whole, increasing year by year mainly due to the extension of facilities, and that the monthly variation of production is less. The safe yield from stream surface water is, therefore, considered to be the lowest production, for each head works, in the recent five years which corresponds to once in five years level.

3.3.3. Groundwater

In the Project area, groundwater is received from aquifers of gravel and sand layers contained in alluvium. Based on the existing data of wells and geology, seven potential zones of well field have been investigated as shown in Figure III-7. Although it is inevitable that a large scale water balance simulation of the entire groundwater basin is to be examined to comprehend availability of groundwater, such data are not available for the time being since monitorings for the existing wells have not been carried out. Available source of groundwater recharge is, therefore, estimated at 20% of annual rainfall. Among the existing developed areas, no more intensive development is desirable in the Sectoral area and Rawalpindi area. Especially Rawalpindi area has been seriously overdeveloped. Since waters drawn from tube wells are, from economic point of view, to be distributed nearby areas of wells, only West Sectoral area, Southwest Sectoral area and a part of West Rawalpindi area have a possibility for development by the end of the target year of 2000 A.D. Availability of groundwater at present and in future is estimated as shown in Table III-9.

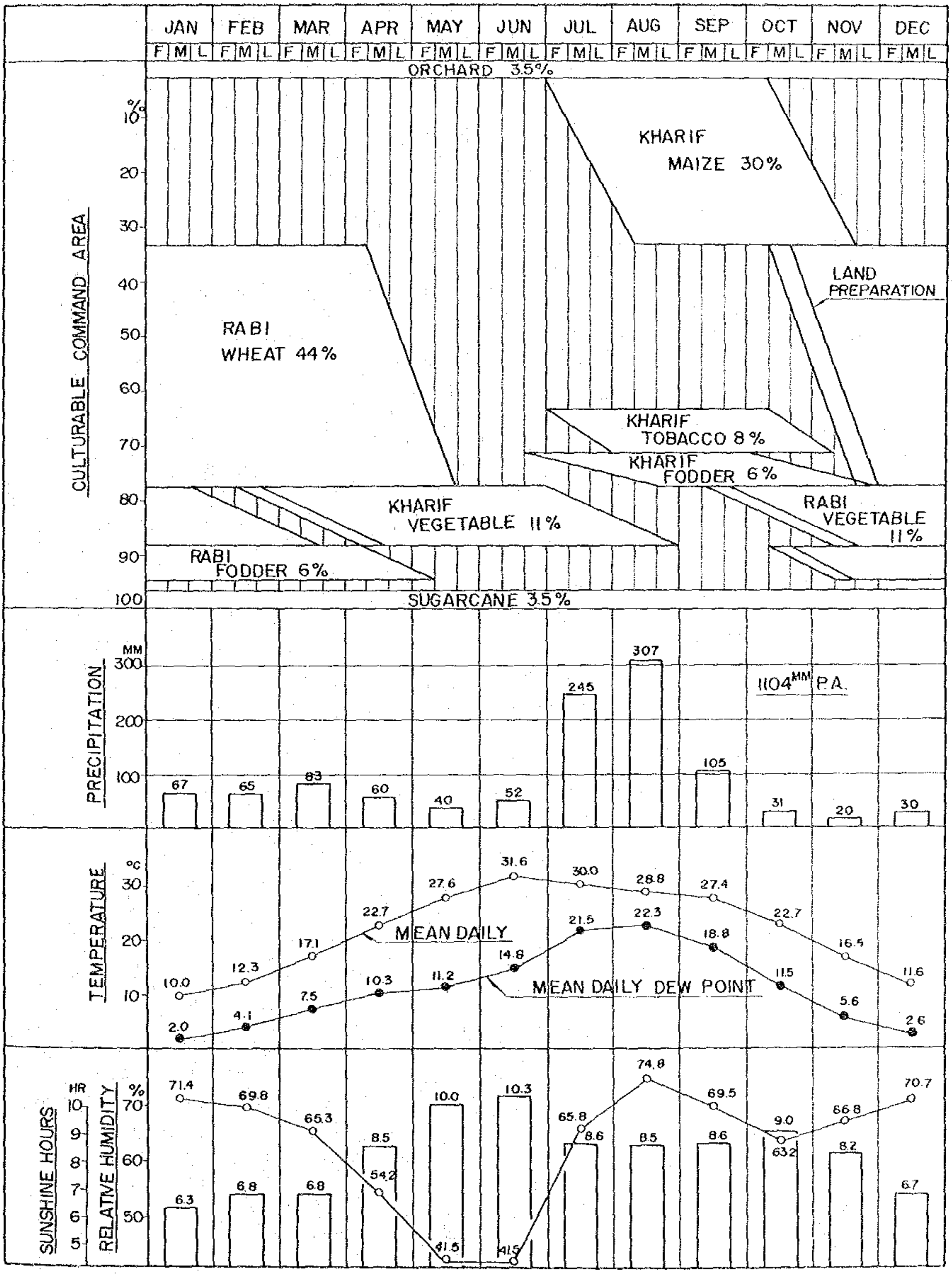
3.4. Water Balance in the Year 2000

The existing and proposed yields from surface water and groundwater are listed in Table III-10. Firm yield from surface waters of stream was estimated on the basis of the actual achievement of water production under the assumption that the lowest value observed in the past five years would correspond to the safe yield of order of 5-year return period. Firm yields from the storage reservoirs have been evaluated in detail through water balance computations. Production of groundwater was estimated from the individual well data and possible developments in future, and the safe yield was obtained multiplying average production by 80% taking into account the reduction of production during dry summer period.

The water demand is defined as the quantity of water to be supplied and consists of water consumption and losses. For both Islamabad and Rawalpindi, water demands have already been computed on the basis of unit water consumption, service population and estimated rate of leakage and wastage.

Taking into account the phasing plans of water resources development, firm yields and demands by year are compared as shown in Figures III-8 and III-9 for Islamabad and Rawalpindi, respectively.

FIGURE III-6 CROPPING PATTERN AND CALENDAR



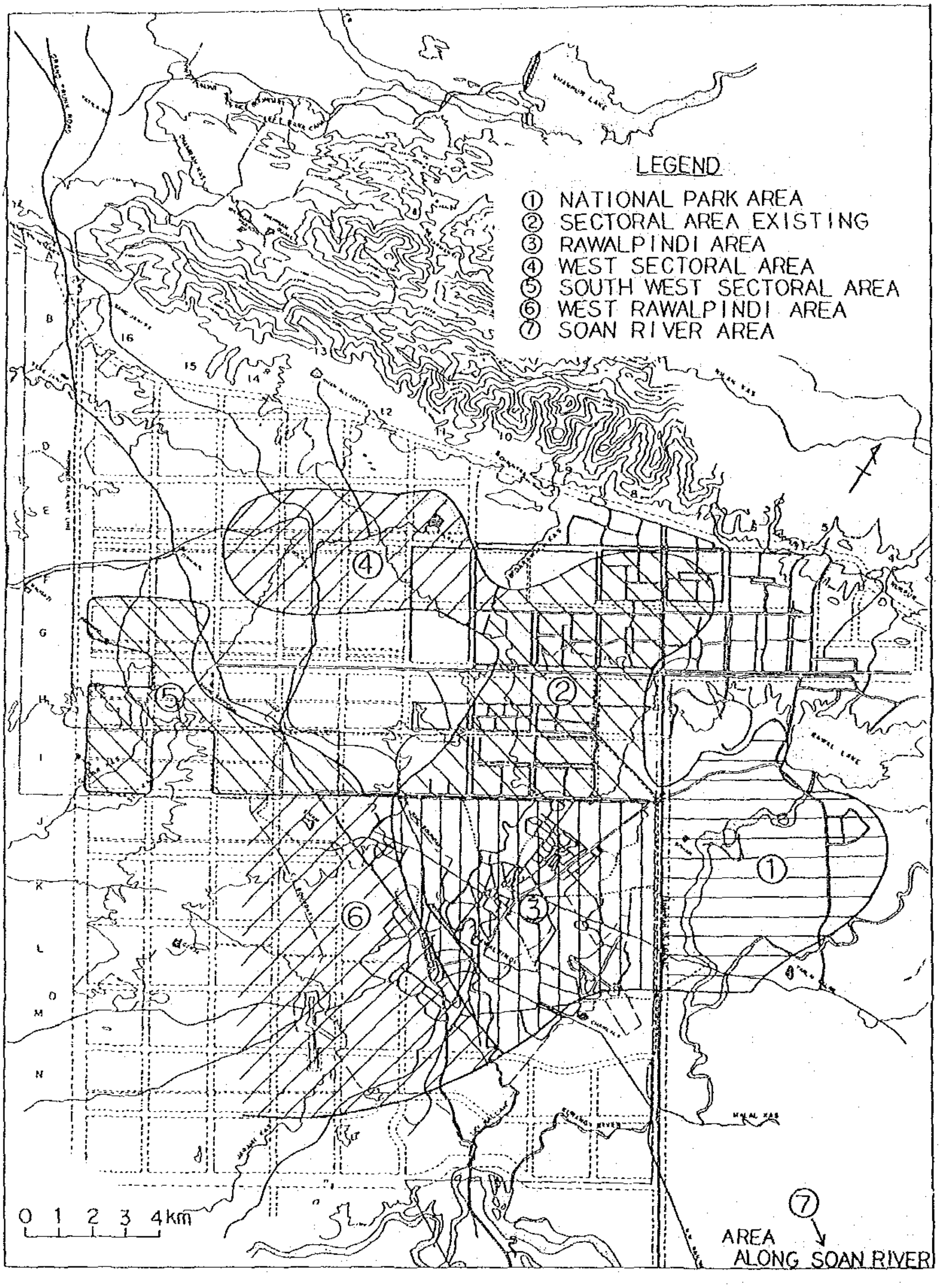


FIGURE III–7 WELL FIELDS IN ISLAMABAD/RAWALPINDI AREA

FIGURE III-8 BALANCE OF AVAILABILITY AND DEMAND OF WATER

(ISLAMABAD)

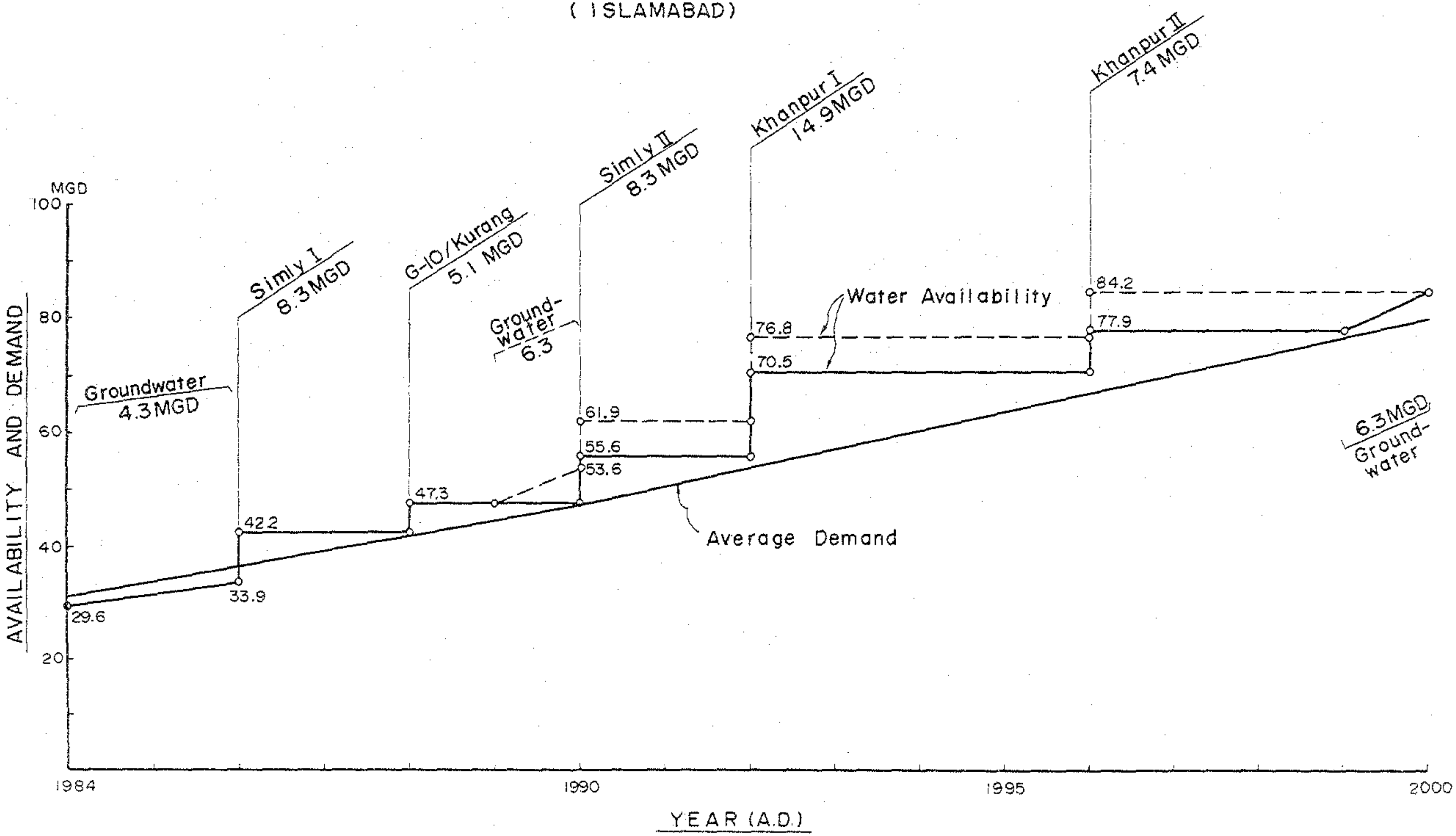


FIGURE III-9 BALANCE OF AVAILABILITY AND DEMAND OF WATER

(RAWALPINDI)

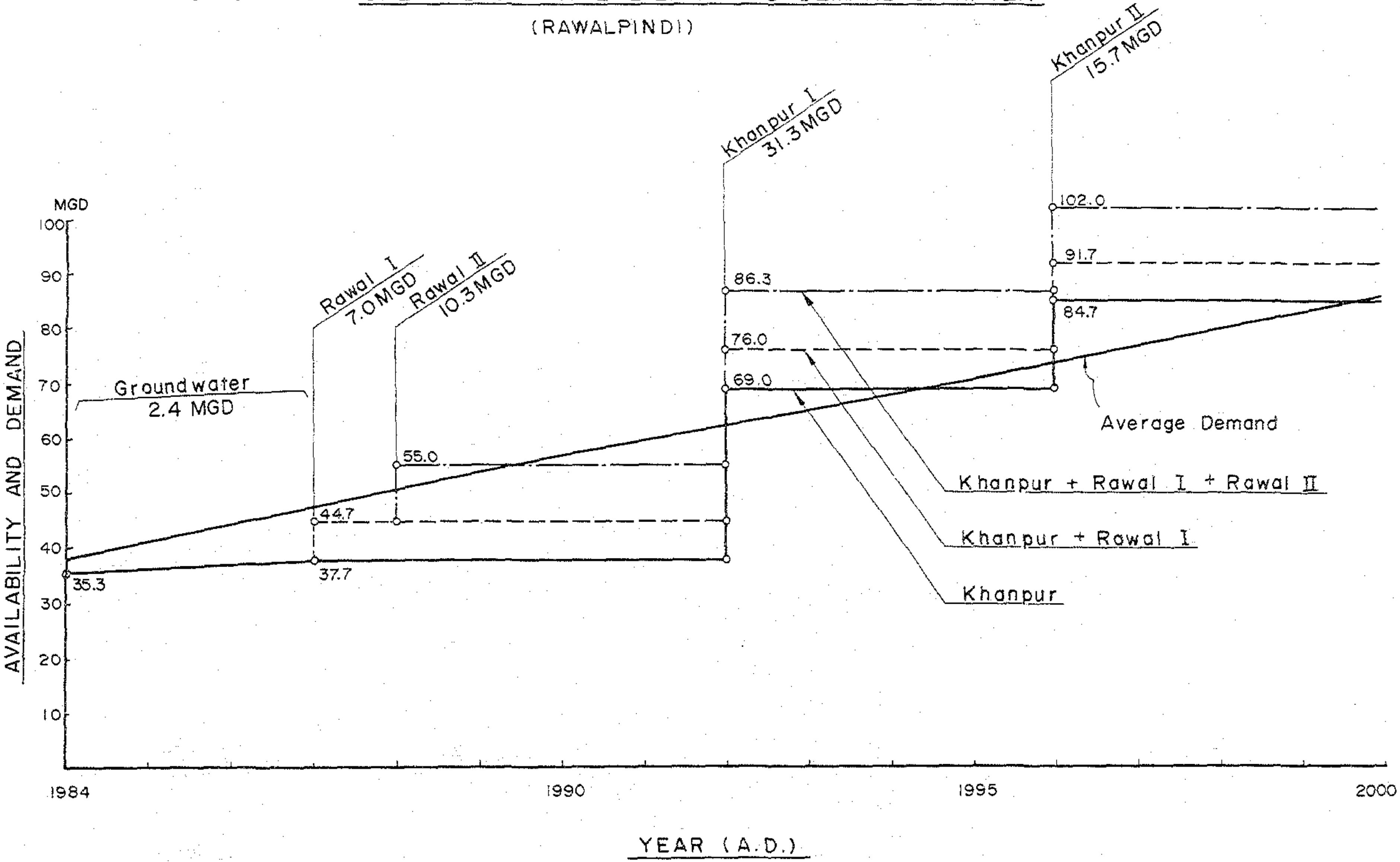


TABLE III-5 HARO RIVER RUNOFF AT KHANPUR

*** HARO RIVER AT KHANPUR (STUDY) ***

UNIT = MCM/MON

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1960	15.514	13.745	21.730	20.071	13.094	8.256	42.185	49.451	35.264	15.275	8.807	5.747	249.138
1961	19.299	26.706	17.099	40.792	22.229	14.122	43.746	50.120	138.991	32.390	17.242	10.425	433.159
1962	6.871	7.404	30.071	19.142	8.322	6.879	24.941	44.538	33.916	15.116	7.316	6.116	210.632
1963	5.701	6.343	29.858	19.806	12.364	6.491	21.591	60.209	40.820	13.985	9.479	7.269	233.917
1964	39.052	25.549	19.804	13.961	7.228	4.479	22.292	60.138	37.926	15.391	8.038	6.861	260.719
1965	6.695	21.790	40.040	116.929	77.935	28.009	22.286	44.877	19.993	11.223	6.317	6.331	402.425
1966	5.518	10.983	22.261	27.504	26.225	10.271	30.785	48.542	38.374	23.267	10.543	7.462	261.736
1967	5.974	35.425	70.344	49.938	27.787	8.718	12.563	45.537	45.198	14.670	6.739	19.808	342.701
1968	26.153	35.926	37.927	21.245	11.098	5.913	17.356	86.833	16.892	12.866	7.280	7.066	286.556
1969	5.982	15.041	18.699	19.133	8.587	5.567	7.637	33.623	16.582	22.714	6.716	3.871	164.154
1970	6.247	5.686	43.791	13.653	4.461	4.120	13.386	67.122	119.081	31.511	9.612	5.257	323.926
1971	5.120	7.806	13.297	6.679	3.169	79.217	78.469	121.886	41.405	15.833	7.169	4.397	383.445
1972	6.973	12.510	36.534	21.944	24.185	9.796	10.685	23.690	26.353	11.092	7.028	12.579	203.369
1973	18.382	21.376	74.846	22.785	10.275	11.842	42.799	134.280	80.249	24.955	10.431	7.408	459.627
1974	8.064	18.529	10.973	6.299	3.867	5.529	19.900	25.965	13.168	7.221	4.183	3.194	126.891
1975	4.821	9.634	16.392	17.914	11.263	8.505	18.752	80.776	29.995	12.503	7.581	4.656	222.791
1976	10.334	39.733	65.640	42.775	19.038	11.514	45.079	243.887	95.805	32.983	14.182	8.424	629.395
1977	12.779	12.719	9.737	19.766	16.894	11.921	98.632	136.553	79.511	56.794	18.376	10.566	484.248
1978	15.604	12.985	38.073	19.126	8.619	8.948	157.391	191.334	64.826	28.282	15.842	8.383	569.414
1979	10.995	24.872	101.157	47.172	19.632	9.032	18.275	48.626	17.756	7.687	4.670	3.005	312.878
1980	15.929	21.386	45.797	25.536	9.524	26.106	28.585	72.219	30.422	15.213	9.021	4.831	304.569
TOTAL	252.009	386.148	764.068	592.167	345.794	284.234	777.331	1670.205	1022.527	420.970	196.574	153.658	6865.672
MEAN	12.000	18.388	36.384	28.198	16.466	13.535	37.016	79.534	48.692	20.046	9.361	7.317	326.937

TABLE III-6 SOAN RIVER RUNOFF AT SIMLY

*** SOAN RIVER AT SIMLY (STUDY) ***

UNIT = MCM/MON

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1961	9.261	4.535	1.433	10.413	1.191	1.076	17.944	26.317	29.601	4.175	1.886	0.914	108.746
1962	0.582	0.864	3.445	1.383	0.408	0.306	10.180	15.640	4.274	0.514	0.921	1.039	39.556
1963	0.348	2.025	4.086	1.004	0.654	0.221	13.407	17.967	12.407	0.465	0.439	0.327	53.350
1964	7.348	2.021	0.884	1.328	0.546	0.308	13.618	23.034	14.951	1.505	0.566	0.554	66.665
1965	0.975	6.882	4.517	17.028	7.149	1.851	13.836	7.882	1.424	0.595	0.369	0.230	62.737
1966	0.166	3.707	4.198	2.957	0.779	1.265	13.431	17.518	6.578	1.701	0.637	0.420	53.357
1967	0.188	3.794	18.401	8.106	1.567	0.381	6.429	22.548	12.061	1.571	0.511	5.255	80.813
1968	5.277	6.733	5.190	2.104	1.040	0.386	8.066	26.972	2.340	1.083	0.540	0.498	60.230
1969	0.345	2.650	1.937	1.064	1.028	0.360	4.666	8.493	2.390	3.025	0.609	0.282	26.850
1970	1.401	1.758	5.049	0.814	0.278	0.971	9.533	44.839	45.528	4.740	1.530	1.094	117.535
1971	0.742	2.831	1.028	5.485	1.596	31.040	16.327	46.903	8.592	1.513	1.166	0.643	117.865
1972	1.528	3.926	6.680	4.612	1.375	1.060	4.889	13.089	11.183	2.058	1.248	2.994	54.643
1973	2.620	3.236	21.491	2.064	1.149	2.846	13.802	29.505	7.542	2.016	1.040	0.830	88.142
1974	0.789	1.917	1.181	0.481	0.367	0.900	11.976	17.905	2.567	0.849	0.353	0.481	39.767
1975	0.381	1.900	1.568	1.806	1.075	0.742	16.727	60.245	25.199	2.267	1.052	0.620	113.581
1976	3.308	15.315	19.186	4.176	1.772	1.380	21.481	72.823	29.069	4.570	1.468	1.034	175.584
1977	1.984	1.085	0.683	4.738	1.619	3.354	68.644	49.336	10.713	8.797	5.262	1.883	158.099
1978	3.549	2.625	5.751	2.098	0.697	1.983	34.469	69.970	19.018	3.579	3.233	1.194	148.165
1979	10.556	23.731	14.157	4.672	1.678	1.260	10.087	15.688	3.823	1.062	0.861	0.737	88.312
TOTAL	51.348	91.536	120.865	76.332	25.971	51.692	309.510	586.672	249.262	46.084	23.690	21.032	1653.995
MEAN	2.703	4.818	6.361	4.017	1.367	2.721	16.290	30.877	13.119	2.425	1.247	1.107	87.052

TABLE III-7 KURANG RIVER RUNOFF AT RAWAL

*** KURANG RIVER AT RAWAL (STUDY) ***

UNIT = MCM/MON

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1960	4.385	3.885	6.142	5.673	3.701	2.334	11.924	13.978	9.968	4.318	2.489	1.624	70.423
1961	5.455	7.549	4.833	11.531	6.283	3.992	12.365	14.167	39.288	9.155	4.874	2.947	122.440
1962	1.942	2.093	8.500	5.411	2.352	1.944	7.050	12.590	9.587	4.273	2.068	1.729	59.539
1963	1.611	1.793	8.440	5.599	3.495	1.835	6.103	17.019	11.539	3.953	2.679	2.055	66.121
1964	11.039	7.222	5.598	3.946	2.043	1.266	6.301	16.999	10.721	4.351	2.272	1.939	73.697
1965	1.892	6.159	11.318	33.052	22.030	7.917	6.300	12.685	5.651	3.172	1.786	1.790	113.752
1966	1.560	3.104	6.292	7.775	7.413	2.903	8.702	13.721	10.847	6.577	2.980	2.109	73.984
1967	1.689	10.013	19.884	14.116	7.855	2.464	3.551	12.872	12.776	4.147	1.905	5.599	96.870
1968	7.393	10.155	10.721	6.005	3.137	1.672	4.906	24.545	4.775	3.637	2.058	1.997	81.000
1969	1.691	4.252	5.286	5.408	2.427	1.574	2.159	9.504	4.687	6.421	1.898	1.094	46.401
1970	1.766	1.607	12.378	3.859	1.261	1.165	3.784	18.973	33.660	8.907	2.717	1.486	91.563
1971	1.447	2.207	3.758	1.888	0.896	22.109	22.180	34.453	11.704	4.475	2.026	1.243	108.387
1972	1.971	3.536	10.327	6.203	6.836	2.769	3.020	6.696	7.449	3.135	1.987	3.556	57.486
1973	5.196	6.042	21.156	6.441	2.904	3.347	12.098	37.956	22.684	7.054	2.949	2.094	129.921
1974	2.279	5.238	3.102	1.781	1.093	1.563	5.625	7.340	3.722	2.041	1.182	0.903	35.868
1975	1.363	2.723	4.633	5.064	3.184	2.404	5.301	22.833	8.479	3.534	2.143	1.316	62.976
1976	2.921	11.231	18.554	12.091	5.381	3.255	12.742	68.939	27.081	9.323	4.009	2.381	177.909
1977	3.612	3.595	2.752	5.587	4.775	3.370	27.880	38.599	22.475	16.054	5.194	2.987	136.881
1978	4.411	3.671	10.762	5.406	2.436	2.529	44.489	54.084	18.324	7.994	4.478	2.370	160.954
1979	3.108	7.031	28.594	13.334	5.549	2.553	5.166	13.745	5.019	2.173	1.320	0.850	88.441
1980	4.503	6.045	12.945	7.218	2.692	7.379	8.080	20.414	8.599	4.300	2.550	1.366	86.092
TOTAL	71.234	109.151	215.977	167.386	97.745	80.344	219.726	472.111	289.034	118.995	55.565	43.434	1940.701
MEAN	3.392	5.198	10.285	7.971	4.655	3.826	10.463	22.481	13.764	5.666	2.646	2.068	92.414

TABLE III-8 UNIT IRRIGATION DIVERSION WATER REQUIREMENT

----IRRIGATION DIVERSION WATFR REQUIREMENT FOR KHANPUR JICA-CDA PROJECT----

CROPPING PATTERN K.MAIZE =0.300 K.TOBACO =0.080 K.FODDER =0.060 K.VEGETBL=0.110 R.WHEAT =0.440
R.FODDER =0.060 R.VEGETBL=0.110 SUGARCANE=0.035 ORCHARD =0.035

CROPPING INTENSITY = 130.0% IRRIGATION EFFICIENCY = 72.0%

(UNIT...MCM/1000HA)

YEAR	(JAN)	(FEB)	(MAR)	(APR)	(MAY)	(JUN)	(JUL)	(AUG)	(SEP)	(OCT)	(NOV)	(DEC)	ANNUAL
1960	0.202	0.665	0.532	0.690	0.669	0.623	0.216	0.217	0.669	0.834	0.634	0.428	6.378
1961	0.320	0.348	0.941	0.457	0.639	0.598	0.263	0.284	0.177	0.618	0.208	0.472	5.324
1962	0.311	0.550	0.528	0.873	0.588	0.559	0.276	0.135	0.643	0.881	0.445	0.217	6.005
1963	0.581	0.571	0.613	0.774	0.422	0.622	0.389	0.052	0.577	0.915	0.270	0.215	6.000
1964	0.101	0.566	0.941	0.744	0.581	0.596	0.189	0.440	0.956	0.938	0.634	0.448	7.132
1965	0.429	0.201	0.482	0.104	0.321	0.598	0.389	0.580	1.001	0.819	0.429	0.405	5.758
1966	0.666	0.312	0.408	0.645	0.542	0.492	0.276	0.310	0.622	0.590	0.523	0.419	5.805
1967	0.360	0.448	0.411	0.714	0.533	0.615	0.222	0.130	0.839	0.758	0.634	0.123	5.788
1968	0.358	0.273	0.524	0.725	0.532	0.620	0.274	0.093	0.997	0.687	0.238	0.171	5.494
1969	0.662	0.370	0.686	0.838	0.466	0.604	0.386	0.257	0.868	0.603	0.136	0.485	6.361
1970	0.498	0.358	0.338	0.913	0.446	0.584	0.283	0.194	0.315	0.661	0.584	0.426	5.800
1971	0.542	0.658	0.730	0.717	0.458	0.389	0.292	0.161	0.645	0.946	0.534	0.486	6.557
1972	0.311	0.233	0.429	0.520	0.603	0.547	0.651	0.823	0.509	0.481	0.327	0.120	5.554
1973	0.366	0.518	0.428	0.868	0.586	0.486	0.145	0.107	0.594	0.750	0.634	0.346	5.829
1974	0.622	0.729	0.849	0.865	0.629	0.472	0.198	0.330	0.910	0.822	0.634	0.264	7.326
1975	0.628	0.284	0.624	0.823	0.445	0.617	0.227	0.194	0.561	0.940	0.634	0.448	6.425
1976	0.252	0.069	0.293	0.550	0.677	0.590	0.246	0.055	0.685	0.529	0.621	0.486	5.053
1977	0.407	0.533	0.956	0.611	0.432	0.491	0.070	0.290	0.978	0.863	0.418	0.366	6.414
1978	0.636	0.594	0.441	0.893	0.657	0.589	0.172	0.026	0.479	0.507	0.024	0.438	5.456
1979	0.234	0.419	0.366	0.890	0.587	0.583	0.351	0.137	0.685	0.697	0.415	0.313	5.677
1980	0.132	0.340	0.339	0.805	0.616	0.523	0.142	0.178	0.610	0.675	0.574	0.368	5.303
MEAN	0.410	0.430	0.565	0.715	0.554	0.562	0.269	0.238	0.682	0.739	0.455	0.354	5.973

TABLE III-9 AVAILABILITY OF GROUNDWATER

Name of Well Field	Area (sq.km)	Present Production 1/ MGD (MLD)	Production Per Area (mm/yr)	Possible Future Production MDG (MLD)	Total MGD (MLD)
National Park Area	55	12.2 (55.5) 2/	370	5.0 (22.8)	17.2 (78.3)
Sectoral Area (Existing)	40	3.8 (17.3)	160	Not recommendable	3.8 (17.3)
Rawalpindi Area	55	13.7 (62.3) 3/	410	Not recommendable	13.7 (62.3)
West Sectoral Area	32	-	-	4.0 (18.2)	4.0 (18.2)
Southwest Sectoral Area	30	-	-	3.5 (15.9)	3.5 (15.9)
West Rawalpindi Area	70	-	-	8.5 (38.7)	8.5 (38.7)
Soan River Area	40	-	-	5.0 (22.8)	5.0 (22.8)
Total		29.7 (135.1)		26.0 (118.4)	55.7 (253.5)

Notes: 1/ Public water supply only.

2/ National Park Area and Golf Course Area of CDA, Sohan Village TW of PHED, and TW of PAF Combined.

3/ Excluding Sohan village TW and PAF TW.

TABLE III-10 EXISTING AND PROPOSED YIELD OF WATER

(Average per day)

Water Source	Present[2/]	2000 A.D	Remarks
Islamabad			
Shahdara H.W[4/]	1.4	1.4	
Nurpur H.W	0.5	0.5	
Saidpur H.W	0.6	0.6	
Golf Course (Old)	2.1	2.1	
- do - (New)	1.7	1.7	
G-10 H.W	1.9	3.8	by the end of 1986
Kurang H.W.	-	3.2	by the end of 1986
Tube Wells in National Park Area	6.4	10.4	
Tube Wells in Sectoral Area	3.0	9.0	
Sub-total	17.6	32.7	
Rawalpindi			
Sohan Camp T.W[5/]	2.8	2.8	
PHED T.W	3.6	3.6	
RMC T.W	4.8	4.8	
CB T.W	2.0	4.4	in a few years
MES (Army) T.W	0.6	0.6	
MES (PAF T.W	0.5	0.5	
Sub-total	14.3	16.7	
Total	31.9	49.4	

Notes:
1/ Unit in MGD.
2/ As of July, 1984.
3/ Production of water from storage dams are excluded.
4/ H.W.: Head works
5/ T.W.: Tube wells
6/ Firm yield from surface water is estimated based on the actual achievement of water production, taking the lowest value observed in the past 5 years.
7/ Firm yield from groundwater is taken as 80% of average production, taking into account the reduction of production in dry summer period.

CHAPTER IV. ALTERNATIVE PLAN

CHAPTER IV. ALTERNATIVE PLAN

4.1. General Description

In order to verify least cost water conveyance systems of Khanpur water, the comprehensive comparison study was conducted based on data/information collected, review of existing study reports, detail field survey, strategies of urban water supply development and design criteria and results of series of discussion meetings with Pakistan Governmental authorities concerned.

Design capacities of conduction main from the Khanpur reservoir are 150 MLD (33 MGD) for Islamabad and 316 MLD (69.37 MGD) for Rawalpindi as annual average of daily water supply.

Available topographic maps for the study are mainly of scale 1 to 50,000 in the entire Project area and of scale 1 to 21,120 in the majority of Project area except north-eastern part of Margala hills. In addition to the above, aerophotograph with a scale of 1 to 20,000 in the Project area is available.

Most suitable system proposal from Khanpur reservoir up to service reservoir through conduction main, water treatment plant and distribution pipelines was made through several procedures such as field reconnaissance, paper location layout, detailed field survey, preliminary design and economic evaluation.

The conduction main proposed for the urban water supply systems will be of a closed type such as pipe conduits, tunnels, syphons and so on, because it prevents the supply system from dust fall, proliferation of water weeds and injury by cattle, and is easy to operate and maintain. In selecting the routes of conduction mains every endeavour has been made to shorten the length of routes as much as possible, taking into consideration the interrelation of tunnel length and pumping lift since the head required for pumping decreases as the length of tunnels increases in addition to topography and geology.

Preliminary design of the facilities for each alternative was carried out taking into account not only technical and economic aspects but also staged development plan of the water supply scheme.

Economic justification of alternative plan was made on the basis of the EIRR (Economic Internal Rate of Return) which can be estimated based on the project cost, operation/maintenance cost including replacement cost of equipment, and benefits.

4.2. Review of Existing Study Reports

4.2.1. Previous Study Reports

Previous study reports on the Khanpur water conveyance project have been issued by various agencies and consultants for cases to convey water to Islamabad only, Rawalpindi only or Islamabad/Rawalpindi combined.

Outlines of major reports are summarized as below;

A. AEC (Allied Engineering Consultants) Lahore in April 1977

AEC, retained by PHED of Punjab, prepared a feasibility report for conveyance of water from Left Bank Canal tail of Khanpur Dam near Nicholson Monument to Rawalpindi. The report indicated a water demand of 69 MGD for Rawalpindi city and cantonment by the year 2000. It proposed the water treatment plant near the outlet of the canal and then pumping of water through Golra to Lunda village, the bifurcation point for Rawalpindi MC and Cantonment Area. The project was considered by PDWP in September 1978 but was deferred for the preparation of P.C-I for carrying out a comprehensive feasibility report.

B. Republic Engineering Consultants Lahore in July 1979

The study proposed storage of raw water, treatment plant near raw water storage tank and pumping of water to Shah Allah Ditta from where water will gravitate. In November 1979 REC submitted to CDA a feasibility report of an alternate route, shifting the intake point from Left Bank Canal tail to RD-38400 of canal, with a plan that water is conveyed to Shah Allah Ditta through a tunnel. However, no detail study was carried out in this respect.

C. NESPAK (National Engineering Service Pakistan) in June 1980

NESPAK submitted to CDA a preliminary design and feasibility report on supply of the Khanpur water to Islamabad. NESPAK examined various alternatives to divert the Khanpur water directly from the reservoir or through the already completed LBC and proposed a plan with a least cost solution. Focus of the study was selection of the least cost conveyance canal route for mainly Islamabad area. Five possible alternative plans were studied, of which three have a tunnel plan and remainder are without tunnel works. Final plan proposed was a route from Khanpur reservoir to Shah Allah Ditta through Tarmakki tunnel.

D. AESL (Associated Engineering Services Ltd.) Canadian Consultants appointed by ADB in August 1980

The AESL examined the problem of water supply and sewerage for Rawalpindi and Islamabad collectively, placing their focus mainly upon groundwater development. The AESL also carried out comprehensive studies of water supply needs for Rawalpindi and Islamabad combined, in which various alternatives on water supply from Khanpur were proposed on the preliminary planning basis with selection of the best solution for a combined supply to twin cities. Final proposal in the study is utilizing LBC to convey water to Maragal treatment plant, from which water is lifted to Shah Allah Ditta reservoir for the higher zone of Islamabad and to Tirnaul and Tomar reservoir for Rawalpindi and lower Islamabad zone.

4.2.2. Problem Area and Necessity of the Comprehensive Study

Previous study reports mentioned above are very useful for the purpose of project justification and implementation. The scope of work, strategies of development plan and basic concept of the project, however, are quite different individually as discussed in detail in Chapter I of Appendix-B.

Major constraints of the NESPAK report are summarized as below.

- The design capacity for Islamabad and Rawalpindi is about 60 MGD and 125 MGD respectively which were calculated from the peak summer day demand. These values are about 1.5 times of average summer day demand, and are rather over estimates as compared to optimum values.

- The beneficiary area of Islamabad by the Khanpur water is spread mainly over the sectors 10 to 12 series, whereas for Rawalpindi service areas are not specified due to the conception of the Project as a supplemental water supply scheme.

- The several data and pieces of information are very useful for further study and project implementation. Design concepts, however, would require some modification or changes to meet the project requirements.

On the other hand, the AESL report has been compiled on the basis of comprehensive study for water supply and sewerage plans in Islamabad and Rawalpindi. Major difficulties of the project are described as under.

- Available water of Khanpur reservoir is assessed to be about 116 MGD as an average instead of 186 MGD suggested by WAPDA. Apportionment of Khanpur available water are revised at 40.5 MGD for both Islamabad and Rawalpindi from original proposal of about 33 MGD for Islamabad and 69.37 MGD for Rawalpindi.

- Some discrepancies have been notified between the report and this study on purpose in Rawalpindi.

Overall study on the Khanpur water supply project, therefore, is required from the viewpoints mentioned above.

4.3. Staged Water Supply Scheme

4.3.1. General

The required urban water for the twin cities of Islamabad and Rawalpindi is presently received from the Simly and Rawal reservoirs, stream flows and groundwater sources such as springs and tubewells. Khanpur reservoir has a proposed water supply capacity of 308 million cubic meter per year for multi-purpose demands and would contribute to meeting future water demands required in the twin cities in the target year 2000.

The water demands to be provided to twin cities for respective target years have been discussed previously in Chapter III of this report. These demands were estimated based on the projected population and unit water demand in various sectors.

The staged supply schemes of Khanpur water are established taking into consideration the balance of water demands and production capacity and water resources availability analyzed through simulation of respective reservoir operation.

4.3.2. Development Plan of Khanpur Water

The relation curve between average/maximum daily demands and production capacity of twin cities in respective target years are shown in Figures III-4 and III-5. The following three staged development plans of the Project up to the target year 2000 were made through assessment of previous plan.

A. Islamabad

Phase	Year	Production Capacity of Treated Water				
		Average		Maximum		Percent
		MLD	(MGD)	MLD	(MGD)	
1st	1986-1990	67.8	(14.9)	84.2	(18.5)	50
2nd	1991-1995	33.6	(7.4)	42.3	(9.3)	25
3rd	1996-2000	33.6	(7.4)	42.3	(9.3)	25
	Total	135.0	(29.7)	168.8	(37.1)	100

Note: 1. Average production capacity is given by multiplying average daily raw water supply by efficiencies of conveyance and water treatment.

33 MGD x (1 - 0.10) = 29.7 MGD

2. Maximum production capacity is given by multiplying average production capacity by ratio of maximum seasonal fluctuation.

29.7 MGD x 1.25 = 37.1 MGD

B. Rawalpindi

Phase	Year	Production Capacity of Treated Water				
		Average		Maximum		Percent
		MLD	(MGD)	MLD	(MGD)	
1st	1986-1990	142.0	(31.2)	177.5	(39.0)	50
2nd	1991-1995	71.0	(15.6)	88.7	(19.5)	25
3rd	1996-2000	71.0	(15.6)	88.7	(19.5)	25
	Total	284.0	(62.4)	354.9	(78.0)	100

Note: Definition of production values is the same as for Islamabad.

According to the results of Khanpur reservoir operation, available water resources of the reservoir is about 75 percent of proposed water demand, that is, 33 MGD for Islamabad and 69.37 MGD for Rawalpindi respectively.

Therefore, supplemental water supply for 25 percent of proposed water demand as a deficit would be procured from other water resources.

The conclusion mentioned above has been confirmed with mutual understanding between CDA and the Study Team.

4.4. Design Criteria

4.4.1. Hydraulic Design

The Manning's formula is applied for open channel and tunnel where the Reynolds number and roughness coefficient are considered to be relatively large, while the Hazen-Williams formula is selected for pipeline where flows of transitional region between smooth and rough are expected.

In consideration of safe and easy operation and maintenance of conduction main and appurtenant structures and equipment, allowable velocity and or standard design velocity are determined as discussed in Chapter III of Appendix-B.

4.4.2. Conduction Main

A. Water Head Allocation

As a basic conception of water head allocation, it is required for a water conduction system that an overall construction cost is to be minimized, by means of allocating more head (available water head) to such structures that need high construction costs (steep) and allotting less head to the structures that require low costs (gentle). The Khanpur water conduction main systems involve tunnel, pipeline and syphon as the major structures. Among these structures, difference of per unit length construction cost is relatively small and lifting of water by pumps inevitably be necessary for each alternative plan. Considering that the total length of conduction main by alternative plan varies with a range from 6.5 km to 12.5 km with required lifting head from 70 m to 105 m, it is clear that the merit of decreasing the construction cost in terms of allocating additional several meters of available head to the conduction main is much bigger than the demerit of increasing the construction cost of pumping stations with additional lifting head of several meters.

B. Tunnel

The cross-section of the tunnel is determined as standard horse shoe type due to its superior workability, although from structural point of view strength is to some extent inferior as compared with circular type. For mechanical construction, the minimum cross-section, in terms of a diameter, is 2.0 m. For the Project in consideration of velocity of flow, a diameter of 2.10 is given for ordinary type of tunnel. For a long tunnel with a length exceeding 3 km, it is often necessary to construct lining concrete immediately after excavation, because steel supports are deformed due to increase of earth pressure especially when excavation works come across fractured fault zone. Even in this case the minimum cross-section is requested to be kept after lining. A diameter of 2.40 m is, therefore, adopted for a long tunnel.

C. Tunnel Geology

Geological investigation around proposed tunnel routes was made employing such procedures as the review of existing reports and geological maps compiled by Geological Survey of Pakistan, analyses based on aerophotographs and so on. Surface geological reconnaissance survey was made mainly along Libana - Khurram Gujar route, Shah Allah Ditta - Sabra - Tarmakki - Choi route and around Portal and Shaft sites.

Geology of Margala hill consists mainly of limestone subordinated by marl and shale with a trace of sandstone. These strata are folded and faulted, and divided into zones by three major thrusts which extend from east to west or northeast to southwest. In such zones in general, the older layer is found to the south while relatively new layer exists to the north of the area, and as a whole the layers are folded southerly overturned.

Three major thrusts run along the southern foot of Margala hills, Khurram Gujar - Bol - Sabra Valley, Nilan Kas Valley near Gramthum (Tarmakki). These thrusts are named tentatively in this report Margala, Sabra and Gramthum faults. Between Gramthum and Sabra faults, there may exist one more small scaled thrust. Margala fault may not be simple and single fault, but may be estimated to be a group of faults aligned in echelon. Depth of fault has not been investigated clearly. However, it is estimated on a basis of outcrops to be more or less 20 to 30 meters.

As concerns geological distribution, Margala hill limestone, Chor Gali formation and Kuldana formation belonging to Eocene age are distributed in the area between Khanpur dam and Gramthum fault, composed mainly of limestone with an unnegligible amount of argillaceous rocks. Between Gramthum and Sabra faults, Samana Suk, Chichali, Lumshiwal formations and Lockhart limestone of Jurassic to Palaeocene age are dominant and their main constituent is limestone. In the area between Sabra and Margala faults, all strata formed in Jurassic to Eocene age are distributed and the greater part is occupied by strata belonging to Palaeocene to Eocene age. They are mainly composed of limestone and marl, and shale is also distributed around a valley along Sabra fault, where Kuldon and Chor Gali formations are found, and on the flat middle ridge where Patala formation dominates. In the southern flank of Margala hills and between Gramthum and Sabra faults, sandstone layers of several ten meters wide, belonging to Chichali formation, are found. To the south of Margala hills, Murree formation consisting of alternating beds of sandstone and mudstone is predominant.

Limestone in this area is generally hard and gray in colour, and contains abundant fossiles of foraminifers and, sometimes, of vivalves. Based on the condition of crack, limestone is classified into three types; namely massive limestone, cracked limestone and nodular limestone. Massive limestone has sparse cracks and used to form a cliff. Nodular limestone is composed of alternating beds of limestone and subordinate shale, and because limestone is more competent than shale when folded, limestone layers are deformed and subdivided into small nodules with diameters of five to 20 cm.

Marl, gray in colour, likely belongs to soft rock, containing abundant foraminifer fissiles. This is classified into two types, namely massive type and fissile type. Shale is brown to greenish brown in colour, fissile and easily eroded. Sandstone contained in Murree formation is gray to reddish brown in colour and classified into two types, very hard type and relatively soft type. Mudstone is generally reddish brown in colour and soft. Dips of strata vary from 20 to 90 degrees, and in general, they are steeper in the north side of the fault and gentle in the south side.

D. Groundwater Condition around Tunnel Routes

Along the valleys in the area of Margala hills, with exception of a few rivers, there exists no stream which keeps flow during the period of no rain. Groundwater flows are appeared as spring waters at the limited points spread along valleys and on the foot of Margala hills. This means that rain water is concentrated deep inside the hill body, and would suggest that some water ways exist to convey groundwater to the above springs. The most important springs are found at Khurram Gujar and Shah Allah Ditta, and the former is proud of the spring water discharge of several thousand cubic meters per day, especially during rainy season. Accordingly, there are some possibilities of happenings that the tunnel comes across massive volume of groundwater during the course of excavation work and/or spring water discharge is influenced by tunnel excavation.

E. Engineering Consideration

a. Rock Type

From viewpoint of tunnel engineering, rocks are classified into four types;

Type I	:	Massive limestone; almost no support needed.
Type II	:	Cracked limestone, alternation of limestone and marl/shale, massive marl, sandstone (cretaceous); supports partly needed.
Type III	:	Shale, alternation of shale and marl, fissile marl, alternation of sandstone and mudstone (Murree formation); supports needed.
Type IV	:	Overburden (clay and gravel); supports heavily needed.

b. Special Problems

As mentioned previously, there exist three major faults along the routes of tunnel. Though dimensions and conditions of these faults are not clear, much care should be taken in excavating the faults because they are rather big scale from every aspect of structural geology and much earth pressure may occur. It is also probable that the tunnel may come across a big scale ground aquifer and, to cope with such situation, a countermeasure should be worked out in advance. Problem would be less against such an accident in the case when the tunnel is excavated through the type I or II rocks and, on the other hand in cases of type III or IV rocks, care must be given to tunnel walls against a breakdown. Especially when excavation work is progressed through fault clay or shale of impermissible layer, much attention should be paid.

4.4.3. Raw Water Reservoir

A. Necessity of Raw Water Reservoir

The Left Bank Canal has been constructed for most of its length along the foot hills of Margala range. There are a number of cross drainage structures and small tunnels including Haro river syphon along the canal alignment. Although the canal itself is lined for its entire length, but closure of the canal for the periodic maintenance and possible repair of various structures must be envisaged. In addition to this possibility of blockage due to rock slides caused by adjacent hill torrents cannot be ignored in an open canal. Therefore, adequate provision for the raw water reservoir during canal closure shall be required.

B. Design Capacity

Under the major premise of additional constructions of culvert at the portions of deep-cut, slope protection works, spillway or wasteway and other overall improvement works for the existing Left Bank Canal, design capacity of raw water reservoir was determined as 2 days capacity, which is reserved for general works of operation and maintenance, rehabilitation works and disaster rehabilitation works.

C. Structural Design

Geological foundation at and around the proposed sites of raw water reservoir is found to be alternation of silty clay layer and sand gravel layer, of which silty clay layer is usable as impervious materials for embankment. However this material is easily erosive and thus protection works on the surface of embankment was designed to be accompanied. In addition, to prevent water leakages through sand gravel layers, earth blanket was designed on the bottom surface of reservoirs.

4.4.4. Pumping Station

A. Type of Pump

In view of required discharge and head for the Project, double suction volute pump was selected to be used because most of proposed pumping plants require more than 30 m pumping heads.

B. Control Method

Considering operational/maintenance and economic advantages, flow control is primarily based on the simplest method of control by charge of operating pump number and on-off control in terms of water level control in the discharge pool. Accordingly HWL and LWL are to be established in both suction and discharge pools, providing proper capacities which are determined as 30 minutes capacity of the maximum design discharge.

C. Number of Pump Unit

In general, the number of pump unit is determined in consideration of following concepts.

- For easy operation and maintenance, the number of pump units should be as small as possible and ones of equal capacity should be adopted.

- The larger is the delivery, the higher the pump efficiency, so the ones with the largest delivery should be used.

- At least one spare unit must be provided. If the total number of pump units is small, spare unit will be costly.

- The number of units should be determined so as to operate effectively corresponding to seasonal charge of water-load, ranging from 1.25 to 0.8 of average.

- Number of units should be decided conforming to the phased plan of facility installation. Rate of required capacity is approximately 2:1:1 corresponding to phase I, II, and III respectively.

Installation of five pumps will finally be most suitable from the operational point of view. Although a plan with four units of pump is most acceptable when phased schedule of facility installation is taken into consideration, but this plan is inferior when necessary cost allocation for spare unit is accounted. Consequently, including one spare unit of pump, number of pumps is determined at six. As concerns booster pumps required for distribution systems, since the design capacity is small, numbers are determined at two units for ordinary uses plus one unit for spare.

4.4.5. Water Treatment Plant

A. Raw Water Quality

The result of water quality analysis for which the water samples were taken three times during field survey period at four points shows the following characteristics:

- Values of turbidity and color were low at every four sampling points.

- Iron and manganese were not found at every sampling point.

- Every sampled water shows high values of pH and alkalinity which is considered to be caused by soil conditions of limestone strata of mountain behind the dam.

- A few numbers of bacteria and coliform groups were found in every sampled water. Pollution of water is considered as low, which is supported by the low contents of chloride and nitrogen.

B. Water Treatment Process

On the basis of the water quality analysis, the treatment process is examined. However, considering insufficient period and number of sampling and the facts that the Khanpur dam was constructed recently, and water quality might be changed in the future, the water quality observed at the Simly and Rawal Lake filtration plants are taken into account for the determination of the treatment process in this study.

Considering that the turbidity shall increase during wet season as shown in the water quality of the existing treatment plant, the rapid filtration method is employed as the general concept. The chemicals applied at the plant are planned to be Alum for coagulation and chlorine for disinfection as used in the existing plant. Pre-chlorination will be applied considering that algae growth might occur in future due to big volume of the reservoir resulting in long retention time and higher temperature in dry season.

The following treatment process is proposed considering the characteristics of raw water and practice of the existing treatment plant:

<u>Pre-chołorination</u>: Pre-chlorination is employed for the purpose of destruction of algal and oxidation of dissolved organic matters.

Color of raw water is considered to be increased according to algae growth. Dosage of chlorine is made at receiving well.

Coagulation : Alum is used for coagulation and dosed at mixing well.

Flocculation : Suspended solid is flocculated by slow mixing.

Sedimentation : Most suspended solid is removed in the sedimentation basin with the optimum retention time.

Filtration : Remained suspended solid in the clarified water is removed by the allowable range of less than 5 ppm.

Post-chlorination: Filtered water is disinfected by chlorine dosage.

C. Design Capacity

Design capacity of the plant is planned at 121.6 MGD (553,000 m^3/d). Five percent of water loss will be allowed for the treatment including washing water of filter bed, desludging in sedimentation basin, chemical solution and other usages within the plant.

4.4.6. Service Reservoir

A. Site Selection

In principle in order to expect uniform rate of water head in the service area, the service reservoir is desirable to be situated near the center of the service area. However for the Project, since the service areas are located on the sloping surface extending from north to south, the proposed site of service reservoir is selected as near from the service area as possible in consideration of the following conditions;

- Conduction pipeline up to the service reservoir is designed with design capacity equivalent to the maximum daily distribution requirement.

- Downwards, distribution facilities are designed with the maximum hourly requirement, which is equivalent to 1.5 times of daily maximum.

B. Capacity

The effective capacity of the reservoir must be enough to maintain balance between demand and supply. The capacity can be obtained by totalling such hourly maximum amount plus hourly margins. It shall be about six hours amount of planned maximum daily water supply, making provision for regulation of purified water and supplied water for fire fighting, power stoppage and unforeseen accident. Detailed discussion on this is made in Chapter III of Appendix B.

C. Effective Depth

Effective depth of service reservoir is defined as a distance between HWL and LWL. Since the service reservoirs are of gravity style and it is difficult for dynamic water pressures in pipes distributed in the service area to be kept within a certain acceptable range, in general, effective depth is desirable to be three to six meters. Every service reservoir for the Project is of a large scale and therefore the effective depth is taken at six meters in consideration of structure and its floor area.

D. Water Level

Basic concepts for determination of optimum water level for each service reservoirs are summarized as follows:

- Estimation of projected population and unit water demand in target year of 2000 is worked out based on available census and data collected. Distribution of population and total water demand within each sector and major water supply networks is made following urban development plans and future water requirements tendency.

- Major water supply pipelines are aligned based on the topographic conditions of each distribution block, water demand and distance from supply pipeline up to the distribution points.

- Treated water supply from the service reservoir to consumers shall be of gravity flow as much as possible.

E. Structure

In view of shape and structure, service reservoirs are classified into the following three types;

A. Flat slab type of reinforced concrete
B. Overhead type of reinforced concrete
C. Ground type of prestressed concrete

The flat slab type is in common use for this purpose and the most economical in cost in case that suitable construction site is found. Overhead type is also commonly used in Pakistan. The allowable maximum capacity of this type is, however, restricted from technical point of view within the limit of about 5,000 cu.m. Ground type PC tank is very popular in the world but construction cost is slightly higher than that of flat slab type.

Consequently, the flat slab type is adopted under the study in principle except for the case that topographic and water level condition is not suitable for this type. Ground type PC tank is applied for the specified construction sites.

4.4.7. Distribution Main

A. Pipelines up to Service Reservoir

Water is supplied to pipelines by gravity and by pumping, categorizing them as gravity mains and force mains respectively. The force main is a pipeline to be laid between a suction pool of a pumping station and a delivery pool or a service reservoir, while the gravity main is a pipeline to connect a service reservoir with a clear water reservoir at a water treatment plant, or a delivery pool at a pumping station. According to water levels in a service reservoir or a discharge pool, pumps are controlled by means of operating pump number and on-off control. Considering the emergent case of sudden stop of operation due to power stoppage, dynamic water pressure should be taken into account for design of pipeline material.

Gravity pipeline system may permit easy operation and prevention of oversupply of water by closing a valve when the water level in the service reservoir reaches a designed full water level.

Pipeline is subject to transient pressures when valves are alternately open or closed or when pumps are alternately started or stopped. Such transient phenomena must be considered in designing the inner pressure of pipes.

B. Pipeline from Service Reservoir

In principle pipeline which connects the service reservoir with a unit of distribution network is of gravity flow type. Water level in the service reservoir depends upon status of water consumption in the distribution unit. Diameter of pipe is determined on a basis of the maximum hourly water consumption.

Effective water head at the site of water treatment varies depending on respective alternatives. Accordingly, distribution system up to the ending point of service area is needed to be differentiated, including routing of distribution main and necessity of installation of booster pumping station. Aiming at economic comparison study, it is therefore needed that the cost evaluation of construction as well as operation and maintenance for distribution facilities between the service reservoir and the ending distribution network be involved in principle in the study, even though it is excluded in the "Scope of Work". However the same system of the smallest unit of distribution networks can be applicable for every alternative plan for the purpose of comparative study, and so it is excluded from the comparative study.

C. Pipe Material

Diameter of pipe for the on-going Project varies from 300 mm to 1,650 mm. Design internal water pressure, inclusive of water hammer pressure, varies with a wide range between about 3 kg/sq.cm and 18 kg/sq.cm. In consideration of diameter as well as water pressure, pipe materials applicable to the Project are as under:

- Prestressed Concrete Pipe (PRCC)
- Prestressed with Steel Sylinder (PRCC)
- Asbestos Cement Pipe (ACP)
- Steel Pipe (SP)
- Ductile Iron Pipe (DIP)

In consideration of economy, strength, durability and workability, pipe materials are selected for the Project as under:

Diameter and Design Pressure		Pipe Materials
For Pressure Pipe		
Diameter	1,350 mm	Steel Pipe
	1,350 mm	Ductile Iron Pipe
For Gravity Flow Pipe		
Design Pressure	12 kg/sq.cm	PRCC (with steel sylinder)
	12 kg/sq.cm	Ductile Iron Pipe

D. Alignment

Pipeline is aligned on the route which is most economic, safe and easy in operation and maintenance. Based on the above conception, pipelines downstream of treatment plant have been aligned on the routes along main roads, which have been planned in the city development plan.

E. Design Pressure

Water hammer pressures vary depending on pipe length, velocity of water, hydrostatic pressure, pipe material and others. However the following empirical values have been adopted in the study.

(i) Pressure Pipe

Water hammer pressure is taken as 100% of dynamic water pressure when it is less than 4.5 kg/sq.cm, and when dynamic pressure exceeds 4.5 kg/sq.cm the bigger value of either 60% of dynamic pressure or 4.5 kg/sq.cm is taken.

(ii) Gravity Flow Pipe

Water hammer pressure is taken as 100% of hydrostatic pressure when it is below 3.5 kg/sq.cm, and as the bigger value of either 40% or 3.5 kg/sq.cm when hydrostatic pressure exceeds 3.5 kg/sq.cm.

F. Distribution Unit

a. Structure and Elevation of Smallest Distribution Unit

The smallest distribution units are partitioned according to divisions on which estimates of population as well as water demands have been based. With exception of some local part of high elevation for which water is boosted by additional booster pumps, ground elevation at each partition is set at such elevation that about 80% of service area is situated below that elevation.

b. Required Effective Head

After considering size of distribution unit and pressure required at each house, the following water head has been given in the study at the inter-connection point of each distribution unit.

Islamabad	:	120 ft
Rawalpindi	:	100 ft

c. Zoning of Service Area

Ground elevations in the service area vary with a relatively wide range of 400 ft from 1,600 ft to 2,000 ft above mean sea level. In this case it is advantageous to divide the distribution area into two zones, namely high zone and low zone, in order that running cost could be reduced in case of boosting up, pipeline structure would be more economic and safe due to deduction of water pressure, and that leakage losses of water would be less and operation & maintenance works would become easy as the fluctuation of distribution pressure decreases.

Topography of Rawalpindi is generally flat, excepting for some elevated area. Zoning was made depending on the available water head at service reservoirs concerned that is determined by topographic conditions.

4.5. Alternative Plan

4.5.1. General Description

The alternative study of Khanpur water supply systems was carried out in review of previous study reports, data and information collected and design criteria as mentioned in the previous section of the report in order to verify the least cost for the water conveyance systems including water treatment plant and appurtenant structures related, as well as operation and maintenance cost.

Design capacities are 150 MLD (33 MGD) for Islamabad and 316 MLD (69.37 MGD) for Rawalpindi as an annual average of daily water demands. Available topographic maps are of scale of 1:50,000 and 1:21,120 for entire and/or part of the Project area as well as aerophotograph with a scale of 1:20,000.

The conduction mains proposed for the urban water supply systems would be of a closed type such as pipe conduits, tunnels, syphons and so on, because it prevents the supply system from dust fall, proliferations of water weeds and injury by cattle, and is easy to operate and maintain. Most of conduction mains will be of low pressure pipes for its low cost. Tunnels will be constructed to penetrate Margala hills to shorten the route and to conserve the head. Syphons will be proposed to cross river channels.

In selecting the routes of conduction mains every endeavour has been made to shorten the length of route as much as possible, taking into consideration the interrelation of tunnel length and pumping lift as well as topography and geology.

In designing hydraulic gradient of the conduction mains being composed of three elements of low pressure pipes, tunnels and syphons, careful examination was made in order to minimize the cost of the conduction mains by optimizing the distribution of the available head among component portions.

4.5.2. Alternative Plan

A. General

Based on the design criteria and general description mentioned in Chapter III and IV of Appendix B, three alternative plans on the water conduction main and appurtenant facilities have been basically proposed as follows:

Alternative I

i. The major purpose of this plan is to make the fullest use of the existing Left Bank Canal; multipurpose water conveyance canals for irrigation, industry and urban water, the downstream portion of which was constructed for exclusive use for urban water.

ii. The project could be completed in a short period so as to meet the urgent water needs in Rawalpindi.

iii. The proposed water conduction system starts from the end of the existing canals near Nicholson Monument, lifts water at Sang Jani, and terminates at the beneficiary areas.

Alternative II

i. The major purpose of this plan is to make the better use of the existing multipurpose canals.

ii. As a result of the study, the route that takes water just downstream of Khanpur reservoir has been selected, which has a shorter length among several possible plans in the Alternative II.

iii. The conduction main conveys water by means of tunnel and pipeline, after lifting it at the left bank of Haro river, to the beneficiary areas via Shah Allah Ditta.

Alternative III

i. The major purpose of this plan is to connect the beneficiary areas with Khanpur Reservoir by the shortest route of tunnel and pipeline.

ii. Potential water head can be conserved and as a result water can be conveyed by gravity to the beneficiary areas to a maximum extent.

iii. The conduction main directly diverts water at Khanpur reservoir to convey it to the beneficiary areas via Golra.

Each of the alternatives mentioned above was sub-divided into two to four, and eight alternatives in total were finally warranted for further studies as discussed in the succeeding sections.

B. Alternative I

Water supply system arrangement of the Alternative I starts from the end point of existing Left Bank Canal near Nicholson Monument, reaching the twin cities of Islamabad and Rawalpindi through water treatment plant and pumping station.

Special consideration shall be made on the improvement of existing Left Bank Canal for the proposed alternative I.

The Left Bank Canal was constructed under the Khanpur Project for multiple use of urban water supply, industrial water supply and irrigation. Hugging the foot of Maragal hills, the Left Bank Canal is subjected to inflow of rainstorms and soils resulting from rainstorms.

When the existing Left Bank Canal is used for urban water supply, every effort must be made to reduce outbreaks of accident in conveyance systems, for which there are two possible countermeasures. One is to prevent the systems from accidents through the rehabilitation and improvement of the system, together with careful operation and maintenance of the systems. Another countermeasure is to provide at the end of the Left Bank Canal a raw water reservoir with a storage capacity enough to meet requirements for several days.

In this Project, the following works for the rehabilitation and improvement of the Left Bank Canal are proposed;

(1) Canals that were constructed in deep cut of more than 10 m height near a tunnel, will be remodeled into a culvert or be covered with reinforced cement concrete plates.

(2) Side slope in cut of more than 4 m height will be protected with stone masonry or cement concrete blocks for the height equivalent to 1/3 to 2/3 of the cut height.

(3) Mortar spraying will be made to such side slopes of rock as are exposed to weathering.

(4) Shoulder ditches will be provided for the reaches where rain water flows in, and lined with cement concrete blocks in case of sharp slopes.

(5) Berm ditches in long reaches in cut will be lined with cement concrete.

(6) Sand traps will be constructed at the berm inlets of the existing lined canals and the canals proposed to be improved under item (5).

(7) Vegetation will be made to side slopes of soils.

In addition to the rehabilitation and improvement of the Left Bank Canal, construction of a raw water reservoir is proposed, in order to make provision for unforeseen trouble in the canal systems, because complete prevention of accidents is impossible, even though the improvement works are undertaken.

Three sub-alternatives for this category were set up based on the topographic conditions and location of beneficiaries area concerned. Brief descriptions for this are as belows:

<u>Alternative I-A</u>	:	(Sang Jani-Shah Allah Ditta-Islamabad and Rawalpindi)
Distribution point	:	Near Shall Allah Ditta
Facility	:	Raw water reservoir, water treatment plant, pumping station, pipeline, discharge pool and service reservoir
<u>Alternative I-B</u>	:	(Sang Jani-Tirnaul-Islamabad and Rawalpindi)
Distribution Point	:	Near Tirnaul
Facility	:	Same as Alt. I-A.
<u>Alternative I-C</u>	:	(Sang Jani-Shah Allah Ditta and/or Tomar-Islamabad and Rawalpindi)
Distribution point	:	Sang Jani
Facility	:	Same as Alternative I-A.

C. Alternative II

Water supply systems arrangement of the Alternative II is basically from the intake points of Existing Left Bank Canal and/or Khanpur Reservoir to twin cities of Islamabad and Rawalpindi through Shah Allah Ditta water treatment plant.

Four sub-alternatives for this category are set up as follows:

<u>Alternative II-A</u>	:	(LBC - Khuram Paracha-Shah Allah Ditta)
Intake Point	:	LBC at RD 40,800
Raw water reservoir	:	Approx. 1.1 MCM
Facilities	:	Feeder conduit, pumping station, pipeline, tunnel, water treatment plant and service reservoir

<u>Alternative II-B</u>	:	(LBC - Julian-Shah Allah Ditta)
Intake Point	:	LBC at RD 13,500
Raw water reservoir	:	Approx. 0.55 MCM
Facilities	:	Feeder canal, pumping station, pipeline, tunnel, conduit, water treatment plant and service reservoir

<u>Alternative II-C</u>	:	(Head regulator R & LBC or LBC - Tarmakki-Shah Allah Ditta)
Intake Point	:	Head regulator at Main Canal or LBC at RD 9,100
Facilities	:	Feeder conduit, tunnel, syphon, pumping station, pipeline, diversion dam, water treatment plant and service reservoir

<u>Alternative II-D</u>	:	(Khanpur dam-Tarmakki-Shah Allah Ditta)
Intake Point	:	Khanpur reservoir
Facilities	:	Intake pit and pumping station, pipeline, tunnel, diversion dam, water treatment plant and service reservoir

Special consideration shall be made on the construction of Tarmakki intake works for this alternative. In Alternatives II-C and II-D, the proposed route of conduction mains closely approaches to Nilan Kas which is one of the tributaries to drain into Khanpur reservoir. The proposed water level of the conduction mains at this point is EL. 642.0 m (2,105 ft), while the elevation of river bed of Nilan Kas is EL. 640.5 m (2,100 ft). Alternatives II-C and II-D convey water to Shah Allah Ditta through Tarmakki, after lifting water at Khanpur reservoir. Tarmakki intake works that divert the river flow of Nilan Kas, being located at elevated point higher than Khanpur reservoir, will save about 2.3 million Rupees per year of electric costs required to operate proposed pumping plants at Khanpur.

D. Alternative III

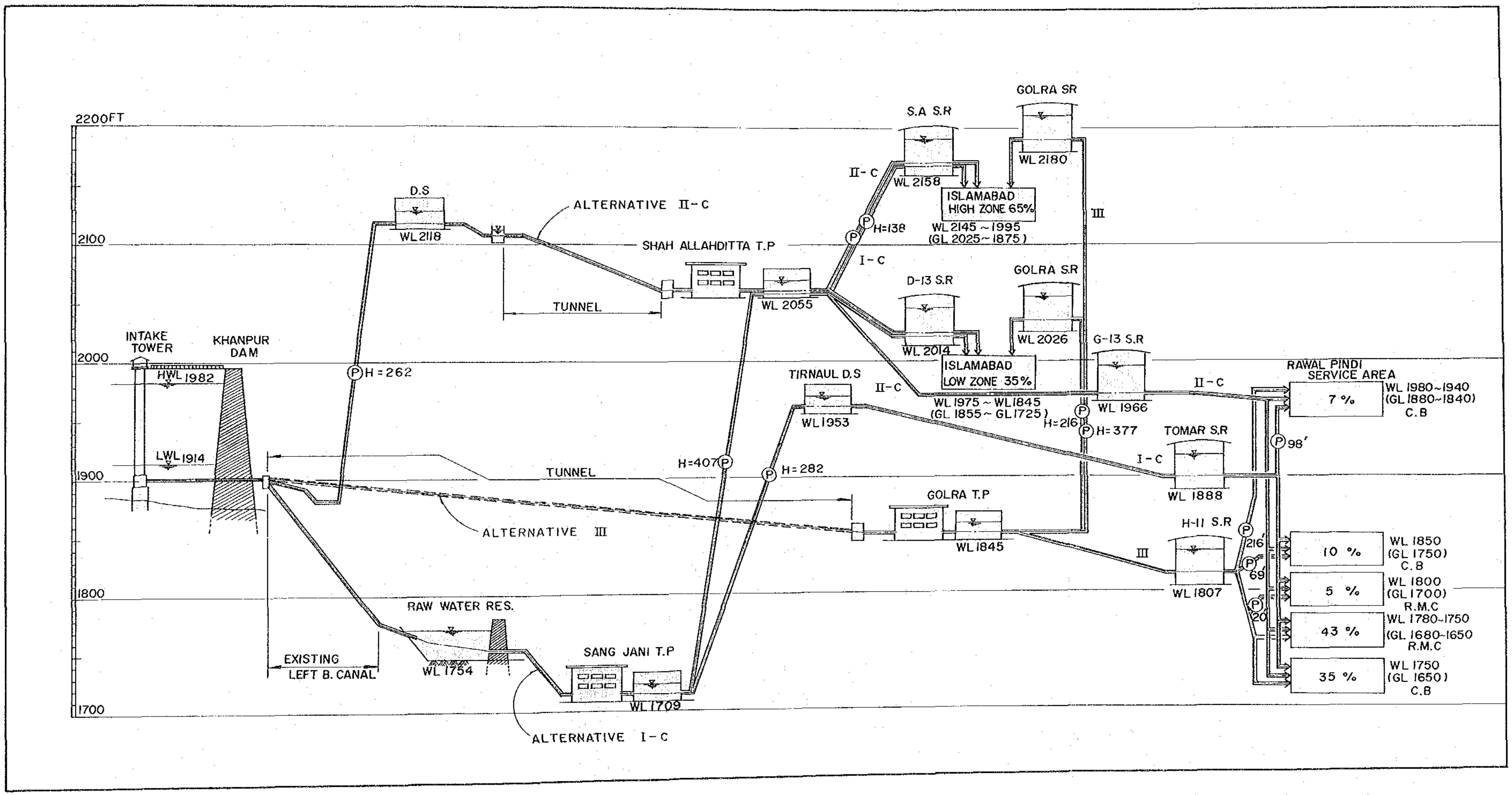
Water supply systems arrangement of the alternative III is foundmentary from the intake point of the existing diversion work and or Khanpur reservoir to beneficiary area through long tunnel under Margala hill and Golra water treatment plant.

Two sub-alternatives for this category are considered as below:

<u>Alternative III-A</u>	:	(Existing diversion work-Tarmakki and Golra Shaft-Golra)
Intake point	:	Existing diversion work
Facility	:	Conduit, syphon, pipeline, tunnel and vertical shaft, pumping station, water treatment plant and service reservoir
<u>Alternative III-B</u>	:	(Intake tower on Khanpur Reservoir - Tarmakki and Golra Shaft-Golra)
Intake point	:	Khanpur reservoir
Facility	:	Intake tower, pipeline, tunnel and vertical shaft, pumping station, water treatment plant and service reservoir

Alternative III-B has been selected as the optimum plan of Alternative III taking into account the length of conduction main and its cost, water level of receiving well at Golra water treatment plant as is discussed in detail in Chapter IV of Appendix B.

FIGURE IV-1 SCHEMATIC MAP OF KHANPUR WATER CONDUCTION SYSTEM



4.5.3. Preliminary Design of Alternatives

A. Raw Water Reservoir

Proposed raw water reservoirs are located at Sang Jani for Alternatives I-A, I-B and I-C, Khuram Paracha for Alternative II-A and Jullian for Alternative II-B. The effective regulating capacities are as below;

Name of Reservoirs	Capacity
Sang Jani	1.1 MCM
Khuram Paracha	1.1 MCM
Jullian	0.55 MCM

B. Tunnel

Number of route and total length of proposed tunnel for Alternatives II and III except Alternative I are summarized as follows;

Alternative	No. of Route	Total Length (m)
II-A	1.0	2,600
II-B	2.0	6,200
II-C	3.0	5,510
II-D	1.0	5,000
III	2.0	11,700

Alternatives II-B, II-C and II-D require an inclined shaft and Alternative III requires two vertical shafts. The diameters of tunnel of standard horse shoe type for Alternative II and of pressure tunnel for Alternative III are 2.10 m and that of free flow tunnel for Alternative III is determined at 2.40 m taking into account the workability as well as economic advantages.

C. Water Treatment Plant

Location and design capacity of water treatment plant are described as under for each alternative.

Alternative	Location	Capacity (m^3 per day)
Alt. I	San Jani	553,000 m^3
Alt. II	Shah Allah Ditta	553,000 m^3
Alt. III	Golra	553,000 m^3

Major components of the plant are as follows:

- Receiving well	:	1 unit
- Mixing well	:	4 wells
- Flocculation basin	:	8 basins
- Sedimentation basin	:	8 basins
- Rapid Sand Filter	:	40 beds
- Clear water reservoir	:	4 reservoirs
- Elevated tank	:	1 tank
- Waste water basin	:	2 basins
- Chemical feeding facility	:	2 units

D. Pumping Station

The specifications of respective pump plants to be installed are summarized as below;

Alternative	Station Name	Specification
I-A	Sang Jani	700 mm x 1,830 kw x 6 unit
	Shah Allah Ditta	350 x 800 x 6
	Tomar	250 x 18.5 x 3
I-B	Sang Jani	700 x 1,380 x 6
	Tirnaul	400 x 220 x 6
	E-14	350 x 230 x 6
	Tomar	350 x 100 x 3
I-C	Sang Jani	400 x 690 x 6
	"	600 x 910 x 6
	Shah Allah Ditta	350 x 150 x 6
	Tomar	350 x 100 x 3
II-A	Khurram Paracha	800 x 1,900 x 6
	Shah Allah Ditta	350 x 160 x 6
	I-13	250 x 18.5 x 3

II-B	Julian	800	x 1,720	x 6
	Shah Allah Ditta	350	x 160	x 6
	I-13	250	x 18.5	x 3
II-C	Mohra Gota	800	x 1,450	x 6
	Shah Allah Ditta	350	x 160	x 6
	I-13	250	x 18.5	x 3
II-D	Khanpur	800	x 1,390	x 6
	Shah Allah Ditta	350	x 160	x 6
	I-13	250	x 18.5	x 6
III	Golra	350	x 430	x 6
	"	250	x 150	x 6
	J-11	250	x 15	x 3
	Westridge	350	x 220	x 3
	"	350	x 100	x 3

E. Pipeline

Design lengths of pipeline with diameter 400 mm upto 1,650 mm are calculated as under:

Alternative	Main (km)	Distribution (km)	Total (km)
I-A	31.2	65.3	96.5
I-B	41.9	60.4	102.3
I-C	43.2	61.1	104.3
II-A	22.4	65.3	87.7
II-B	18.4	65.3	83.7
II-C	24.0	65.3	89.3
II-D	26.5	65.3	91.8
III	16.3	66.1	82.4

F. Service Reservoir

Two types of service reservoirs of flat slab and prestressed concrete tank (PC) have been proposed as follows:

Alternative	Name	Type	Capacity Effective (cu.m)	Capacity Design (cu.m)
I-A	Shah Allah Ditta	PC	26,100	18,800x2
	D-13	RC	14,100	15,300x1
	G-13	PC	84,400	27,100x4
I-B	E-14	PC	14,100	26,100x1
	Shah Allah Ditta	PC	26,100	18,800x2
	Tomar	RC	84,400	23,000x4
I-C	Shah Allah Ditta	PC	26,100	18,800x2
	D-13	RC	14,100	15,300x1
	Tomar	RC	84,400	23,000x4
II-A,B,C,D	Shah Allah Ditta	PC	26,100	18,800x2
	D-13	RC	14,100	15,300x1
	G-13	PC	84,400	27,100x4
III	Colra (1)	RC	26,100	16,500x2
	Golra (2)	RC	14,100	15,300x1
	H-11	RC	84,400	23,000x4

4.5.4. Preliminary Cost Estimate

A. Construction Costs

The preliminary cost estimates were made for major works such as tunnels and pipelines on the basis of work quantity calculated and unit prices provided by authorities concerned, and for other works such as buildings and service reservoirs relative costs obtained from similar works were applied. Prices of materials and equipment to be imported from foreign countries were estimated. Duties and taxes to be levied on such imports are included in the cost estimates in accordance with Pakistan Customs Tariff and Import Trade Guide.

The estimated costs include costs for construction works and procurement of materials and equipment. For the sake of comparative study of alternatives, the expenses needed for pre-construction works are not included in these cost estimates; they are costs for topographic and geological surveys, detailed design, consulting services, administration, supervision of construction works and so on. Physical contingencies (10%) were added to the construction costs.

Cost summary of alternatives is given in Table IV-1; Details are indicated in Chapter IV of Appendix-B.

B. Operation and Maintenance Cost

The running expenses for operation and maintenance of the proposed water supply systems include electric power cost, labour wage, material supply, repairs of equipment and construction works, and administration. Electric power costs are estimated in accordance with WAPDA Tariff B-3, and labour wage and material for water treatment are calculated on the basis of quantity and unit prices. For repairs of equipment and construction works and administration, 1% of the construction costs including procurement costs is assumed. Yearly operation and maintenance costs at the target year are given below.

	Construction Costs		O & M Cost/Year	
Alternative	(Rs. Million)	Ratio	(Rs. Million)	Ratio
I-A	2,055	1.19	71.75	1.53
I-B	1,977	1.15	69.49	1.48
I-C	1,917	1.11	67.61	1.44
II-A	2,070	1.20	73.82	1.58
II-B	2,021	1.17	70.15	1.50
II-C	1,971	1.14	63.16	1.35
II-D	2,012	1.17	62.81	1.34
III	1,726	1.00	46.83	1.00

4.5.5. Selective Comparison of Alternatives

A. Preliminary Comparison of Sub-alternative

a. Economic Consideration

Economic internal rate of return (EIRR) as one of the indexes of economic evaluation is computed below.

Alternative	EIRR (%)
I-A	6.88
I-B	6.97
I-C	7.05
II-A	6.69
II-B	6.83
II-C	7.02
II-D	6.98
III	7.56

Note: In computing EIRR costs of distribution networks were not incorporated in the project costs.

b. Engineering Consideration

Alternative I

Alternative I-C is proposed to provide separate distribution systems of treated water to both cities, while common use systems are proposed for Alternatives I-A and I-B. Separate systems may permit easier operation and maintenance than the systems of Alternatives I-A and I-B. Hence, Alternative I-C is recommendable among three alternatives.

Alternative II

- The construction of main pumping station in Khanpur reservoir for Alternative II-D will need somewhat skillful engineering works compared to the construction of other pumping stations for Alternatives II-A, II-B, and II-C.

- Operation and maintenance of vertical shaft type pumps proposed in Alternative II-D is relatively difficult as compared to horizontal shaft type pumps proposed in Alternatives II-A, II-B and II-C.

- Alternatives II-A, II-B and II-C rank same from a viewpoint of engineering; However, Alternative II-C is recommendable in consideration of EIRR, though difference in EIRR is slight.

B. Conclusions

1) From technical point of view, all of Alternatives I, II and III are feasible.

2) It will take five years under Alternatives I and II to complete the first phase in which fifty percent utilization of Khanpur urban water is envisaged. Whereas, in case of Alternative III, it will take six years. However, this one year delay will not bring a serious problem for the staging plan of water supply.

3) Operations of Left Bank Canal under Alternative I may raise technical problems for urban water supply, arising from the control of water diversion to irrigation and industry. In contrast, in Alternatives II and III, water is directly taken from the reservoir and, therefore, diversion operations for urban water supply will be easy.

4) In Alternative III, out of the total amount of the water to be distributed to Rawalpindi area, about 78% would be served by gravity. It puts this alternative in an economically advantageous position in an indisputable manner.

5) The table below shows a summary picture of the three alternatives:

(Unit: Rs. Million)

Alternatives	EIRR (%)	Construction Cost	O/M Cost/Year
I	7.05	1,917	68
II	7.02	1,971	63
III	7.56	1,726	47

Note: EIRR (Economic Internal Rate of Return) is an index expressing a degree of feasibility in economic terms.

A clear grasp can be had of the situation where Alternative III is recommendable as the most optimum plan.

It might be emphasized that annual recurring costs are the least under this alternative, which will lessen and relieve burdens on water supply organizations and on the users as well for the project life of half a century.

TABLE IV-1 CONSTRUCTION COSTS OF ALTERNATIVES

(Unit: Rs. Million)

Item	Alternative							
	I-A	I-B	I-C	II-A	II-B	II-C	II-D	III
1. Raw water reservoir	95.0	95.0	95.0	109.9	57.7	-	-	-
2. Feeder facilities	27.4	27.4	27.4	28.1	9.4	34.4	12.5	44.5
3. Tunnel	-	-	-	52.8	134.2	119.0	111.9	320.7
4. Water treatment	442.2	442.2	442.2	541.4	541.4	541.4	541.4	397.7
5. Pumping Station	218.1	263.5	263.0	266.4	267.4	239.9	287.9	146.3
6. Pipeline	791.6	723.4	697.1	589.3	534.1	564.3	582.6	402.9
7. Service reservoir	232.5	182.3	157.4	232.5	232.5	232.5	232.5	189.4
8. Electric works	61.3	64.0	60.6	61.6	60.4	60.6	60.2	67.8
Sub-total	1,868.1	1,797.7	1,742.6	1,882.1	1,837.0	1,792.2	1,829.2	1,569.2
9. Physical contingencies	186.8	179.7	174.2	188.2	183.7	179.2	182.9	156.9
Total	2,054.9	1,997.4	1,916.8	2,070.3	2,020.7	1,971.4	2,012.1	1,726.1

Note: Differences in colum Sub-total are due to rounding.

CHAPTER V. PROPOSED PROJECT

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5.1. Project Formulation

5.1.1. Necessity of the Project

According to the Sixth Five-Year Plan (1983-1988) which has been set up by the Federal Government of Pakistan, it is clearly mentioned that the lack of potable water supply and sanitation facilities is a major cause of many serious diseases. Although reliable statistics regarding the incidence of water borne diseases are not available, it is well known that contaminated drinking water is one of the principal agents of disease and death in the country. The provision of potable water supplies and proper sanitary facilities to the population at large should, therefore, help bring down appreciably the incidence of disease in the country.

The capital city of Islamabad is, after recent completion of Simly Dam, getting about more than 30 MGD of water which is adequate to meet the present needs of the developed/developing sectors of Islamabad. However, additional water supplies would be needed as and when development of new sectors is taken in hand. This additional requirement including for Rawalpindi will be met by the Khanpur water which will be initiated during the Sixth Plan.

5.1.2. Objective of the Project

The main purpose of the project is to provide improved living conditions through stabilized water supply for people living in the project area. In addition to the above, the related objectives are to support growth of industries, commercial enterprises and institution such as school and hospitals etc.

There are many constraints and difficulties on the water supply aspects which were discussed in the previous chapters. The major objectives and strategies of the project implementation are summarized as under.

i. The situation of Islamabad is that it is being developed and this water supply project is one of the important sector for new city development scheme because water supply scheme must go side by side with the development plan along with housing and road construction. Besides, the water demand increasing in Rawalpindi as a part of Metropolitan area is faced with serious problems the year round. Stabilized water supply for twin cities of Islamabad and Rawalpindi, therefore, is obviously and urgently required. The Khanpur water supply project as a regional development scheme will contribute to meeting human needs of the people in the project area.

ii. Upgrading of service standard, such as house connection, stand post, commercial and industrial water supply is also a fundamental requirement of the project target. Served population in Rawalpindi as of 1984 is about 70 percent of total population while it is almost 100% in Islamabad. Approximately 70% of total served population receives clear water from house connection system. The final goals of service standard of Rawalpindi in the year 2000 are proposed to provide water to 90 percent of total population.

iii. Another aim of the project is to assist the twin cities in improving water supply service to all the consumers through a net 420 MLD (92 MGD) increment of production, better control of distribution through wastage and leakage losses reduction and introducing household metering to monitor patterns of demand with a view to ultimately achieving more rational water use.

iv. The project will support and strengthen the new water supply entity in its effort to become operationally and financially viable by providing it management assistance to improve management information systems, accounting procedures and billing and collection by the computerization. The final targets of the aspect are to collect 100 percent water charges from consumers concerned and to reduce wastage losses.

5.1.3. Scope of the Project

The project scope is new construction of intake tower which will be made in the Khanpur reservoir, conduction main consisting of pressure and free flow tunnel with energy dissipating facility, Golra water treatment plant, pumping stations, service reservoirs and pipelines upto respective service reservoirs from clear water reservoir at water treatment plant and or pumping stations.

In addition to the construction of main facilities incorporated in this Project, distribution systems including distribution networks upto house connection will have to be implemented in parallel with main facilities implementation as associated project in order to realize quick benefit.

5.1.4. Project Description

The components of the proposed project are summarized below:

i. Raw Water Conveyance:

- Intake Tower: Providing intake tower in the Khanpur reservoir with about 6.74 cu.m/sec maximum intake capacity;

- Conduction Tunnel and Conduits: Provision of about 13.1 km long conduction main, including pressure tunnel of 824 m with breaking pressure basin, concrete culvert conduit of 106 m, free flow tunnel of 11,480 m, pipe conduit of 650 m, respectively.

ii. Water Treatment Plant:

- Plant capacity and location: Provision of about 553,000 cu.m (121.6 MGD) production capacity at E-10 sector of Golra area.

iii. Pumping:

- Pumping Station: Provision of Golra pumping station at near water treatment plant to raise clear water to Islamabad high and low zone beneficial area;

- Electric Power Line: Provision of about 25 km 11 KV electrical transmission systems including substation.

iv. Distribution Main:

- Golra No.1 Main: Providing about 1.5 km long and 700 mm diameter of twin pipelines for high zone of Islamabad

- Golra No.2 Main: Providing about 1.6 km long and 800 mm diameter of pipeline for low zone of Islamabad

- Rawalpindi Main: Providing about 6.5 km long and 1,500 mm diameter of twin pipelines for Rawalpindi

v. Service Reservoir:

- Golra No.1 Service Reservoir: Provision of PC type tank with 26,000 cu.m capacity for high zone of Islamabad

- Golra No.2 Service Reservoir: Provision of PC type tank with 16,600 cu.m capacity for low zone of Islamabad

- H-11 Service Reservoir: Provision of flat-slab type tank with 89,200 cu.m capacity for Rawalpindi

vi. Procurement:

- Equipments: Procurement of equipment on project implementation and operation and maintenance including vehicles and office equipment.

vii. Services:

- Consulting Services: Assisting in project implementation, including geological investigation for tunnel works, preparation of detail design and tender documents as well as construction supervision.

5.2. Preliminary Design

5.2.1. Intake Tower and Conduction Main

A. Intake Tower

The intake tower will be constructed at a small bay of Khanpur reservoir, 500 m east of the left sub-dam, which is convenient for construction of a coffer dam and is safe for leakage of storage water of reservoir.

The elevation of lowest inlet sill corresponds to the proposed sediment level of Khanpur reservoir. The intake tower has four inlets at different elevations, and each inlet is equipped with two gates of 1.30 m wide and 2.60 m high (Drawing No.11, Appendix D).

B. No.1 Tunnel and Pressure Break Basin

Water taken from the Reservoir with intake tower is led in the pressure break basin through No.1 pressure tunnel having a length of 770 m.

Jet-flow gates are employed to dissipate energy for its good water measurability and less loss-head. For safety against emergency, two-way flow system has been employed, and butterfly valves have also been designed at upstream of jet-flow gates for inspection and repair (Drawing No.12, Appendix D).

Cross-section of No.1 Tunnel, as same as that of No.2 Tunnel, is standard horseshoe-shaped with 2.4 m diameter. Though inner pressure is as low as 2.8 kg/cm^2, supplemental reinforcement steel bar for lining concrete and grouting between lining concrete and excavated cross section has been planned. Furthermore water-stop grouting along tunnel lining has also been planned (Drawing No.13, Appendix D).

In addition, a gate (2.7 m x 2.7 m) has been designed at entrance of the tunnel to enable inspection of the pressure tunnel.

C. No.2 Tunnel and Culvert

Stilled water with energy dissipator is led to Golra thru 106 m of culvert and 11,480 m of connected No.2 Tunnel.

No.2 Tunnel is a free-flow tunnel with standard horseshoe shape (diameter 2.4 m). Three types of the tunnel have been designed, corresponding to rock class (Drawing No.14, Appendix D).

The area is located at west end of Himalaya Mountains and No.2 Tunnel has to pass fault belt, which is geologically considered as structural fault, at three places. Height of ground above tunnel is less than 500 m so that earth pressure will not be much. However, because of limestone, much ground water flow and intensive resurgence while construction are anticipated.

For safety against the said earth pressure and intensive resurgence. Chemical grouting at the three faults in advance to excavation has been planned to stabilize earth body.

No.2 Tunnel is as long as 11,480 m, and two vertical shafts are designed for quick construction. Depth of No.1 and No.2 vertical shaft are 97 m at Tarmakki and 59 m at Golra respectively. Cross-section has been designed circular with 6.0 m diameter so as to accommodate two skip lifts, one lift for equipment and materials and another lift for staff by taking account of volume of muck and transportation of construction equipment. The vertical shaft will be so decisive to control tunnel construction that it will be a concrete structure, and will be in operation for four years.

Culvert connected to entrance of the tunnel has been designed square-shaped (2.4 m x 2.4 m) for simplicity of construction.

D. Pipeline

A 650 m pipeline between outlet of No.2 Tunnel and Golra Water Treatment Plant has been designed as twin steel-cored PRCC pipelines (ø1,650 mm).

E. Effects on Existing Diversion Works (for irrigation and industrial water) along Left Bank Canal

Three existing diversion works are located along Left Bank Canal. With the proposed project, water level in the Left Bank Canal shall be lowered due to less flow discharge caused by no water release for domestic water. Therefore improvement works to lower elevation of diversion crest by 0.63 m (2.1 ft) shall be carried out.

Diversion work at entrance of Mohra Muradu Tunnel (RD 29,000) is equipped with check gate, and other diversion works are equipped with diversion pipes at the sill of main canal. Therefore, improvement of these diversion work will not be necessary.

5.2.2. Water Treatment Plant

In accordance with the design criteria and the staged water supply scheme, the preliminary design was prepared. The details of major facilities for Golra water treatment plant are presented in Table V-1, and the general layout and the hydraulic profile of the plant are shown in Drawing No.16 - 23, Appendix D.

A. Condition of the Preliminary Design

a. Capacity of the plant

- treatment capacity : 121.6 MGD (553,000 m^3/d)
- production capacity : 115.5 MGD (525,500 m^3/d)

b. Intake and Conduction

- intake : at intake tower in Khanpur reservoir
- conduction : by gravity flow through tunnel
- receiving water level: +1,878 ft (+572.7 m)

B. Overview of the Preliminary Design

Proposed plant site is placed at the location of about 700 m east from the main road between 10 and 11 series in E-10 Sector, and along the main road between E and F series.

About a half of the proposed plant site is presently used for cultivation and the rest area is vacant. The present ground elevation varies from about +1,860 to +1,880 ft. Planned ground elevation is +1,870 ft for treatment facilities and +1,860 ft for the clear water reservoir and adjacent pump station.

According to the soil investigation of the plant site, the formation is favorable for construction of civil structure, and no special substructure will be necessary.

A total head loss for the various treatment process is 18 ft based on the hydraulic analysis (see Appendix-B). And, water level of the clear water reservoir is +1,860 ft at high water level and +1,847 ft at low water level.

TABLE V-1. WATER TREATMENT FACILITIES

* expanded capacity
unit in meter

Item	Description	Phase I (60.8 MGD)	Phase II (30.4 MGD)*	Phase III (30.4 MGD)*
Receiving Well	W 8.0 x L 15.0 x D 5.0, RC made	1 well	-	-
Mixing well	W 6.0 x L 6.0 x D 5.0, RC made, with vertical type flush mixer	2 wells	1	1
Flocculation basin	Over-and-under baffles, V 1,430 m^3/basin, RC made	4 basins	2	2
Sedimentation basin	Rectangular horizontal flow type, W 32.0 x L 90.0 x D 4.0, RC made, V 11,500 m^3, with bridge type travelling girder sweeper	4 basins	2	2
Rapid sand filter	Single media declining rate filtration, RC made, 128 m^2/unit, 120 m^3/m^2.d, Perforated plate underdrain, backwashing together with surface washing	20 units	10	10
Clear water reservoir	W 40.0 x L 40.0 x D 4.0, V 6,400 m^3, RC made	2 reservoirs	1	1
Elevated tank	Dia. 19.5 x D 2.5 , V 700 m^3, RC made	1 tank	1	-
Waste water basin	W 15.0 x L 27.0 x D 2.5, V 1,000 m^3, RC made	2 basins	-	-
Buildings	Administration, 1,510 m^2 Alum: 860 m^2 Chiorination: 540 m^2	1 LS	-	-
Alum feeding facility		1 LS	1	-
Chlorination facility		1 LS	-	-

5.2.3. Pumping Station, Distribution Main and Service Reservoir

A. Service Reservoir

Service area of the twin cities is divided into three zones: namely, Islamabad High Zone, Islamabad Low Zone and Rawalpindi. One service reservoir is proposed to be constructed in each zone. Control water level in each service reservoir is determined so that water is delivered to the terminal unit of distribution. In consideration of required capacity corresponding to the hourly change of water demand as well as effective capacity to cope with power stoppage, capacity of the service reservoir is taken as six hours capacity of the projected maximum daily water supply.

In review of capacity, water level, distribution area, topographic and other conditions concerning the service reservoir, Golra-1 and Golra-2 service reservoirs respectively for Islamabad High and Low Zones are proposed with PC tanks at the sites situated on hill-tops located to the north of the treatment plant in Sector E-10. A RC flat slab type service reservoir is also constructed in Sector H-11 to distribute water to the service areas of Rawalpindi. Major dimensions of service reservoir are summarized as under;

DIMENSIONS OF SERVICE RESERVOIR

Service Reservoir	Effective Capacity	Structure	HWL	LWL
Golra-1	13,000 cu.m x 2	P.C	673.0 m (2,207 ft)	663.0 m (2,174 ft)
Golra-2	16,600 cu.m x 1	P.C	624.5 (2,048 ft)	614.5 (2,015 ft)
H-11	22,300 cu.m x 4	R.C	557.0 (1,826 ft)	551.0 (1,807 ft)

B. Distribution Main

Distribution main pipelines to convey water from treatment plant up to service reservoirs for both Islamabad High and Low Zones are pressured by pumps. Taking water pressures to be operated, workability for construction, economy and back-up in case of emergency into consideration, the following dimensions are given;

DISTRIBUTION MAIN FOR ISLAMABAD

Distribution Main	Diameter x No. of Line	Length
For Islamabad High Zone	DIP ø700 mm x 2 line	1,530 m
For Islamabad Low Zone	DIP ø800 mm x 1 line	1,550 m

Distribution main pipeline for Rawalpindi service area is proposed as gravity flow type. Water pressures operated are relatively low, therefore, PRCC (with steel core) is selected for its low cost. From hydraulic point of view, twin pipeline system with a diameter of 1,500 mm is proposed.

DISTRIBUTION MAIN FOR RAWALPINDI

Distribution Main	Diameter x No. of Line	Length
For Rawalpindi	PRCC (with steel core)ø1,500mmx2	6,500 m

C. Pumping Station

Water conveyed to the service reservoirs for Islamabad is pressured by pumps. Pumping station is proposed at the site situated in the compound of the treatment plant. In review of operation, convertibility, economy and others, number of pumps are determined at five units of equal capacity. Six unit of lifting pumps inclusive of one spare unit are installed in each pumping station. Horizontal Shaft Double Suction Volute Pump is selected in consideration of the required capacity and total pumping head. In addition to the lifting pumps, back-wash pumps and surface-wash pumps for the use of treatment plant are also installed in the pumping station.

DIMENSION OF PUMP

Pump	Bore (mm)	Capacity (cu.m/min)	Total Head (m)	Motor (KW)	Units
No.1 (High Zone)	ø300 x 200	14.32	117.5	400	6 (1)
No.2 (Low Zone)	ø300 x 200	9.22	68.0	150	6 (1)
No.3 (Surface Wash)	ø450 x 350	25.00	20.0	132	4 (2)
No.4 (Back Wash)	ø450 x 400	23.30	15.0	90	3 (1)

5.3. Project Implementation and Cost Estimate

5.3.1. Project Implementation

The project would be implemented over a 14 year period, starting in 1987 with implementation of Phase I project being followed by Phase II project in 1992 and Phase III project in 1997 to end in 2000 (Table V-2). By this, the project could supply bulk water to meet the water demand prospected in the target year of 2000.

The Capital Development Authority would be responsible for overall planning and coordination of the project. A Project Coordination Committee, comprising representatives from CDA, WAPDA, PHED, MES, RMC, CB and other authorities concerned, would be established to coordinate their activities related to the project (Figure V-1).

5.3.2. Cost Estimate

The total project cost in August 1984 prices, including physical contingencies and price escalation, is estimated at Rs. 2,900 million, of which Rs. 1,925 million is for Phase I project, Rs. 558 million for Phase II project and Rs. 417 million for Phase III project. The foreign exchange component for the total project is Rs. 1,171.5 million, or 40% of the total cost (Table V-3 - 10).

Engineering and administration costs amount to Rs. 183.2 million for detailed investigation, detail design, and supervision and administration of the project. Physical contingencies of 10% have been added to all estimated costs. Price increases were estimated by applying the annual rates of price escalation of 10% for local costs and 6% for foreign costs.

Construction works would be carried out by international competitive bidding. CDA would retain consulting firms, composed of foreign specialist in association with local consultant to assist in the detail design of project, preparation of design and contract documents, and supervision of construction.

The total project cost of Rs. 2,900 million was allocated to the respective areas of Islamabad, Rawalpindi Municipal Cooperation (RMC) and Rawalpindi Cantonment Board (RCB) on condition that costs of common use facilities are allocated to areas concerned in proportion to respective water production, and other costs (project offices, land acquisition, office equipment, engineering, administration and contingency) are allocated in proportion to respective construction costs of facilities. Allocated costs are summarized as under (refer to TABLE C.II-22-25, Appendix);

SUMMARY OF COST ALLOCATION

- Unit: Rs. Million -

Area	Phase I	Phase II	Phase III	Total
1. Islamabad	779.7	173.0	125.1	1,077.8
2. Rawalpindi				
- RMC -	546.6	184.1	138.9	869.6
- CB -	598.7	200.9	153.0	952.6
Total	1,925.0	558.0	417.0	2,900.0

FIGURE V-1 ORGANIZATIONAL STRUCTURE OF PROJECT IMPLEMENTATION

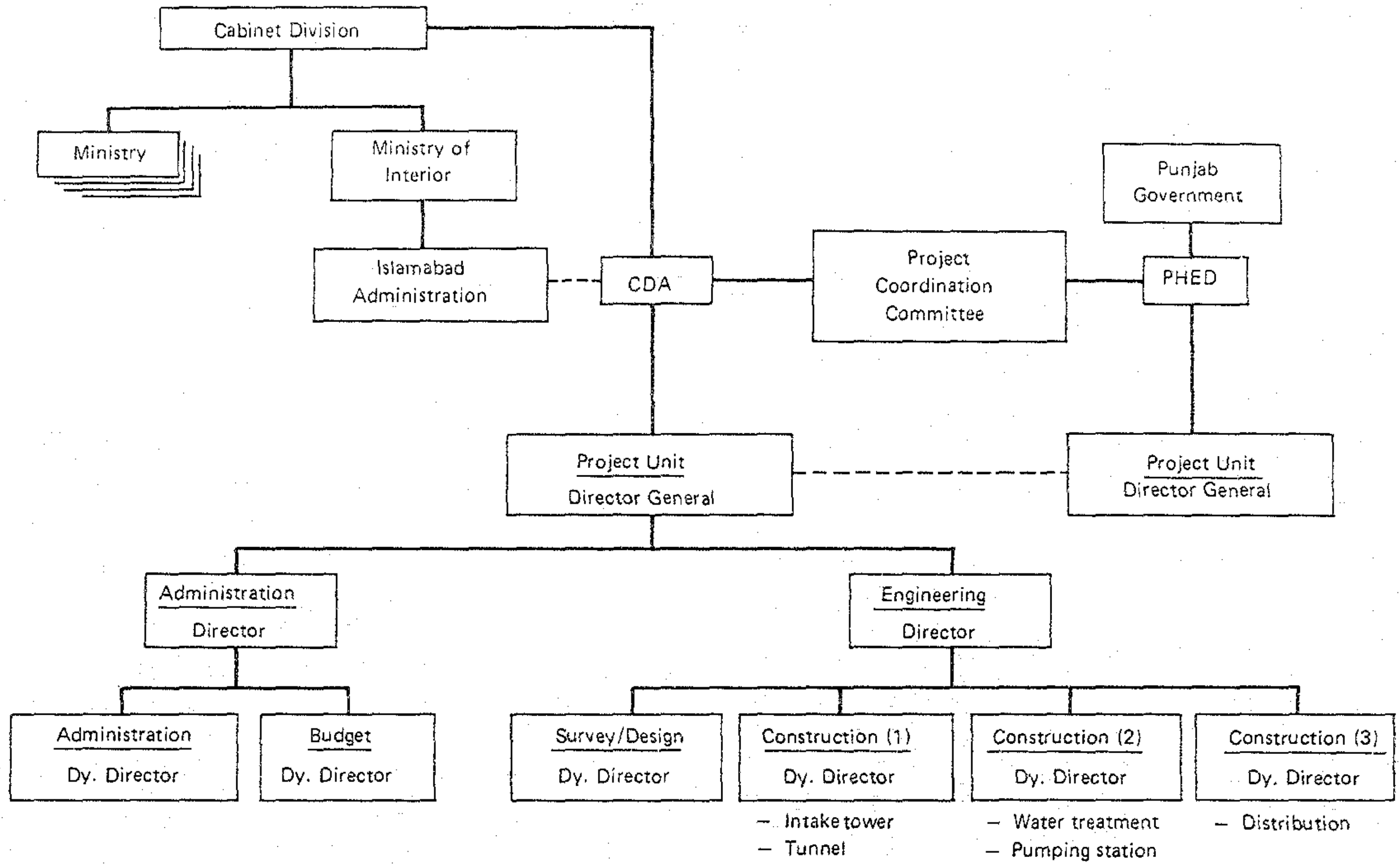


TABLE V–2 IMPLEMENTATION SCHEDULE

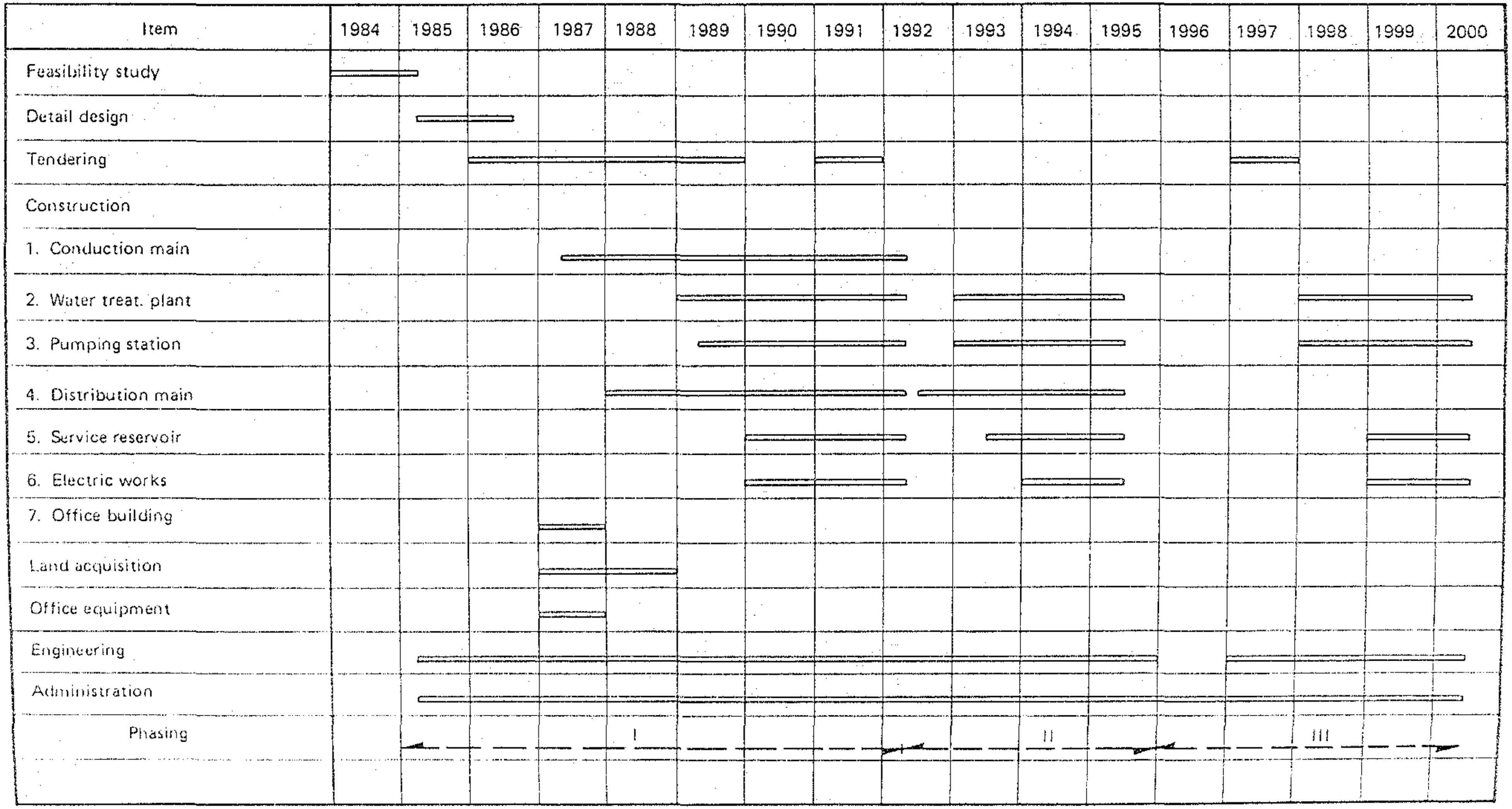


TABLE V-3 COST SUMMARY (1)

	Item	Local	Foreign	Total	Foreign
		---- Rs. Million		-------	(%)
1.	Conduction main	249.7	177.8	427.5	42
2.	Water treatment plant	190.3	184.9	375.2	49
3.	Pumping station	51.6	54.1	105.7	51
4.	Distribution main	70.5	70.5	141.0	50
5.	Service reservoir	112.8	77.8	190.6	41
6.	Electric works	13.8	23.3	37.1	63
	Sub-total (1 ~ 6)	688.7	588.4	1,277.1	46
7.	Project office	12.0	-	12.0	-
8.	Land acquisition	35.6	-	35.6	-
9.	Office equipment	2.2	6.3	8.5	74
10.	Engineering	31.2	116.4	147.6	79
11.	Administration	35.6	-	35.6	-
	Sub-total (7 ~ 11)	116.6	122.7	239.3	51
	Base Cost (1 ~ 11)	805.3	711.1	1,516.4	47
12.	Physical contingency	80.5	71.1	151.6	
13.	Price escalation	842.7	389.3	1,232.0	
	Total Cost	1,728.5	1,171.5	2,900.0	40

TABLE V-4 COST SUMMARY (2)

(Unit: Rs. Million)

	Item	Phase I	Phase II	Phase III	Total
1.	Conduction main	427.5	-	-	427.5
2.	Water treatment plant	196.1	101.2	77.9	375.2
3.	Pumping station	89.4	10.4	5.9	105.7
4.	Distribution main	76.0	65.0	-	141.0
5.	Service reservoir	124.6	43.0	23.0	190.6
6.	Electric works	32.2	3.4	1.5	37.1
	Sub-total (1∿6)	945.8	223.0	108.3	1,277.1
7.	Project office	12.0	-	-	12.0
8.	Land acquisition	35.6	-	-	35.6
9.	Office equipment	8.5	-	-	8.5
10.	Engineering	121.1	17.8	8.7	147.6
11.	Administration	27.8	4.5	3.3	35.6
	Sub-total (7∿11)	205.0	22.3	12.0	239.3
	Base Cost (1∿11)	1,150.8	245.3	120.3	1,516.4
12.	Physical contingency	115.1	24.5	12.0	151.6
13.	Price escalation	659.1	288.2	284.7	1,232.0
	Total Cost	1,925.0	558.0	417.0	2,900.0

TABLE V-5 COST SUMMARY - PHASE I

(Unit: Rs. Million)

	Item	Local	Foreign	Total
1.	Conduction main	249.7	177.8	427.5
2.	Water treatment plant	99.6	96.5	196.1
3.	Pumping station	44.2	45.2	89.4
4.	Distribution main	38.2	37.8	76.0
5.	Service reservoir	72.1	52.5	124.6
6.	Electric works	11.9	20.3	32.2
	Sub-total (1 ∿ 6)	515.7	430.1	945.8
7.	Project office	12.0	-	12.0
8.	Land acquisition	35.6	-	35.6
9.	Office equipment	2.2	6.3	8.5
10.	Engineering	25.8	95.3	121.1
11.	Administration	27.8	-	27.8
	Sub-total (7 ∿ 11)	103.4	101.6	205.0
	Base Cost (1 ∿ 11)	619.1	531.7	1,150.8
12.	Physical contingency	61.9	53.2	115.1
13.	Price escalation	448.4	210.7	659.1
	Total Cost	1,129.4	795.6	1,925.0

TABLE V-6 COST SUMMARY - PHASE II

(Unit: Rs. Million)

Item	Local	Foreign	Total
1. Conduction main	-	-	-
2. Water treatment plant	51.4	49.8	101.2
3. Pumping station	4.6	5.8	10.4
4. Distribution main	32.3	32.7	65.0
5. Service reservoir	26.4	16.6	43.0
6. Electric works	1.3	2.1	3.4
Sub-total (1∿6)	116.0	107.0	223.0
7. Project office	-	-	-
8. Land acquisition	-	-	-
9. Office equipment	-	-	-
10. Engineering	3.6	14.2	17.8
11. Administration	4.5	-	4.5
Sub-total (7∿11)	8.1	14.2	22.3
Base Cost (1∿11)	124.1	121.2	245.3
12. Physical contingency	12.4	12.1	24.5
13. Price escalation	193.4	94.8	288.2
Total Cost	329.9	228.1	558.0

TABLE V-7 COST SUMMARY - PHASE III

(Unit: Rs. Million)

	Item	Local	Foreign	Total
1.	Conduction main	-	-	-
2.	Water treatment plant	39.3	38.6	77.9
3.	Pumping station	2.8	3.1	5.9
4.	Distribution main	-	-	-
5.	Service reservoir	14.3	8.7	23.0
6.	Electric works	0.6	0.9	1.5
	Sub-total (1 ∿ 6)	57.0	51.3	108.3
7.	Project office	-	-	-
8.	Land acquisition	-	-	-
9.	Office equipment	-	-	-
10.	Engineering	1.8	6.9	8.7
11.	Administration	3.3	-	3.3
	Sub-total (7 ∿ 11)	5.1	6.9	12.0
	Base Cost (1 ∿ 11)	62.1	58.2	120.3
12.	Physical contingency	6.2	5.8	12.0
13.	Price escalation	200.9	83.8	284.7
	Total Cost	269.2	147.8	417.0

TABLE V-8 SCHEDULE OF EXPENDITURE - PHASE I

(Unit: Rs. Million)

	1985	1986	1987	1988	1989	1990	1991	1992	Total
1. Conduction main	-	-	26.2	78.8	90.0	91.9	96.6	44.0	427.5
2. Water treatment plant	-	-	-	-	43.2	104.6	47.5	0.8	196.1
3. Pumping station	-	-	-	-	1.9	35.5	36.5	15.5	89.4
4. Distribution main	-	-	-	17.0	21.5	27.1	8.2	2.2	76.0
5. Service reservoir	-	-	-	-	-	49.7	49.7	25.2	124.6
6. Electric works	-	-	-	-	-	1.5	18.7	12.0	32.2
Sub-total (1 ~ 6)	-	-	26.2	95.8	156.6	310.3	257.2	99.7	945.8
7. Project office	-	-	12.0	-	-	-	-	-	12.0
8. Land acquisition	-	-	6.0	29.6	-	-	-	-	35.6
9. Office equipment	-	-	8.5	-	-	-	-	-	8.5
10. Engineering	24.9	16.6	8.1	7.8	11.9	23.9	19.9	8.0	121.1
11. Administration	5.5	3.4	0.6	1.9	3.1	6.2	5.1	2.0	27.8
Sub-total (7 ~ 11)	30.4	20.0	35.2	39.3	15.0	30.1	25.0	10.0	205.0
Base Cost (1 ~ 11)	30.4	20.0	61.4	135.1	171.6	340.4	282.2	109.7	1,150.8
11. Physical contingency	3.0	2.0	6.1	13.5	17.2	34.1	28.2	11.0	115.1
12. Price escalation	1.2	2.5	15.5	50.1	80.6	203.6	206.0	99.6	659.1
Total Cost	34.6	24.5	83.0	198.7	269.4	578.1	516.4	220.3	1,925.0

TABLE V-9 SCHEDULE OF EXPENDITURE - PHASE II

(Unit: Rs. Million)

		1992	1993	1994	1995	Total
1.	Conduction main	-	-	-	-	-
2.	Water treatment plant	-	37.7	43.9	19.6	101.2
3.	Pumping station	-	4.0	4.3	2.1	10.4
4.	Distribution main	19.5	19.5	19.5	6.5	65.0
5.	Service reservoir	-	8.6	21.5	12.9	43.0
6.	Electric works	-	-	2.4	1.0	3.4
	Sub-total (1 ~ 6)	19.5	69.8	91.6	42.1	223.0
7.	Project office	-	-	-	-	-
8.	Land acquisition	-	-	-	-	-
9.	Office equipment	-	-	-	-	-
10.	Engineering	1.6	5.6	7.3	3.3	17.8
11.	Administration	0.4	1.4	1.8	0.9	4.5
	Sub-total (7 ~ 11)	2.0	7.0	9.1	4.2	22.3
	Base Cost (1 ~ 11)	21.5	76.8	100.7	46.3	245.3
12.	Physical contingency	2.1	7.7	10.1	4.6	24.5
13.	Price escalation	18.7	79.9	123.7	65.9	288.2
	Total Cost	42.3	164.4	234.5	116.8	558.0

TABLE V-10 SCHEDULE OF EXPENDITURE - PHASE III

(Unit: Rs. Million)

		1998	1999	2000	Total
1.	Conduction main	-	-	-	-
2.	Water treatment plant	29.0	43.4	5.5	77.9
3.	Pumping station	2.3	2.4	1.2	5.9
4.	Distribution main	-	-	-	-
5.	Service reservoir	-	16.1	6.9	23.0
6.	Electric works	-	1.0	0.5	1.5
	Sub-total (1~6)	31.3	62.9	14.1	108.3
7.	Project office	-	-	-	-
8.	Land acquisition	-	-	-	-
9.	Office equipment	-	-	-	-
10.	Engineering	2.5	5.1	1.1	8.7
11.	Administration	0.9	1.9	0.5	3.3
	Sub-total (7~11)	3.4	7.0	1.6	12.0
	Base Cost (1~11)	34.7	69.9	15.7	120.3
12.	Physical contingency	3.4	7.0	1.6	12.0
13.	Price escalation	72.2	170.4	42.1	284.7
	Total Cost	110.3	247.3	59.4	417.0

5.4. Operation and Maintenance

5.4.1. Basic Concepts of Organization Set-up and Operation and Maintenance Activities

The organization of operation and maintenance on the Khanpur Water supply project shall be considered comprehensively from viewpoints of function of existing organizations related, policy of future metropolitan area development, modernization and efficiency of their activities, and water resources availability for twin cities of Islamabad and Rawalpindi.

Water resource of this project, as discussed in previous sections, is storage water of Khanpur reservoir which was constructed for the purpose of irrigation, industrial and urban water supply.

The present operation and maintenance of water supply systems in the twin cities are basically performed by CDA and PHED for bulk water supply. The O/M of distribution systems are undertaken by CDA for Islamabad and RMC, MES and CB for Rawalpindi respectively.

The organizations which are illustrated in Figures V-2 - 5 are proposed to operate and maintain the existing and planned facilities in the most effective and efficient manner based on regional scope and perspective encompassing both Islamabad and Rawalpindi areas.

Ultimate targets of respective aspects on operation and maintenance are summarized as under.

A. Budgetary Management

- Budget for the development of water resources as well as the operation/maintenance of water supply systems will be regularly compiled.
- Budget will be formulated on the premise that this organization is financially on its own feet.
- Financial resources will be mainly derived from its own coffer. But, some of them will be in the form of tax on citizens and or loans.

B. Operation and Maintenance

- Bulk and other water supply facilities will be operated and maintained.
- Total and complete metering of connection will be attained.
- Also, water supply 24 hours all the year round will be attained.
- The date on which a pipeline is laid, its materials, quality, quantity and economic life will be recorded, and maintenance will be performed accordingly. Repairing of pipelines as needs be and their replacement in accordance with their life will be strictly observed.
- Vigilance will be maintained to detect system leakages and prompt measures and actions will be taken to correct and remedy the situation.
- Personnel and wages & salaries will be established so that relevant facilities will be attended to in an optimal manner.
- Materials and spares will be effectively and efficiently managed and controlled.
- Water quality will be tested, analysed and assessed regularly at each stage of water intake, conveyance, treatment and consumption, and necessary measures will be taken.
- Quality control of material and equipment will be strictly observed.

C. Water Tariff

- Tariff will be determined and will be changed based on the cost analysis of water supply services as well as on the paying ability of consumers.
- Flat rate system will be abolished and in its stead a tariff system under which charges will be imposed proportionate to the volume of water consumed will be totally and completely applied.
- A progressive tariff system under which the more water is consumed the more expensive the charges on unitary consumption of water will be introduced.
- One and the same tariff system will be introduced to be uniformly applied to the respective citizens of Islamabad, Rawalpindi city and Cantonment.
- Ways to compromise with Islamic concept and belief on water will be sought.
- Water tariff systems in other major cities in Pakistan will be constantly monitored to maintain a balance with them. Charges on unitary volume of water will be examined and assessed from international standpoint.
- Water charges will be evaluated in terms of the ratio of water charges payment vis-a-vis income. Water charges will be analysed from the angle of basic human needs.
- Billing and collection will be rationalized and ultimately computerized.

D. Financial Management

- Operation and maintenance costs including depreciation and interest payment will be calculated on a monthly basis.
- Water charges and other receipts will be monthly computed and matched with corresponding expenditures.
- Irregular and/or abrupt increase of costs and or decrease of revenue will be intercepted, examined and analysed, and countermeasures will be taken.

- Statistics on population, water consumption, production, revenue, costs, etc. will be historically recorded and maintained.
- Financial statements including profit and loss statement, cash flow and balance sheet will be regularly reported and assessed.
- Financial viability will be attained.

5.4.2. Proposed Organization and Functions

A. Boards

The Water Management Board on the Khanpur water will be organized consisting of the representatives of Ministry of Water and Power, Ministry of Agriculture, Ministry of Industry, Ministry of Defence, Capital Development Authority, Water and Power Development Authority, Government of Punjab and Government of NWFP. The major purposes of the board are to decide on water allocation of Khanpur water for respective consumers, to direct revision for seasonal fluctuation of water requirement and priority of water release from Khanpur reservoir during drought period, to decide on water charge revision if required and other political matters concerning Khanpur water.

Under the supervision of the water management board, Regional Water Supply System Operation and Maintenance Board (RWSSB), which will be consisted of Capital Development Authority (CDA), Public Health Engineering Department (PHED) of Punjab Government, Rawalpindi Municipal Corporation (RMC), Cantonment Board (CB) and Military Engineering Services (MES), will be organized.

Major functions of RWSSB are to decide on treated water allocation and adjustment for common use water supply system between Islamabad and Rawalpindi, to decide on water charges and tariff system for respective consumers, to deliberate and evaluate annual operation and maintenance budget, to evaluate operation and maintenance activities on the water supply systems.

B. Committees

The Water Supply System Coordinating Committee on the Khanpur Water (CCKW) is established to undertake the following activities. Members of CCKW consist of WAPDA, CDA, PHED, RMC, RCB, MES, Irrigation Department of Punjab and NWFP Government, POF and PIDC of Industry.

- To prepare annual operation and maintenance programmes on the Khanpur water
- To prepare annual water supply programmes including seasonal requirements
- To decide on and arrange detailed water release plan for each consumers based on the direction of Water Management Board on Khanpur water on the revision of water allocation and release schedules
- To evaluate annual operation and maintenance cost of raw water and treated water including repairing works for common use facilities
- To prepare annual and periodical assessment reports which will be directed by the Boards
- To function as working group for the Boards

Another committee concerned is Water Supply System Coordinating Committee on other water sources such as Simly and Rawal dams, groundwater developed in the twin cities and surface water in Islamabad area. Functions of this committee will be similar to those of CCKW.

C. Operation and Maintenance Offices

Under the control of Regional Water Supply System Operation and Maintenance Board and Water Supply System Coordinating Committee on

Khanpur Water, three offices are proposed, namely WAPDA Khanpur Dam O.M Office, Islamabad Water Supply O.M Office and Rawalpindi Water Supply O. M Office. Major function and responsibility of divisions in respective offices are described in Appendix C.

a. WAPDA Khanpur Dam Operation/Maintenance Office

Under the WAPDA Superintendent, three divisions are organized such as Administration and Finance, Khanpur Dam and Canal Control Division.

The Office, headed by the Superintendent of WAPDA will take care of overall operation and maintenance work on the Khanpur dam and Left and Right Bank Main Canal as well as related appurtenant facilities including operation of intake tower, diversion facilities and head regulators along the main canals.

b. Islamabad Water Supply Operation/Maintenance Office

Under the CDA Superintendent, five divisions are organized such as Administration and Finance, Khanpur dam, Simly dam, Headwork and Tubewell, and Distribution Division

The Office, headed by the Superintendent of CDA, will take care of overall operation and maintenance work on the water supply systems within Islamabad Capital area for the time being.

c. Rawalpindi Water Supply Operation/Maintenance Office

Under the PHED Superintendent four divisions such as Administration & Finance, Khanpur Dam, Rawal Dam, and Distribution Divisions are organized.

The office, headed by PHED superintendent, will take care of overall operation and maintenance works on the water supply systems upto main distribution points and instruct operation and maintenance manners for respective terminal consumer agencies concerned.

FIGURE V-2 PROPOSED ORGANIZATION CHART OF WATER SUPPLY SYSTEM OPERATION AND MAINTENANCE

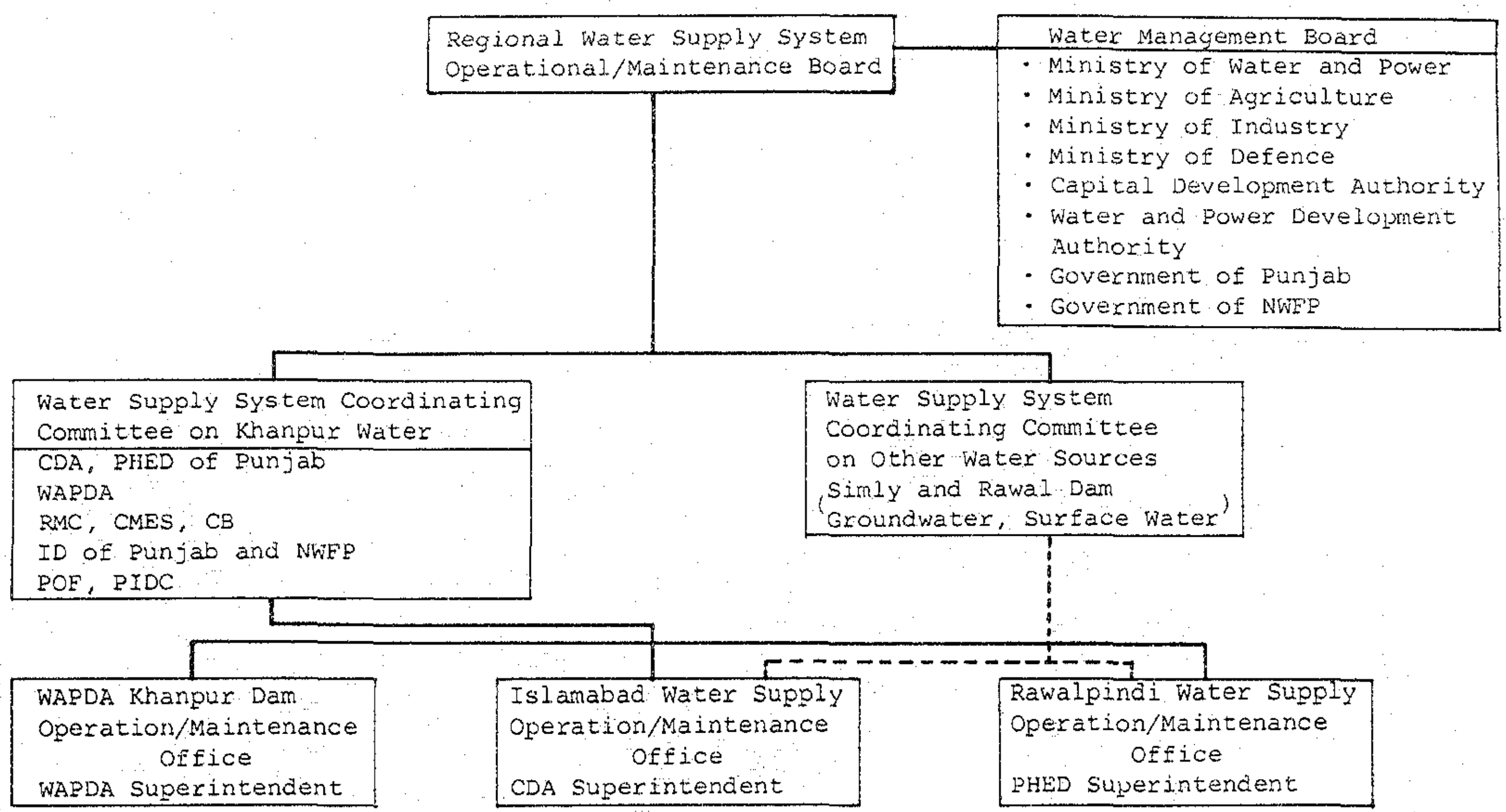


FIGURE V-3 PROPOSED ORGANIZATION CHART OF WATER SUPPLY SYSTEM OPERATION AND MAINTENANCE

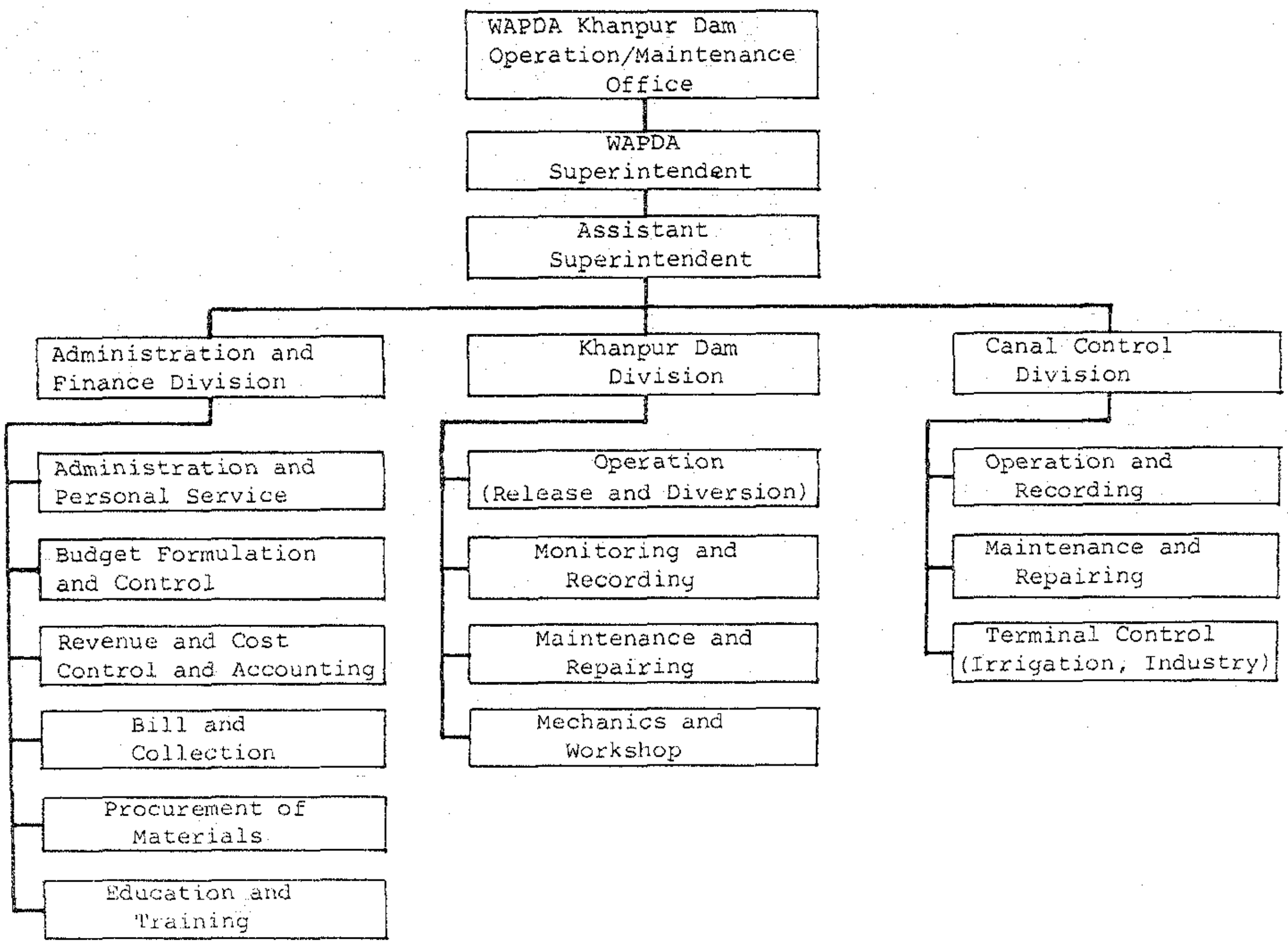


FIGURE V-4 PROPOSED ORGANIZATION CHART OF WATER SUPPLY SYSTEM OPERATION AND MAINTENANCE

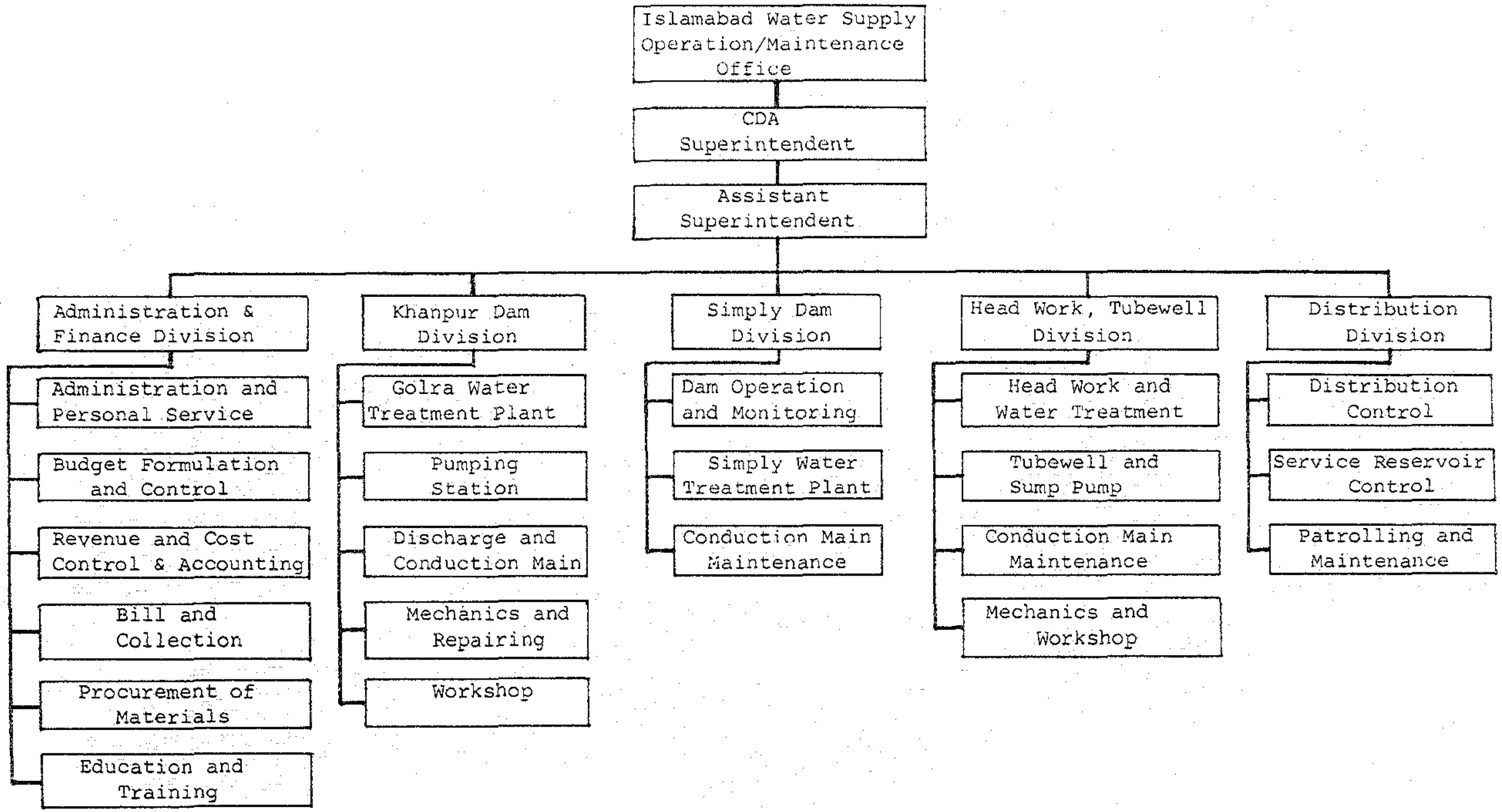
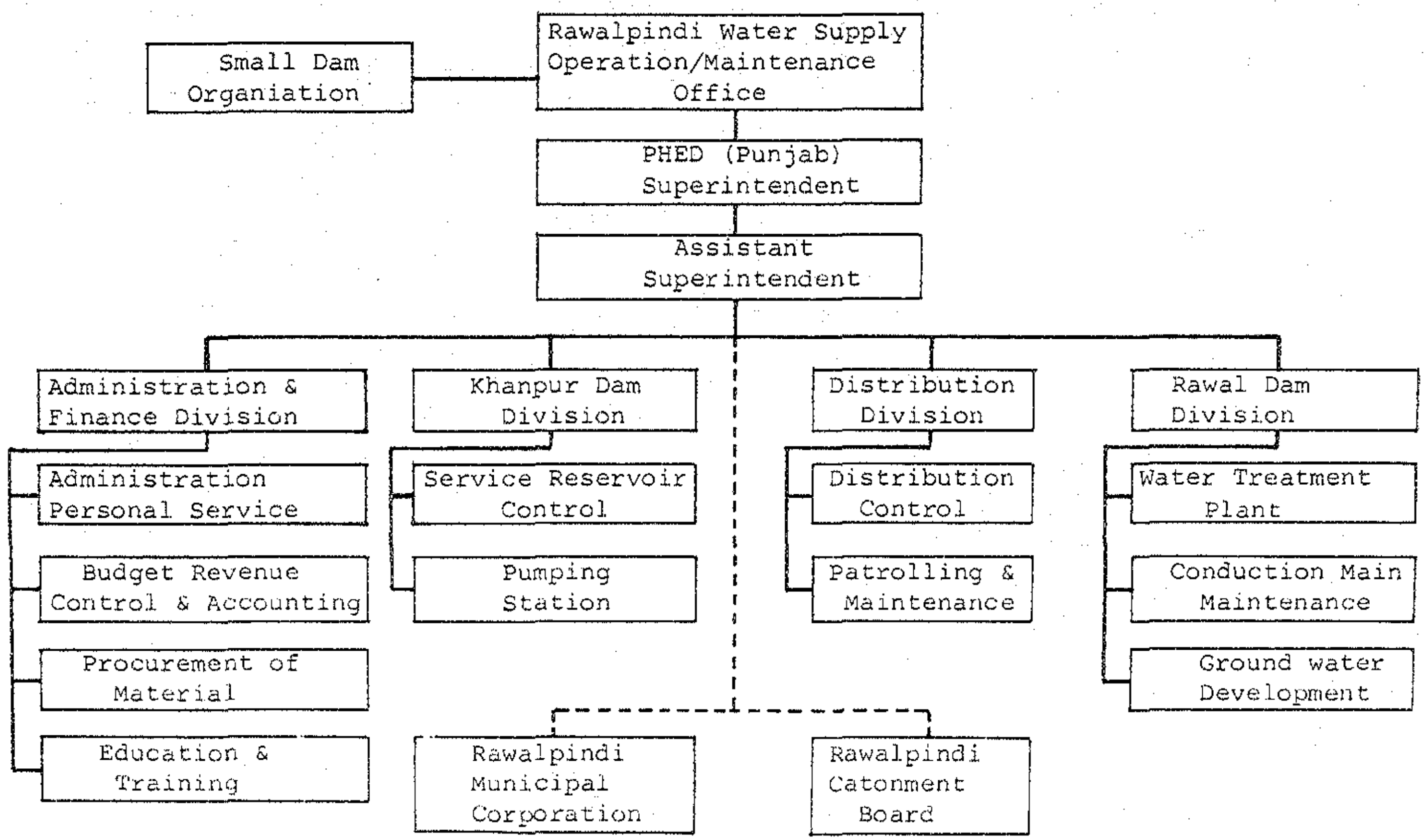


FIGURE V-5 PROPOSED ORGANIZATION CHART OF WATER SUPPLY SYSTEM OPERATION AND MAINTENANCE



CHAPTER VI. PROJECT JUSTIFICATION

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6.1. General

The primary objective of this study is to find out the optimum route from the Khanpur reservoir up to the service reservoir as studied in detail in the previous sections. In this regard, the present study does not cover the entire water supply system and, therefore, it is not easy to discuss the cost and benefit of the whole water supply. However, if the cost of distribution system is included in the project cost, benefit/cost analysis can be made using benefit derived from water sold.

Hereunder, the Project will be evaluated in terms of economic and financial aspects incorporating approximate cost of the distribution system estimated for the purpose of the analysis only.

6.2. Project Benefit

6.2.1. Overall Effects of Urban Water Supply

Urban water is essential for human life as a basic human need. At the same time, industrial and commercial development hinges on the supply of water. It is well known that ancient civilizations arose and prospered on the great rivers. Water holds a key for human existence and industrial activities.

A. Intrinsic Utilities

Water is a prerequisite for living things. For human life urban water is vital because of its intrinsic utilities: we need it for drinking, cooking, bathing, washing, draining and other uses. We all remember that helpless feeling when water supply is interrupted, and also that relieved sentiment when water starts coming again.

Similarly, urban water is indispensable for manufacturing, service, commercial and other industries as raw materials and other similar uses and purposes.

To measure these utilities in economic terms, house visit inquiry investigations were conducted by the Study Team. The result is that domestic and commercial/industrial users who are satisfied with the present water charges are willing to pay Rs. 6.80 and Rs. 5.62 per thousand gallons of water respectively. This, further, boils down to the weighted average value of Rs. 6.49 per thousand gallons of water.

B. Health Benefits

It is noticed in the developing countries that there is a high incidence of diseases in rural areas, contrasting with the situation in urban areas. Usually in villages and small towns the ratio of the population served with urban water is much lower than in big towns and cities. From this it is inferred that there is a strong association between the reduction of diseases and water supply.

However, a difficulty is encountered when one attempts to quantitatively link them, for there can be other causes for bringing down the occurrence of diseases. Due to this limitation coupled with lack of sufficient data, quantification of health benefits has not been performed.

It cannot be denied that health benefits are a principal motive behind the construction of water supply infrastructure. According to some sources they are the ultimate project benefits.

C. Saving of Labor and Time

The provision of more house connections and standpipes will free many people from the daily labor of fetching and carrying water.

If evidences of the time consumed, the unitary value of time, etc. were provided, the economic value accruing from the saving of labor and time could be calculated.

However, due to unavailability of sufficient authentic data and information it was not done.

D. Indirect Benefits

All the benefits described above can be realized or expected immediately after a water supply project is completed. There are other benefits that will come later, but their effects will be far-reaching.

The improvement of people's health is inseparably connected with the enhancement of human resources, which in turn is conductive to socio-economic development.

The provision of domestic water will lead to an elevation of the quality of domestic and social life, and the supply of commercial/industrial water will accelerate and eventually multiply economic activities in and around the areas.

The labor spent for water fetching can be usefully channelled for more productive uses.

6.2.2. Environmental Assessment

As has been already mentioned, the supply of urban water is contributive to the reduction of water-borne diseases, although it is difficult to quantitatively single out its part in effecting it.

By controlling the incidence of diseases the Project saves the costs of constructing and maintaining hospitals and clinics for generations to come. From the standpoint of home economy, it relieves households of medical expenses.

Also, it eventually increases socio-economic potentiality by creating healthier and happier people.

6.2.3. Project Benefit

Indirect benefits of the Project described above have not been quantitatively assessed, as it involves a complex socio-economic system model.

As has been already mentioned, field surveys were conducted to know how much the beneficiaries in the Project areas are willing to pay for water supply service.

This willingness to pay pertains to the direct benefits, and will incorporate intrinsic utilities of urban water. It may also in some degree contain health and labor/time saving benefits.

The number of samples subjected to the surveys reached approximately 3,000. The areas visited were Islamabad, Rawalpindi City and Rawalpindi Cantonment, and both domestic and commercial/industrial users were covered.

Analysis of answers has disclosed that the beneficiaries are on the average willing to pay Rs. 5.37 per thousand gallons of water consumed. In other words, the urban water in the Project areas has an economic value of Rs. 5.37/000 gal.

When analysis is confined to those consumers who voiced their satisfaction with the present water charges, the willingness to pay works out to Rs. 6.49 per thousand gallons. Since those who are dissatisfied with the existing status of water supply, be it water charges or otherwise, will not express the true and real level of their willingness, the latter figure has been ultimately adopted as representing the unitary economic value of urban water. Those who are satisfied with the present water charges comprise 73.9 percent of the total consumers.

To calculate the total yearly economic value of the Khanpur water, the volume of the water to be consumed in a certain future year is mutiplied by this unitary economic value of water.

However, the benefit of water will increase as years go by, even on the assumption that the volume of water to be supplied remain the same. This is because people attach more economic value per unitary consumption of water as their income grows. In economists' jargons, it is called the income elasticity of economic value of water. As a result of the surveys, it has been found that the elasticity is fifty percent, with means that when income increases by ten percent the economic value of water will increase by five percent. This income elasticity factor has been intergrated in the computer programs to determine the economic benefit of the supply of the Khanpur Dam urban water.

In doing so, it was assumed that future annual growth rate of the national economy of Pakistan will be 6.5 percent on the basis of the Sixth Five Year Plan and also that income growth in the Project areas will go side by side with economic growth. (Refer to Table C.IV-1)

As mentioned above, the willingness to pay of Rs. 6.49 per thousand gallons of water will incorporate the intrinsic utilities of urban water, namely the uses for drinking, cooking washing, bathing, draining and others. Also, it may partly include the benefits of the reduction of water-borne diseases and the saving of labor and time, though they should be basically treated separately.

If one piles up the benefits of disease reduction and time saving on top of the willingness to pay, and again the indirect benefits of socio-economic impacts on top of them, then the result will be much higher than the value of willingness to pay. That is to say, Rs. 6.49/000 gal. represents the very minimum of the economic benefit of the Project.

6.3. Financial Analysis and Tariff

6.3.1. Water Tariff

Economic analysis is an analytical process to see if a given project is feasible from the standpoint of the national economy. In contrast, financial analysis is an assessment of the financial situation of an organization directly involved in a project.

In making a financial analysis one of the most important aspects is to decide on the water tariff. Firstly, it will be determined in the form of the average water rate per thousand gallons. Then, it will be structured so that it may integrate the fundamental concept that water is a basic human need and the modern notion that water is an economic commodity.

A. Average Water Rate

To determine the average water rate per thousand gallons, in the first place one must see if it can cover the project costs under a reasonable financial internal rate of return. Here, the project costs depend to a very great extent upon the lending terms under which investment capital is loaned. If the terms are hard to this particular project, it will inevitably push up the water rate to make both ends meet, resulting in a situation where it is unacceptable in terms of consumers' paying ability.

After extensive simulation analysis, it has been assumed that the lending terms are 5% annual rate of interest, the repayment period of 30 years and the grace period of 10 years for foreign exchange portion of the construction costs, and 11% annual rate of interest, the repayment period of 25 years and the grace period of 5 years for local currency portion. The prevailing bank rate per annum in Pakistan is around 14%, and the difference of 3% will be borne by the central government.

If the average water rate is set at Rs. 9.0 per thousand gallons under this assumption, it produces the FIRR value of 6.6%.

It is to be remembered that in computing the above value the costs of distribution facilities including mains and networks have been incorporated in the projects costs.

A household in the Project areas on the average earns Rs. 1,890 per month. It monthly consumes 4.2 thousand gallons of water on the average. If the above water rate is adopted, it will spend Rs. 37.8 per month as a water bill payment, which corresponds to 2% of its monthly income. In other words, water charge under the proposed rate is well within the paying ability of a household.

However, the water rate of Rs. 9.0 (/000 gal.) is by Rs. 2.51 higher than the willingness to pay of Rs. 6.49 (/000 gal.). Also, it is higher than the existing water rates of Rs. 3 to Rs. 6. An effort has been made to absorb the difference through tariff structuring. Nevertheless, it cannot be denied that some compulsory elements are involved in the proposed water rate.

So far as average water rate is concerned, it is assumed to be uniformly applied to both domestic and commercial/industrial users, although tariff structuring should be different between them.

Supposing the costs of distribution facilities are deducted from the project costs because of uncertain factors associated with their estimation, the average water rate per thousand gallons is calculated at Rs. 6.03 (= Rs. 6.0) by applying to Rs. 9.0 the coefficient of 0.6705, which is the ratio of the costs up to service reservoir to be incurred over fifty years of project life (= Rs. 11,426 million) to the costs incorporating distribution to be required over the same period (= Rs. 17,040 million).

If this water rate is adopted so as to cover the costs up to service reservoir, FIRR works out to 6.9% under the aforementioned lending terms.

B. Water Tariff Structure

Under the average water rate of Rs. 9.0 per thousand gallons a household pays the water bill corresponding to two percent of its monthly income. It is known that a household has the ability to pay for water 4% to 5% of its income. In this regard the rate is not an unduly hard one for the beneficiaries.

The water tariff proposed here is based on this average water rate and is so structured that up to a certain volume of water to be consumed unitary charge is low, and from there on unitary charge progressively goes up in parallel with the rise of water consumption.

As shown in Table VI-1, water charge per thousand gallons is Rs. 2 up to two thousand gallons of water to be consumed per month. If monthly water consumption exceeds two thousand gallons, for the third one thousand gallons Rs. 4 are charged. Likewise, for the fourth, fifth and sixth one thousand gallons Rs. 20, Rs. 36 and Rs. 46 are charged. For instance, when a household consumes five thousand gallons of water a month, it shall pay Rs. 64 (=2 + 2 + 4 + 20 + 36).

This volume-related progressive water tariff is so intended that the notion of water as a basic human needed will be met, and at the same time the costs of water supply service will be borne according to the size of income as is clearly evinced in the latter half of Table VI-1.

It is to be remembered that the water tariff will be applied only to domestic users.

C. Subsidizing of Water Rate

It is true that the beneficiaries are able to pay the bill under the proposed average water rate of Rs. 9.0/000 gal. in terms of international standard. But, it is also true that the rate is unusually high compared with the prevailing domestic standards. You can bring a horse to a pond, but you cannot force it to drink. However a water rate is theoretically justified, it is of little use if the beneficiaries are opposed to it. In that case, the average water rate will be Rs. 6.49 per thousand gallons since this is the rate they are willing to pay. And the difference of Rs. 2.51 per thousand gallons will be subsidized by the Government. The subsidy will amount to Rs. 67.7 million (=102.37 MGD x 1,000 x 0.95 x 0.95 x 0.80 x Rs. 2.51 x 365 days/1,000,000) per annum.

The water tariff under the average rate of Rs. 6.49/000 gal. will be structured as shown in Table VI-2.

6.3.2. Financial Analysis

As has been mentioned, a financial analysis is an analysis of a project from the viewpoint of a particular organization directly involved in the Project. It has been stated that the project costs are dependent upon the terms under which the lending agencies loan investment funds, and they are already fixed. On the other hand, project benefits are determined by water rate and volume, both of which are already known.

In this section, in the first half the flows of costs and benefits will be analysed, and in the second the discount factor that renders the present worths of costs and benefits equal will be found.

A. Cash Flow Analysis

Project costs are composed of the costs of raw water, construction, operation/maintenance and replacement, whereas project benefits are water charges receipts. Incremental benefits result by subtracting the former from the latter.

a. Costs

Raw water will be purchased from WAPDA at the rate of Rs. 2.77 per thousand gallons. This rate is necessary to cover the financial costs for the construction and operation/maintenance of the Khanpur Dam. (Refer to Table C.IV-2) The volume of water to be supplied will be 51.185 MGD from 1992 to 1995, 76.778 MGD from 1996 to 2000 and 102.370 MGD from 2001 on.

The capital for the construction of Khanpur water conduction facilities will be invested during the construction period of 1985 to 2000. It will be borrowed from external and domestic sources. Lending terms for foreign exchange component will be 5% annual rate of interest and the payback period of 30 years with 10 years grace period. Terms for local currency component will be 11% annual rate of interest and the payback period of 25 years with 5 years grace period. Financial costs arise in the form of principal and interest to be repaid to the lenders.

The costs for the maintenance and operation of the facilities concerned will arise from 1992 when water will start to be supplied, recurring over the whole period of project life.

Lastly, the capital for the replacement of some equipment in pumping stations and treatment plant will be required during 50 years of project life.

b. Benefits

Benefits are calculated by multiplying the volume of water to be consumed by water rate. The average rate will be Rs. 9.0 per thousand gallons. From 1992 to 1995 30.4 to 35.9 MGD, from 1996 to 2000 48.6 to 59.0 MGD and from 2001 on 70.9 to 73.9 MGD will be consumed. It is assumed that the rates of conveyance, treatment and distribution losses are 5%, 5% and 20 to 27% respectively.

c. Cash Flow Table

The third page of Table VI-4 shows the cash flow of the Project over 50 years of project life. It can be observed in the table that for 28 years since the commencement of the Project incremental benefits are negative, but from the 29nd year on they are positive and increase as years progress. So far as accumulated incremental benefits are concerned, they continue to be negative until the 37st years. That is to say, the capital recovery period is 36 years.

Further, it is to be observed that at the end of the project life accumulated costs and benefits come to Rs. 17,040 million and Rs. 27,260 million respectively. It means that accumulated incremental benefits are Rs. 10,219 million, and the benefits/costs ratio is 160%.

B. FIRR

a. Computation of FIRR

FIRR (financial internal rate of return) is a discount rate (discount factor) at which the present worth (present value) of financial costs equals that of financial benefits. That is to say, when the FIRR value is applied as the discount rate the accumulated incremental benefits in the cash flow table are rendered zero.

As shown in the first page of Table VI-4, the value of FIRR for the Khanpur water conduction facilities construction project works out to 6.6%.

At the same time, the water price covering the costs up to service reservoir has been calculated in order to put benefits in a balanced position.

If distribution costs are excluded, and along with it water rate is proportionately cut, the resultant FIRR value is put at 6.9% as shown in the first page of Table C.IV-11.

Generally speaking, a project can be said to be financially viable if the value of FIRR is beyond the annual rate of the opportunity cost of capital. It varies from one country to another, and from one period to another. It can be known from the prevailing annual rate of interest in bank loans. In Pakistan it is now around 14%.

What is to be stressed here is that the ultimate objective of the Project is to supply urban water to the public and industry, and in this sense it is basically different from an undertaking in the private sector.

If "no loss, no profit" principle is to be followed as a public project, theoretically the value of FIRR for the Project should be zero. However, to meet unexpected expenditure in the unforeseen future and to alleviate financial losses in the first half of project life, that is to say, to maintain financial safety and security a certain level of FIRR will be necessitated. It is to be determined side by side with water rate and lending terms on investment capital so as to keep a balance among them. Ultimately it settled down to about half the value of the prevailing bank rate in Pakistan.

b. B/C Ratio and NPW

FIRR is a discount rate at which benefits to costs ratio is one, and the net present worth is zero as described above. At zero percent discount rate B/C ratio is 160% and NPW Rs. 10,219 million as already observed. (The net present worth (= net present value) or NPW (= NPV) is another expression of accumulated incremental benefits.)

B/C ratios and NPW at different discount rates falling between 5% and the FIRR value are as shown in the first page of Table VI-4.

TABLE VI-1 PROPOSED WATER TARIFF STRUCTURE

- AVERAGE RATE: Rs. 9.0/000 gal. -

1. Water Tariff Structure

Consumption (000 gal.)	0	1	2	3	4	5	6
Rate/000 gal (Rs.)	2	2	4	20	36	46	(46)
Charges (Rs.)	0	2	4	8	28	64	110

2. Water Charges by Income

No.	Income (Rs./M)	Share of Household	Water Cons. /M(000 gal.)	Water Charges /M (Rs.)	Water Charge /000 gal.(Rs.)
1	300	4.4	2.9	7.6	2.6
2	750	22.3	3.6	20.0	5.6
3	1,500	38.0	4.1	31.6	7.7
4	2,500	17.9	4.3	38.8	9.0
5	3,500	9.8	4.8	56.8	11.8
6	4,500	3.5	5.1	68.6	13.5
7	5,270	4.1	7.1	160.1	22.5
Ave.	1,890	-	4.2	37.6	9.0

TABLE VI-2 PROPOSED WATER TARIFF STRUCTURE

- AVERAGE RATE: Rs. 6.49/000 gal.-

1. Water Tariff Structure

Consumption (000 gal.)	0–1	1–2	2–3	3–4	4–5	5–6	6–
Rate/000 gal (Rs.)	1.5	1.5	3	16	28	34	(34)

Consumption (000 gal.)	0	1	2	3	4	5	6
Charges (Rs.)	0	1.5	3	6	22	50	84

2. Water Charges by Income

No.	Income (Rs./M)	Share of Household	Water Cons. /M(000 gal.)	Water Charges /M (Rs.)	Water Charges /000 gal.(Rs.)
1	300	4.4	2.9	5.7	2.0
2	750	22.3	3.6	15.6	4.3
3	1,500	38.0	4.1	24.8	6.0
4	2,500	17.9	4.3	30.4	7.1
5	3,500	9.8	4.3	44.4	9.3
6	4,500	3.5	5.1	53.4	10.5
7	5,270	4.1	7.1	121.4	17.1
Ave.	1,890	-	4.2	27.3	6.5

TABLE VI-3 ABBREVIATION TABLE

- FINANCIAL EVALUATION -

Abbreviation	Meaning
WP	Water Price per Thousand Gal. (Rs.)
CCF	Construction Cost, Foreign Exchange Component (Rs.mln)
CCL	Construction Cost, Local Currency Component (Rs.mln)
OM	Operations and Maintenance Cost (Rs.mln)
MM	Number of Replacement Years
RY	Replacement Year
RCF	Replacement Cost, Foreign Exchange Component (Rs.mln)
RCL	Replacement Cost, Local Currency Component (Rs.mln)
I1	Annual Interest Rate, Foreign Exchange Component
PB1	Payback Period, Foreign Exchange Component (Years)
G1	Grace Period, Foreign Exchange Component (Years)
I2	Annual Interest Rate, Local Currency Component
PB2	Payback Period, Local Currency Component (Years)
G2	Grace Period, Local Currency Component (Years)
DC.RT	Discount Rate
PW.BF	Present Worth, Benefit (Rs.mln)
PW.CW	Present Worth, Raw Water Cost (Rs.mln)
PW.CC1	Present Worth, Construction Cost-Foreign Exchange Component (Rs.mln)
PW.CC2	Present Worth, Construction Cost-Local Currency Component (Rs.mln)
PW.CC	Present Worth, Construction Cost (Rs.mln)
PW.RC	Present Worth, Replacement Cost (Rs.mln)
PW.OM	Present Worth, Operations and Maintenance Cost (Rs.mln)
PW.CS	Present Worth, Cost (Rs.mln)
PW.NPW	Net Present Worth (Rs.mln)
BC.RT	Benefit Cost Ratio (%)
X	Discount Rate
YR	Year
BNFT	Benefit (Rs.mln)
CW	Raw Water Cost (Rs.mln)
CC	Construction Cost (Rs.mln)
RC	Replacement Cost (Rs.mln)
OM	Operations and Maintenance Cost (Rs.mln)
COST	Cost (Rs.mln)
CSFL	Incremental Benefit (Rs.mln)
AC.BF	Accumulated Benefit (Rs.mln)
AC.CW	Accumulated Raw Water Cost (Rs.mln)
AC.CC	Accumulated Construction Cost (Rs.mln)
AC.RC	Accumulated Replacement Cost (Rs.mln)
AC.OM	Accumulated Operations and Maintenance Cost (Rs.mln)
AC.CS	Accumulated Cost (Rs.mln)
AC.CF	Accumulated Incremental Benefit(Rs.mln)

TABLE VI-4 FINANCIAL EVALUATION (1)
- WP = 9, I1 = 5%, I2 = 11% -

[FINANCIAL EVALUATION]

< INPUT >

WP= 9

CCF 1	= 22.44	CCL 1	= 10.978
CCF 2	= 27.26	CCL 2	= 12.318
CCF 3	= 29.961	CCL 3	= 45.109
CCF 4	= 67.373	CCL 4	= 110.853
CCF 5	= 170.672	CCL 5	= 187.499
CCF 6	= 305.324	CCL 6	= 312.866
CCF 7	= 237.137	CCL 7	= 264.068
CCF 8	= 103.059	CCL 8	= 116.825
CCF 9	= 67.234	CCL 9	= 67.206
CCF 10	= 113.595	CCL 10	= 118.334
CCF 11	= 102.449	CCL 11	= 106.671
CCF 12	= 35	CCL 12	= 36
CCF 13	= 0	CCL 13	= 0
CCF 14	= 19.524	CCL 14	= 18.615
CCF 15	= 59.351	CCL 15	= 64.935
CCF 16	= 40.98	CCL 16	= 42.171
CCF 17	= 14.9	CCL 17	= 15.2

OM 8 = 32.81
OM 9 = 37.371
OM 10 = 42.001
OM 11 = 46.301
OM 12 = 55.796
OM 13 = 57.239
OM 14 = 57.239
OM 15 = 59.339
OM 16 = 61.439
OM 17 = 67.425
OM 18 = 68.19
OM 19 = 68.296

MM= 9

RY 1 = 22	RCF 1 = 0	RCL 1 = 63.499
RY 2 = 26	RCF 2 = 0	RCL 2 = 28.728
RY 3 = 27	RCF 3 = 0	RCL 3 = 42.32
RY 4 = 31	RCF 4 = 0	RCL 4 = 24.559
RY 5 = 36	RCF 5 = 0	RCL 5 = 11.701
RY 6 = 37	RCF 6 = 0	RCL 6 = 63.499
RY 7 = 41	RCF 7 = 0	RCL 7 = 28.727
RY 8 = 46	RCF 8 = 0	RCL 8 = 7.363
RY 9 = 47	RCF 9 = 0	RCL 9 = 42.32
I1= 0.05	PB1= 30	G1= 10
I2= 0.11	PB2= 25	G2= 5

< FIRR COMPUTATION >

DC.RT	PW.BF	PW.CW	PW.CC1	PW.CC2	PW.CC	PW.RC	PW.OM	PW.CS	NPW	BC.RT
0.050	5823	1094	1032	2308	3340	116	752	5304	+519	109
0.060	4477	876	863	1911	2774	81	605	4337	+139	103
0.070	3492	711	727	1590	2318	56	492	3579	-87	97

- Cont'd -

TABLE VI-4 FINANCIAL EVALUATION (2)

X= 0

< CASH FLOW ANALYSIS >

YR	BNFT	CW	CC	RC	OM	COST	CSFL	AC.BF	AC.CW	AC.CC	AC.RC	AC.OM	AC.CS	AC.CF
1	0	0	1	0	0	1	-1	0	0	1	0	0	1	-1
2	0	0	2	0	0	2	-2	0	0	3	0	0	3	-3
3	0	0	3	0	0	3	-3	0	0	7	0	0	7	-7
4	0	0	7	0	0	7	-7	0	0	14	0	0	14	-14
5	0	0	15	0	0	15	-15	0	0	30	0	0	30	-30
6	0	0	33	0	0	33	-33	0	0	64	0	0	64	-64
7	0	0	47	0	0	47	-47	0	0	112	0	0	112	-112
8	128	51	62	0	32	147	-18	128	51	174	0	32	259	-130
9	141	51	89	0	37	178	-37	270	103	264	0	70	438	-167
10	154	51	134	0	42	228	-74	424	155	399	0	112	666	-242
11	167	51	207	0	46	305	-137	591	207	606	0	158	971	-379
12	234	77	266	0	55	399	-165	826	284	872	0	214	1371	-545
13	254	77	292	0	57	427	-172	1081	362	1164	0	271	1798	-717
14	276	77	310	0	57	445	-169	1357	439	1475	0	328	2244	-886
15	298	77	346	0	59	483	-184	1656	517	1822	0	388	2727	-1071
16	323	77	385	0	61	524	-201	1979	595	2208	0	449	3252	-1273
17	401	103	404	0	67	575	-174	2380	698	2612	0	516	3828	-1447
18	428	103	407	0	68	579	-151	2808	802	3020	0	585	4407	-1598
19	445	103	412	0	68	584	-138	3254	905	3432	0	653	4991	-1737
20	460	103	429	0	68	601	-140	3714	1009	3862	0	721	5593	-1878
21	475	103	440	0	68	612	-137	4189	1112	4302	0	790	6205	-2015
22	490	103	442	0	68	614	-123	4680	1216	4745	0	858	6819	-2139
23	506	103	439	0	68	610	-104	5187	1319	5184	0	926	7430	-2243
24	523	103	436	0	68	608	-85	5710	1423	5621	0	994	8039	-2329
25	540	103	436	0	68	608	-68	6250	1526	6057	0	1063	8647	-2397
26	557	103	432	0	68	604	-47	6807	1630	6490	0	1131	9252	-2444
27	575	103	427	13	68	612	-37	7383	1733	6918	13	1199	9865	-2481
28	594	103	414	13	68	599	-5	7977	1837	7332	26	1268	10465	-2487
29	613	103	387	13	68	572	+41	8591	1940	7720	40	1336	11037	-2446
30	633	103	344	13	68	529	+104	9225	2044	8064	53	1404	11567	-2341
31	654	103	273	19	68	464	+189	9879	2147	8338	73	1472	12032	-2152
32	675	103	212	28	68	412	+262	10555	2251	8550	101	1541	12445	-1889
33	697	103	183	28	68	383	+314	11252	2354	8733	130	1609	12828	-1575
34	720	103	162	28	68	362	+357	11972	2458	8896	158	1677	13190	-1217
35	743	103	125	28	68	325	+417	12716	2561	9021	187	1746	13516	-799
36	767	103	84	33	68	290	+477	13484	2665	9106	220	1814	13806	-322
37	792	103	63	33	68	268	+523	14276	2768	9169	254	1882	14075	+201
38	818	103	56	33	68	262	+556	15095	2872	9226	288	1951	14337	+757
39	845	103	48	33	68	253	+591	15940	2975	9274	321	2019	14591	+1348
40	872	103	27	33	68	233	+639	16813	3079	9302	355	2087	14825	+1987
41	900	103	13	36	68	221	+679	17713	3182	9316	391	2155	15046	+2667
42	930	103	7	49	68	229	+700	18644	3286	9323	441	2224	15275	+3368
43	960	103	7	49	68	228	+731	19604	3389	9331	490	2292	15504	+4100
44	991	103	6	49	68	227	+764	20596	3493	9337	540	2360	15732	+4864
45	1023	103	2	49	68	224	+799	21619	3596	9340	589	2429	15956	+5663
46	1057	103	0	55	68	228	+828	22677	3700	9341	645	2497	16184	+6492
47	1091	103	0	42	68	214	+877	23768	3803	9341	687	2565	16398	+7369
48	1126	103	0	42	68	214	+912	24895	3907	9341	730	2634	16612	+8282
49	1163	103	0	42	68	214	+949	26059	4010	9341	772	2702	16826	+9232
50	1201	103	0	42	68	214	+987	27260	4114	9341	814	2770	17040	+10219

BC.RT= 159.972332403

- Cont'd -

TABLE VI-4 FINANCIAL EVALUATION (3)

X= 0.07

< CASH FLOW ANALYSIS >

YR	BNFT	CW	CC	RC	OM	COST	CSFL	AC.BF	AC.CW	AC.CC	AC.RC	AC.OM	AC.CS	AC.CF
1	0	0	1	0	0	1	-1	0	0	1	0	0	1	-1
2	0	0	2	0	0	2	-2	0	0	3	0	0	3	-3
3	0	0	3	0	0	3	-3	0	0	6	0	0	6	-6
4	0	0	5	0	0	5	-5	0	0	12	0	0	12	-12
5	0	0	11	0	0	11	-11	0	0	23	0	0	23	-23
6	0	0	22	0	0	22	-22	0	0	45	0	0	45	-45
7	0	0	29	0	0	29	-29	0	0	75	0	0	75	-75
8	75	30	36	0	19	85	-10	75	30	112	0	19	161	-86
9	76	28	48	0	20	97	-20	151	58	160	0	39	258	-106
10	78	26	68	0	21	116	-37	230	84	229	0	60	374	-144
11	79	24	98	0	21	145	-65	309	109	327	0	82	519	-209
12	104	34	118	0	24	177	-73	413	143	445	0	107	697	-283
13	105	32	121	0	23	177	-71	519	175	567	0	131	874	-354
14	107	30	120	0	22	172	-65	626	205	687	0	153	1047	-420
15	108	28	125	0	21	175	-67	735	234	813	0	175	1222	-487
16	109	26	130	0	20	177	-68	844	260	944	0	195	1400	-555
17	126	32	128	0	21	182	-55	971	293	1072	0	217	1582	-610
18	126	30	120	0	20	171	-44	1098	323	1192	0	237	1753	-655
19	123	28	114	0	18	161	-38	1221	352	1306	0	256	1915	-693
20	118	26	110	0	17	155	-36	1340	379	1417	0	273	2070	-730
21	114	24	106	0	16	147	-33	1455	404	1524	0	290	2218	-763
22	110	23	99	0	15	138	-27	1565	427	1623	0	305	2357	-791
23	106	21	92	0	14	128	-22	1672	449	1716	0	320	2486	-813
24	103	20	86	0	13	120	-16	1775	469	1802	0	333	2606	-830
25	99	19	80	0	12	112	-12	1875	488	1883	0	346	2718	-842
26	96	17	74	0	11	104	-8	1971	506	1957	0	357	2822	-850
27	92	16	68	2	10	98	-5	2064	523	2026	2	368	2920	-856
28	89	15	62	2	10	90	+0	2153	538	2088	4	379	3011	-857
29	86	14	54	1	9	80	+5	2239	553	2143	6	388	3091	-851
30	83	13	45	1	8	69	+13	2323	566	2188	7	397	3161	-838
31	80	12	33	2	8	57	+23	2403	579	2222	10	406	3218	-814
32	77	11	24	3	7	47	+30	2480	591	2246	13	414	3265	-784
33	74	11	19	3	7	41	+33	2555	602	2266	16	421	3306	-751
34	72	10	16	2	6	36	+35	2627	613	2282	19	428	3343	-715
35	69	9	11	2	6	30	+39	2697	622	2294	22	434	3373	-676
36	67	9	7	2	5	25	+41	2764	631	2301	25	440	3399	-634
37	64	8	5	2	5	21	+42	2829	640	2306	27	446	3421	-591
38	62	7	4	2	5	20	+42	2892	648	2311	30	451	3441	-548
39	60	7	3	2	4	18	+42	2952	655	2314	32	456	3459	-506
40	58	6	1	2	4	15	+42	3010	662	2316	35	460	3474	-464
41	56	6	0	2	4	13	+42	3066	668	2317	37	465	3488	-421
42	54	6	0	2	3	13	+40	3121	674	2317	40	469	3501	-380
43	52	5	0	2	3	12	+39	3173	680	2318	42	472	3514	-340
44	50	5	0	2	3	11	+38	3224	685	2318	45	476	3526	-301
45	48	4	0	2	3	10	+38	3272	690	2318	47	479	3536	-263
46	47	4	0	2	3	10	+36	3319	695	2318	50	482	3546	-226
47	45	4	0	1	2	8	+36	3365	699	2318	51	485	3555	-190
48	43	4	0	1	2	8	+35	3409	703	2318	53	488	3564	-155
49	42	3	0	1	2	7	+34	3451	707	2318	55	490	3571	-120
50	40	3	0	1	2	7	+33	3492	711	2318	56	492	3579	-87

BC.RT= 97.5691116904

TABLE VI-5 ABBREVIATION TABLE
- ECONOMIC EVALUATION -

1) Input

CC	:	Construction Costs (Rs. million)
Mm	:	Number of Replacement Years
RY	:	Replacement Year
RC	:	Replacement Costs (Rs. million)
OMC	:	Operation & Maintenance Costs (Rs. million)

2) IRR Computation

DC.RT:	Discount Rate (= Discount Factor)
PW.BF:	Present Worth (= Present Value) of Benefit (Rs. million)
RW.CS:	Present Worth (= Present Value) of Cost (Rs. million)
NPW :	Net Present Worth (= Net Present Value) (Rs. million)
BC.RT:	Benefit Cost Ratio (%)

3) Cash Flow Analysis

YR :	Year
BNFT :	Benefit (Rs. million)
COST :	Cost (Rs. million)
CSFL :	Cash Flow (Rs. million)
AC.BF:	Accumulated Benefit (Rs. million)
AC.CS:	Accumulated Cost (RS. million)
AC.CF:	Accumulated Cash Flow (Rs. million)

TABLE VI-6 ECONOMIC EVALUATION (1)

< ECONOMIC EVALUATION >

< INPUT >

CC 1= 23.418
CC 2= 39.578
CC 3= 65.631
CC 4= 151.861
CC 5= 303.69
CC 6= 509.935
CC 7= 396.121
CC 8= 179.079
CC 9= 107.904
CC 10= 189.796
CC 11= 173.673
CC 12= 60.2
CC 13= 0
CC 14= 34.231
CC 15= 108.468
CC 16= 71.349
CC 17= 25.5

OM 8= 32.81
OM 9= 37.371
OM 10= 42.001
OM 11= 46.301
OM 12= 55.796
OM 13= 57.239
OM 14= 57.239
OM 15= 59.339
OM 16= 61.439
OM 17= 67.425
OM 18= 68.19
OM 19= 68.296

MM= 9
RY 1= 22 RC 1= 63.499
RY 2= 26 RC 2= 28.728
RY 3= 27 RC 3= 42.32
RY 4= 31 RC 4= 24.559
RY 5= 36 RC 5= 11.701
RY 6= 37 RC 6= 63.499
RY 7= 41 RC 7= 28.728
RY 8= 46 RC 8= 7.363
RY 9= 47 RC 9= 42.32

< IRR COMPUTATION >

DC.RT	PW.BF	PW.CS	NPW	BC.RT
0.050	4199	3401	798	123
0.060	3229	3126	103	103
0.070	2518	2900	-382	87

%= 0.06

< CASH FLOW ANALYSIS >

YR	BNFT	COST	CSFL	AC.BF	AC.CS	AC.CF
1	0	908	-908	0	908	-908
2	0	35	-35	0	943	-943
3	0	55	-55	0	998	-998
4	0	120	-120	0	1118	-1118
5	0	227	-227	0	1345	-1345
6	0	359	-359	0	1705	-1705
7	0	263	-263	0	1968	-1968
8	58	133	-75	58	2101	-2043
9	60	86	-26	119	2187	-2068
10	62	129	-67	181	2316	-2136
11	64	116	-52	244	2432	-2188
12	84	58	26	328	2490	-2162
13	86	27	59	415	2517	-2102
14	88	40	48	503	2557	-2055
15	90	70	20	592	2627	-2035
16	92	52	40	684	2680	-1995
17	107	35	73	792	2714	-1922
18	108	24	84	900	2738	-1838
19	106	23	84	1006	2761	-1754
20	103	21	82	1110	2782	-1672
21	101	20	81	1210	2802	-1592
22	98	37	62	1309	2839	-1530
23	96	18	78	1404	2856	-1452
24	93	17	76	1497	2873	-1376
25	91	16	75	1588	2889	-1301
26	88	21	67	1676	2911	-1234
27	86	23	63	1763	2933	-1171
28	84	13	70	1846	2947	-1100
29	82	13	69	1928	2959	-1031
30	80	12	68	2008	2971	-964
31	77	15	62	2085	2987	-901
32	75	11	65	2161	2997	-836
33	74	10	64	2234	3007	-773
34	72	9	62	2306	3017	-711
35	70	9	61	2376	3025	-650
36	68	10	58	2444	3035	-592
37	66	15	51	2510	3051	-541
38	64	7	57	2574	3058	-484
39	63	7	56	2637	3065	-428
40	61	7	55	2698	3072	-373
41	60	9	51	2758	3081	-323
42	58	6	52	2816	3086	-271
43	57	6	51	2872	3092	-220
44	55	5	50	2927	3097	-170
45	54	5	49	2981	3102	-121
46	52	5	47	3033	3107	-74
47	51	7	44	3084	3115	-30
48	50	4	45	3134	3119	15
49	48	4	44	3182	3123	59
50	47	4	43	3229	3126	103

BC.RT= 103.2833508047

- Cont'd -

TABLE VI-6 ECONOMIC EVALUATION (2)

X= 0

< CASH FLOW ANALYSIS >

YR	BNFT	COST	CSFL	AC.BF	AC.CS	AC.CF
1	0	910	-910	0	910	-910
2	0	40	-40	0	949	-949
3	0	66	-66	0	1015	-1015
4	0	152	-152	0	1167	-1167
5	0	304	-304	0	1470	-1470
6	0	510	-510	0	1980	-1980
7	0	396	-396	0	2376	-2376
8	93	212	-119	93	2588	-2495
9	102	145	-44	195	2734	-2539
10	111	232	-121	306	2965	-2659
11	121	220	-99	427	3185	-2758
12	169	116	53	596	3301	-2705
13	184	57	127	780	3359	-2579
14	199	91	108	979	3450	-2471
15	215	168	48	1194	3618	-2424
16	233	133	100	1427	3751	-2323
17	289	93	196	1717	3844	-2127
18	309	68	241	2025	3912	-1886
19	321	68	253	2347	3980	-1633
20	332	68	264	2679	4048	-1370
21	343	68	274	3021	4117	-1095
22	354	132	222	3375	4248	-873
23	365	68	297	3740	4317	-576
24	377	68	309	4118	4385	-267
25	389	68	321	4507	4453	54
26	402	97	305	4909	4550	359
27	415	111	305	5324	4661	663
28	429	68	360	5753	4729	1024
29	443	68	374	6196	4797	1398
30	457	68	389	6653	4866	1787
31	472	93	379	7124	4959	2166
32	487	68	419	7612	5027	2585
33	503	68	435	8114	5095	3019
34	519	68	451	8634	5164	3470
35	536	68	468	9170	5232	3938
36	554	80	474	9724	5312	4412
37	572	132	440	10295	5444	4852
38	590	68	522	10886	5512	5374
39	609	68	541	11495	5580	5915
40	629	68	561	12124	5649	6476
41	650	97	553	12774	5746	7028
42	671	68	602	13444	5814	7631
43	693	68	624	14137	5882	8255
44	715	68	647	14852	5950	8902
45	738	68	670	15590	6019	9572
46	762	76	687	16353	6094	10258
47	787	111	676	17140	6205	10935
48	813	68	744	17952	6273	11679
49	839	68	771	18791	6342	12450
50	866	68	798	19658	6410	13248

BC.RT= 306.6802480636

6.4. Project Justification

6.4.1. Economic Justification

A. Economic Evaluation

The internal economic rate of return (= EIRR) is an index assessing the feasibility of a project from the viewpoint of national economy.

Annual benefits are computed by multiplying the volume of water to be sold in a given year by the unitary economic value of water (= Rs. 6.49/000 gal.). They are added together over the entire period of project life.

Project costs are composed of construction, operations/maintenance and replacement costs of Khanpur water storage, conduction, treatment and distribution facilities.

The construction costs, allocable to urban water, of Khanpur Dam including Left Bank Canal is incorporated in the costs. They amount to Rs. 876.106 million at 1984 prices. (Refer to Table C.IV-2)

Costs are estimated on a yearly basis and ultimately aggregated over the entire period of project life.

In totalizing yearly benefits and costs a discount rate that equalizes the present worths of both of them is sought and found.

The value of EIRR for the Project has been computed at 6.2% as shown in Table VI-6. If the costs of distribution facilities including mains and networks are excluded from the project costs because of uncertain elements involved in their estimation, then it works out to 5.5% as shown in Table C.VI-5. It is to be remembered that the unitary economic value of water is cut to Rs. 3.75 in calculating the second value of EIRR.

The costs over the entire period of project life amount to Rs. 6,410 million. When distribution costs are excluded they come to Rs. 3,705 million. The coefficient of 0.578 deriving from the cost ratio (3,705/6,410) is applied to Rs. 6.49, resulting in Rs. 3.75.

The EIRR value of 6.2% is low compared with standard levels of the rate of the opportunity cost of capital which fall between 8 and 15%. It is to be stressed, however, that 5 to 6% is a standard level as an EIRR value for a project in water supply sector.

The value is based upon the project benefits calculated from consumers' willingness to pay for water supply service. It is, as has been seen, Rs. 6.49 per thousand gallons. It is to be reminded that it expresses the very minimum of the unitary value of water, because such major benefits as health and time saving benefits may not be included in it, and also because indirect benefits in the form of far-reaching socio-economic impacts are excluded from it.

Supposing all the benefits deriving from water supply are quantitatively expressed, the unitary economic value of water will be pushed up to a much higher level, which in turn will bring up the value of EIRR to a proper and reasonable height.

It is not uncommon in a project for the construction of a social infrastructure and whose primary objective is the provision of public service to have an EIRR value in the range of 3 to 5%, and in spite of it to be judged feasible because of the magnitude of expected intangible benefits.

B. Sensitivity Analysis

Sensitivity analysis has been conducted to see how the value of EIRR is affected if conditions and premises under which it is computed are changed. This is necessary because a project is a future undertaking and there are inevitably a lot of uncertainties in the future.

Firstly, an analysis has been made to observe the effect to EIRR if the completion of the first phase of construction works is delayed. As a result of the analysis it has been found that one year delay lowers EIRR by 0.1% to 6.1%, and 2 years delay brings down the index by 0.2% to 6.0%. This comparatively light negative impact of the delays in tunnel construction will be mainly accounted for by the fact that only 50% of Khanpur urban water will be supplied at the end of Phase I.

The second analysis is to find how it will affect EIRR if an overrun of construction costs occurs. The result reveals that the overrun by 10% reduces EIRR by 0.3% to 5.9%. If it is by 20%, the index goes down by 0.5% to 5.7%. It shows a considerable extent to which EIRR is affected if estimate of construction costs is not proper and exact. But the Study Team is confident that its estimate is correct and firm, and any overrunning will not happen.

The third analysis is based on the supposition that Khanpur water is not sold 100%. Supposing it is demanded by 90%, EIRR is reduced by 0.6% to 5.6%. If only 80% is sold, the feasibility index is further reduced by 1.3% to 4.9%. It testifies to the importance of the study of water demand and supply.

Lastly, an analysis has been performed, supposing the situation where all the negative aspects in the preceding three cases are combined together. One instance is the combination of one year completion delay of Phase I, 10% overrun of construction costs and water sale ratio of 90%. In the next one, 2 years delay, 20% overrun and water sale of 80% are put together.

Computation resulted in the EIRR value of 5.3% for the first instance, and 4.3% in the second. If things go bad as in the two instances, the feasibility of the Project will be strongly affected, though not to the extent that it is rendered nil. Besides, it is improbable that things will turn out altogether adverse and negative.