000 l (Rs.1.20/000 gal.)
2)	Domestic	Rs.0.88/000 l (Rs.4/000 gal.)
3)	Commercial/Industrial	Rs.1.32/000 l (Rs.6/000 gal.)

2. Supply of Water Through Unmetered System

1) According to the Sizes of Ferrule

Sizes of Ferrule	Flat Rate (per month)
a. 1/2" Ferrule	Rs.6
b. 3/4" Ferrule	Rs.12
c. 1" Ferrule	Rs.15
d. 1-1/2" Ferrule	Rs.22
e. 2" Ferrule	Rs.30

2) According to the Covered Area

Covered Area	Flat Rate (per month)
a. up to 836 m^2 (up to 1,000 Yd^2)	Rs.25
b. above 836, not more than 1,672 m^2 (above 1,000, not more than 2,000 Yd^2)	Rs.35
c. above 1,672 m^2 (above 2,000 Yd^2)	Rs.50

Source: MES

C.B.

1. Supply of Water Through Metered System

1)	Domestic	Rs.0.88/000 l (Rs.4/000 gal.)
2)	Commercial/Industrial	Rs.1.32/000 l (Rs.6/000 gal.)

2. Supply of Water Through Unmetered System

1) Domestic

Covered Area	Flat Rate (per month)
a. up to 836 m^2 (up to 1,000 Yd^2)	Rs.20
b. above 836, not more than 1,672 m^2 (above 1,000, not more than 2,000 Yd^2)	Rs.40
c. above 1,672 m^2 (above 2,000 Yd^2)	Rs.60

2) Commercial/Industrial

Different according to the categories and sizes of establishment/institutions.

Source: CB

CHAPTER III. WATER DEMAND AND WATER RESOURCES

CHAPTER III. WATER DEMAND AND WATER RESOURCES

3.1. City Development Plan and Population Projection

3.1.1. City Development Plan

A. Islamabad

The master plan for the Capital City of Islamabad was prepared in 1960 by M/S. Doxiades Associates of Greece. The plan provided an outline and broad frame of concepts and criteria for the development. The implementation of the plan had been carried out with several amendments due to some limitations as well as over-provisions of certain functions of the original plan. Figure III-1 shows the up-to-date land use plan by CDA.

The administrative area of the new Capital is 906.5 sq.km and the City is composed of three parts, namely, Islamabad Proper covering 220.15 sq.km, Islamabad Park occupying 220.15 sq.km and Islamabad Rural area of 466.20 sq.km. Islamabad proper, located between the Margala hills and Shahran-e-Kashmir highway, is planned that various sectors are located in parallel belts from the east to the west and they will develop simultaneously according to the necessity.

As shown in Figure III-1, Administrative Sector is located at the eastern end of Islamabad and Diplomatic Enclave is planned to the south of the Administrative Sector for the chanceries and residences of Foreign Missions. At the west of Administrative Sector, Public Buildings area is placed and is meant for the head offices of autonomous and semiautonomous organizations.

Residential Sectors have been planned in rows on both sides of the main civic and commercial centre called as Blue Area, which is designed in a linear form allowing its growth parallel to the residential sectors. This will have multi-storey commercial and office buildings along the main avenue Khyaban-e-Quaid-i-Azam. Industrial Zones are placed in close proximity to Rawalpindi and service industry zone is located in a belt on the two-lane service road skirting the southern edge of the residential sectors.

At present, CDA is undertaking the development of new sectoral areas in accordance with the 15 Years Development Programme, as shown in Table A.I-1 of Appendix A.

B. Rawalpindi

The Master Plan, target year of 1990, for the city development of Rawalpindi is available at present. The plan was prepared in 1970 by the Department of Housing and Physical Planning. The development of both Municipal Corporation and Cantonment was projected beyond the existing administrative boundary by 1990 in the Master Plan. The actual development of Rawalpindi is, however, differed from the said plan in some aspect.

However, the concept of the Master Plan, especially on the land use plan, is utilized for this study with some modifications especially on development area and demographic aspect which is one of the basic factor for future water demand projection.

The development area is planned to be still limited within the present administrative boundary even until 2000 considering the past trend of the development and as the result of consultation with officials concerned.

The future land use is planned in the Master Plan as the regional urban core in the light of the Islamabad Master Plan. The land use was categorized in Residential, Commercial, Governmental, Industrial sectors and Park and Airport. The land use plan is presented in Figure III-2.

The Master Plan proposes the population distribution in such manner that the density will decrease from the present congested central part in the Municipal Corporation to surrounding areas in proportion to the distance from the center in lines with land cost and needs of intensive land utilization of surrounding areas. The whole area is classified into six zones by density, R-25 (25 persons/acre), R-50, R-75, R-100, R-150 and R-250.

3.1.2. Population Projection

To estimate the future population in the study area, which is one of the basic factors of water demand projection, the census made by the Population Census Organization of Pakistan is used as the most reliable demographic data.

A. Islamabad

The existing population projection for the Islamabad sectoral area was made by CDA. CDA estimated at 575,000 in 2000 and 1,000,000 in 2030. The population projection in the sectoral area is made based on the census of 1972 and 1981 and expansion of the proper area according to the CDA development plan. Three sets of calculations are prepared in Table III-1, namely, the linear formula, the power formula and the logistic curve formula.

The population in the year 1984, 1990, 1995 and 2000 are estimated at 206,000, 341,000, 480,000 and 621,000 respectively on the basis of the logistic curve method as the most applicable one considering the saturated population of about 1.0 million.

TABLE III-1 POPULATION PROJECTION OF ISLAMABAD

Equation	1984 (X=3)	1990 (X=9)	1995 (X=14)	2000 (X=19)
$Y = 143,902 + 7,812X$	167,338	214,210	253,270	292,330
$Y = 143,902 \times 1.0773^{X}$	179,919	281,253	408,114	592,193
$Y = \dfrac{1,000,000}{1 + e^{1.6971-0.1154X}}$	205,723	341,077	479,636	621,401

B. Rawalpindi

The existing population projection for Rawalpindi was made by AESL for Rawalpindi Water Supply and Sewerage Project in May 1980, ADB. Their estimation of population in 2000 and 2030 is 1,400,000 and 1,700,000 respectively. The population projection for Rawalpindi is made based on the population census data up to 1981. Five sets of calculations are prepared in Table III-2, namely, the linear formula, the power formula and the logistic curve formula.

The population in the year 1984, 1990, 1995 and 2000 are estimated at 888,000, 1,046,000, 1,167,000 and 1,275,000 respectively, on the basis of the least square method as the most applicable one considering the saturated population of about 1.7 million.

TABLE III-2 POPULATION PROJECTION OF RAWALPINDI

Equation	1984 (X=3)	1990 (X=9)	1995 (X=14)	2000 (X=19)
$Y = 774,398 + 19,107X$	831,719	946,361	1,041,896	1,137,431
$Y = 797,686 + 22,759X$	865,963	1,002,517	1,116,312	1,230,107
$Y = 794,843 \times 1.0322^{X}$	874,124	1,057,197	1,238,726	1,451,425
$Y = \dfrac{1,700,000}{1 + e^{0.2976-0.0445X}}$	780,414	893,694	987,088	1,077,202
$Y = \dfrac{1,700,000}{1 + e^{0.0994-0.0631X}}$	888,182	1,045,549	1,167,121	1,275,283

3.1.3. Future Served Area and Population Served

The future served area and population served are projected considering the population increase, socio-economic condition, and the target of the future city plan.

A. Islamabad

The future served area of Islamabad is projected on the basis of the population increase in the proper area and saturated population in each sectoral area according to the CDA 15 Years Development Programme. The programme has a plan of development up to the sectoral series 15 by the year 2000. The future served area is planned to expand up to the series 15 in accordance with the development, as shown in Figure III-3.

The present service ratio is estimated at 100% based on the Housing Census Report in 1980. The service ratio in the future is therefore to be 100%. The future served population is estimated at 341,000 in 1990, 480,000 in 1995 and 621,000 in 2000 respectively including those in the villages of Golra and Nurpur Shahan from 1990.

B. Rawalpindi

The future served area of Rawalpindi is projected to over all the administrative area of RMC and CB up to 2000 including planned industrial area in zone 27, as shown in Figure III-3.

The present service ratio is estimated at about 70%. The future service ratio is projected at 80% in 1990, 85% in 1995 and 90% in 2000 with gradual increase based on the target service ratio of 90% in 2000. The future served population is estimated at 837,000 in 1990, 992,000 in 1995 and 1,148,000 in 2000.

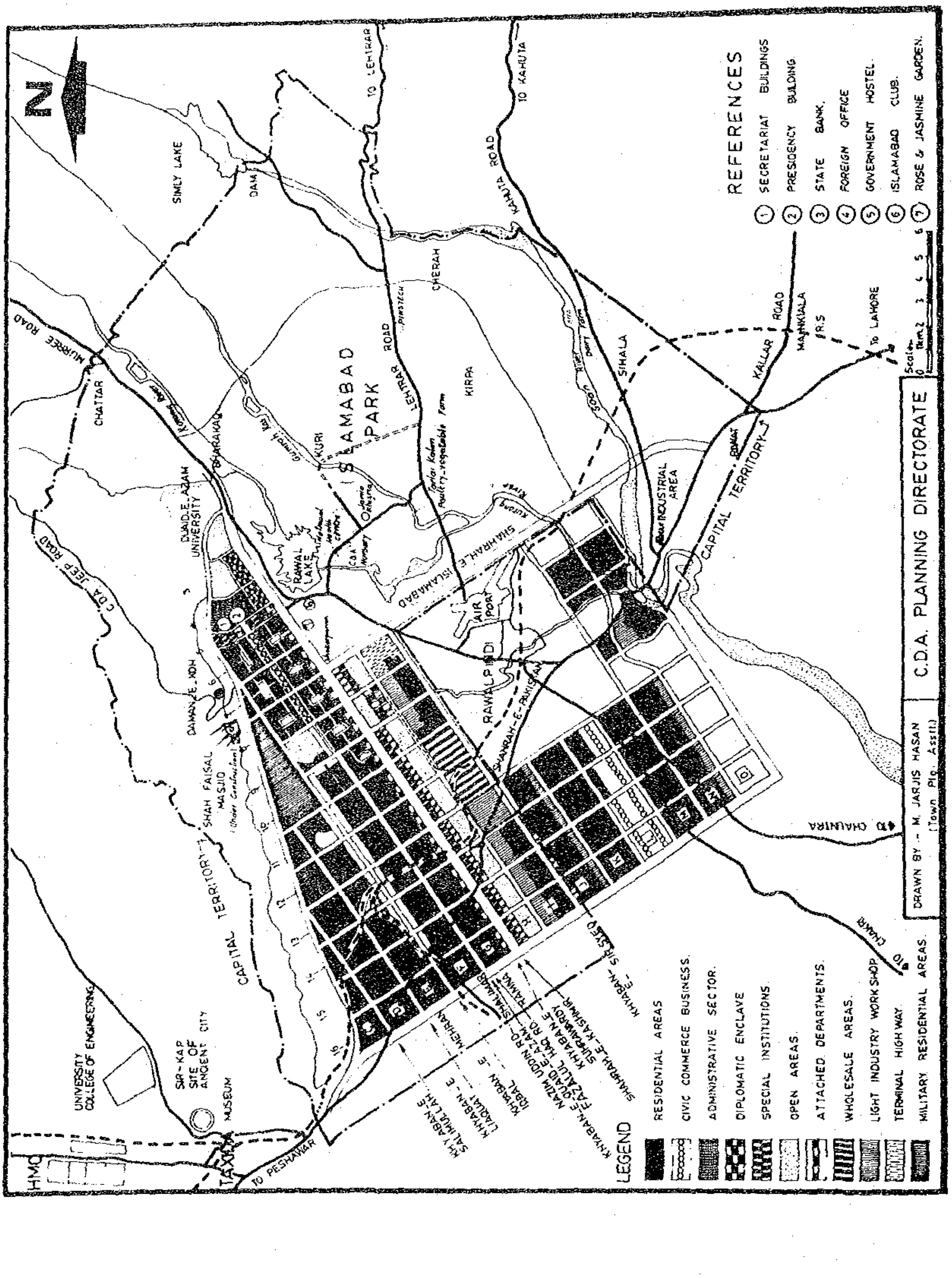

N
REFERENCES
1 SECRETARIAT BUILDINGS
2 PRESIDENCY BUILDING
3 STATE BANK
4 FOREIGN OFFICE
5 GOVERNMENT HOSTEL
6 ISLAMABAD CLUB
7 ROSE & JASMINE GARDEN
LEGEND
RESIDENTIAL AREAS
CIVIC COMMERCE BUSINESS
ADMINISTRATIVE SECTOR
DIPLOMATIC ENCLAVE
SPECIAL INSTITUTIONS
OPEN AREAS
ATTACHED DEPARTMENTS
WHOLESALE AREAS
LIGHT INDUSTRY WORK SHOP
TERMINAL HIGH WAY
MILITARY RESIDENTIAL AREAS
C.D.A. PLANNING DIRECTORATE
DRAWN BY :- M. JARJIS HASAN
(Town Plg. Asstt.)
ISLAMABAD PARK
CAPITAL TERRITORY
RAWALPINDI
AIR PORT
RAWAL LAKE
SIMLY LAKE
DAM
MURREE ROAD
C.D.A. JEEP ROAD
LEHTRAR ROAD
KAHUTA ROAD
KALLAR ROAD
TO LEHTRAR
TO KAHUTA
TO LAHORE
TO PESHAWAR
TO CHAUNTRA
TO CHAKRI
CHATTAR
KURI
CHERAH
KIRPA
SIHALA
QUAID-E-AZAM UNIVERSITY
SHAH FAISAL MASJID
DAMAN-E-KOH
INDUSTRIAL AREA
SHAHRAH-E-ISLAMABAD
SHAHRAH-E-PAKISTAN
TAXILA
HMC
UNIVERSITY COLLEGE OF ENGINEERING
SIR-KAP SITE OF ANCIENT CITY
MUSEUM

FIGURE III-2 LAND USE PLAN AND ZONING CHART OF RAWALPINDI

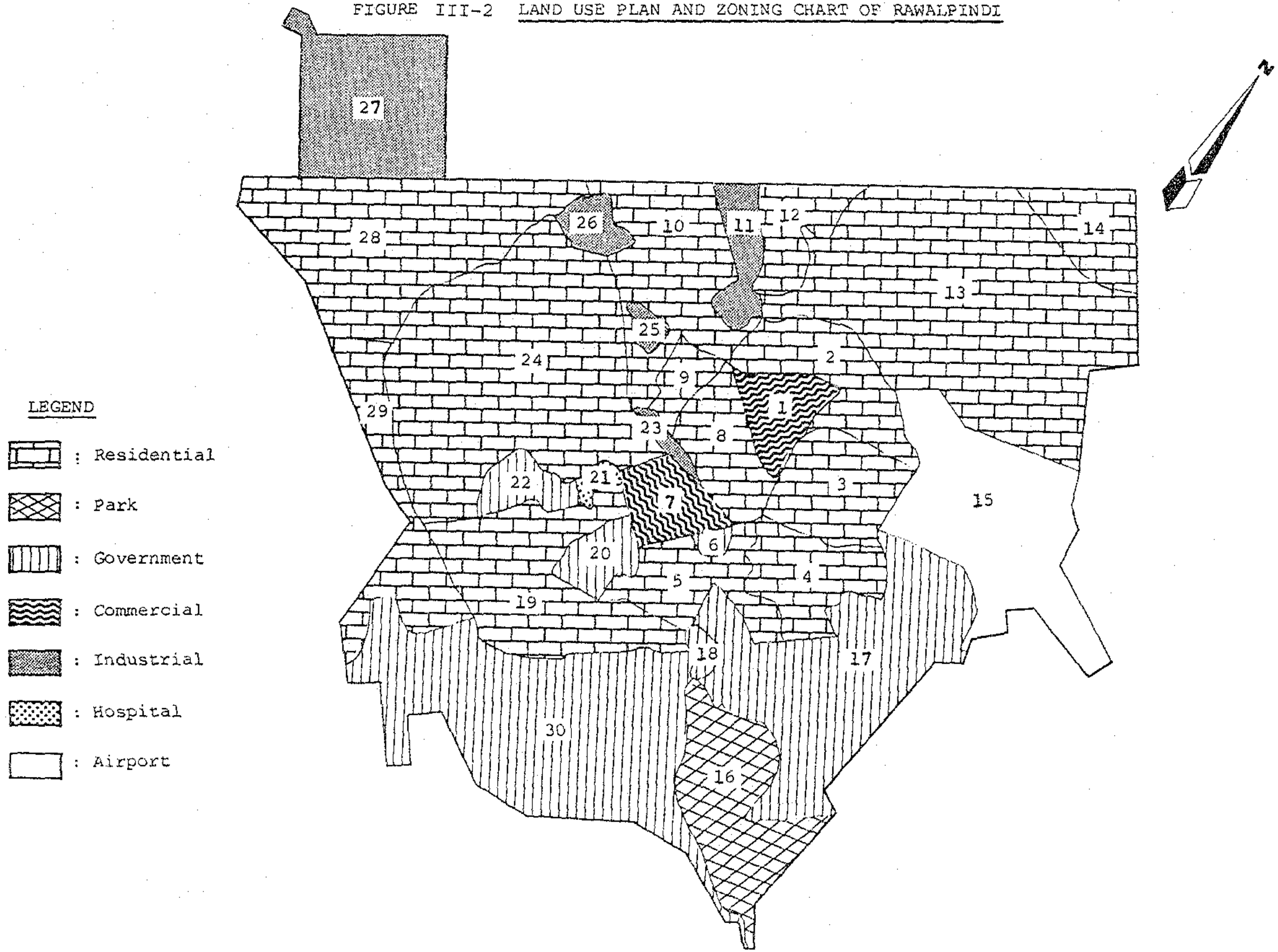
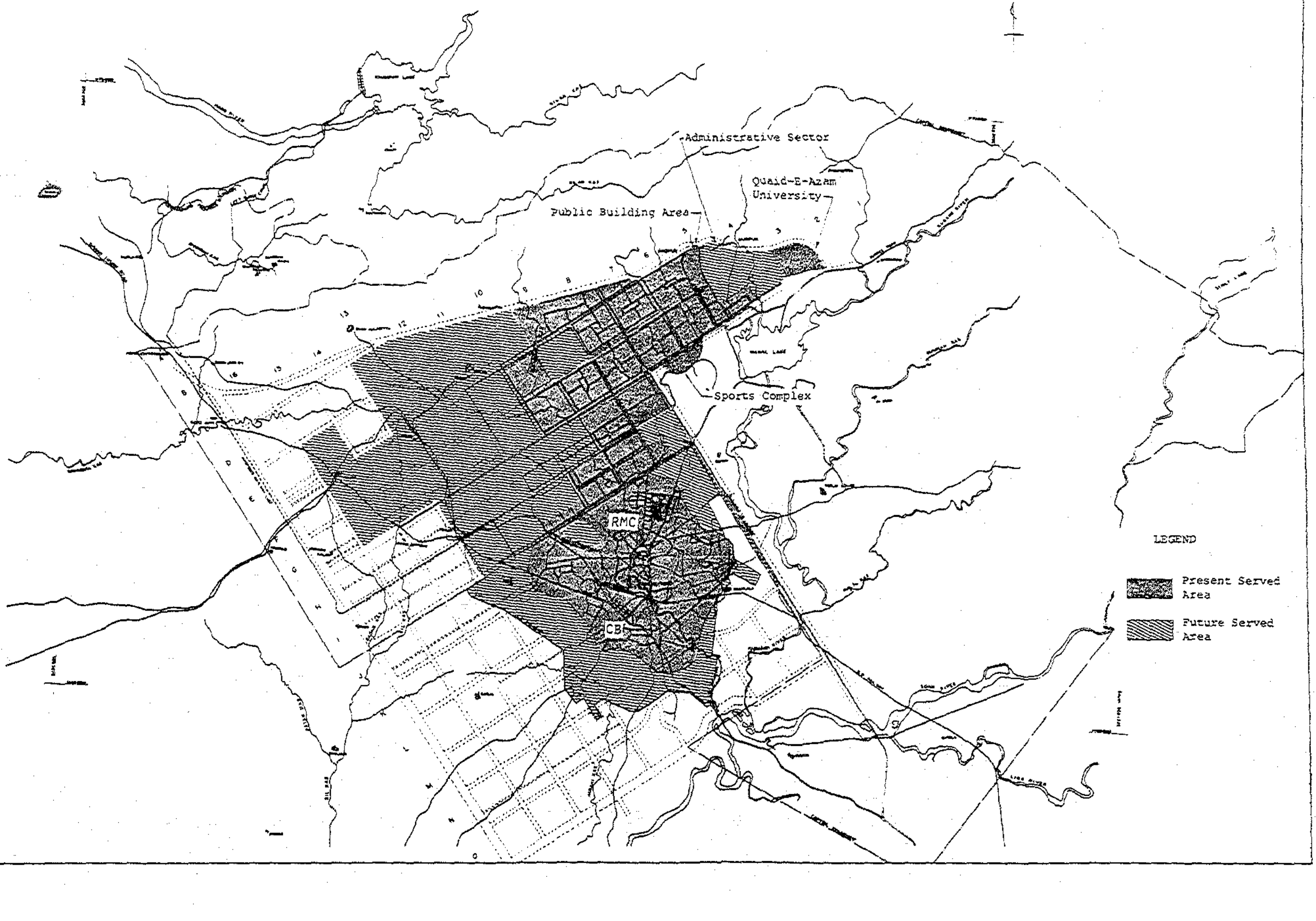


FIGURE III-3 SERVED AREA FOR THE PROJECT



3.2. Water Demand Projection

Water demand is defined as water consumption of various users and leakage and wastage of the water supply system. Future water demand is estimated every five years from the present up to the year 2000 for the both cities of Islamabad and Rawalpindi including Rawalpindi Cantonment area.

Water consumption is classified into the following consumer categories of consumer, they are:

- Domestic,
- Public,
- Commercial and Industrial, and
- Military (for only Rawalpindi).

Future water consumption is estimated based on the present water consumption of each category considering the future development plan, population increase and other concerning data obtained during field survey and informations from officials concerned.

Leakage and wastage of the system for every five years are estimated on the basis of the analysis of the present figure and target figure in the year 2000 considering present water supply system.

3.2.1. Islamabad

A. Domestic Consumption

The domestic water consumption is classified into two classes by consumption level according to the classification of house. Those are Class A and Class B (refer to Appendix A).

The future water consumption for domestic use is estimated based on the projected per capita consumption and population served of each class as shown below:

Unit: MLD (MGD)

Item	1948	1990	1995	2000
Class A	17.1 (3.7)	34.9 (7.7)	53.9 (11.9)	73.9 (16.2)
Class B	20.8 (4.6)	37.1 (8.1)	53.8 (11.8)	72.7 (16.0)
Total	37.9 (8.3)	72.0 (15.8)	107.7 (23.7)	146.6 (32.2)

Where per capita consumption and population distribution of each class is as follows:

Item	1984	1990	1995	2000
Class A				
Per Capita (l, gal)	300 (66)	320 (70)	330 (73)	340 (75)
Population (%)	29	32	34	35
Class B				
Per Capita (l, gal)	150 (33)	160 (35)	170 (37)	180 (40)
Population (%)	71	68	66	65

B. Public Consumption

The consumer includes such establishments as government office, educational institutions, embassies, hospitals, mosques and parks. The future water consumption of educational institutions, hospitals and mosques are estimated using the growth rate of population served. While that of governmental offices is estimated using lower increase rate as half of growth rate. The future consumption of embassies is estimated at 1% of increase rate per annum. Estimated future water consumption of public use is presented below:

Unit: MLD (MGD)

1984	1990	1995	2000
33.1 (7.3)	45.2 (9.9)	61.2 (13.4)	77.5 (17.0)

C. Commercial and Industrial Consumption

The consumption composes of those for shops, hotels, restaurants, factories and manufacturers. The future water consumption is estimated based on the present consumption, 23.7 MLD (5.2 MGD), using annual increase rate of 7% or around considering both increase rate of population growth and GDP at 6.5% per annum in the 6th Five-Year Plan of Pakistan, as presented below:

Unit: MLD (MGD)

1984	1990	1995	2000
23.7 (5.2)	36.9 (8.1)	50.8 (11.2)	66.1 (14.5)

D. Leakage and Wastage

The future leakage and wastage is estimated as shown below on the basis of the present percentage as 33% of production and proposed target of 20% to the total demand in the year 2000.

1984	by 1990	by 1995	by 2000
33%	28%	24%	20%

3.2.2. Rawalpindi

A. Domestic Consumption

The domestic water consumption is classified into three classes by consumption level according to the classification of houses. They are Class C, Class D and Class E (refer to Appendix A).

The future water consumption for domestic use is estimated based on the projected per capita consumption and population served of each class as shown follows:

Unit: MLD (MGD)

Item	1984	1990	1995	2000
Class C	33.3 (7.3)	53.3 (11.7)	75.6 (16.6)	102.0 (22.4)
Class D	22.2 (4.9)	43.9 (9.7)	63.0 (13.9)	86.1 (18.9)
Class E	12.4 (2.7)	11.0 (2.4)	8.2 (1.8)	4.5 (1.0)
Total	67.9 (14.9)	108.2 (23.8)	146.8 (32.3)	192.6 (42.3)

Where per capita consumption and population distribution of each class are as follows:

Item	1984	1990	1995	2000
Class C				
Per Capita (l, gal)	150 (35)	170 (40)	185 (43)	200 (46)
Population (%)	36	38	41	44
Class D				
Per Capita (l, gal)	100 (24)	120 (29)	135 (31)	150 (33)
Population (%)	36	44	47	50
Class E				
Per Capita (l, gal)	70 (15)	70 (15)	70 (15)	70 (15)
Population (%)	28	18	12	6

Per capita consumption will be higher than the present one at about 80 liter (18 gal) in average when the supply capacity meet demand and it is assumed at 150 liter (33 gal), 100 liter (22 gal) and 70 liter (gal) for Class C, D and E respectively. These figures are applied for domestic consumption in 1984.

B. Public Consumption

The public consumers include such establishments as government offices, educational institutions, hospitals, mosques and parks. The future water consumption is estimated as shown in the table below based on the present consumption using same approach as Islamabad.

Unit: MLD (MGD)

1984	1990	1995	2000
16.5 (3.6)	20.1 (4.4)	22.7 (5.0)	25.3 (5.6)

C. Commercial and Industrial Consumption

The consumer includes shops, hotels, restaurants, industries and manufacturers. The future water consumption is estimated based on the present consumption using the same approach as Islamabad, as shown below:

Unit: MLD (MGD)

1984	1990	1995	2000
28.6 (6.3)	37.7 (8.3)	46.1 (10.1)	55.2 (12.1)

D. Military Consumption

The consumer composes of Army, Air Force, their residential use and International Airport. The future water consumption is estimated on the basis of the potential demand of 18.2 MLD (4.0 MGD) and assumption that the water consumption will increase proportionately to the growth rates of population served and per capita consumption, as presented in the table below:

Unit: MLD (MGD)

1984	1990	1995	2000
15.9 (3.5)	24.6 (5.4)	29.7 (6.5)	34.9 (7.7)

E. Leakage and Wastage

The future leakage and wastage is estimated as shown below on the basis of the present percentage at 36% of production and proposed target of 20% to the total demand in the year 2000.

1984	by 1990	by 1995	by 2000
36%	30%	25%	20%

F. Maximum Day Demand Projection

According to the monthly production record in 1983, seasonal fluctuation of production is low which will be derived from the limited production capacity of the system. The maximum day demand is estimated at 125% of average demand taking into consideration weather condition with fluctuation of temperature and rainfall and the size of the both cities. According to the information of Lahore City, similar to Islamabad/Rawalpindi on the scale of water demand in 2000, the ratio of maximum/average demand is 1.22 at present.

The summary of the water demand projection of Islamabad and Rawalpindi are presented in Tables III-3 and III-4 respectively.

Proposed production and demand of Islamabad and Rawalpindi are illustrated in Figures III-4 and III-5.

TABLE III-3 PROJECTED POPULATION AND WATER DEMAND OF ISLAMABAD

Item Year	1984	1990	1995	2000
Total Population	206,000	341,000	480,000	621,000
Population Served	195,000 1/	341,000	480,000	621,000
Service Ratio (%)	100	100	100	100
Water Demand				Unit : MLD (MGD)
Domestic Use	37.9(8 .3)	72.0(15.8)	107.7(23.7)	146.6(32.2)
Public Use	33.1(7 .3)	45.2(9.9)	61.2(13.4)	77.5(17.0)
C/I Use 2/	23.7(5 .2)	36.9(8.1)	50.8(11.2)	66.1(14.5)
Leakage/Wastage	47.3(10.4)	59.9(13.2)	69.4(15.2)	72.5(16.0)
(%) 3/	(33)	(28)	(24)	(20)
Total	142.0(31.2)	214.0(47.0)	289.1(63.5)	362.7(79.7)
Average Day Demand	142.0(31.2)	214.0(47.0)	289.1(63.5)	362.7(79.7)
Maximum Day Demand	177.5(39.0)	267.5(58.8)	361.3(79.4)	453.2(99.6)
Dayly Per Capita Demand				Unit : 1 (gal)
Domestic Use	194(43)	211(46)	224(49)	236(52)
Total	728(160)	628(138)	602(132)	584(128)

Note : 1/ execluding population of Golra and Nurpur Shahan.
2/ C/I Use : Commercial and Industrial Use.
3/ Percentage of leakage/wastage to demand.

TABLE III-4 PROJECTED POPULATION AND WATER DEMAND OF RAWALPINDI

Item Year	1984	1990	1995	2000
Total Population	888,000	1,046,000	1,167,000	1,275,000
Population Served	622,000	837,000	992,000	1,148,000
Service Ration (%)	70	80	85	90
Water Deman				Unit : MLD (MGD)
Domestic Use	67.9(14.9)	108.2(23.8)	146.8(32.3)	192.6(42.3)
Public Use	16.5(3.6)	20.1(4.4)	22.7(5.0)	25.3(5.6)
C/I Use 1/	28.6(6.3)	37.7(8.3)	46.1(10.1)	55.2(12.1)
Military Use	15.9(3.5)	24.6(5.4)	29.7(6.5)	34.9(7.7)
Leakage/Wastage	72.5(15.9)	81.7(18.0)	81.8(18.0)	77.0(16.9)
(%) 2/	(36)	(30)	(25)	(20)
Total	201.4(44.2)	272.3(59.9)	327.1(71.9)	385.0(84.6)
Average Day Demand	201.4(44.2)	272.3(59.9)	327.1(71.9)	385.0(84.6)
Maximum Day Demand	251.8(55.3)	340.4(74.8)	408.9(89.9)	481.3(105.8)
Daily Per Capita Demand				Unit : 1 (gal)
Domestic Use	109(24)	129(28)	148(33)	168(37)
Total	324(71)	325(71)	330(73)	335(74)

Note : 1/ C/I Use : Commercial and Industrial Use
2/ Percentage of leakage/wastage to demand

FIGURE III-4 **PRODUCTION AND DEMAND OF ISLAMABAD**

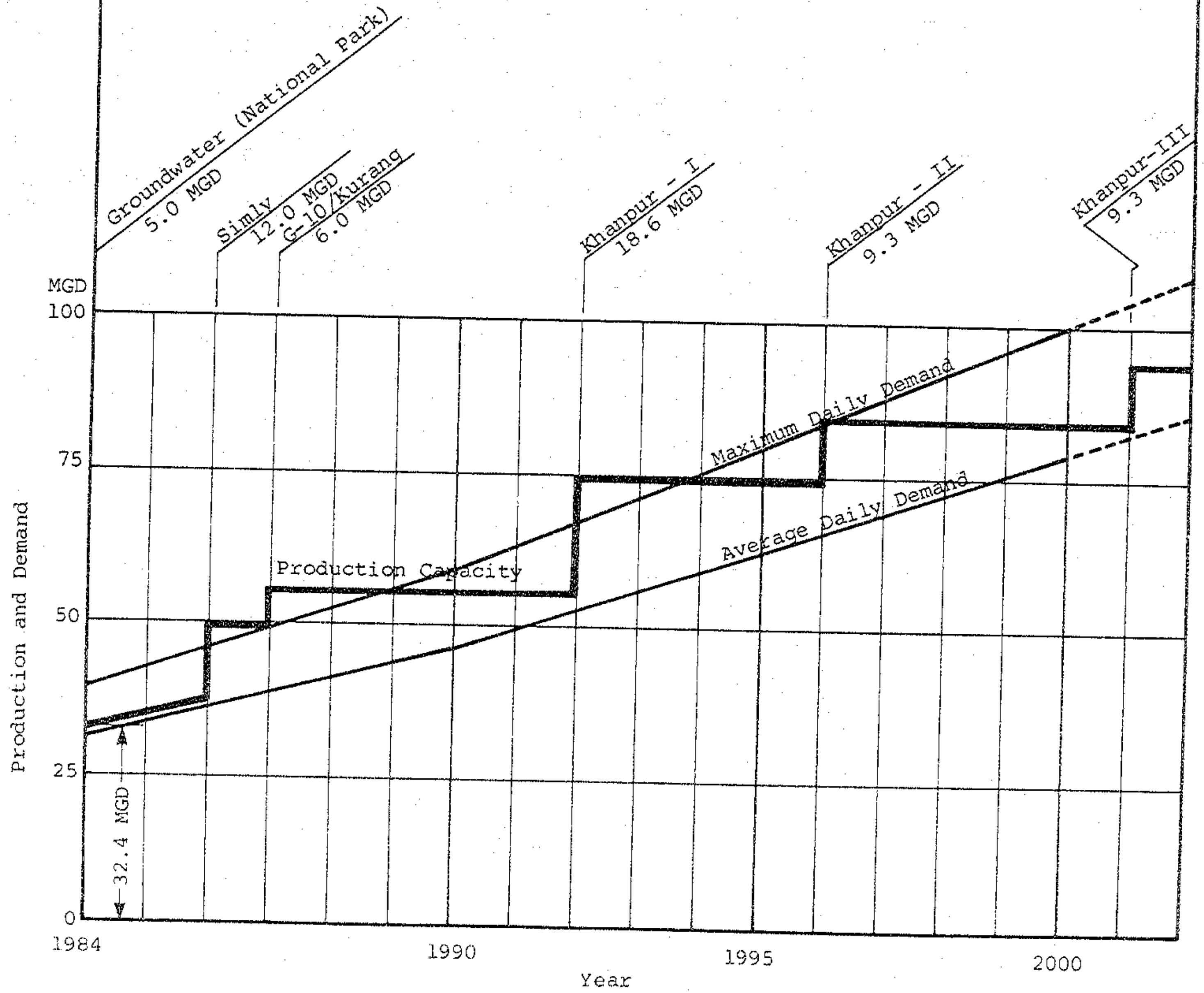
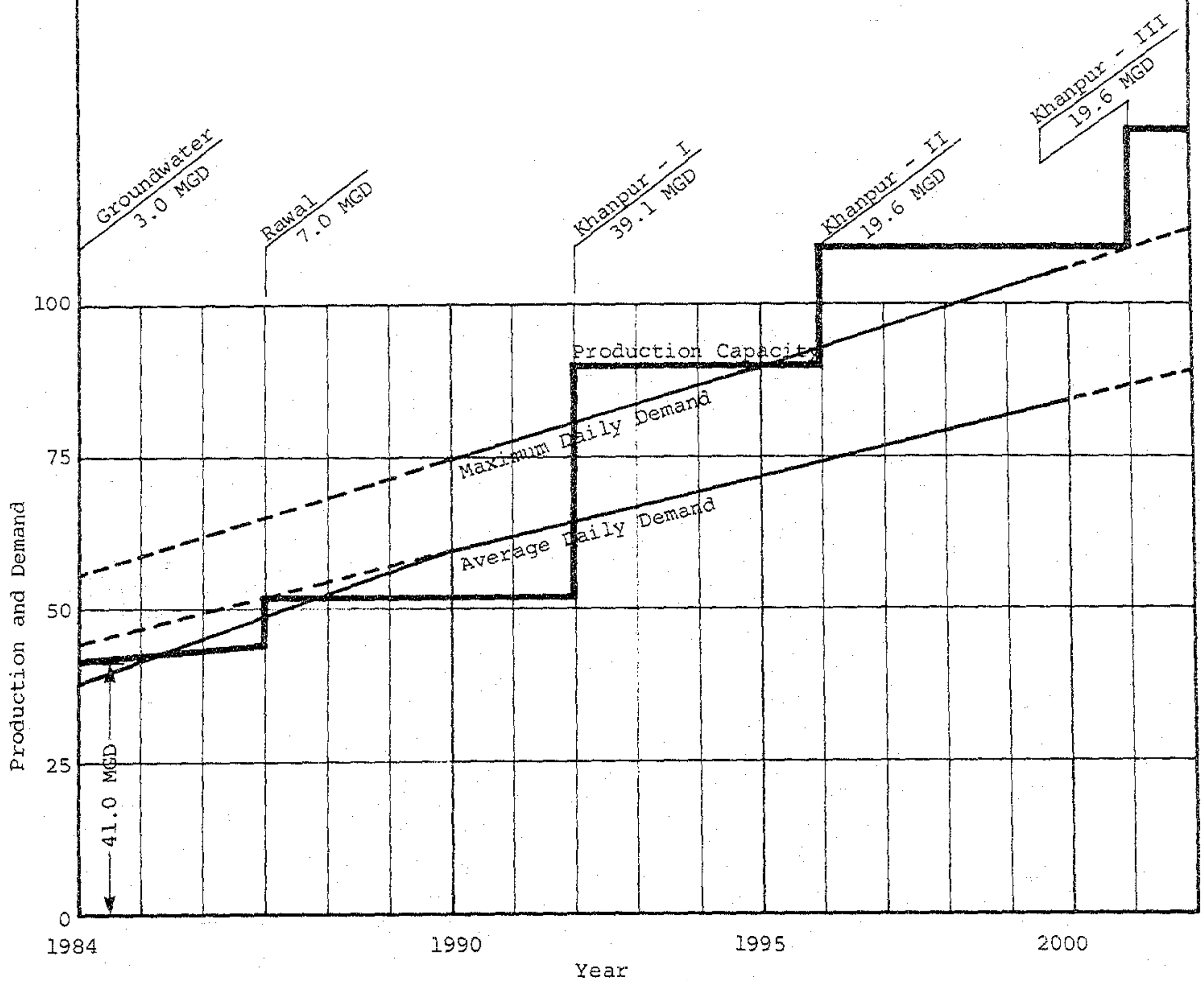


FIGURE III-5 PRODUCTION AND DEMAND OF RAWALPINDI



3.3. Water Resources

3.3.1. Storage Dams

Aiming at confirmation of surface water availability from the Haro, Kurang and Soan rivers and to evaluate the expected firm yield from reservoirs, detailed water balance simulations were carried out for the entire period of available data. The study was mainly based on the fundamental dimensions of the Projects given in P.C. I Proformas and Completion Reports, and on hydro-meteorological data prepared and provided by CDA and WAPDA as well as by Regional Meteorological Centre, Lahore.

A. Runoff

Runoff observations of the Haro river near Khanpur have been recorded by Surface Water Hydrology Project, WASID, WAPDA since 1960 on the right bank about 400 m upstream from Taxila-Haripur Road Bridge. Daily mean runoffs vary with a wide range from 0.1 cu.m/sec (4 cusec) to 501 cu.m/sec (17,700 cusec), and the annual average runoff for the period of 21 years up to 1980 has been reported at 307.1 MCM (24,900 acre ft). Since it is notified that the record excludes small irrigation diversion on the left bank for the existing irrigation systems which may carry considerable portion of low water discharge, the water balance computations for the Khanpur reservoir were conducted under the assumption that 60% of the culturable command area on the Left Bank Canal was being irrigated by the Haro river water diverted upstream of the river gauging station. Thus, the Khanpur inflow would be WAPDA measurement plus irrigation requirement for 60% of CCA, that is equivalent to 327.0 MCM/yr or 265,000 AF/yr. Table III-5 presents monthly runoffs of the Haro river employed in the study.

There are two different measurements of runoff at and near the Simly dam site on Soan river. The data for the Soan at Simly were collected by the WAPDA Resident Engineer of CDA for the period of 10 years from 1964 to 1973. Additional runoff data are available from SWHP, WAPDA on the Soan at Chirah which is 13 km downstream from the dam. Comparison studies were made on runoff measurements and, consequently, WAPDA's measurements at Chirah was used to estimate inflow of the Simly reservoir after treatment of data by means of areal conversion.

CDA's abstraction of Soan river water at Simly was started in 1969 and daily data of diverted water have been provided by CDA. These data were added to the Soan runoffs to generate actual amount of inflow into the Simly reservoir. Table III-6 presents monthly runoff of Soan river at Simly employed in the study.

Regarding runoffs of the Kurang river at Rawal dam, the Small Dams Organization of Punjab Government, which is responsible in operating the dam, has been collecting records of dam operation on monthly basis including storage, elevations and releases from 1962 onwards. Although there are some potential sources of error in the SDO's data and so the data can not be directly used in water balance computation, the estimated figures of inflow, from which runoff coefficient of 17% is resulted, indicate possible negative margin of Kurang runoff as compared to those obtained from Haro and Soan rivers.

Rainfall studies made to grasp areal rainfalls over the catchments show that the Rawal catchment has been receiving almost same amount of areal rainfall as compared with that of Khanpur catchment. The Khanpur runoff could, therefore, be useful measures to estimate Rawal runoff. On the contrary from inspection of rainfall-runoff relationships observed by WAPDA elsewhere in and around the basins between the Indus and Jhelum rivers, it could be concluded that there is some geographic effect on yield from drainage basins, with more mountainous catchments yielding more than catchments which contain more low-elevated and flat land.

Consequently, the Rawal runoff has been estimated as 80% of Haro runoff at Khanpur with reduction in proportion to the catchment areas, resulting in 92.4 MCM/yr of annual runoff or 21.8% of annual precipitation within the catchment. Table III-7 summarizes monthly runoffs of Kurang river at Rawal employed in the study.

B. Sedimentation

Among several methods available to calculate suspended sediment load of rivers, the method using flow duration and sediment rating curve was employed in the study to evaluate sediment inflow to reservoirs. As the basic data for preparation of sediment rating curves, two parameters are to be needed namely (1) mean daily discharges of the river for a specific period of analysis and (2) sediment concentration with instantaneous river discharge on a number of occasions at different stages of river flow obtainable by sediment samplings.

Fortunately sufficient volume of such data are available from SWHP, WAPDA at Khanpur on the Haro river for evaluation of Khanpur sediment inflow and at Chirah on Soan river for Simly sediment inflow. Each set of sediment concentration and discharge was plotted to produce representative rating curves which were derived by using method of least square.

Suspended Sediment Rating Curve

River	Rating Curve
Haro River at Khanpur	$PPM = 27.9495Q^{1.2278}$
Soan River at Chirah	$PPM = 121.2807Q^{0.6810}$

Notes: (1) Suspended sediment concentration expressed in PPM by weight.

(2) Discharge in cu.m/sec.

To determine duration and magnitude of river discharges, daily runoffs of the rivers at the points under consideration were ranked according to their magnitudes, and then combined with the rating curves to compute suspended sediment inflows. An estimated bed load of 30% of suspended load thus obtained was added to arrive at the total sediment load which would flow into the reservoirs.

As concerns sediment inflow to the Rawal lake, data from actual survey of sedimentation prepared by WAPDA, Dams Monitoring Organization (DMO), were directly employed in the study. Reservoir sedimentations and effective live storages of reservoirs, thus estimated in future, are summarized as below:

Effective Live Storage of Reservoir

Year	Khanpur (acre ft)	Simly (acre ft)	Rawal (acre ft)
1990	91,000	30,300	33,445
2000	89,200	30,300	30,205
2010	80,890	30,300	26,965
2020	72,580	30,300	23,725
2030	64,360	30,300	20,525

C. Water Availability of Khanpur Reservoir

a. Water Demand

Seasonal variations of the projected water demand for municipal (urban) water supply for both Rawalpindi and Islamabad have been projected as below. In this connection, rate of industrial water consumption is considered to be uniform throughout a year.

Seasonal Variation of Water Supply

Month	Municipal Water Rate	Islamabad (MGD)	Rawalpindi (MGD)	Industrial Water Rate	POF (MGD)	PIDC (MGD)
Jan	0.80	26.40	55.50	1.00	15.0	13.5
Feb	0.85	28.05	58.96	1.00	15.0	13.5
Mar	0.90	29.70	62.43	1.00	15.0	13.5
Apr	1.00	33.00	69.37	1.00	15.0	13.5
May	1.15	37.95	79.78	1.00	15.0	13.5
Jun	1.25	41.25	86.71	1.00	15.0	13.5
Jul	1.05	34.65	72.84	1.00	15.0	13.5
Aug	1.00	33.00	69.37	1.00	15.0	13.5
Sep	1.05	34.65	72.84	1.00	15.0	13.5
Oct	1.05	34.65	72.84	1.00	15.0	13.5
Nov	1.00	33.00	69.37	1.00	15.0	13.5
Dec	0.90	29.70	62.43	1.00	15.0	13.5
Average	1.00	33.00	69.37	1.00	15.0	13.5

Regarding irrigation water requirements, a detailed study was conducted, for which brief explanation is given as in the followings:

Irrigation intensities of cultivation are available in P.C. I Proforma, second revised, as under.

- Cropping Intensity 130%
- Kharif Rabi Ratio 1:1.1

Rabi Cropping	Wheat	44.0%	
	Sugar Cane	3.5	
	Fodder	6.0	
	Orchards	3.5	
	Others	11.0	Total 68%
Kharif Cropping	Maize	30.0	
	Tobacco	8.0	
	Fodder	6.0	
	Orchard	3.5	
	Sugar Cane	3.5	
	Others	11.0	Total 62%

Since no information on cropping schedule is available, an appropriate cropping schedule was prepared by JICA Study Team, based on the information provided in "Irrigation Requirements of Crops in the Punjab" by Directorate of Land Reclamation, Irrigation and Power Department, Government of Punjab, in June 1980. Figure III-6 presents the cropping pattern and calendar employed in the study.

Reference crop evapotranspirations by season were calculated based on the climatic conditions observed at Rawalpindi Meteorological Station by applying Modified Penman Method through procedures given in FAO Technical Publication No.24.

Crop growth stage coefficients (kc) developed for Pakistan using experimental data collected in the country are available in "On Farm Water Management, Field Manual, Volume IV: Irrigation Water Management", published in December 1980 by Water Management Wing, Ministry of Food, Agriculture & Cooperatives. The FAO method of developing kc values was also used to supplement experimental data.

Effective rainfall was computed by a carry-over system under the following conditions:

- If a daily rainfall is less than or equal to 5 mm, then the effective rainfall is zero

- If the daily rainfall is more than 5 mm, then the effective rainfall is obtainable by multiplying the daily rainfall by 80%

Total readily available moisture content (TRAM) value of 50 mm derived from soil condition was employed. The daily moisture content value was memorized in the computer and the carry-over is construed as a soil moisture heldover to the following day. When the moisture exceeded TRAM value, the surplus water would be spilled as surface flow or deep percolation.

Total amount of water of 50 mm in depth was added for crops planted during dry period, to meet water requirement for land preparation.

Computation was made on a daily basis taking into account the carry-over of soil moisture and rotational irrigation with seven day intervals. In the study, an overall irrigation efficiency was taken as 72.0% (90% for conveyance system x 80% for application) including all of efficiencies from diversion point up to the root zone of crops. Unit diversion water requirement for irrigation so computed is presented in Table III-8.

b. Water Balance Simulation

Water balance study of the Khanpur reservoir was undertaken combining every aspect of hydrology, such as inflow into the reservoir, water demand for municipal and industrial water supply and for irrigation, and water losses from the reservoir surface and bottom.

To cope with the simulation of actual reservoir operation under the conditions prepared by the Project, various cases of water balance computations were processed giving various combinations of water demands requested by beneficiaries, aiming at finding firm yield from the reservoir which would be satisfied even during critically droughty period of once in five years probability. Regarding the return period of drought, it has been agreed at the meeting held on 24th September, 1984 in the office of Member (Water), WAPDA, Wapda House, Lahore, that the study is based on the drought of five year return period.

The computation was made for the period of 21 years from 1960 to 1980 with a ten-daily unit, employing a simple assumption that the surplus water in the reservoir above full water level during any ten-daily interval would be released through a spill during the corresponding ten-daily interval. Regarding water losses from the reservoir, deduction of 10% from the available inflow was considered to be sufficient to account for both evaporation and seepage.

In review of various cases of water balance study, size or capacity of the Khanpur reservoir would be sufficient to satisfy various water requirements. However, inflow is small in contrast with demand, and hence there are frequent occasions of relatively long period before the reservoir water level comes back to its full water level meaning that practically water shortage would occur in most years. Frequency of shortage decreases with deduction of water demand to be released from the reservoir, but the benefit also decreases correspondingly. A review of the study in terms of probability of shortage occurrence indicates that about 75% of the present water requirement would be optimal when the capacity of the reservoir and the rate of inflow are combined. with deduction of water demand to 75% of that presently projected, the Khanpur reservoir would provide full amount of water supply just to meet requirement even during a drought period of once in five years frequency.

D. Water Availability of Simly Reservoir

The water supply system of Islamabad has been planned on the basis of two major water sources viz. Khanpur dam and Simly dam. The Simly dam has been commissioned in 1982 and 12.0 MGD of water is at present being received from the dam and conveyed to Islamabad through one conduction main pipe. The Simly Filtration Plant, located nearby the dam site, has already been completed in 1965 with the designed water production capacity of 24.0 MGD. The other conduction line is expected to be ready by the end of 1984, and thus full yield of 24.0 MGD of Simly reservoir is scheduled to be available soon.

In parallel with this, installation of three 25 ft high gates are advantageouly programmed in near future within five years to raise the conservation level of the reservoir to 2,315 ft accordingly increasing live storage by 11.8 MCM, resulting in gain of a substantial safe yield from the reservoir. In this connection, CDA's estimate on safe yield from the reservoir after raising the dam has been reported as 48.0 MGD.

To confirm the availability of water, at present and in future, from the reservoir, detailed studies of water balance simulation were carried out through procedures employed for Khanpur reservoir operation. Computed results were then put into statistical evaluation, and it is concluded that (1) the Simply reservoir under the existing condition of storage capacity would satisfy the scheduled amount of water supply even in five-year dry year, and (2), on the contrary, after raising of the dam the reservoir would produce 38.4 MGD of firm yield, which is equivalent to 160% of the present requirement or 80% of the CDA's estimate under the future condition of the dam.

E. Water Availability of Rawal Reservoir

The existing condition of water supply of the Rawal Reservoir is, according to Small Dams Organization, as under.

Distribution	Supply (MGD)	Remarks
Rawalpindi Water Supply	21.0	
CDA	2.0	Temporary
CDA by Pumping Up	1.5 - 2.0	-do-
Irrigation	Balance	
Total	28.0	when available

The above allocation of water will be revised in near future and by the end of 1986 it is scheduled that the whole amount of Rawal yield is conveyed to Rawalpindi and Cantonment. It is therefore considered as the existing condition that only the water supply to Rawalpindi (including Cantonment) is the consumer of Rawal water, and to confirm the availability of reservoir water detailed studies of water balance simulation were conducted. After examination of sedimentation study, the following dimensions of the reservoir were inputted;

Dimension of Rawal Reservoir

Description		Present (1984)	Future (2000)
Full Water Level	(ft)	1,752	1,752
Dead Water Level	(ft)	1,722	1,729
Maximum Storage	(MCM)	58.59	58.59
Dead Storage	(MCM)	14.93	21.33
Effective Storage	(MCM)	43.66	37.26

Then statistical evaluations were progressed on shortage of reservoir water and major findings are summarized as follows:

- The existing Rawal reservoir would provide scheduled amount of firm yield successfully throughout periods of once in five-year probability drought and still have some excess water available in the reservoir.

- In the year 2000 A.D., 180% of at present programmed yield would still be available from the reservoir. This is equivalent to 50.4 MGD as maximum or 40.3 MGD as average after treatment.

3.3.2. Streams

Actual measurement of water production from the existing head works, which are receiving water from streams inclusive of spring water, are available from CDA. Average monthly productions of water by source have also been obtained for selected years of 1977 and 1983. Both data indicate that the production of water is, as a