Project Cost Comparison

(Unit: Rs. Million)

Item	Alternative I-C	Alternative II-C	Alternative III
Civil Works	1,742.6	1,792.2	1,569.2
Others	341.7	322.8	281.3
Contingencies	1,745.7	1,795.0	1,599.5
Total	3,830.0	3,910.0	3,450.0

4.3.2. 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 (refer to Table B.IV-16);

Alternative	Construction Costs (Rs. Million)	Construction Costs Ratio	O & M Cost/Year (Rs. Million)	O & M Cost/Year 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

TABLE B.IV-8 CONSTRUCTION COST BY WORKS

-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 plant	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	1,977.4	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.

TABLE B.IV-9 COST OF RAW WATER RESERVOIR

Unit : Rs 1,000

Name of reservoir	Earth Work	Structures	Overhead	Total
Sang Jani (1.1. MCM)	41,789	24,611	28,552	94,952
Khuram Paracha (1.1 MCM)	57,652	15,880	36,399	109,931
Julian (0.55 MCM)	28,826	9,752	19,097	57,675

Note: Sang Jani reservoir for Alt. I-A, -B and -C.
Khuram Paracha reservoir for Alt. II-A,
Julian reservoir for Alt. II-B.

TABLE B.IV-10 COST OF FEEDER FACILITIES

Unit : Rs. 1,000

Alt.	L.B.C Improve	Feeder Conduit	Feeder Tunnel	Intake Tower	Division Dam	Syphon	Pipe Work	Others*	Total
I-A	8,942	-	9,000	-	-	-	-	9,421	27,363
I-B	8,942	-	9,000	-	-	-	-	9,421	27,363
I-C	8,942	-	9,000	-	-	-	-	9,421	27,363
II-A	7,017	11,070	-	-	-	-	-	10,019	28,106
II-B	3,195	1,880	-	-	-	-	-	4,275	9,350
II-C	-	5,400	-	-	8,340	8,400	-	12,245	34,385
II-D	-	-	-	-	8,340	-	-	4,170	12,510
III	-	-	-	8,533	-	-	5,805	30,142	44,480

* Note : 1) Cost of others includes some miscellaneous works, temporary works and overhead charges.

2) Cost of others for III (Rs. 30,142,000) includes the cost of Rs. 16,318,00 for valves (dia.1,000 mm) and civil works for pressure break basin.

TABLE B.IV-11 COST OF TUNNEL

Alt.	Type-A		Type-B		Type-C		Shaft	Others*	Total	Remark
	Length	Cost	Length	Cost	Length	Cost				
II-A	1,555 m	15,895	543 m	9,339	502 m	11,154	-	16,456	52,844	Dia 2100 mm
II-B	3,200	32,710	1,860	31,988	1,140	25,331	2,610	41,541	134,180	Dia 2100 mm
II-C	2,970	30,359	1,446	24,868	1,094	24,309	2,610	36,867	119,013	Dia 2100 mm
II-D	2,715	27,753	1,191	20,483	1,094	24,309	2,610	36,742	111,897	Dia 2100 mm
III	5,060	58,038	3,906	72,628	2,734	65,881	13,672	110,513	320,732	Dia 2100 mm 2400 "

* Note : Cost of others includes temporary works and overhead charges.

TABLE B.IV-12 COST OF WATER TREATMENT PLANT

Unit : Rs 1000

Name of Plant	Earth Work	Concrete Work	Pipe & Equipment	Others	Total
Sang Jani	46,296	166,320 2/	147,556	82,108	442,280
Shah Allahditta	131,875 1/	134,081	147,556	127,891	541,403
Golra	31,452	117,138	147,556	101,547	397,693

Note: 1/ High cost of earth works due to mostly rock excavation.

2/ Feeder pipe cost of 2.0 km long between raw water reservoir and plant is included into this estimation.

TABLE B.IV-13 COST OF PUMPING STATION

Unit: Rs 1000

Alternative	Pump Station	Pump Plant	Discharge Pool	Total
I-A	17,798	179,819	20,479	218,096
I-B	18,511	226,021	18,963	263,495
I-C	24,366	216,028	22,591	262,985
II-A	45,916	193,247	27,257	266,420
II-B	53,488	187,657	26,227	267,372
II-C	27,782	176,217	35,930	239,929
II-D	58,182	205,753	24,009	287,944
III	11,259	135,001	-	146,260

TABLE B.IV-14 COST OF PIPELINE

Unit : Rs 1000

Alternative	Rising Main	Gravity	Distribution	Total
I-A	285,697	99,556	406,321	791,574
I-B	412,207	112,102	199,057	723,366
I-C	366,524	124,244	206,327	697,095
II-A	35,851	147,107	406,303	589,261
II-B	37,350	90,455	406,303	534,108
II-C	42,670	115,353	406,303	564,326
II-D	27,458	148,879	406,303	582,640
III	37,460	92,307	273,094	402,861

TABLE B.IV-15 COST OF SERVICE RESERVOIR

Unit : Rs 1000

Alternative	Name	Civil Work	Service Reservoir	Total
I - A	Shah Allah.	3,432	55,272	58,704
	D-13	153	13,464	13,617
	G-13	290	159,936	160,226
	Total	3,875	228,672	232,547
I - B	E - 14	51	38,514	38,565
	Shah Allah.	3,432	55,272	58,704
	Tomar	4,081	80,960	85,041
	Total	7,564	174,746	182,310
I - C	Shah Allah	3,432	55,272	58,704
	D-13	153	13,464	13,617
	Tomar	4,081	80,960	85,041
	Total	7,666	149,696	157,362
III	Golra (1)	33,017	48,804	81,821
	" (2)	12,687	13,464	26,151
	H - 11	423	80,960	81,383
	Total	46,127	143,228	189,355

Note: Total Costs for Alt. II-A,B,C and D are same as Alt. 1-A

TABLE B.IV-16 OPERATION AND MAINTENANCE COST

Unit : Rs. 1,000/year

Alterantive	Pumping Station	Treatment Plant 1/	Others2/	Total
I-A	35,785	19,090	16,876	71,751
I-B	34,081	19,090	16,322	69,493
I-C	32,543	19,090	15,977	67,610
II-A	37,099	19,090	17,627	73,816
II-B	34,007	19,090	17,048	70,145
II-C	27,455	19,090	16,617	63,162
II-D	26,817	19,090	16,899	62,806
III	13,194	19,090	14,543	46,827

Note: 1/ Chemical and other material of about 12.8 million rupees is included in the cost of water treatment plant.

2/ Others mean maintenance and repair cost of overall water supply systems and administration cost served by the Khanpur Water

3/ Rs. 98,477,000/year of expenses to purchase raw water from Khanpur porject are not included.

4.4. Selective Comparison of Alternatives

4.4.1. Preliminary Comparison of Sub-alternative

A. Economic Consideration

Economic internal rate of return (EIRR) as one of the index 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 the 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, in contrast to common use systems for Alternative I-A and I-B. Separate systems may permit easier operation and maintenance than the systems of Alternative 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 Alternative II-A, II-B, and II-C.

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

- Alternative 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 of EIRR is slight.

4.4.2. Comparison of Alternative I, II and III.

Alternative I is represented by I-C, and Alternative II by II-C, respectively as mentioned above. The construction costs and EIRR are again summarized as below;

Alternative	Construction Cost (Rs. Million)	Ratio	EIRR (%)
I	1,917	1.11	7.05
II	1,971	1.14	7.02
III	1,726	1.00	7.56

The followings are summary of comparison of Alternative I, II and III in respect to engineering advantage and disadvantage:

A. Alternative I

(1) Advantage

i. The existing Left Bank Canal would be effectively utilized as originally designed.

ii. It is technically possible to shorten the construction times, when necessity arises, by starting the construction works from the several job sites at the same time.

iii. Distribution of treated water to both cities would be easy because of separate distribution systems.

(2) Disadvantage

i. The existing Left Bank Canal needs careful maintenance of canals that are mostly composed of open conduits, and operation of water distribution to different sectors of urban water, irrigation and industry.

ii. It involves constructing three railway crossings including two tunnels and one aqueduct. In driving tunnels beneath the railway, skillful workmanship is required, as well as reinforcement of the railway to be crossed.

iii. The length of pressure pipelines, especially high pressure pipelines is longest among alternatives.

iv. The Left Bank Canal would be rehabilitated and improved with the Project, however, careful maintenance would still be needed against slope erosion, silting in canals and cross drainage conduits, piping and so on.

B. Alternative II.

(1) Advantage

i. Diversion works and conduction mains would be constructed for exclusive use of urban water supply.

ii. The length of conduction mains is shortest among three alternatives which might bring about easy maintenance of conduction mains.

(2) Disadvantage

i. The Left Bank Canal that was constructed for the multipurpose uses would not be utilized for urban water supply scheme. Operation and maintenance of the Left Bank Canal might be a burden to the remaining sectors of irrigation and industry.

ii. Two tunnels with the length of two km and three km respectively would be constructed, for which more sillful workmanship than that for Alternative I would be required.

iii. In addition to Khanpur dam, proposed Tarmakki diversion dam needs stationing staffs for operation and maintenance of facilities.

iv. Regulating capacities of discharge flowing into the main pumping station is less than that of Alternative I, because no raw water reservoir is constructed.

v. There exists possibility that flow discharge from springs around Shah Allah Ditta might be reduced during the period of tunnel construction.

C. Alternative III

(1) Advantage

i. Diversion works and conduction mains would be constructed for exclusive use of urban water supply.

ii. About 53% of water could be distributed by gravity to the service area.

iii. Skillful civil engineering technology is required for construction of tunnels; however, the construction of tunnels shall contribute to transfer of such technology.

(2) Disadvantage

i. The construction of tunnel shall not be completed by the end of phase I period.

ii. Skillful civil engineering technology shall be required for construction of conduction mains such as intake tower to be constructed in the reservoir, pressure break basin, especially.

iii. Prior to the construction works, detailed investigation is necessary with regard to engineering such as the properties of rock, faults, fracture zone, groundwater table, permeability, unconsolidated layers, and so on, together with a detailed construction plan for the proposed intake tower.

iv. It is hardly possible to shorten the construction times for tunnel and feeder facilities, even if sufficient disbursement of budget is made.

v. There is possibility of accident in construction of tunnels, when compared to other construction works, Alternative III involves providing high vertical shaft and it needs a construction period of more than four years to complete tunnel works. Once the ground water flows into the tunnel, special countermeasures should be taken, resulting in delay of construction works.

D. Conclusions

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

2) It will take five years under Alternative 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 the 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:

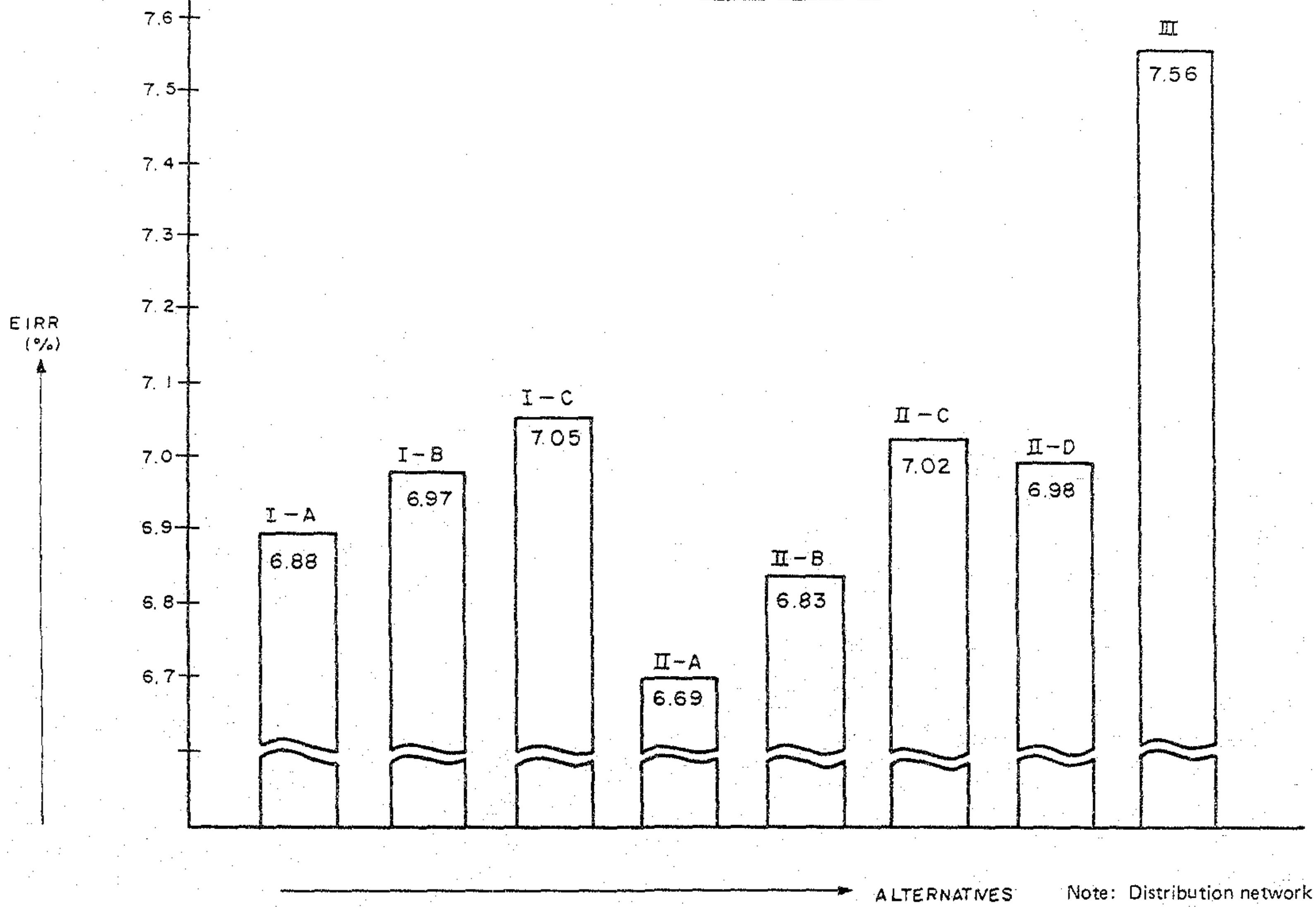
(Unit: Rs. Million)

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

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.

FIGURE B.IV-26 EIRR BY ALTERNATIVES



Note: Distribution network costs are not incorporated.

TABLE B.IV-17 EIRR BY ALTERNATIVES (1)

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)
PW.CS	: Present Worth (=Present Value) of Cost (Rs. million)
NPW	: Net Present Worth (= Net Present Value) (Rs. million)
BC.RT	: Benefit Cost Ratio (%)

Note: Distribution network costs are not incorporated.

ALT. < I - A >

< INPUT >

CC 1= 0
CC 2= 113.308
CC 3= 396.578
CC 4= 396.578
CC 5= 226.616
CC 6= 0
CC 7= 43.373
CC 8= 151.803
CC 9= 151.804
CC 10= 86.745
CC 11= 0
CC 12= 12.08
CC 13= 42.279
CC 14= 42.278
CC 15= 24.16

MM= 5
RY 1= 21 RC 1= 2.366
RY 2= 26 RC 2= 0.584
RY 3= 31 RC 3= 42.397
RY 4= 36 RC 4= 23.956
RY 5= 41 RC 5= 13.224

OMC= 71.751

< IRR COMPUTATION >

DC.RT	PW.BF	PW.CS	NPW	BC.RT
0.050	4324	3062	1262	141
0.051	4211	3038	1173	139
0.052	4102	3015	1087	136
0.053	3996	2993	1004	134
0.054	3894	2971	923	131
0.055	3795	2949	845	129
0.056	3698	2928	770	126
0.057	3605	2908	698	124
0.058	3515	2887	627	122
0.059	3427	2868	559	120
0.060	3342	2848	494	117
0.061	3260	2830	430	115
0.062	3180	2811	369	113
0.063	3103	2793	310	111
0.064	3028	2775	252	109
0.065	2955	2758	196	107
0.066	2884	2741	143	105
0.067	2815	2725	91	103
0.068	2749	2708	40	101
0.069	2684	2692	-8	100

TABLE B.IV-17 EIRR BY ALTERNATIVES (2)

ALT. < I - B >

< INPUT >

CC 1= 0
CC 2= 114.329
CC 3= 400.15
CC 4= 400.15
CC 5= 228.656
CC 6= 0
CC 7= 39.531
CC 8= 138.36
CC 9= 138.36
CC 10= 79.063
CC 11= 0
CC 12= 9.356
CC 13= 32.744
CC 14= 32.744
CC 15= 18.711

MM= 5
RY 1= 21 RC 1= 2.366
RY 2= 26 RC 2= 0.584
RY 3= 31 RC 3= 46.041
RY 4= 36 RC 4= 24.867
RY 5= 41 RC 5= 17.252

OMC= 69.493

< IRR COMPUTATION >

DC.RT	PW.BF	PW.CS	NPW	BC.RT
0.050	4324	3007	1317	144
0.051	4211	2984	1227	141
0.052	4102	2962	1140	139
0.053	3996	2940	1056	136
0.054	3894	2919	975	133
0.055	3795	2898	897	131
0.056	3698	2878	821	129
0.057	3605	2858	747	126
0.058	3515	2839	676	124
0.059	3427	2820	608	122
0.060	3342	2801	541	119
0.061	3260	2783	477	117
0.062	3180	2765	415	115
0.063	3103	2748	355	113
0.064	3028	2731	297	111
0.065	2955	2714	241	109
0.066	2884	2698	186	107
0.067	2815	2682	133	105
0.068	2749	2666	82	103
0.069	2684	2651	33	101
0.070	2621	2636	-15	99

ALT. < I - C >

< INPUT >

CC 1= 0
CC 2= 112.816
CC 3= 394.854
CC 4= 394.854
CC 5= 225.631
CC 6= 0
CC 7= 37.65
CC 8= 131.776
CC 9= 131.776
CC 10= 75.301
CC 11= 0
CC 12= 9.304
CC 13= 32.564
CC 14= 32.565
CC 15= 18.608

MM= 5
RY 1= 21 RC 1= 2.366
RY 2= 26 RC 2= 0.584
RY 3= 31 RC 3= 40.275
RY 4= 36 RC 4= 24.378
RY 5= 41 RC 5= 16.763

OMC= 67.61

< IRR COMPUTATION >

DC.RT	PW.BF	PW.CS	NPW	BC.RT
0.050	4324	2958	1366	146
0.051	4211	2936	1275	143
0.052	4102	2915	1188	141
0.053	3996	2893	1103	138
0.054	3894	2873	1021	136
0.055	3795	2853	942	133
0.056	3698	2833	865	131
0.057	3605	2814	791	128
0.058	3515	2795	720	126
0.059	3427	2776	651	123
0.060	3342	2758	584	121
0.061	3260	2741	519	119
0.062	3180	2724	456	117
0.063	3103	2707	396	115
0.064	3028	2690	337	113
0.065	2955	2674	281	110
0.066	2884	2658	226	108
0.067	2815	2643	173	107
0.068	2749	2628	121	105
0.069	2684	2613	71	103
0.070	2621	2598	23	101
0.071	2560	2584	-23	99

TABLE B.IV-17 EIRR BY ALTERNATIVES (3)

ALT. < II - C >

< INPUT >

CC 1= 0
CC 2= 121.918
CC 3= 426.713
CC 4= 426.713
CC 5= 243.836
CC 6= 0
CC 7= 30.646
CC 8= 107.26
CC 9= 107.26
CC 10= 61.292
CC 11= 0
CC 12= 13.61
CC 13= 47.636
CC 14= 47.636
CC 15= 27.221

MM= 5
RY 1= 21 RC 1= 2.366
RY 2= 26 RC 2= 0.584
RY 3= 31 RC 3= 39.819
RY 4= 36 RC 4= 23.485
RY 5= 41 RC 5= 12.753

OMC= 63.162

< IRR COMPUTATION >

DC.RT	PW.BF	PW.CS	NPW	BC.RT
0.050	4324	2958	1366	146
0.051	4211	2937	1274	143
0.052	4102	2917	1186	141
0.053	3996	2896	1100	138
0.054	3894	2877	1017	135
0.055	3795	2857	937	133
0.056	3698	2838	860	130
0.057	3605	2820	785	128
0.058	3515	2802	713	125
0.059	3427	2784	643	123
0.060	3342	2767	575	121
0.061	3260	2750	510	119
0.062	3180	2733	447	116
0.063	3103	2717	385	114
0.064	3028	2701	326	112
0.065	2955	2686	269	110
0.066	2884	2671	213	108
0.067	2815	2656	160	106
0.068	2749	2641	108	104
0.069	2684	2627	57	102
0.070	2621	2613	9	100
0.071	2560	2599	-39	99

ALT. < II - D >

< INPUT >

CC 1= 0
CC 2= 123.12
CC 3= 430.919
CC 4= 430.919
CC 5= 246.239
CC 6= 0
CC 7= 32.076
CC 8= 112.266
CC 9= 112.266
CC 10= 64.152
CC 11= 0
CC 12= 13.794
CC 13= 48.279
CC 14= 48.279
CC 15= 27.588

MM= 5
RY 1= 21 RC 1= 2.366
RY 2= 26 RC 2= 0.584
RY 3= 31 RC 3= 46.499
RY 4= 36 RC 4= 25.155
RY 5= 41 RC 5= 14.423

OMC= 62.806

< IRR COMPUTATION >

DC.RT	PW.BF	PW.CS	NPW	BC.RT
0.050	4324	2977	1348	145
0.051	4211	2955	1256	142
0.052	4102	2935	1168	140
0.053	3996	2914	1082	137
0.054	3894	2895	999	135
0.055	3795	2875	919	132
0.056	3698	2856	842	129
0.057	3605	2838	768	127
0.058	3515	2819	695	125
0.059	3427	2802	626	122
0.060	3342	2784	558	120
0.061	3260	2767	493	118
0.062	3180	2751	430	116
0.063	3103	2734	368	113
0.064	3028	2718	309	111
0.065	2955	2703	252	109
0.066	2884	2687	197	107
0.067	2815	2672	143	105
0.068	2749	2658	91	103
0.069	2684	2643	41	102
0.070	2621	2629	-8	100

TABLE B.IV-17 EIRR BY ALTERNATIVES (4)

ALT. < II - A >

< INPUT >

CC 1= 0
CC 2= 130.268
CC 3= 455.936
CC 4= 455.936
CC 5= 260.535
CC 6= 0
CC 7= 32.275
CC 8= 112.963
CC 9= 112.963
CC 10= 64.55
CC 11= 0
CC 12= 13.732
CC 13= 48.061
CC 14= 48.061
CC 15= 27.463

MM= 5
RY 1= 21 RC 1= 2.366
RY 2= 26 RC 2= 0.584
RY 3= 31 RC 3= 44.234
RY 4= 36 RC 4= 24.588
RY 5= 41 RC 5= 13.856

OMC= 73.816

< IRR COMPUTATION >

DC.RT	PW.BF	PW.CS	NPW	BC.RT
0.050	4324	3164	1160	137
0.051	4211	3140	1071	134
0.052	4102	3116	986	132
0.053	3996	3093	903	129
0.054	3894	3071	823	127
0.055	3795	3049	746	124
0.056	3698	3027	671	122
0.057	3605	3006	599	120
0.058	3515	2986	529	118
0.059	3427	2966	462	116
0.060	3342	2946	396	113
0.061	3260	2927	333	111
0.062	3180	2908	272	109
0.063	3103	2889	213	107
0.064	3028	2871	156	105
0.065	2955	2854	101	104
0.066	2884	2836	48	102
0.067	2815	2819	-4	100

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CC 13= 47.91
CC 14= 47.91
CC 15= 27.377

MM= 5
RY 1= 21 RC 1= 2.366
RY 2= 26 RC 2= 0.584
RY 3= 31 RC 3= 42.663
RY 4= 36 RC 4= 24.196
RY 5= 41 RC 5= 13.464

OMC= 70.145

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0.051	4211	3055	1156	138
0.052	4102	3033	1069	135
0.053	3996	3011	985	133
0.054	3894	2990	904	130
0.055	3795	2969	826	128
0.056	3698	2948	750	125
0.057	3605	2928	677	123
0.058	3515	2908	606	121
0.059	3427	2889	538	119
0.060	3342	2871	472	116
0.061	3260	2852	408	114
0.062	3180	2834	346	112
0.063	3103	2817	286	110
0.064	3028	2800	228	108
0.065	2955	2783	172	106
0.066	2884	2766	118	104
0.067	2815	2750	65	102
0.068	2749	2734	14	101
0.069	2684	2719	-35	99

TABLE B.IV-17 EIRR BY ALTERNATIVES (5)

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CC 13= 42.016
CC 14= 42.016
CC 15= 24.008

MM= 5
RY 1= 21 RC 1= 2.366
RY 2= 26 RC 2= 0.584
RY 3= 31 RC 3= 21.871
RY 4= 36 RC 4= 18.824
RY 5= 41 RC 5= 16.644

OMC= 46.827

< IRR COMPUTATION >

DC.RT	PW.BF	PW.CS	NPW	BC.RT
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0.051	4165	2569	1596	162
0.052	4056	2553	1503	159
0.053	3950	2537	1413	156
0.054	3848	2522	1326	153
0.055	3749	2507	1242	150
0.056	3653	2493	1160	147
0.057	3560	2479	1082	144
0.058	3470	2465	1005	141
0.059	3383	2451	932	138
0.060	3298	2438	860	135
0.061	3216	2425	791	133
0.062	3136	2412	724	130
0.063	3059	2400	660	127
0.064	2984	2387	597	125
0.065	2912	2375	536	123
0.066	2841	2364	477	120
0.067	2773	2352	421	118
0.068	2706	2341	365	116
0.069	2642	2330	312	113
0.070	2579	2319	260	111
0.071	2519	2308	210	109
0.072	2460	2298	162	107
0.073	2403	2288	115	105
0.074	2347	2278	69	103
0.075	2293	2268	25	101
0.076	2240	2258	-18	99

FIGURE B.IV-27 SCHEMATIC MAP OF KHANPUR WATER CONDUCTION SYSTEM

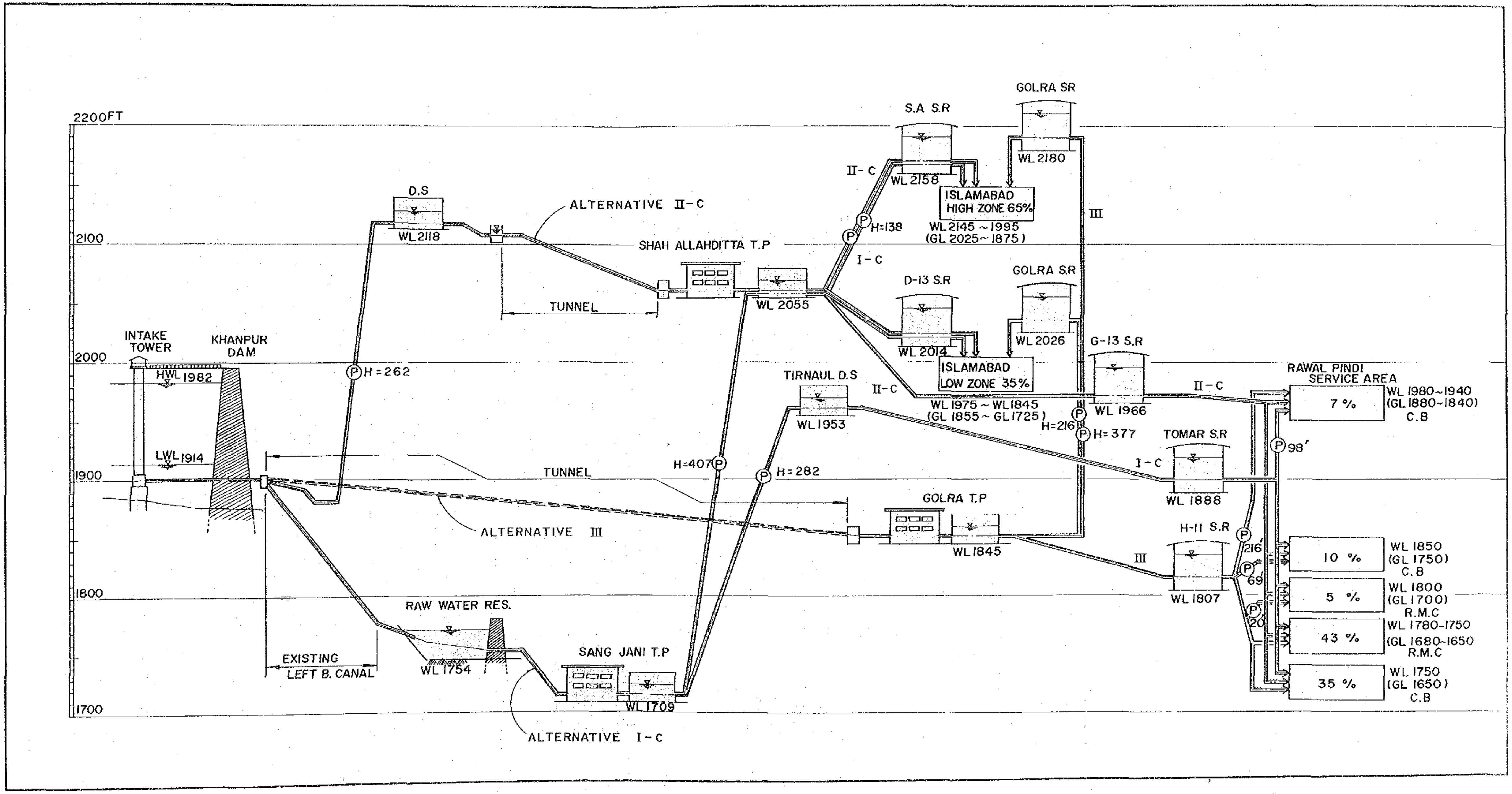


TABLE B.IV-18 PROJECT COST OF ALTERNATIVE I-C

(Unit: Rs.Million)

Item	Local	Foreign	Total
1. Raw Water Reservoir	52.3	42.7	95.0
2. Feeder Facilities	15.9	11.5	27.4
3. Tunnel	-	-	-
4. Water Treatment Plant	225.5	216.7	442.2
5. Pumping Station	128.9	134.1	263.0
6. Pipeline	348.6	348.5	697.1
7. Service Reservoir	92.9	64.5	157.4
8. Electric Works	22.4	38.1	60.5
Sub-total (1 - 8)	886.5	856.1	1,742.6
9. Project Office	12.0	-	12.0
10. Land Acquisition	71.2	-	71.2
11. Office Equipment	2.2	6.3	8.5
12. Engineering	42.3	159.1	201.4
13. Administration	48.6	-	48.6
Sub-total (9 - 13)	176.3	165.4	341.7
Base Cost (1 - 13)	1,062.8	1,021.5	2,084.3
14. Physical Contingencies	106.3	102.2	208.5
15. Price Escalation	1,027.9	509.3	1,537.2
Sub-total (14 - 15)	1,134.2	611.5	1,745.7
Total Cost	2,197.0	1,633.0	3,830.0

TABLE B.IV-19 PROJECT COST OF ALTERNATIVE II-C

(Unit: Rs.Million)

Item	Local	Foreign	Total
1. Raw Water Reservoir	-	-	-
2. Feeder Facilities	20.0	14.4	34.4
3. Tunnel	71.4	47.6	119.0
4. Water Treatment Plant	276.1	265.3	541.4
5. Pumping Station	117.5	122.4	239.9
6. Pipeline	282.2	282.1	564.3
7. Service Reservoir	137.1	95.4	232.5
8. Electric Works	22.5	38.2	60.7
Sub-total (1 - 8)	926.8	865.4	1,792.2
9. Project Office	12.0	-	12.0
10. Land Acquisition	45.1	-	45.1
11. Office Equipment	2.2	6.3	8.5
12. Engineering	43.5	163.7	207.2
13. Administration	50.0	-	50.0
Sub-total (9 - 13)	152.8	170.0	322.8
Base Cost (1 - 13)	1,079.6	1,035.4	2,115.0
14. Physical Contingencies	108.0	103.5	211.5
15. Price Escalation	1,067.0	516.5	1,583.5
Sub-total (14 - 15)	1,175.0	620.0	1,795.0
Total Cost	2,254.6	1,655.4	3,910.0

TABLE B.IV-20 PROJECT COST OF ALTERNATIVE III

(Unit: Rs.Million)

Item	Local	Foreign	Total
1. Raw Water Reservoir	-	-	-
2. Feeder Facilities	25.8	18.7	44.5
3. Tunnel	192.4	128.3	320.7
4. Water Treatment Plant	202.8	194.9	397.7
5. Pumping Station	71.7	74.6	146.3
6. Pipeline	201.5	201.4	402.9
7. Service Reservoir	111.7	77.7	189.4
8. Electric Works	25.0	42.7	67.7
Sub-total (1 - 8)	830.9	738.3	1,569.2
9. Project Office	12.0	-	12.0
10. Land Acquisition	35.6	-	35.6
11. Office Equipment	2.2	6.3	8.5
12. Engineering	38.1	143.3	181.4
13. Administration	43.8	-	43.8
Sub-total (9 - 13)	131.7	149.6	281.3
Base Cost (1 - 13)	962.6	887.9	1,850.5
14. Physical Contingencies	96.3	88.8	185.1
15. Price Escalation	957.3	457.1	1,414.4
Sub-total (14 - 15)	1,053.6	545.9	1,599.5
Total Cost	2,016.2	1,433.8	3,450.0

CHAPTER V. PROPOSED FACILITIES

CHAPTER V. PROPOSED FACILITIES

5.1. Major Revision of Facility Design Concept

Through series of discussion meeting on the alternative study and review of design criteria for final preliminary design, the following design concepts are revised from original one which was described in Chapter III of this Appendix B.

A. Water Losses of Water Treatment Plant

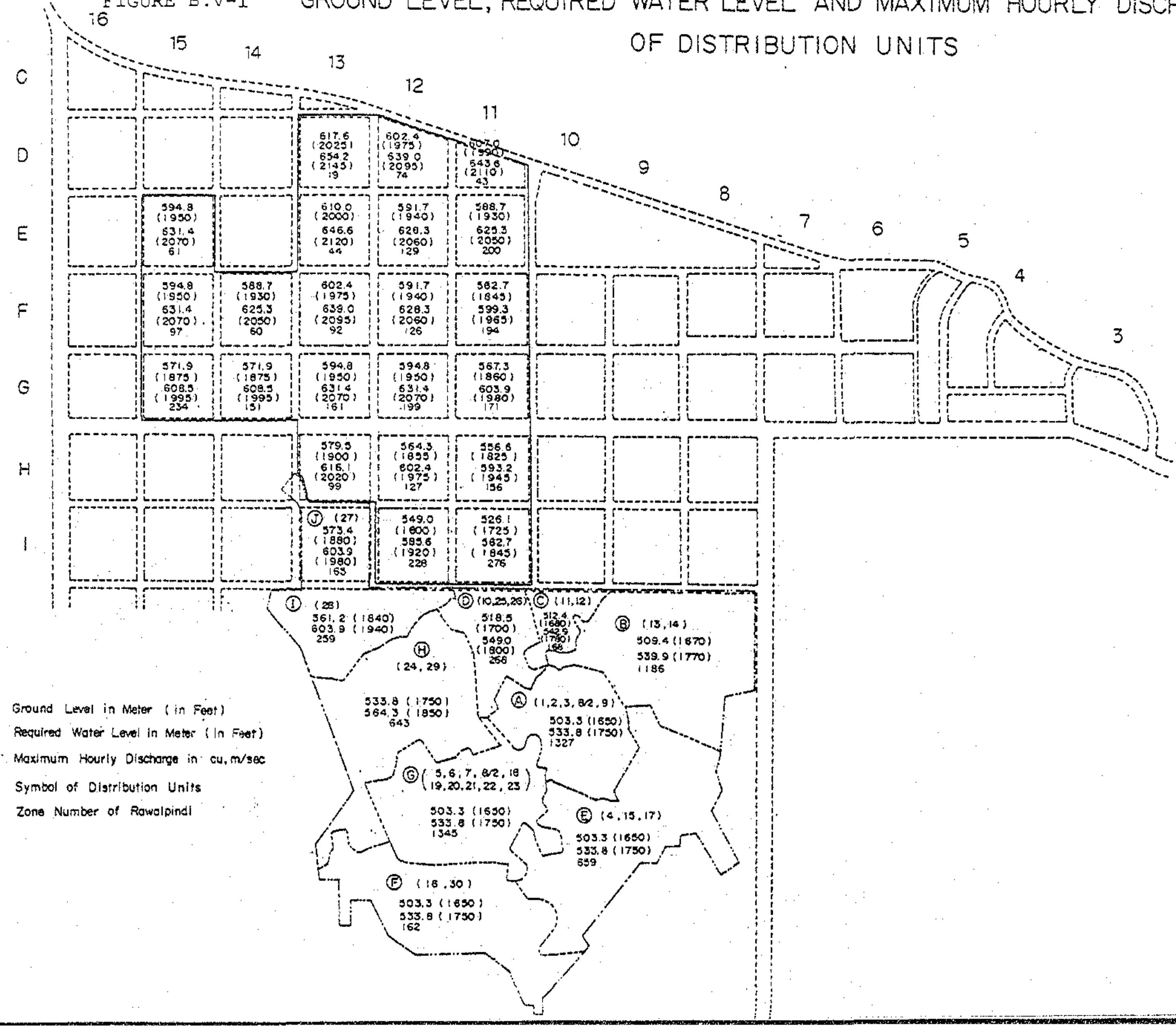
Initial proposed water losses at water treatment plant was assumed about 10 percent of daily raw water inflow in receiving well of the plant. During course of field study in Pakistan, detailed discussion has been made between the team and CDA staff concerned. Finally the value of water losses was revised to 5% from original one. (Please refer to discussion materials item-10 in Chapter V of Appendix C)

Revised distribution discharges for each sector in Islamabad and Rawalpindi are indicated in Table B.V-1 and B.V-2, respectively.

B. Cross Section of Pressure Tunnel

Cross section of pressure tunnel just downstream of intake tower is changed to 2,400 mm diameter from 2,100 mm original one taking into consideration distribution of hydraulic gradient, water losses of jet flow valve and efficient utilization of concrete placing steel form etc.

FIGURE B.V-1 GROUND LEVEL, REQUIRED WATER LEVEL AND MAXIMUM HOURLY DISCHARGE OF DISTRIBUTION UNITS



(NOTE)

591.7 (1940) 628.3 (2060) 124	The Upper	:	Ground Level in Meter (in Feet)
	The Middle	:	Required Water Level in Meter (in Feet)
	The Lower	:	Maximum Hourly Discharge in cu, m/sec
	Ⓐ~Ⓙ	:	Symbol of Distribution Units
	(1)~(30)	:	Zone Number of Rawalpindi

TABLE B.V-1 ISLAMABAD WATER SUPPLY IN THE YEAR OF AD2000
(DISTRIBUTION OF KHANPUR DAM WATER)

Sector	(1) Max. Daily Demand cu.m/D	(2) %	(3) Max. Daily Discharge cu.m/D	(4) Max. Hourly Discharge ℓ/s
D-11	2,095	1.45	2,456	43
E-11	9,819	6.81	11,535	200
F-11	9,539	6.61	11,196	194
G-11	8,376	5.81	9,841	171
H-11	7,641	5.30	8,978	156
I-11	13,538	9.39	15,905	276
D-12	3,625	2.51	4,252	74
E-12	6,350	4.40	7,453	129
F-12	6,185	4.29	7,267	126
G-12	9,758	6.77	11,468	199
H-12	6,235	4.32	7,318	127
I-12	11,175	7.75	13,128	228
D-13	906	0.63	1,067	19
E-13	2,139	1.48	2,507	44
F-13	4,489	3.11	5,268	92
G-13	7,912	5.49	9,299	161
H-13	4,830	3.35	5,674	99
F-14	2,925	2.03	3,439	60
G-14	7,419	5.14	8,707	151
E-15	3,017	2.09	3,540	61
F-15	4,781	3.31	5,607	97
G-15	11,482	7.96	13,483	234
Total	144,236	100.00	169,388	2,941

Notes: $(2) = \frac{(1)}{\text{Total }(1)} \times 100$

$(3) = 33\text{ MGD} \times \frac{4.55}{1000} \times 0.95 \times 0.95 \times 1.25 \times \frac{(2)}{100} = 1693.88 \times (2)$

$(4) = (3) \times 1.5/86{,}400$

TABLE B.V.-2 RAWALPINDI WATER SUPPLY IN THE YEAR OF AD2000
(Distribution of Khanpur Dam Water)

			(1) Max. Daily Demand		(2)	(3) Max.Daily Discharge	(4) Max.Hourly Discharge
	Zone	Sector	M.D.D. (cu.m/D)	Total (cu.m/D)	%	(cu.m/D)	(cu.m/D)
R.M.C	A	1	31,799	104,719	45.0	76,438	1.327
		2	32,565				
		3	22,495				
		8/2	7,340				
		9	10,520				
	B	13	81,376	93,639	40.2	68,285	1.186
		14	12,263				
	C	11	5,336	13,189	5.7	9,682	0.168
		12	7,853				
	D	10	18,191	21,064	9.1	15,457	0.268
		25	776				
		26	2,097				
	Sub-total		232,611	232,611	100.0	169,862	2.949
C.B	E	4	9,646	51,958	20.4	37,989	0.659
		15	16,161				
		17	26,151				
	F	16	974	12,785	5.0	9,311	0.162
		30	11,811				
	G	5	11,945	105,934	41.6	77,468	1.345
		6	2,435				
		7	9,545				
		8/2	7,340				
		18	1,624				
		19	62,436				
		20	3,774				
		21	440				
		22	5,255				
		23	1,140				
	H	24	45,659	50,617	19.9	37,058	0.643
		29	4,958				
	I	28	20,495	20,495	8.0	14,898	0.259
	J	27	12,999	12,999	5.1	9,497	0.165
	Sub-total		254,788	254,788	100.0	186,221	3.233
Grand Total			487,399	487,399	-	356,083	6.182

Notes: Av. Discharge : 69.37MGD = 3.653 cu.m/s
Max. Daily Discharge : 3.653 x 1.25 = 4.566 cu.m/s
Effective Max.Daily Discharge: 4.566x0.95x0.95 = 4.121cu.m/s
RMC Eff. Max. D. Discharge : 4.121 x 0.477* = 1.966cu.m/s
C.B. Eff. Max. D. Discharge : 4.121 x 0.523* = 2.155cu.m/s

* The Ratio of Max. Daily Demand in the Year of AD2000

Max. D. D(2000)	RMC; 232,611	C.B; 254,788
(Ratio)	(0.477)	(0.523)

$(2) = \frac{(1)}{\text{Sub Total}(1)} \times 100$ (3) (R.M.C.) = 1.966x86,400x(2)/100
(C.B.) = 2.155x86,400x(2)/100

(4) = (3) x 1.5/86,400

5.2. Hydraulic Computation of the Facility

5.2.1. Conduction Main

Conduction main has a total length of 13.06 km (8.11 miles) to be constructed between the intake tower at the Khanpur reservoir and Golra treatment plant with the design discharge of 6.74 cu.m/sec (238 cusecs). Connected with the intake tower, which is installed within the reservoir area, a pressure tunnel of 770 m long and an energy dissipator facility of 54 m in length are planned to be constructed. Waters released from the reservoir are conveyed to the treatment plant through a conduit of 106 m, free-flow tunnel of 11,480 m and pipeline of 650 m long.

Double pipeline system with a couple of energy dissipator valves are proposed taking the future repair works into consideration, while a single line of tunnel is constructed based on an economic reason as well as on the actual achievements, as reported in many countries, showing no serious damages and accidents during operation & maintenance works. The lowest intake gate of the intake tower is located at the first-stage dead water level. However, the minimum reservoir level to pass the design discharge through outlet facility as required for municipal water supply is estimated at 583.62 m (1,913.5 ft) in case of single dissipator valve and at 582.57 m (1,910 ft) in case of double valves. As a consequence in the study, the design headwater level is determined at 582.57 m.

Effective storage between elevations 582.57 and 580.11 m (1,902 ft) is estimated as 6.15 MCM (5,000 acre-ft), corresponding to about six days capacity for municipal water supply. In such an unusual case when the reservoir level falls around the elevation 1,910 ft, it is thought that the full amount of design discharge is rarely released because saving water practice is commonly accompanied. As falls the reservoir level to 1,910 ft or lower, amount of water to be released decreases gradually. Structure of the energy dissipator, however, allows 3.37 cu.m/sec or 50% of design discharge to pass through outlet facility.

Hydraulic calculations for the conduction main for the section from the inlet of conduit up to Golra treatment plant are presented in Tables B.V-3 and B.V-4. Delivery water level at the receiving well of the treatment plant is determined at 572.67 m (1,877.6 ft).

5.2.2. Water Treatment Plant

Detailed hydraulic calculations prepared for water treatment plant, from the receiving well up to the clear water reservoir, are briefly discussed as below:

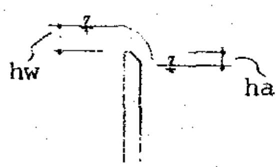
Water Level of Receiving Well

+ 572.67 m (1,877.6 ft)

A. Receiving Well

$Q = CBH^{3/2}$

$hw = (Q/CB)^{2/3}$



where

Q : flow rate 3.20 m^3/sec

C : weir discharge coefficient 1.89

B : width of weir 3.85 m

hw: weir overflow depth

$hw = (3.20/1.89 \times 3.85)^{2/3} = 0.58$ m

allowance, ha = 0.08 m

Water Level at Effluent of Receiving Well

+ 572.67 - (0.58 + 0.08) = + 572.01 m

B. Head Loss of Interconnecting Pipe (Receiving Well - Mixing Well)

a) Friction loss

$$hf = 10.666 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85} \times L$$

where $D1 = 1.65$ m, $L1 = 30$ m, $Q^1 = 3.20\ m^3/sec$, $C = 130$

$D2 = 1.20$ m, $L2 = 40$ m, $Q^2 = 1.60\ m^3/sec$, $C = 130$

$hf1 + hf2 = 0.08$ m

b) Minor loss

$hm = hi + ht + hb + hv + ho = 0.27$ m

where hi: influent, ht: tee, hb: bend, hv: valve,

ho: effluent

Water Level of Mixing Well

+ 572.01 - (0.08 + 0.27) = + 571.66 m

C. Mixing Well

$Hw = (1.60/1.88 \times 18.00)^{2/3} = 0.13$ m

No allowance is considered.

D. Head Loss by Baffled Channels in Flocculation Basin

lower bend $hb = fb \times v^2/2g$, $fb = 4.5$

overflow $ho = fo \times v^2/2g$, $fo = 2.5$

Stage	Height of baffle (m)	Width of channel (m)	Velocity (m/sec)	$v^2/2g$ (m/sec)	No. of baffles	No. of channels
1	1.80	1.50	0.30	4.59	L - 4 O - 4	2
2	1.80	2.00	0.22	2.47	L - 4 O - 4	2
3	1.80	2.90	0.15	1.15	L - 4 O - 4	2

hb (m)	ho (m)	Total (m)	Capacity of channel (m^3)	Retention time (sec)	G value (sec^{-1})	GT value
0.083	0.046	0.26	336	420	72.5	30,000
0.044	0.25	0.14	448	560	45.9	26,000
0.021	0.0115	0.06	659	813	26.1	21,000
Total		0.46	1,434	1,793		77,000

Water Level of Sedimentation Basin

$+ 571.66 - (0.13 + 0.46) = \underline{+ 571.07\ m}$

E. Head Loss by Effluent Trough of Sedimentation Basin

$q = 0.80^3/sec \times 1/9 = 0.089\ m^3/sec$

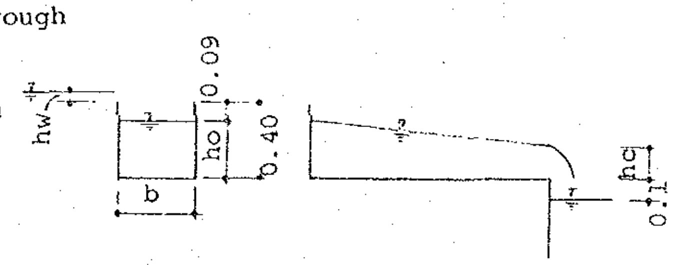
$hc = (\alpha q^2/gb^2)^{1/3}$

where q : flow rate per trough

hc: critical depth

α : coefficient 1.10

b : width of trough



$hc = 0.177\ m$

$ho = 3^{1/2} \times hc$

where ho: water depth of upper end

$ho = 0.307\ m$

weir overflow depth

$hw = (0.044/1.89 \times 5.00)^{2/3} = 0.03\ m$

Water Level at Effluent of Sedimentation Basin

$+ 571.07 - (0.03 + 0.40 + 0.10) = \underline{+ 570.54\ m}$

F. Head Loss of Interconnecting Pipe (Sedimentation Basin - Filter)

a) Friction loss

$hf = 10.666 \times 130^{-1.85} \times 1.65^{-4.87} \times 3.20^{1.85} \times 50$

$= 0.05\ m$

b) Minor loss

$h\ m = hi + ho = 0.17\ m$

where hi : influent, he : effluent

Water Level of Filter

$+ 570.54 - (0.05 + 0.17) = \underline{+ 570.32\ m}$

G. Head Loss for Filter

Total Head loss of filter is determined at 2.50 m.

H. Head Loss of Interconnecting Pipe (Filter - Clear Water Reservoir)

1) Friction loss

$hf1 = 10.666 \times 130^{-1.85} \times 1.65^{-4.87} \times 3.20^{1.85} \times 85 = 0.08$ m

$hf2 = 10.666 \times 130^{-.185} \times 1.20^{-4.87} \times 1.60^{1.85} \times 30 = 0.04$ m

$hf1 + hf2 = 0.12$ m

2) Minor loss

hm = 0.27 m

I. Clear Water Reservoir

$hw = (1.60/1.86 \times 11.30)^{2/3} = 0.18$ m

allowance, ha = 0.03 m

High Water Level of Clear Water Reservoir

+ 570.32 - (2.50 + 0.12 + 0.27 + 0.18 + 0.03) = + 567.22 m

effective depth : 4.00 m

Low Water Level of Clear Water Reservoir

+ 567.22 - 4.00 = + 563.22 m (1,846.6 ft)

5.2.3. Distribution System

A. Water Level of Service Reservoir

Based on the flow diagram as illustrated in Figure B.V-2, required water levels of service reservoirs are determined so as to satisfy necessary water head and discharge at the delivery point of each distribution unit. Required water head at each distribution unit is taken as + 120 ft and + 100 ft above ground level respectively for Islamabad and Rawalpindi, and computations are based on the maximum hourly discharge. Hydraulic calculations are summarized in Tables B.V-5 to V.B-8. In this connection, water levels of service reservoir as calculated are given in terms of the lowest water levels (LWL), and at LWL the design maximum hourly discharge is to be deliverable to each distribution unit.

Although distribution system is desirable to be proposed by means of gravity flow system, which would need less costs for construction as well as operation and maintenance, service areas of Islamabad are not deliverable by gravity since the required water head at each distribution unit is much higher than the available water head of 563.2 m (1,846.6 ft) at the clear water reservoir of Golra treatment plant as obtained from Khanpur reservoir level. On the other hand in Rawalpindi, most part of service area is deliverable by a gravity system. Accordingly for Islamabad, as previously discussed in Chapter III, service area is divided into two zones, namely High zone and Low zone. Golra-1 service reservoir and Golra-2 service reservoir are proposed for High and Low zones, respectively, and waters are pumped up from the treatment plant. For Rawalpindi, water conveyed from treatment by gravity are delivered to the service reservoir to be constructed in the sector H-11, and then distributed to the most part of serve area by gravity. For distribution units D, H, I and J where insufficient water heads are only available, waters are further lifted by booster pumps. Water levels and service reservoirs are summarized as under:

Islamabad		LWL
High Zone:	Golra-1 Service Reservoir	663.0 m (2,174 ft)
Low Zone :	Golra-2 Service Reservoir	614.5 m (2,015 ft)
Rawalpindi		
H-11 Service Reservoir		551.0 m (1,807 ft)

5.2.4. Hydraulic Distribution of the Proposed System

Hydraulic distribution of the proposed system based on the hydraulic computations is summarized and illustrated as in Figure B.V-3.

5.2.5. Hydraulic Consideration on the Existing Division Works

The Left Bank Canal of the Khanpur Dam (L.B.C) has been constructed so as to convey combined water supply for municipal, industrial and irrigation. Hydraulic profile of L.B.C will be influenced and water surface elevation will considerably fall due to the change of design discharge, if the municipal water is excluded from the design discharge of L.B.C. Accordingly the crest elevation of the existing division works should be lowered to divert required amount of water through facilities. Sample computation is given as under for the selected division work located at RD9358 of L.B.C.

<u>Hydraulic Dimension of L.B.C at RD9358</u>

Design Discharge	Q = 12.326 cu.m/sec (434 cusecs)
Bottom Width of Canal	b = 1.754 m (5.75 ft)
Water Depth	d = 1.754 m (5.75 ft)
Side Slope of Canal	m = 1.5:1
Longitudinal Slope	S = 1/1,650
Roughness Coefficient	n = 0.015

When municipal water is excluded, the design discharge will be revised as;

$Q' = 12.326 - 6.74 \times 1.1 = 4.912$ cu.m/sec

$d' = 1.13$ m (3.70 ft)

$v = 1.25$ m/sec : flow velocity

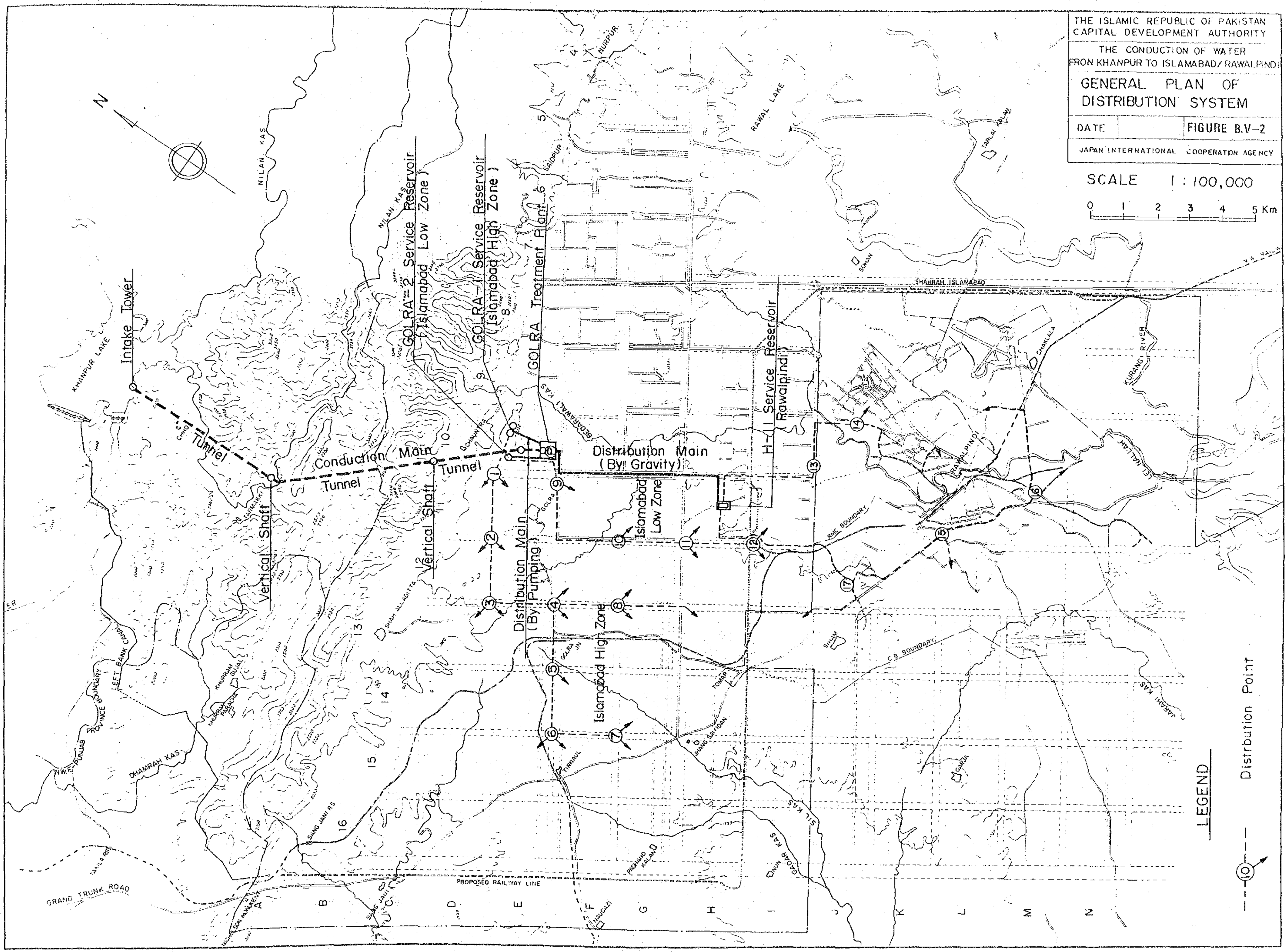
$A = 3.897$ sq.m : flow area

$R = 0.668$ m : Hydraulic radius

Water surface elevation will, therefore, fall as;

$$\Delta d = 1.754 \text{ m} - 1.130 \text{ m} = 0.624 \text{ m (2.05 ft)}$$

Accordingly, structure of the existing division work should necessarily be modified.


THE ISLAMIC REPUBLIC OF PAKISTAN
CAPITAL DEVELOPMENT AUTHORITY
THE CONDUCTION OF WATER
FRON KHANPUR TO ISLAMABAD/RAWALPINDI
GENERAL PLAN OF
DISTRIBUTION SYSTEM
DATE
FIGURE B.V-2
JAPAN INTERNATIONAL COOPERATION AGENCY
SCALE 1 : 100,000
0 1 2 3 4 5 Km
Intake Tower
Tunnel
Vertical Shaft
Conduction Main
Tunnel
Vertical Shaft
Tunnel
GOLRA-2 Service Reservoir
(Islamabad Low Zone)
GOLRA-1 Service Reservoir
(Islamabad High Zone)
GOLRA Treatment Plant
Distribution Main
(By Gravity)
Distribution Main
(By Pumping)
Islamabad Low Zone
Islamabad High Zone
H-11 Service Reservoir
(Rawalpindi)
RAWAL LAKE
KHANPUR LAKE
NILAN KAS
SHAHRAH ISLAMABAD
RAWALPINDI
CHAKLALA
KURANG RIVER
LEI NALLAH
GRAND TRUNK ROAD
PROPOSED RAILWAY LINE
LEFT BANK CANAL
PROVINCE BOUNDARY
NWFP PUNJAB
DHAMRAH KAS
SIL KAS
GADAR KAS
C.B. BOUNDARY
RMC BOUNDARY
A B C D E F G H I J K L M N
LEGEND
Distribution Point

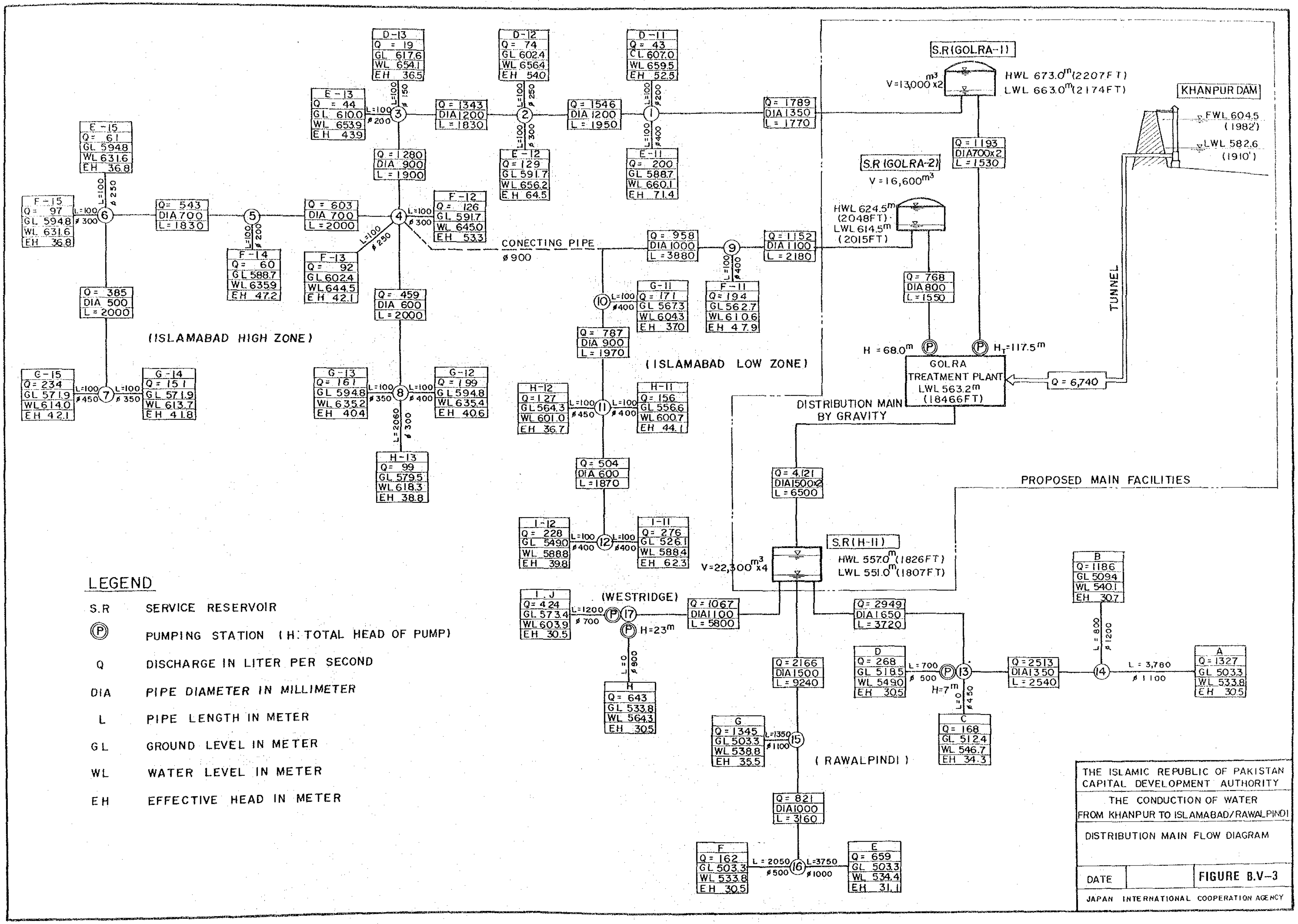

S.R (GOLRA-1)
V=13,000 m3 x2
HWL 673.0m (2207FT)
LWL 663.0m (2174FT)
KHANPUR DAM
FWL 604.5 (1982')
LWL 582.6 (1910')
S.R (GOLRA-2)
V=16,600 m3
HWL 624.5m (2048FT)
LWL 614.5m (2015FT)
TUNNEL
Q = 6,740
GOLRA TREATMENT PLANT LWL 563.2m (18466FT)
H = 68.0m
HT = 117.5m
DISTRIBUTION MAIN BY GRAVITY
PROPOSED MAIN FACILITIES
S.R (H-11)
V=22,300 m3 x4
HWL 557.0m (1826FT)
LWL 551.0m (1807FT)
(ISLAMABAD HIGH ZONE)
(ISLAMABAD LOW ZONE)
(WESTRIDGE)
(RAWALPINDI)
CONECTING PIPE ø900
H=23m
H=7m
D-13 Q = 19 GL 617.6 WL 654.1 EH 36.5
D-12 Q = 74 GL 602.4 WL 656.4 EH 54.0
D-11 Q = 43 GL 607.0 WL 659.5 EH 52.5
E-13 Q = 44 GL 610.0 WL 653.9 EH 43.9
E-12 Q = 129 GL 591.7 WL 656.2 EH 64.5
E-11 Q = 200 GL 588.7 WL 660.1 EH 71.4
E-15 Q = 61 GL 594.8 WL 631.6 EH 36.8
F-15 Q = 97 GL 594.8 WL 631.6 EH 36.8
F-14 Q = 60 GL 588.7 WL 635.9 EH 47.2
F-13 Q = 92 GL 602.4 WL 644.5 EH 42.1
F-12 Q = 126 GL 591.7 WL 645.0 EH 53.3
F-11 Q = 194 GL 562.7 WL 610.6 EH 47.9
G-11 Q = 171 GL 567.3 WL 604.3 EH 37.0
G-15 Q = 234 GL 571.9 WL 614.0 EH 42.1
G-14 Q = 151 GL 571.9 WL 613.7 EH 41.8
G-13 Q = 161 GL 594.8 WL 635.2 EH 40.4
G-12 Q = 199 GL 594.8 WL 635.4 EH 40.6
H-13 Q = 99 GL 579.5 WL 618.3 EH 38.8
H-12 Q = 127 GL 564.3 WL 601.0 EH 36.7
H-11 Q = 156 GL 556.6 WL 600.7 EH 44.1
I-12 Q = 228 GL 549.0 WL 588.8 EH 39.8
I-11 Q = 276 GL 526.1 WL 588.4 EH 62.3
I.J Q = 424 GL 573.4 WL 603.9 EH 30.5
H Q = 643 GL 533.8 WL 564.3 EH 30.5
B Q = 1186 GL 509.4 WL 540.1 EH 30.7
A Q = 1327 GL 503.3 WL 533.8 EH 30.5
D Q = 268 GL 518.5 WL 549.0 EH 30.5
C Q = 168 GL 512.4 WL 546.7 EH 34.3
G Q = 1345 GL 503.3 WL 538.8 EH 35.5
F Q = 162 GL 503.3 WL 533.8 EH 30.5
E Q = 659 GL 503.3 WL 534.4 EH 31.1
Q = 1789 DIA 1350 L = 1770
Q = 1546 DIA 1200 L = 1950
Q = 1343 DIA 1200 L = 1830
Q = 1280 DIA 900 L = 1900
Q = 543 DIA 700 L = 1830
Q = 603 DIA 700 L = 2000
Q = 385 DIA 500 L = 2000
Q = 459 DIA 600 L = 2000
Q = 1193 DIA 700x2 L = 1530
Q = 958 DIA 1000 L = 3880
Q = 1152 DIA 1100 L = 2180
Q = 768 DIA 800 L = 1550
Q = 787 DIA 900 L = 1970
Q = 504 DIA 600 L = 1870
Q = 4121 DIA 1500x2 L = 6500
Q = 1067 DIA 1100 L = 5800
Q = 2949 DIA 1650 L = 3720
Q = 2513 DIA 1350 L = 2540
Q = 2166 DIA 1500 L = 9240
Q = 821 DIA 1000 L = 3160
LEGEND
S.R SERVICE RESERVOIR
(P) PUMPING STATION (H: TOTAL HEAD OF PUMP)
Q DISCHARGE IN LITER PER SECOND
DIA PIPE DIAMETER IN MILLIMETER
L PIPE LENGTH IN METER
GL GROUND LEVEL IN METER
WL WATER LEVEL IN METER
EH EFFECTIVE HEAD IN METER
THE ISLAMIC REPUBLIC OF PAKISTAN
CAPITAL DEVELOPMENT AUTHORITY
THE CONDUCTION OF WATER FROM KHANPUR TO ISLAMABAD/RAWALPINDI
DISTRIBUTION MAIN FLOW DIAGRAM
DATE
FIGURE B.V-3
JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE B.V-4 HYDRAULIC PROFILE OF WATER SUPPLY SYSTEM

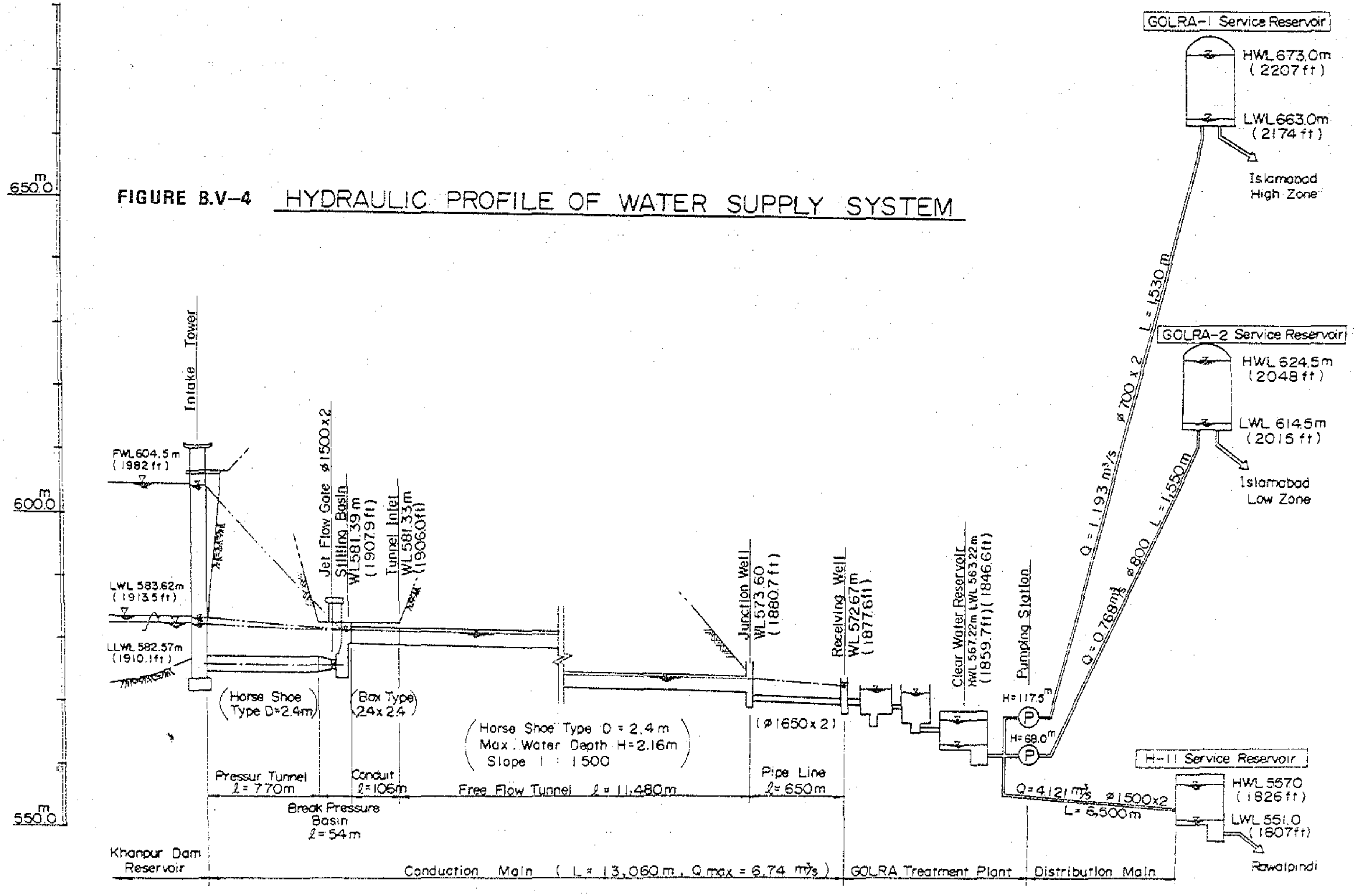


TABLE B.V-3 LOSS HEAD COMPUTATION OF CONDUCTION MAIN

Description	Length (m)	Energy Gradient	Friction Loss (m)	Other Losses (m)	Total Loss (m)	Water Level (El.)
Khanpur Reservoir						583.62 m (1,913.5 ft) [582.57] m (1,910.1 ft)
Intake Tower			-	0.17	0.17	
						583.45 [582.40]
Pressure Tunnel	770	1:1,320	0.58	0.03	0.61	
						582.84 [581.79]
Valve & Brake Pressure Basin	54		0.06 [0.02]	1.39 [0.38]	1.45 [0.40]	
						581.39 (1,907.0 ft)
Conduit	106	1:1,850	0.06	-	0.06	
						581.33
Free Flow Tunnel	11,480	1:1,500	7.65	0.08	7.73	
						573.60
Pipeline	650	1: 860	0.76	0.17	0.93	
Receiving Well at Treatment Plant						572.67 (1,877.6 ft)

Note: Figures in square brackets are provided for the case that two jet-flow valves are fully opened.

TABLE B.V-4 HYDRAULIC CALCULATION OF CONDUCTION MAIN

Description	Shape & Size	Water Depth	Velocity (m/sec)	Energy Gradient	Coefficient of Roughness "n"
Pressure Tunnel	Horseshoe D = 2.40 m	Full	1.41	1:1,320	0.014
Free Flow Tunnel	Horseshoe D = 2.40 m	2.16 m	1.48	1:1,500	0.014
Conduit	2.40 m x 2.40 m	2.16 m	1.30	1:1,850	0.015
Pipeline	ϕ1,650 mm x 2	Full	1.58	1: 860	0.012

Note: Design Discharge Q = 6.75 cu.m/sec (238 cusecs)

TABLE B.V-5 HYDRAULIC CALCULATION (T.P - S.R)

(GENERAL)

POINT	G.LEVEL (M)	H.LENGTH (M)	HEIGHT (M)	P.LENGTH (M)	DIAMETER (MM)	DISCHARGE (L/S)	VELOCITY (M/S)	HYDR.GRAD. (M/1000M)	H.LOSS (M)	WATER LEVEL (M)	EFFEC.HEAD (M)
G.TP	563.20									563.200	0.0
SR-1 (EP)	673.00	1530.00	109.80	1533.93	700.	596.50	1.558	3.897	5.977	557.223	-115.777 (HT=117.5M)
G.TP	563.20									563.200	0.0
SR-2 (EP)	624.50	1550.00	61.30	1551.21	800.	768.00	1.535	3.246	5.035	558.165	-66.335 (HT=68.0M)
G.TP	563.20									563.200	0.0
SR-H (EP)	557.00	6500.00	-6.20	6500.00	1500.	2060.50	1.171	0.943	6.132	557.068	0.068

TABLE B.V-6 HYDRAULIC CALCULATION

(S.R(GOLRA:1)--ISLAMABAD HIGH ZONE)

POINT	G.LEVEL (M)	H.LENGTH (M)	HEIGHT (M)	P.LENGTH (M)	DIAMETER (MM)	DISCHARGE (L/S)	VELOCITY (M/S)	HYDR.GRAD. (M/1000M)	H.LOSS (M)	WATER LEVEL (M)	EFFEC.HEAD (M)
S.R	663.00									663.000	0.0
1	594.80	1770.00	-68.20	1771.31	1350.	1789.00	1.255	1.213	2.149	660.850	66.050
2	594.80	1950.00	0.0	1950.00	1200.	1546.00	1.373	1.644	3.205	657.645	62.845
3	602.40	1830.00	7.60	1830.02	1200.	1343.00	1.193	1.267	2.319	655.326	52.926
4	588.70	1900.00	-13.70	1900.05	900.	1280.00	2.021	4.705	8.941	646.385	57.686
5	610.00	2000.00	21.30	2000.11	700.	603.00	1.575	3.975	7.951	638.434	28.434
6	597.80	1830.00	-12.20	1830.04	700.	543.00	1.418	3.275	5.993	632.441	34.641
7	573.40	2000.00	-24.40	2000.15	500.	385.00	1.972	8.924	17.849	614.593	41.193
G-15 (EP)	571.90	100.00	-1.50	100.01	450.	234.00	1.480	5.934	0.593	613.999	42.099
4	588.70									646.385	57.686
8	579.50	2000.00	-9.20	2000.02	600.	459.00	1.632	5.084	10.168	636.218	56.718
H-13 (EP)	579.50	2060.00	0.0	2060.00	300.	99.00	1.410	8.705	17.932	618.285	38.785
1	594.80									660.850	66.050
D-11 (EP)	607.00	100.00	12.20	100.74	200.	43.00	1.379	13.407	1.351	659.500	52.500
1	594.80									660.850	66.050
E-11 (EP)	588.70	100.00	-6.10	100.19	400.	200.00	1.601	7.876	0.789	660.061	71.361
2	594.80									657.645	62.845
D-12 (EP)	602.40	100.00	7.60	100.29	250.	74.00	1.518	12.346	1.238	656.406	54.007
2	594.80									657.645	62.845
E-12 (EP)	591.70	100.00	-3.10	100.05	300.	129.00	1.837	14.205	1.421	656.223	64.523
3	602.40									655.326	52.926
D-13 (EP)	617.60	100.00	15.20	101.15	150.	19.00	1.084	12.010	1.215	654.111	36.511
3	602.40									655.326	52.926
E-13 (EP)	610.00	100.00	7.60	100.29	200.	44.00	1.411	13.989	1.403	653.923	43.923
4	588.70									646.385	57.686
F-12 (EP)	591.70	100.00	3.00	100.04	300.	126.00	1.794	13.600	1.361	645.025	53.325
4	588.70									646.385	57.686
F-13 (EP)	602.40	100.00	13.70	100.93	250.	92.00	1.887	18.470	1.864	644.521	42.121
5	610.00									638.434	28.434
F-14 (EP)	588.70	100.00	-21.30	102.24	200.	60.00	1.924	24.831	2.539	635.895	47.195
6	597.80									632.441	34.641
E-15 (EP)	594.80	100.00	-3.00	100.04	250.	61.00	1.252	8.636	0.864	631.577	36.777
6	597.80									632.441	34.641
F-15 (EP)	594.80	100.00	-3.00	100.04	300.	97.00	1.382	8.382	0.839	631.603	36.802
7	573.40									614.593	41.193
G-14 (EP)	571.90	100.00	-1.50	100.01	350.	151.00	1.579	8.973	0.897	613.695	41.795
8	579.50									636.218	56.718
G-12 (EP)	594.80	100.00	15.30	101.16	400.	199.00	1.593	7.803	0.789	635.428	40.628
8	579.50									636.218	56.718
G-13 (EP)	594.80	100.00	15.30	101.16	350.	161.00	1.684	10.103	1.022	635.196	40.396

TABLE B.V-7 HYDRAULIC CALCULATION

(S.R(GOLRA:2)--ISLAMABAD LOW ZONE)

POINT	G.LEVEL (M)	H.LENGTH (M)	HEIGHT (M)	P.LENGTH (M)	DIAMETER (MM)	DISCHARGE (L/S)	VELOCITY (M/S)	HYDR.GRAD. (M/1000M)	H.LOSS (M)	WATER LEVEL (M)	EFFEC.HEAD (M)
S.R	614.30									614.500	0.200
9	567.30	2180.00	-47.00	2180.51	1100.	1152.00	1.218	1.457	3.178	611.322	44.022
10	564.30	3880.00	-3.00	3880.00	1000.	958.00	1.226	1.648	6.394	604.928	40.628
11	564.30	1970.00	0.0	1970.00	900.	787.00	1.243	1.913	3.769	601.158	36.858
12	530.70	1870.00	-33.60	1870.30	600.	504.00	1.792	6.044	11.304	589.854	59.154
I-12 (EP)	549.00	100.00	18.30	101.66	400.	228.00	1.825	10.036	1.020	588.834	39.834
9	567.30									611.322	44.022
F-11 (EP)	562.70	100.00	-4.60	100.11	400.	194.00	1.553	7.444	0.745	610.577	47.877
10	564.30									604.928	40.628
G-11 (EP)	567.30	100.00	3.00	100.04	400.	171.00	1.369	5.894	0.590	604.338	37.038
11	564.30									601.158	36.858
H-11 (EP)	556.60	100.00	-7.70	100.30	400.	156.00	1.249	4.974	0.499	600.659	44.059
11	564.30									601.158	36.858
H-12 (EP)	564.30	100.00	0.0	100.00	450.	127.00	0.804	1.916	0.192	600.967	36.667
12	530.70									589.854	59.154
I-11 (EP)	526.10	100.00	-4.60	100.11	400.	276.00	2.209	14.291	1.431	588.424	62.323

TABLE B.V-8 HYDRAULIC CALCULATION

(S.R(H-11)--RAWALPINDI)

POINT	G.LEVEL (M)	H.LENGTH (M)	HEIGHT (M)	P.LENGTH (M)	DIAMETER (MM)	DISCHARGE (L/S)	VELOCITY (M/S)	HYDR.GRAD. (M/1000M)	H.LOSS (M)	WATER LEVEL (M)	EFFEC.HEAD (M)
S.R	551.00									551.000	0.0
13	512.40	3720.00	-38.60	3720.20	1650.	2949.00	1.384	1.151	4.283	546.717	34.317
14	506.30	2540.00	-6.10	2540.01	1350.	2513.00	1.762	2.275	5.780	540.937	34.637
A	503.30	3780.00	-3.00	3780.00	1100.	1327.00	1.403	1.893	7.156	533.782	30.482
(EP)											
13	512.40									546.717	34.317
C	512.40	0.0	0.0	0.0	450.	168.00	1.063	3.214	0.0	546.717	34.317
(EP)											
14	506.30									540.937	34.637
B	509.40	800.00	3.10	800.01	1200.	1186.00	1.053	1.007	0.805	540.132	30.732
(EP)											
S.R	551.00									551.000	0.0
15	503.30	9240.00	-47.70	9240.12	1500.	2166.00	1.231	1.035	9.561	541.439	38.139
16	503.30	3160.00	0.0	3160.00	1000.	821.00	1.050	1.239	3.914	537.525	34.225
E	503.30	3750.00	0.0	3750.00	1000.	659.00	0.843	0.825	3.093	534.431	31.131
(EP)											
15	503.30									541.439	38.139
G	503.30	1350.00	0.0	1350.00	1100.	1345.00	1.422	1.941	2.620	538.819	35.519
(EP)											
16	503.30									537.525	34.225
F	503.30	2050.00	0.0	2050.00	500.	162.00	0.830	1.799	3.688	533.836	30.536
(EP)											
S.R	551.00									551.000	0.0
17	543.20	5800.00	-7.80	5800.00	1100.	1067.00	1.128	1.265	7.335	543.665	0.465
I,J	573.40	2400.00	30.20	2400.19	700.	424.00	1.108	2.072	4.974	538.692	-34.708 (HT=67.0)
(EP)											
17	543.20									543.665	0.465
H	533.80	0.0	-9.40	9.40	800.	643.00	1.286	2.337	0.022	543.643	9.843 (HT=23.0)
(EP)											
13	512.40									546.717	34.317
D	518.50	700.00	6.10	700.03	500.	268.00	1.373	4.566	3.196	543.521	25.021 (HT=7.0)
(EP)											

5.3. Preliminary Design of Intake Tower and Conduction Main

5.3.1. Tunnel Design

Cutting line of tunnel section to ensure the designed thickness of lining (A-line), pay line of excavation and lining concrete, and dimension of steel support are determined following guidelines and design standards prepared by United States Bureau of Reclamation as well as by Japanese Ministry of Agriculture, Forestry and Fisheries.

Three types of standard cross section of tunnel are established. For three fractured zones, which are geologically considered to be tectonic faults and through which the tunnel is proposed to pass, special reinforcement works preceded excavation are carried in execution. In the case that steel supports deforms after excavation work due to increase of earth pressure at the places of fault and fractured zone, lining work is to be made by using centre forms.

A. A-line

Standards for A-lines are as under;

DESIGN THICKNESS OF LINING (A-LINE)

Tunnel Type	No.1 Tunnel Arch Side	No.1 Tunnel Invert	No.1 Tunnel Concrete	No.2 Tunnel Arch Side	No.2 Tunnel Invert	No.2 Tunnel Concrete
Type A	$\frac{Di}{20} \geqq 20$	$\frac{Di}{20} \geqq 20$	Reinforced Concrete	$\frac{Di}{20} \geqq 15$	$\frac{Di}{20} \geqq 15$	Plain Concrete
	∴ 20 cm	∴ 20 cm	$\sigma 28 = 210$	∴ 15 cm	∴ 15 cm	$\sigma 28 = 180$
Type B	$\frac{Di}{20} \geqq 20$	$\frac{Di}{20} \geqq 25$	- do -	$\frac{Di}{20} \geqq 20$	$\frac{Di}{20} \geqq 15$	- do -
	∴ 20 cm	∴ 25 cm		∴ 20 cm	∴ 15 cm	
Type C	-	-	-	$\frac{Di}{15} \geqq 20$	$\frac{Di}{15} \geqq 20$	- do -
				∴ 20 cm	∴ 20 cm	

Note: Di denotes inner diameter of tunnel

In this connection, nothing except steel ribs or a part of original hard foundation should not be remained. In addition, nothing except concrete itself should not be remained within the distance of 10 cm from inner face of lined concrete.

B. Excavation Pay Line and Concrete Pay Line (B-line)

In consideration of rock classification of the foundation, construction method and etc., tunnel pay lines for excavation and concrete, as required for estimation of construction cost, are determined as presented in Table B.V-9.

Foundation Geology at Proposed Intake Tower Site

At and around the proposed site of intake tower, rocks are outcropped and foundations are composed of alternating beds of hard limestone, in which fissures are to some extent developed, and massive marl. Bearing capacity of foundation is estimated to be sufficient to support the intake tower. There is, however, some possibility of leakage of the reservoir water during the course of foundation excavation and it is recommended that careful investigation is executed as advance to check permeability of soil layer.

Geology along Tunnel Routes

Geological profiles along tunnel routes are compiled in the separate volume "Drawings". Length of tunnel, as classified by rock types, is given as below:

ROCK TYPES ENCOUNTERED ALONG TUNNELS

(Unit: meter)

Tunnel	Rock Type I	Type II	Type III	Type IV	Total
Tunnel 1	0	770	0	0	770
Tunnel 2-1	940	2,590	370	50	3,950
Tunnel 2-2	2,140	2,100	950	0	5,190
Tunnel 2-3	0	320	1,310	710	2,340
Total	3,080	5,780	2,630	760	12,250

As concerns geological survey, a detailed investigation is recommended to be progressed preceding to detailed design works. General condition of geology and groundwater is described also in Chapter III, 3.2 of this appendix. In review of at present available data, special attention on the planning of tunnel excavation is to be paid, firstly to taking measure to cope with spring water (groundwater) and secondly to treatment of faults. In addition, it is estimated that little swelling rock is distributed along the tunnel route.

5.3.2. Construction Planning

A. Intake Tower

Since the proposed site of intake tower is presented in a shape of a small bay, water levels in the reservoir are desirable to be kept as low as possible during construction works, by means of releasing excess water through the spillway gates. Coffer dam is proposed with double sheet-piles filled up with sand. The crest elevation of the coffer dam is set at 1.5 m above the crest of the spillway.

B. Tunnel

Pressure tunnel is excavated from its outlet side, while No.2 tunnel is excavated at six faces in total, inclusive of inlet, outlet and both faces of two vertical shafts.

Tunnel excavation is executed with 3 units of 40 kg-class legdrills and prefabricated footholds. Blasted tunnel muckings are placed in steel muck cars of 3 m^3 capacity by rocker shovels of 0.23 m^3 bucket capacity and 7.5 kw-class trainloader. About 24 m^3 of mucks produced by one blasting is hauled by 8 units of muck cars pulled by a 8 ton locomotive. Locomotive and carriers are switched at expanded sections of 1.0 m wide and 10 m long placed with 500 m interval. Concrete is transported from batcher plant to each tunnel face with agitator trucks of 3 m^3 capacity, and lined by a 3 m^3 presscrete. Steel forms are of 12 m long and running cycle is determined at one cycle per day. After completion of arch side wall lining works, invert concrete is placed from the inner side of tunnel. Back-filling grouting is constructed about 2 weeks to a month after placing concrete, and after completion of back-filling grouting, weep holes are drilled.

Prior to tunnel excavation through 3 fractured zones, chemical grouting is executed for the purpose of reinforcement. In the case where increase of earth pressure after excavation is remarkable, lining work is to be made immediately after excavation, by use of centre metal forms.

Regarding a batcher plant, one unit of 1.0 m^3 compelling mixer is installed at the suitable site of both Khanpur side and Golra side. Kneaded concrete is transported by agitator trucks of 3 m^3 capacity to each construction site.

A vertical shaft is the lifeline for tunnel construction, and therefore, 2 sets of facilities or equipments such as skip elevator for mucking, drainage pump, drainage pipe and other are to be prepared. Major machinery and equipments are listed as under;

Machine & Equipment	Specification	No.	Remarks
Compressor	75 kw	4	
- do -	55 kw	4	
Legdrill	40 kg class	28	
Rocker Shovel	0.23 m^3 (RS55)	6	
Train Loader	7.5 kw, ℓ = 30 m	6	
Steel Muck Car	3 m^3	50	
Battery Car	8 ton	6	
- do -	6 ton	7	
Presscrete	3 m^3	5	
Steel Form	D = 2.4 m, ℓ = 12 m	3	
Centre Form	1.5 m	5	
Batcher Plant	1.0 m^3 Mixer	2	
Agitator Truck	3 m^3	5	
Dump Truck	8 - 10 ton	5	
Truck	6 - 8 ton	3	
Jeep		5	For Supervision
Elevator (For Shaft)	22 kw	4	For Muck
- do -	5.5 kw	2	For Materials
- do -	5.5 kw	2	For Personnel
Drainage Pump	4.5 m^3/min, 125 kw	4	
- do -	3.7 kw	15	
Water Supply Pump	3.7 kw	4	
Blower	22 kw	12	
Bulldzoer	8 ton	2	
Generator	200 KVA	3	For Power Stoppage
Truck Crane	10 ton	1	

FIGURE B.V-5 CONSTRUCTION SCHEDULE OF CONDUCTION MAIN

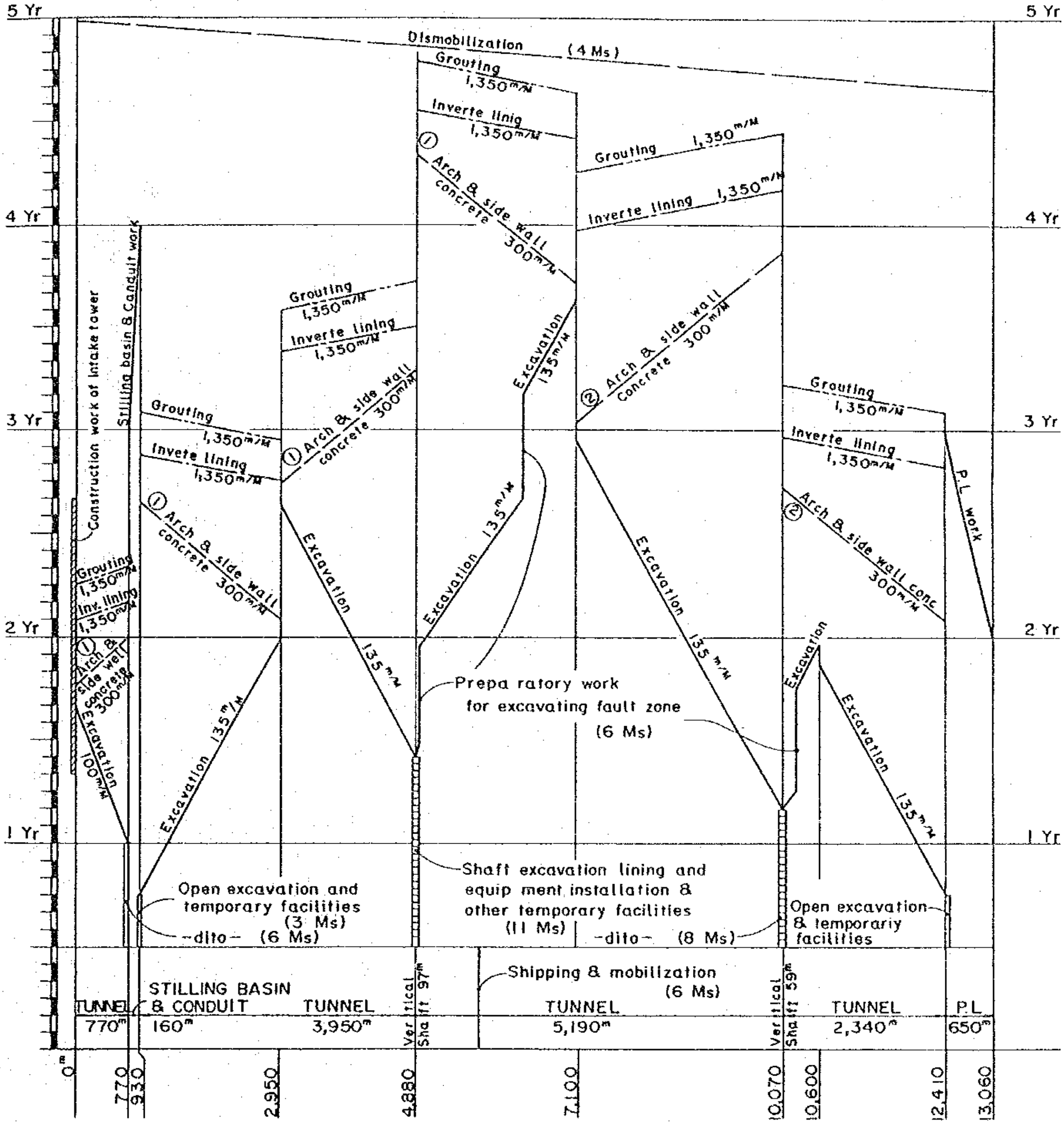


TABLE B.V-9 TUNNEL PAY LINE (B-LINE)

No. 1 Tunnel							No.2 to No.4 Tunnel					
Design Thickness (td)		Excavation Pay Line		Concrete Pay Line		Tunnel	Design Thickness (td)		Excavation Pay Line		Concrete Pay Line	
Arch	Invert	Arch	Invert	Arch	Invert	Type	Arch	Invert	Arch	Invert	Arch	Invert
20	20	td + 20 =20 + 20 =40	td + 5 =20 + 5 =25	td + 10 =20 + 10 =30	td + 5 =20 + 5 =25	Type A	15	15	td + 20 =15 + 20 =35	td + 5 =15 + 5 =20	td + 10 =15 + 10 =25	td + 5 =15 + 5 =20
20	25	td + 25 =20 + 25 =45	td + 5 =25 + 5 =30	td + 15 =20 + 15 =35	td + 5 =25 + 5 =30	Type B	20	15	td + 20 =20 + 20 =40	td + 5 =15 + 5 =20	td + 10 =20 + 10 =30	td + 5 =15 + 5 =20
-	-	-	-	-	-	Type C	20	20	td+tr+20 =20+10+20 = 50	td+5 =20+5 =25	td+tr+10 =20+10+10 =40	td+5 =20+5 =25

Notes: 1. Figures show lining thickness in cm. measured from the inner face of lined concrete.

2. Pay line is expressed in average thickness.

3. td denotes designed thickness (A-line).

4. tr denotes the height of steel support rib (tr = 10 cm).

5.4. Water Treatment Plant

5.4.1. major Facilities of Treatment Plant

Based on the design criteria, preliminary design of the treatment plant was conducted. General layout of the treatment plant and its hydraulic profile are presented in the separate volume Appendix D "Drawings". Dimensions and specifications of major facilities of the plant are presented as below:

<u>Receiving Well</u>

Number of wells	:	one
Dimensions	:	W8.0 m x L15.0 m x D5.0 m (R.C)
Effective volume	:	about 600 m^3
Appurtenances	:	overflow weir L = 7.7 m
		flow meter and shut-off valve (two sets)

<u>Mixing Well</u>

Number of wells	:	4
Dimensions	:	W6.0 m x L6.0 m x D5.0 m (R.C)
Flush Mixer	:	vertical mixer
		motor 22 kw

<u>Flocculation Basin</u>

Number of basins	:	8
Number of channels	:	6
Dimensions	:	1st stage W1.5 m x L32.5 m x D3.5 m x 2 channels
		2nd stage W2.0 m x L32.5 m x D3.5 m x 2 channels
		3rd stage W2.9 m x L32.5 m x D3.5 m x 2 channels
Effective volume	:	1,430 m^3 (R.C)

Sedimentation Basin

Number of basins	:	8
Dimensions	:	W32.0 m x L90.0 x D4.0m (R.C)
Effective volume	:	11,500 m^3
Sludge Scraper	:	Bridge type traveling girder with suspended retractable sweeper
Desluding pipes	:	desluding main ø400 mm
and valves	:	desluding values ø200 mm x 6 sets/basin
Effluent trough	:	W0.4 m x H0.4 m x L5.0 m x 24 nos/basin

Rapid Sand Filter

Number of filter beds	:	40 (including 4 spare)
Surface area	:	W4.0 m x L16.0 m x 2 beds = 128 m^2
Filter media	:	thickness 70 cm
		effective size 0.65 mm
		uniformity coefficient 1.5
Supporting gravel	:	thickness 25 cm
		grading 4 - 40 mm
Underdrain	:	perforated plate
Backwash	:	backwash rate 0.6 m^3/m^2.min
		from elevated tank
Surfacewash	:	surfacewash rate 0.2 m^3/m^2.min
		by pump ø450 x ø300 x 25 m^3/min x 20 m x 4 units (including 2 standby)

Clear Water Reservoir

Number of reservoirs	:	4
Dimensions	:	W40.0 m x L40.0 m x D4.0 m (R.C)
Appurtenances	:	inlet weir L = 11.3 m
		valves inlet ø1,200 mm x 1 no./basin
		outlet ø1,350 mm x 2 nos/basin
		ø1,500 mm x 2 nos/basin

Elevated Tank

Number of tanks	:	2
Dimensions	:	Dia. 19.5 m x D 2.5 m (R.C)
Effective volume	:	700 m^3
Lifting pump for backwashing	:	ø450 mm x ø400 mm x 23.3 m^3/min x 15 m x 3 units (including 1 stand-by)

Waste Water Basin

Number of basins	:	2
Dimensions	:	W15.0 m x L27.0 m x D2.5 m (R.C)
Effective volume	:	1,000 m^3

Buildings

Administration bldg	:	B12.0 m x L63.0 m x 2 stories composing of control room, electric room, laboratory, chief room, office, meeting room and etc.
Chemical building (Alum)	:	B18.0 m x L24.0 m x 2 stories composing of alum dilution tank room, air blower and alum transfer pump room, alum feeding room, alum storage room, etc.
Chlorination building	:	B18.0 m x L30.0 m x 1 story composing of chlorine container storage room, chlorinator room, neutralization room, etc.

Chemical Feeding Facilities

Alum feeding facilities:

alum dilution tank	15 m^3 x 4 units	
alum solution storage tank	300 m^3 x 4 units	
alum transfer pump	500 l/min x 4 units (including 2 stand-by)	
alum feed pump	500 l/min x 4 units (including 2 stand-by)	
elevated tank	15 m^3 x 4 units	
head tank	100 l x 2 units	

Chlorination facilities:	evaporator	200 kg/hr x 2 units for pre-cl_2 (including 1 stand-by)
	chlorinator	150 kg/hr x 2 units for pre-cl_2 (including 1 stand-by)
		50 kg/hr x 2 units for post-cl_2 (including 1 stand-by)

According to above preliminary design of the facilities and hydraulic analyses, plans and typical section of sedimentation basin, rapid sand filter and clear water reservoir are shown in Appendix D "Drawings" together with chemical feeding system diagram and instrumentation diagram.

5.4.2. Consideration of Reusing Waste Water

Water available from the Khanpur Reservoir is planned at 37,400 million gallons or 102.4 MGD on the average. Analysis of water balance of the Haro River indicates that the above quantity of water may not be taken during drought year. Water supply system is charged for raw water at the rate of Rs. 2.77/000 gal. Reusing of waste water might have an advantage from the view points of economy and full utilization of limited raw water.

Water loss during treatment process is estimated at about 5% of water production when all waste water is drained. As for the recirculation operation for reusing of waste water, the following processes are available according to the extent of the treatment of waste water.

Case - 1: All waste water from sedimentation basin and filter is reused. Waste water from sedimentation basin is treated and supernatant water is returned to receiving well. On the other hand, all waste water from filter is returned without treatment. Water loss will be reduced to 1%.

Case - 2: Only waste water from filter is reused. Waste water is once stored in waste water basin and supernatant water is returned to receiving well. Water loss is estimated at 3%.

Case - 3: Only waste water from filter is returned. But water is returned directly to receiving well without any treatment.

The flow diagram and required major facilities of each case are presented in the attached Figure B.V-6.

The benefit of the reusing of waste water is calculated as the saving cost of raw water charge. The benefit of each case is obtained multiplying saving raw water amount by raw water rate as Rs. 2.77/000 gals. According to the tentative cost estimate, cost and benefit analysis was made as shown in the below table.

Case	Water Loss (%)	Benefit (000 Rs)	Initial Cost (000 Rs)	O & M Cost (000 Rs/y)	Annual Cost (000 Rs/year)
1	1	5,000	26,000	1,530	4,400
2	3	2,500	9,000	440	1,400
3	2	3,600	5,500	1,530	2,100

Note: O & M cost includes electric and chemical cost only.
Annual cost is estimated on condition of interest rate of 10% per annum and amortization period of 30 years with six years grace period.

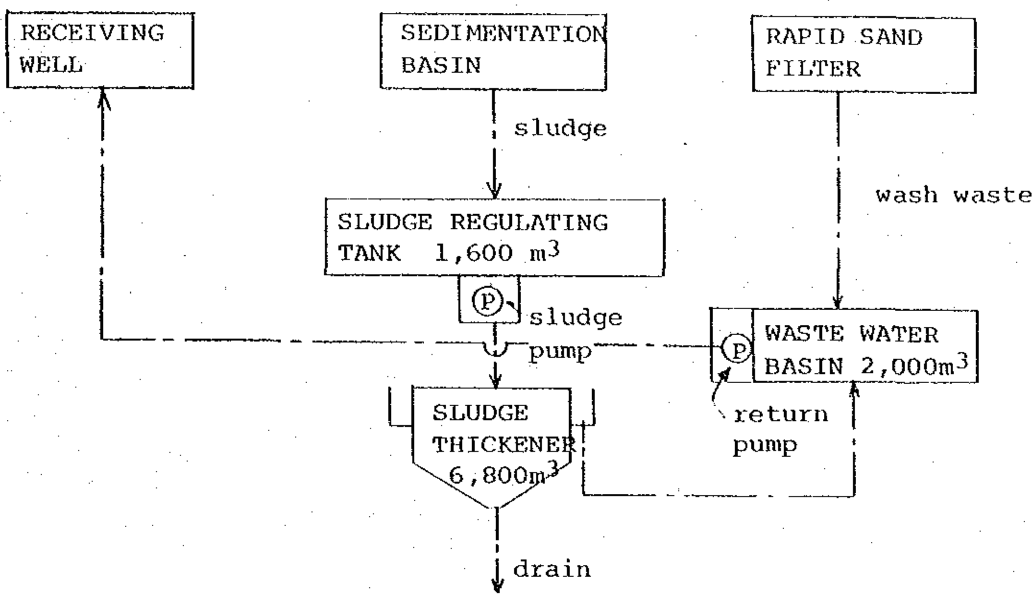
The effect on environment caused by the drain of highly concentrated waste water to stream is to be carefully examined. As for the case 1, the final treatment of sludge is not included and the cost for that will be considerably high and needs large space for treatment. In general, detailed analysis of waste water quality and some test using test plant are required to decide the proper treatment process and necessary facilities with adequate size. The process and size of facilities are much different according to the quality of waste water.

From the above study, the reusing of waste water is, at moment, not employed in the preliminary design and cost estimate. It will be worthy to examine on the reusing of waste water in detail during design stage from the viewpoints of economy, importance of saving limited raw water available and environmental effects.

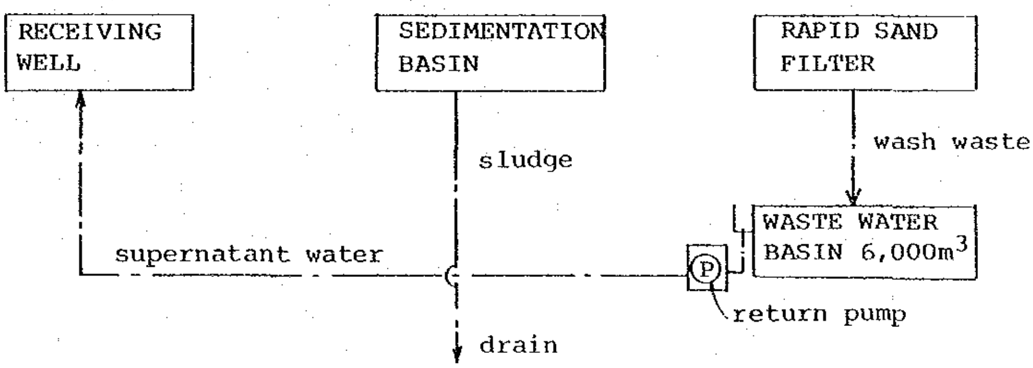
5.4.3. Foundation Geology at Treatment Plant Site

As discussed previously in Chapter III, 3.2 of this Appendix, foundation geology at the proposed site of treatment plant is mainly composed of silty clay of Alluvium accompanied with some layers of sand and gravel. With exception of surface layers, silty clay has sufficient bearing capacities with "N" valves ranging from 20 to 30 and subsidence is also considered to be less. Silty clay at the site appears massive and uniform faces with little possibility of differential settlement. It is, however, recommendable to investigate in detail during the course of detail design.

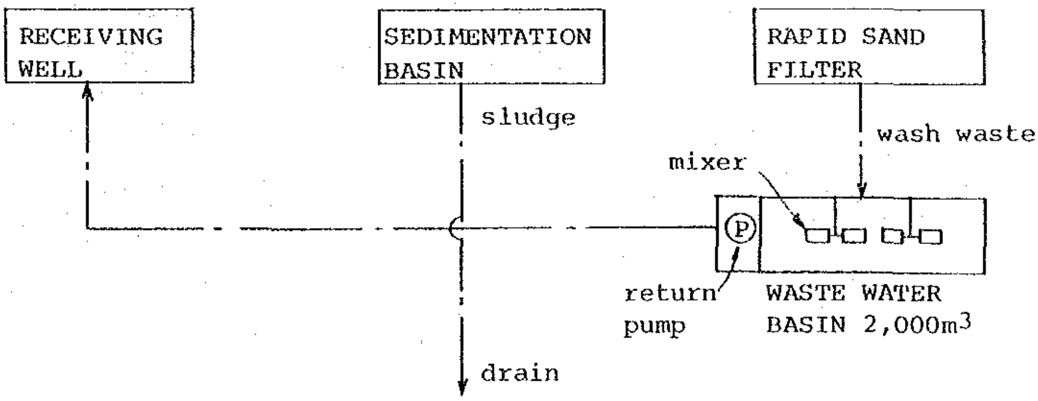
FIGURE B.IV-6 PROCESS AND MAJOR FACILITY FOR REUSING OF WASTE WATER



Case - 1



Case - 2



Case - 3

5.5. Preliminary Design of Distribution Main Including Pumping Station and Service Reservoir

5.5.1. Service Reservoir

A. Golra-1 Service Reservoir to Islamabad High Zone

The lowest water level (LWL) of the service reservoir is, based on hydraulic calculations, determined at 663.0 m (2,174 ft). In review of location, length of pipeline to be installed, elevation to be required and geological features, the proposed site of service reservoir is selected at a hill situated to the north of treatment plant with the maximum elevation of 674 m (2,210 ft) above mean sea level.

a. Service Reservoir Capacity

Capacity of service reservoir is taken as six hours capacity of the maximum daily discharge, that is prescribed by the design criteria. Therefore,

V = 1.193 cu.m/sec x 6 hours
= 25,769 cu.m
≑ 26,000 cu.m = 13,000 cu.m x 2 units
(2.86 MG x 2 units)

b. Structure

In consideration of the required capacity, structures of service reservoir acceptable for the Project are as under;

- Flat Slab Type of Reinforced Concrete
- Ground Type of Prestressed Concrete (PC Tank)

A ground type of prestressed concrete (PC Tank) was selected for Golra-1 service reservoir in review of the followings;

- Since the proposed site is situated on the top of a hill, large lot is not available.

- A flat slab type needs relatively large space because that a tall wall is not preferable from structural point of view, while a PC tank needs relatively narrow space with high walls.

- Geology of the site is composed of rocks and high costs for excavation are needed to secure a large space.

- A PC tank is superior to present a fine spectacle.

Taking into account the topography of the Site, two units of tanks are suitable to be constructed, and thus, ground elevation after grading is determined at 663.4 m (2,175 ft).

c. Effective Depth of Water

In case of PC tank, a ratio (D/H) of diameter (D) to water depth (h) is, in general, economically acceptable between 3 and 5. Values of H and D against the unit capacity of the service reservoir of 13,000 cu.m are given as follows;

D/H	3	to	5
H (m)	12.3	to	8.7
D (m)	36.8	to	43.6

On the other hand, as the effective depth of water increase, fluctuation of dynamic pressures also increases giving undesired effects upon the terminal units of distribution. Considering economy, available space for construction as well as effective range of dynamic pressures, the effective depth of water is determined at 10.0 m. Consequently the high water level (HWL) is worked out as 663.0 + 10.0 = 673.0 (2,207 ft). Thus, required diameter of the tank comes to about 40.7 m producing the ratio of D/H of about 4.1.

B. Golra-2 Service Reservoir to Islamabad Low Zone

LWL is produced from hydraulic calculations as LWL = 614.5 m (2,015 ft). As is similar to the Golra-1 service reservoir, the Golra-2 service reservoir is proposed at the top of a hill, which is located adjacent north to the treatment plant, for the sake of not only minimizing quantity of each work but also operation and maintenance.

a. Service Reservoir Capacity

V = 0.768 cu.m/sec x 6 hours
= 16,589 cu.m
= 16,600 cu.m = 3.65 MG x 1 unit

b. Structure

Based on LWL, grading level is determined at 614.6 m (2,015 ft). One unit of PC tank is constructed at the site taking into account the following conditions;

- To cope with an emergency or an accident, the reservoir can be connected with the Golra-1 service reservoir, that is in charge of distribution of water to High zone of Islamabad.

- A pipeline is presumed to be constructed in parallel with the force main resulting that direct pumping distribution become possible by means of constructing connection pipes.

c. Effective Depth

Effective depth of water is taken at 10.0 m as is similar to Golra-1 service reservoir. In this case, the required diameter of tank comes to about 46.0 m resulting in a value D/H of about 4.6, that is still within an economical range. Accordingly HWL of the service reservoir is 624.5 m (2,048 ft).

C. H-11 Service Reservoir to Rawalpindi

According to hydraulic calculations LWL of the H-11 service reservoir is given at 551.0 m (1,807 ft). The site is proposed at the sector H-11, where is situated near from service areas, an apron of 2,010 ft contour line exists and therefore required water head is available.

a. Service Reservoir Capacity

V = 4.121 cu.m/sec x 6 hours
= 89,014 cu.m
≑ 89,200 cu.m = 22,300 cu.m x 4 units
(4.90 MG x 4 units)

b. Structure

The proposed site has a sufficient space and the ground elevation hydraulically requested is also secured. On the other hand, there is little margin in an available water head under the condition that water is conducted from the treatment plant and then further conveyed to each distribution unit by gravity. Under these conditions, only a little allowance is available for the effective depth of water and, therefore, a flat slab type is selected as the most suitable after economic consideration.

The service reservoir is of a large scale and is suitable to be divided into four units, taking the phasing plan of the Project into consideration.

c. Effective Depth

In consideration of the following conditions, the effective depth of water is taken at 6.0 m.

- Effective depth is restricted hydraulically within the available water head, because gravity flow system is introduced.

- In review of structure and dimension of the existing reservoirs, a deep reservoir constructed with high retaining walls would result in structural and engineering problems of less waterproof and less quakeproof.

- Since the service reservoirs are of gravity flow type and it is difficult for dynamic water pressures in pipes to be kept within a certain acceptable range, and in general a proper range of effective depth is considered to be 3 to 6 m.

Taking the effective depth at 6.0 m, HWL is produced as 557.0 m (1,826 ft).

D. Specification of Service Reservoir

Dimensions and specifications of service reservoirs are summarized as below.

Name	Golra-1	Golra-2	H-11
Service Area	Islamabad High Zone	Islamabad Low Zone	Rawalpindi
Capacity of Unit (cu.m)	13,000	16,600	22,300
Number of Units	2	1	4
Effective Depth (m)	10.0	10.0	6.0
HWL (m)	673.0	624.5	557.0
HWL (ft)	(2,207)	(2,048)	(1,826)
LWL (m)	663.0	614.5	551.0
(ft)	(2,174)	(2,015)	(1,807)
Structure	PC Tank	PC Tank	RC Flat Slab

E. Foundation Geology at Service Reservoir Sites

Service reservoirs, Golra-1 and Golra-2, are both constructed on the top of small hills situated on the northeast of Golra. Geology of the sites is mainly composed of limestone with alternating beds of marl, which is belonging to Chor Gali Formation of Eocene age. Distributed rocks are, as a whole, poor in beddings but have well-developed relatively fine cracks. Inclination of the layer around the sites is about 70° to the south. As a whole surface soil and softened weathered zone have not well developed. Rocks are hardly deformable and so strong with sufficient bearing capacities as to be foundation of the service reservoirs.

Foundation geology at the site of the proposed H-11 service reservoir is mainly composed of silty clay of Alluvium, which may contain some gravel layers. This area is located on the marginal line of the outcropping rock zone with a relatively thin layers of alluvium. It is estimated however that no rock would appear at the depth of the reservoir foundation. Judging from the existing data investigated elsewhere near the proposed site, silty clay is expected to have, except surface layers, a "N" value of more than 20, and so considered to have a sufficient bearing capacity. As concerns differential settlement of the structure, no severe problem is presumed since subsidence is not a type of consolidated subsidence and existing layers of clay are not too thick. However, further investigation is recommendable.

5.5.2. Distribution Main

Pumping pressure pipelines are constructed to connect the clear water reservoir of the treatment plant with service reservoirs to serve the High and Low zones of Islamabad, while a gravity flow pipeline is constructed to serve Rawalpindi.

A. Number of Pipeline

Two lines of pressure pipes in parallel are proposed to link Golra-1 service reservoir for Islamabad High zone with pumping station, to cope with either emergency or operation & maintenance. Two lines of free-flow pipes are also proposed to connect H-11 service reservoir for Rawalpindi service area with pumping station. A pressure pipeline between Golra-2 service reservoir for Islamabad Low zone with pumping station is proposed economically with single line since the water of Golra-1 service reservoir is hydraulically convertible in case of emergency, and since the water can be directly pumped up into distribution systems when distribution pipes are constructed in parallel with the distribution main in future.

B. Diameter of Pipe

The most suitable diameter for pressure pipelines are investigated economically and hydraulically involving running and construction costs of pumps, and it is found that the most economic velocity of flow exists somewhere around 1.5 m/sec. Accordingly distribution main for Golra-1 service reservoir is proposed as ø700 mm x 2 lines while the one for Golra-2 is ø800 mm x 1 line. Gravity flow pipeline for H-11 service reservoir is proposed hydraulically as ø1,500 mm x 2 lines.

C. Pipe Material

Distribution main pipeline of Golra-1 service reservoir, which is a pumping pressure pipe, sustains hydro-static pressure of about 12 kg/sq.cm and design pressure of about 18 kg/sq.cm inclusive of impact pressure. As for pipeline of Golra-2 service reservoir, about 7 kg/sq.cm of hydro-static pressure and 11 kg/sq.cm of design pressure are also estimated. Considering that the pipe is pressured, and from economic reason ductile cast iron pipe is selected.

On the contrary a gravity flow pipe of H-11 service reservoir receives about 5 kg/sq.cm of hydro-static pressure, as the maximum at the limited local portion, and about 8 kg/sq.cm of design pressure. PRCC with steel core is therefore selected mainly from economic point of view.

D. Laying a Pipe Underground

As shown in design criteria, the minimum earth covering is proposed at 1.2 m. For the section where a pressure pipe runs across steep slopes, pipes are lined with concrete in consideration of the followings;

- Sites are all covered with rocks. From economical viewpoint, it is needed to minimize excavation works.

- Site refilled with earth will be easily eroded by rain water running along a pipe.

- It is needed to prevent pipes from sliding especially where the construction site is inclined steeply.

- Exposed pipe of aqueduct style needs skillful construction works and higher costs for construction as well as for operation & maintenance.

Some parts of gravity flow pipes for Rawalpindi are laid deep underground at the places where the pipeline runs across rivers, and therefore such parts as required are lined with reinforced concrete to cope with earth pressures or erosion.

E. Appurtenant Structure

To expect safe and easy operation & maintenance works of pipelines, the following appurtenant structures are proposed to be equipped.

- Air Valve
- Stop Valve
- Blow-off
- Manhole
- Connecting Pipe

5.5.3. Pumping Station

Waters conveyed to the service reservoirs of Islamabad are pressured by pumps. Pumping station is built within the compound of Golra Treatment Plant. In the pumping station, three units of lifting pump for back washing and four units of surface wash pump in addition to lifting pumps, which pressures waters to Islamabad, are installed. Clear water reservoir with LWL of 563.2 m (1,846.6 ft) functions as a suction sump.

A. Total Pump Head

The total water head of lifting pumps (H_T) is given as an aggregate of an actual pumps head, which is shown as the difference between HWL of the service reservoir and LWL of the clear water reservoir, and friction and other loss heads of pipeline (Hf) and loss heads in the pumping station ($H\ell$).

Item	Islamabad High Zone	Low Zone
Suction Head (Clear Water Res.LWL)	563.20 m	563.20 m
Discharge Head (Service Res. HWL)	673.00 m (Golra-1)	624.50 m (Golra-2)
Actual Pump Head (Ha)	109.80 m	61.30 m
Conveyance Loss (Hf)	5.98 m	5.04 m
Losses in P. Station ($H\ell$)	1.72 m	1.66 m
Total Pump Head (H_T)	117.50 m	68.00 m

B. Number of Pumps and Capacity

As previously mentioned in design criteria, five pumps of equal capacities with one spare unit are installed for both High and Low zones of Islamabad. Design discharges and diameters are given as under.

Dimensions	Islamabad High Zone	Low Zone
Total Discharge (cu.m/min)	71.58	46.08
No. of Unit	5	5
Spare Unit	1	1
Total Units	6	6
Discharge/Unit (cu.m/min)	14.32	9.22
Bore (Suction x Discharge)	ø300 mm x ø200 mm	ø300 x ø200

C. Selection of Pump Type

Judging from the required dimensions of discharges and total pump heads, Horizontal Shaft Double Suction Volute Pump is selected as the most economic and suitable for the Project.

D. Motor Capacity

Output of motor is given in the following equation;

$$P = 0.163 \times \frac{\gamma \times Q \times H}{\eta} \times (1 + \alpha)$$

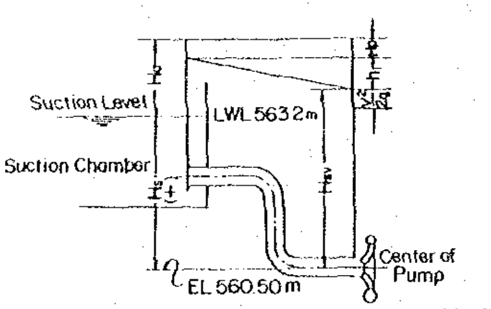
where, P: Output (kw)
γ: Unit weight of water = 1.0 kg/ℓ
Q: Discharge (cu.m/min)
H: Total pump head (m)
η: Pump efficiency
α: coefficient

Computations are shown as below;

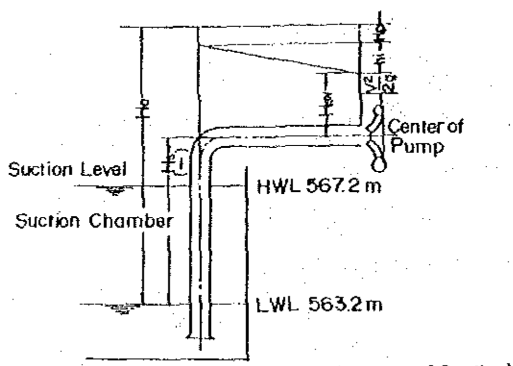
Pump Dimension	Islamabad High Zone	Low Zone
Q (cu.m/min)	14.3	9.22
H (m)	117.50	68.00
η	0.79	0.79
α	0.15	0.15
P (kw)	400	150

E. Cavitation

Clear water reservoir to be used as suction sump of pumps is constructed underground with a wide-range fluctuation of water levels. Moreover many pumps are installed. When aggregate pipe system is considered, pushing method, as illustrated in the following figures, is proposed;



(A) Effective Suction Head Hsv (in Case of Pushing)



(B) Effective Suction Head Hsv (in Case of Suction)

When cavitation is occurred in the pump, pumping discharge is extremely reduced because of the vibrations and noises, and as a result, the material of the affected parts eroded to a regrettable extent. Growth of cavitation depends upon the degree of pressure drop within the pump. For pump to be operated without cavitation growth, it is essentially needed that the effective suction head be upwards of a certain definite valve. This effective usable suction head is termed "Available NPSH (Net Positive Suction Head)."

$$Hsv = Ha - Hp + Hs - hl$$

where,

Hsv: available NPSH (m)

Ha : atmospheric pressure as expressed in head (m) = 10.33 m

Hp : steam pressure at the particular water temperature as expressed in head (m) = 0.33 m (25°C)

Hs : actual suction head (m)
in case of suckup (-)
in case of push-in (+) = 2.70 m

hl : head loss in suction pipe (m) ≒ 0.50 m

$$\therefore Hsv \fallingdotseq 10.33\ m - 0.33\ m + 2.70\ m - 0.50\ m \fallingdotseq 12.20\ m$$

In addition to the above, there is a critical point for effective suction head required in operation according to the variations in the total head, delivery and rotational number of the pump, which has been called "Required NPSH". This is the smallest of the required head as needed for the water to be sucked into the impeller, which is proper to each type of the pump, and generally, expressed by the formula.

$$hsv = \alpha x H$$

in here,

hsv: NPSH as needed by the pump (m)

α: Thoma's cavitation coefficient

H: total head of pump (m)

The critical value in cavitation coefficient is, in general, expressed in terms of the function Ns (= specific speed) of the pump.

When rotation speed of pump is assumed to be 1,460 rpm (50 Hz, 4P), specific speed of pump is 109.5 and 132.4 respectively for Islamabad High and Low zones. Thomas' cavitation coefficients are also given as 0.041 and 0.055, respectively. Accordingly, NPSH as needed by pump is given as follows;

Pumps for High zone hsv = 0.041 x 117.5 = 4.82 m

Pumps for Low zone hsv = 0.055 x 68.0 = 3.74 m

To be safe from cavitation, effective suction head available must be larger than that required for pumps. That means;

$$Hsv > hsv$$

In general, Hsv - hsv > 1.0 m is recommended. As a consequence, pumps for both High and Low zones of Islamabad are thoroughly safe against cavitation and thus rotational speed of pump is determined at 1,460 rpm (50 Hz, 4P).

F. Water Hammer

When the supply of power to the pump in operation is suddenly cut because of power suspension and the like, there may come a sudden change in pressure on the delivery side of the pump. As it is an important thing to prevent or reduce such a water hammering action, from the viewpoint of planning pumping equipment, surveys in advance on hammering action in the pumping system are right in order.

As shown in Figure B.V-7 and B.V-8, no countermeasure is needed by pumps for Islamabad High zone. For Low zone, pumps are safe from injurious negative pressures if they are equipped with fly wheels of about 20 kg.sqm (GD^2) per a unit of pump.

G. Specification of Pumps

No. Pump (To Islamabad High Zone)

Horizontal Shaft Double Suction Volute Pump

Bore	Suction ø300	Discharge ø200	(6 units)
Capacity	14.232 m^3/min		
Total Head	117.5 m		
Revolution	1,460 rpm		
Motor	400 kw 50 Hz 4P		

No.2 Pump (Low Zone)

Horizontal Shaft Double Suction Volute Pump

Bore	Suction ø300	Discharge ø200	(6 units)
Capacity	9.22 m^3/min		
Total Head	68 m		
Revolution	1,460 rpm		
Motor	150 kw 50 Hz 4P		

No.3 Pump (for Surface Wash)

Horizontal Shaft Double Suction Volute Pump

Bore	Suction ø450	Discharge ø350	(4 units)
Capacity	25 m^3/min		
Total Head	20 m		
Revolution	990 rpm		
Motor	132 kw 50 Hz 6P		

No.4 Pump (for Back Washing)

Horizontal Shaft Double Suction Volute Pump

Bore	Suction ø450	Discharge ø400	(3 units)
Capacity	23.3 m^3/min		
Total Head	15 m		
Revolution	990 rpm		
Motor	90 kw 50 Hz 6P		

H. Foundation Geology at Pumping Station

Since pumping station is constructed in the compound of the treatment plant, the same condition as mentioned for the treatment plant is expected. Foundation of the pumping station is excavated as deep as 9 m below ground surface and there is some possibility that the foundation reaches below groundwater table. This would, however, produce no severe problem because drainage facilities are also proposed to be accompanied. Special attention should be paid that the workability is quite inferior in silty clay below groundwater table.

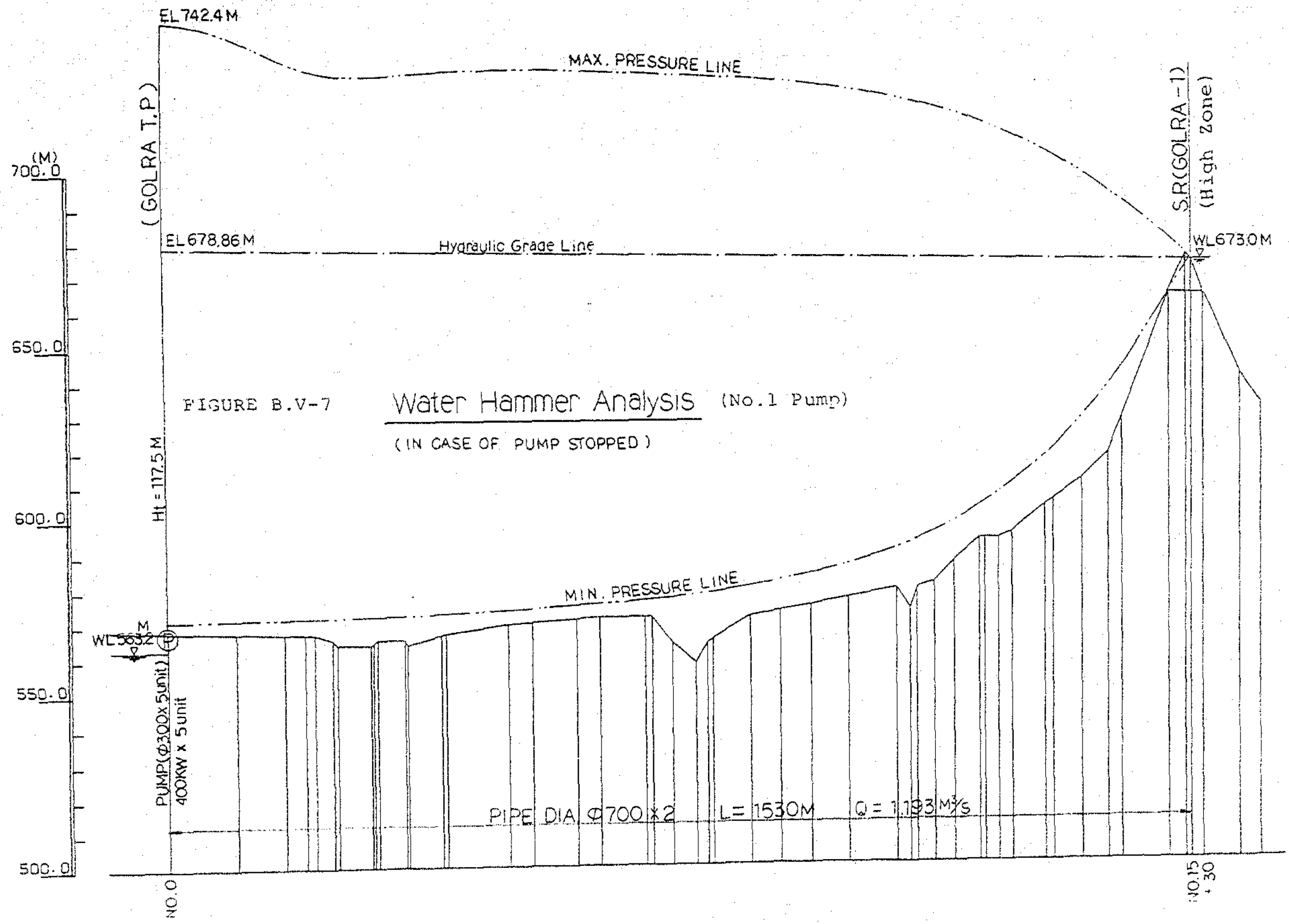
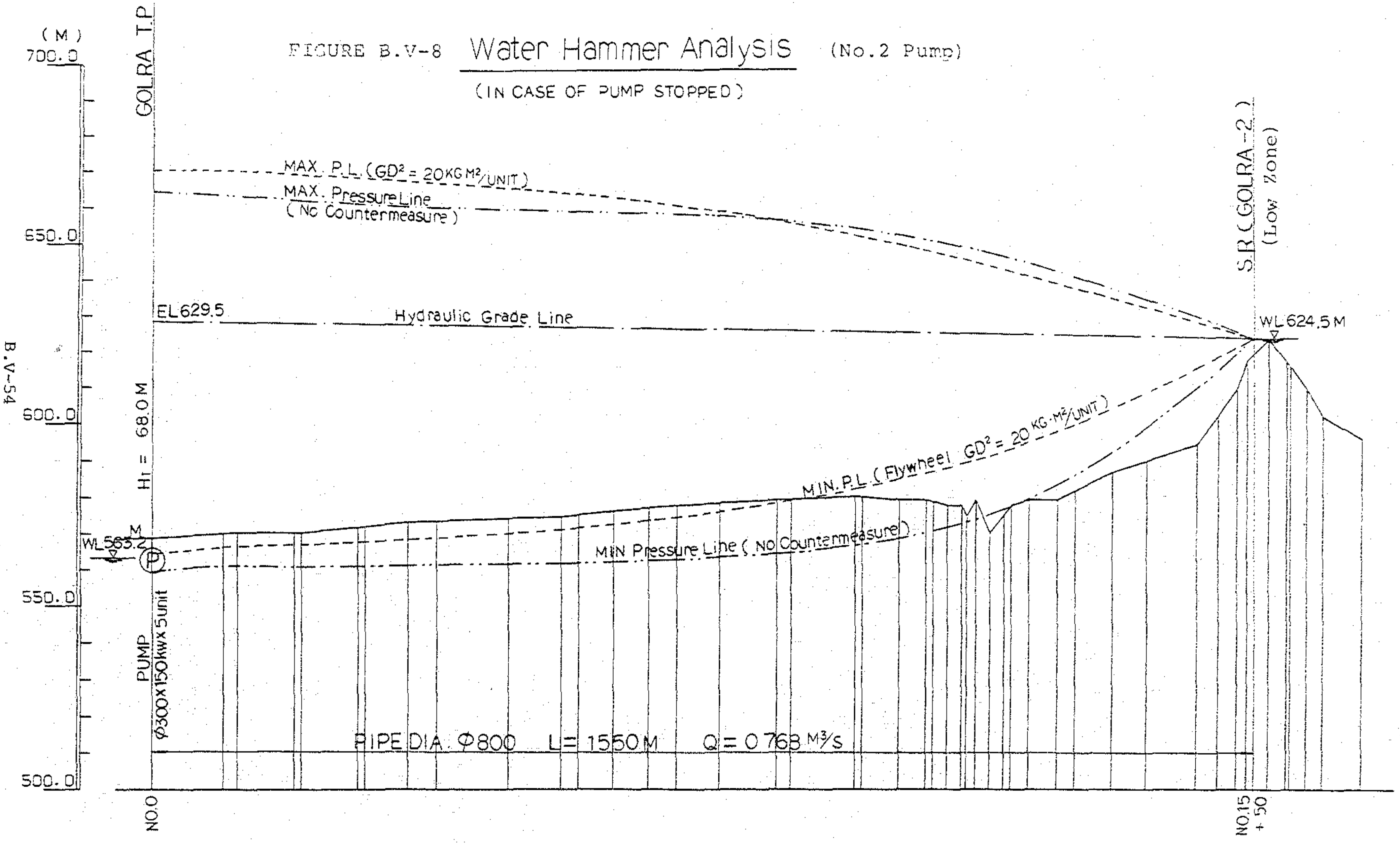


FIGURE B.V-7 Water Hammer Analysis (No.1 Pump)
(IN CASE OF PUMP STOPPED)

FIGURE B.V-8 Water Hammer Analysis (No.2 Pump)

(IN CASE OF PUMP STOPPED)



CHAPTER VI. CHANGEABILITY OF WATER RESOURCES IN ISLAMABAD

CHAPTER VI. CHANGEABILITY OF WATER RESOURCES, IN ISLAMABAD

6.1. General Description

According to the results of water balance study of the Simly reservoir made by the JICA study team, the availability of water resources of the reservoir after installation of spillway control gates and emergency spillway is prospected about 1.90 cu.m/sec (36 MGD) when critical drought is occurred once in five years.

CDA has been constructed No.1 and No.2 conduction main with capacity about 1.26 cu.m/sec (24 MGD) from Simly filtration plant upto service reservoir existed in Islamabad. Third conduction main will also be constructed with 0.63 cu.m/sec (12 MGD) capacity to convey clear water to developing sectors.

On the other hand, the Khanpur water will be supplied directly from Khanpur reservoir to commandable area of 11 to 15 sectors through Margala tunnel, water treatment plant and pumping station.

Receiving water level of existing service reservoir, which is situated nearby F-5 sector and receives the water from Simly filtration plant, is approximately 620 m (2,010 - 2,045 ft). Besides, the water level of proposed service reservoir which will be constructed near E-10 sector as additional programme is also approximately 600 m (1,960 - 1,980 ft). Whereas, the water level of clear water at Golra water treatment plant is about 563 m (1,946 ft), when the raw water conveyed from Khanpur.

The ground elevation of commandable water supply area by both the Simly and Khanpur dam ranges from 520 m to 640 m (1,700 - 2,000 ft) with rather complicated topographic conditions.

In this connection, the study on most suitable water resources distribution manner shall be made taking into consideration available changeability of water resources, technical and economical viewpoints as well as operation and maintenance aspects.

6.2. Comparative Study

6.2.1. Plan Description

Existing and proposed water supply systems in Islamabad are rather complicate due to water resources and topographic conditions. In order to simplify the comparative study, the service area to be studied are shown in Figure B.VI-1, -2 and -3.

- The Original Plan:

  The Simly water as a main water resources for developed area will be supplied up to 10 sector from northern part of city with stream and groundwater, while Khanpur water will be served in new developing area from 11 to 15 sector.

- The Alternative Plan:

  The Simly water will mainly be supplied in rather high zone of developed and or developing area, whereas, Khanpur water will be supplied to low zone of commandable area.

6.2.2. Distribution Main and Hydraulic Computation of Both Plan

A. Distribution Main

Proposed distribution mains, which are indicated in Figure B.VI-1 and B.VI-2, are aligned taking into consideration most economic routes, topographic conditions and convenience of operation and maintenance works.

B. Hydraulic Computation

The computation of both plans was made based on the design discharge, representative elevation of each sectors, pipe length and pipe diameter assumed etc. The results of computation are shown in Table B.VI-1 to -7, respectively.

6.2.3. Major Construction Cost and Operation and Maintenance Cost

A. Construction Cost

The summary of specification of proposed facilities for both plans and its construction cost required are indicated in Table B.VI-8.

B. Operation and Maintenance Cost

a. Electricity Charge

Plan	Motor Output (kw)	Annual Operation Hour (H)	Charge (Rs.1,000) Fixed Rate 924 Rs/kw/Yr.	Operating Rate 0.35 Rs/KWH	Total
Original					
SHZ	270	7,008	249	662	911
KHZ	1,400	7,008	1,294	3,434	4,728
KLZ	435	7,008	402	1,067	1,469
Total	2,105		1,945	5,163	7,108
Alternative					
SWZ	525	7,008	485	1,288	1,773
SEZ	270	7,008	249	662	911
KWZ	1,200	7,008	1,109	2,943	4,052
KEZ	380	7,008	351	932	1,283
Total	2,375		2,194	5,825	8,019

b. Labour Wages

Plan	Pump Operator	Technician	Total
Original	6x12x2,000 = 144,000	6x12x1,500 = 108,000	Rs.252,000
Alternative	8x12x2,000 = 192,000	8x12x1,500 = 144,000	Rs.336,000

c. Repairing and Maintenance Cost

The cost assumes about 2 percent of pumping plant cost.

6.2.4. Comparative Study

A. economic Comparison

The summary of required initial and OM cost including electric charge is as under.

	Item	Original (Rs.1,000)	Alternative (Rs.1,000)
I.	Initial Cost		
	Pumping plant	96,120	116,800
	Pipe work	106,600	140,200
	Service reservoir	79,260	91,340
	Total	281,980	348,340
	(Ratio)	(100)	(124)
II.	Operation/Maintenance Cost		
	Electric charge	7,108	8,019
	Labour cost	252	336
	Maintenance cost	1,922	2,336
	Total	9,282	10,691
	(Ratio)	(100)	(115)

B. Conclusion

The result of comparison for both initial and operation/maintenance cost show that original plan is more economical than that of alternative. Major reason for this are mainly pumping up cost related to H-9, H-10, I-9, I-10 sectors of alternative plan against gravity flow of original plan. Therefore, original plan should be recommendable for water supply system of the Project.

FIGURE B.VI-1 ORIGINAL PLAN

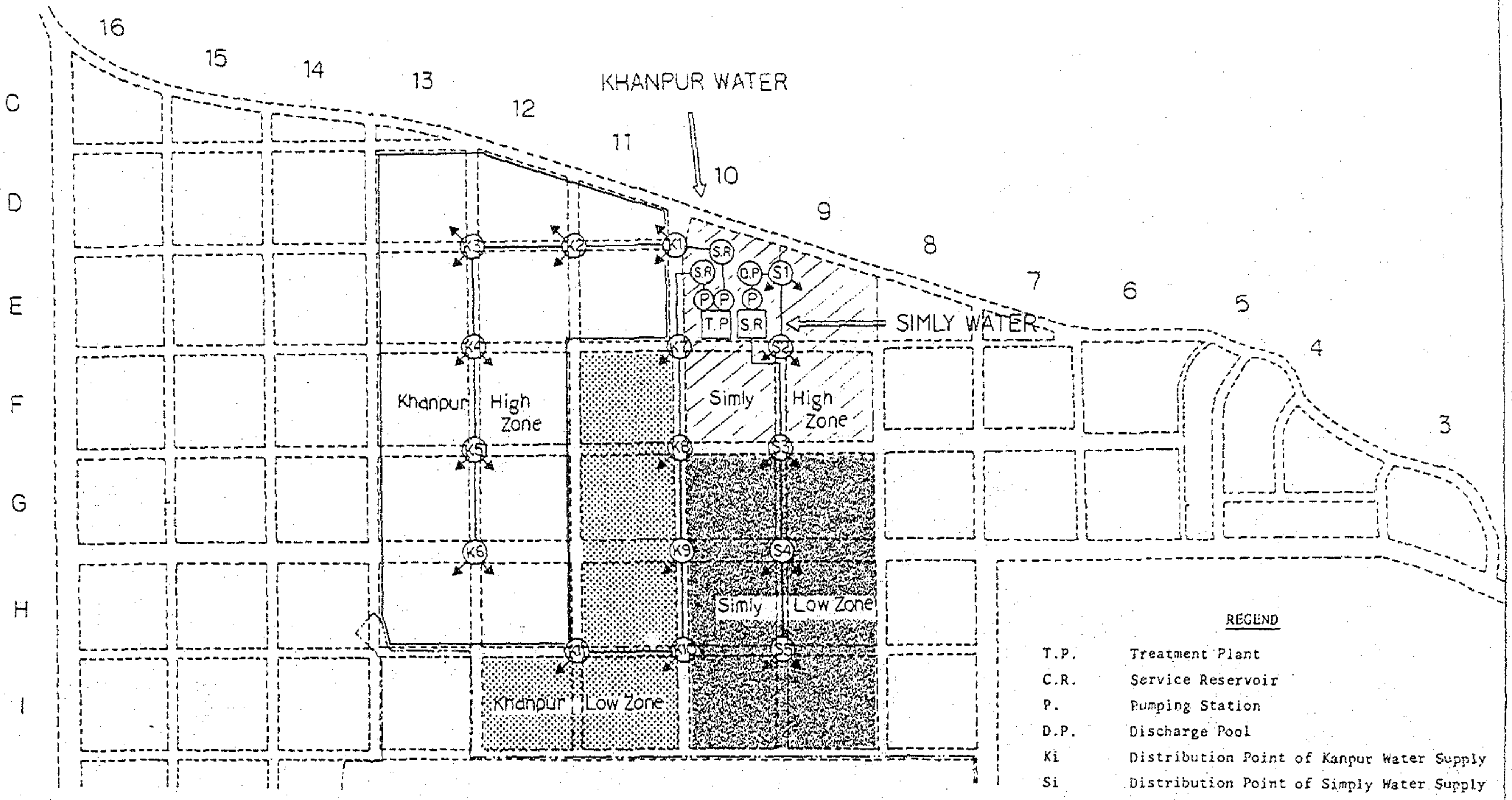


FIGURE B.VI-2 ALTERNATIVE PLAN

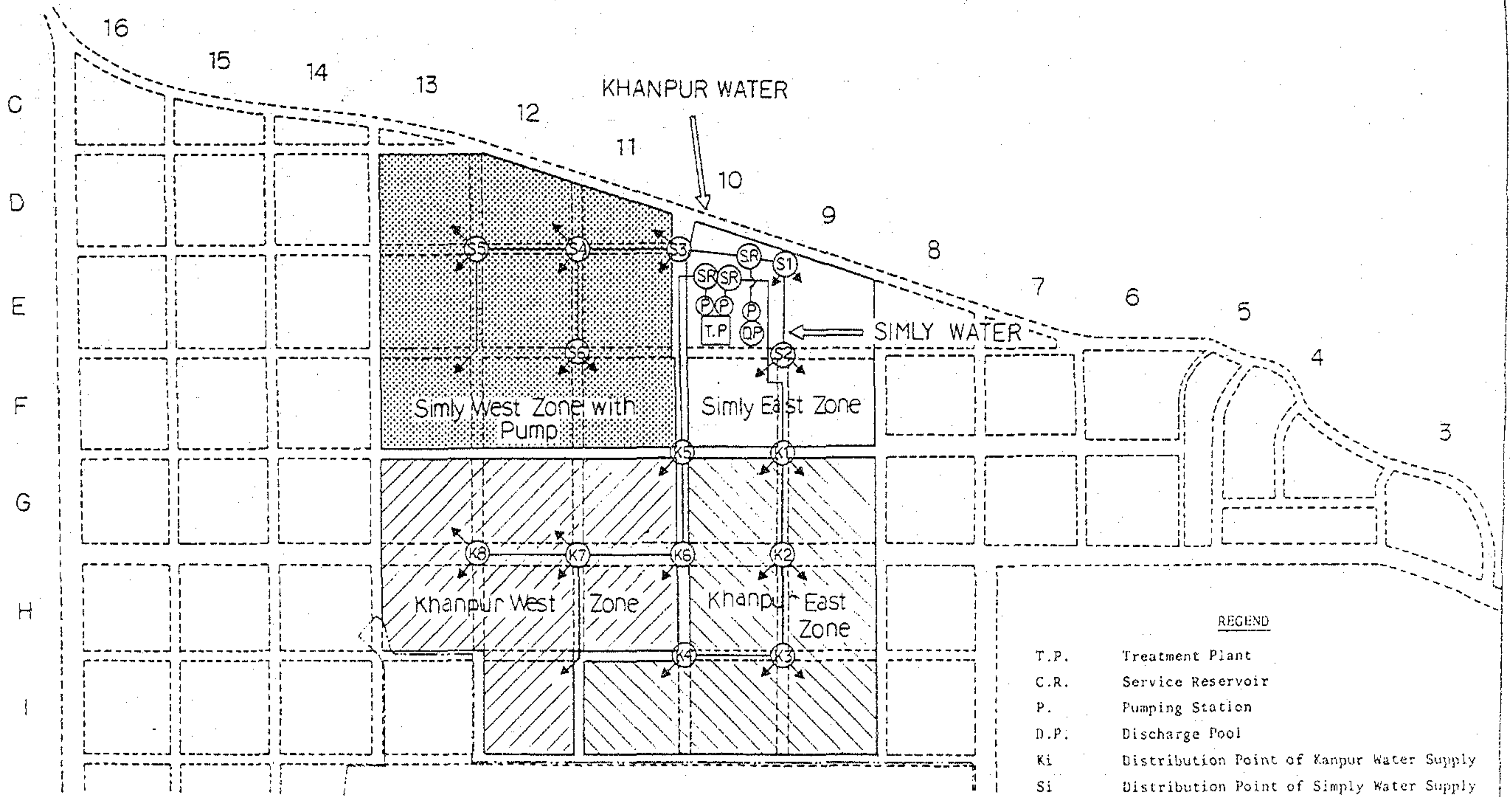


FIGURE B.VI-3 GROUND LEVEL AND MAX. HOURLY DISCHARGE OF DISTRIBUTION UNITS

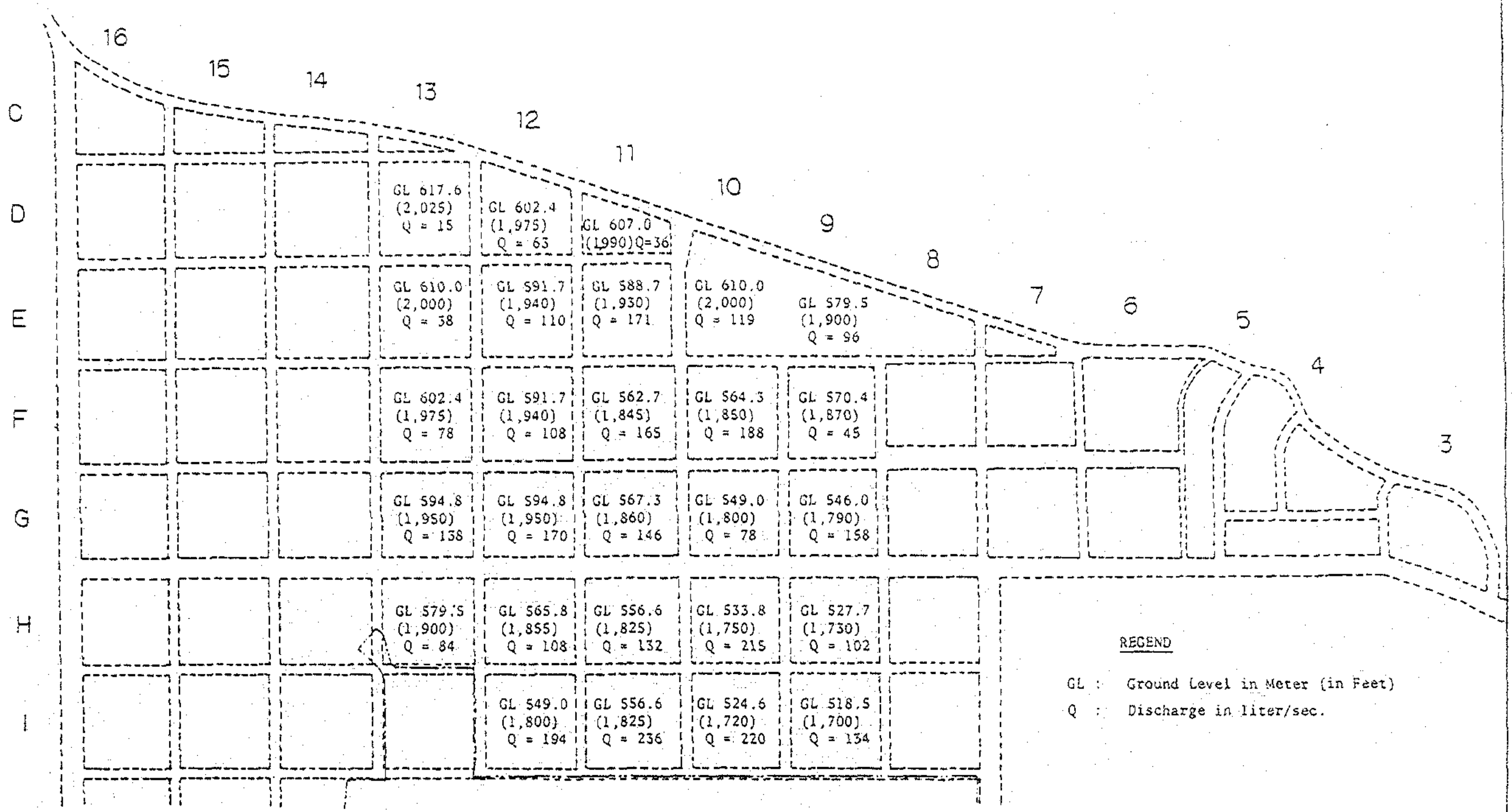


TABLE B.VI-1 HYDRAULIC CALCULATION

ORIGINAL PLAN(SIMLY HIGH ZONE)

POINT	G.LEVEL (M)	H.LENGTH (M)	HEIGHT (M)	P.LENGTH (M)	DIAMETER (MM)	DISCHARGE (L/S)	VELOCITY (M/S)	HYDR.GRAD. (M/1000M)	H.LOSS (M)	WATER LEVEL (M)	EFFEC.HEAD (M)
D.P	655.80									648.500	-7.300
S1	594.80	500.00	-61.00	503.71	700.	448.00	1.170	2.294	1.156	647.344	52.544
S2	567.30	1400.00	-27.50	1400.27	400.	233.00	1.865	10.447	14.629	632.715	65.415
F-9 (EP)	570.40	100.00	3.10	100.05	200.	45.00	1.443	14.583	1.459	631.256	60.856
S1	594.80									647.344	52.544
E-9 (EP)	579.50	100.00	-15.30	101.16	250.	96.00	1.969	19.983	2.022	645.323	65.823
S1	594.80									647.344	52.544
E-10 (EP)	610.00	100.00	15.20	101.15	350.	119.00	1.245	5.775	0.584	646.760	36.760
S2	567.30									632.715	65.415
F-10 (EP)	564.30	100.00	-3.00	100.04	350.	188.00	1.966	13.459	1.346	631.369	67.069

TABLE B.VI-2 HYDRAULIC CALCULATION

ORIGINAL PLAN (SIMLY LOW ZONE)

POINT	G.LEVEL (M)	H.LENGTH (M)	HEIGHT (M)	P.LENGTH (M)	DIAMETER (MM)	DISCHARGE (L/S)	VELOCITY (M/S)	HYDR.GRAD. (M/1000M)	H.LOSS (M)	WATER LEVEL (M)	EFFEC.HEAD (M)
S.R	597.80									593.100	-4.700
S3	547.50	2500.00	-50.30	2500.51	900.	907.00	1.433	2.488	6.221	586.879	39.379
S4	530.70	2000.00	-16.80	2000.07	700.	671.00	1.752	4.844	9.689	577.190	46.490
S5	521.60	2000.00	-9.10	2000.02	500.	354.00	1.813	7.640	15.280	561.909	40.309
I-9 (EP)	518.50	100.00	-3.10	100.05	300.	134.00	1.908	15.240	1.525	560.385	41.885
S3	547.50									586.879	39.379
G-9 (EP)	546.00	100.00	-1.50	100.01	400.	158.00	1.265	5.092	0.509	586.370	40.370
S3	547.50									586.879	39.379
G-10 (EP)	549.00	100.00	1.50	100.01	250.	78.00	1.600	13.609	1.361	585.518	36.518
S4	530.70									577.190	46.490
H-9 (EP)	527.70	100.00	-3.00	100.04	250.	102.00	2.092	22.355	2.236	574.953	47.253
S4	530.70									577.190	46.490
H-10 (EP)	533.80	100.00	3.10	100.05	400.	215.00	1.721	9.003	0.901	576.289	42.489
S5	521.60									561.909	40.309
I-10 (EP)	524.60	100.00	3.00	100.04	400.	220.00	1.761	9.394	0.940	560.969	36.369

TABLE B.VI-3 HYDRAULIC CALCULATION

ORIGINAL PLAN (KHANPUR HIGH ZONE)

POINT	G.LEVEL (M)	H.LENGTH (M)	HEIGHT (M)	P.LENGTH (M)	DIAMETER (MM)	DISCHARGE (L/S)	VELOCITY (M/S)	HYDR.GRAD. (M/1000M)	H.LOSS (M)	WATER LEVEL (M)	EFFEC.HEAD (M)
D.P	600.00									685.000	85.000
K1	597.80	1900.00	-2.20	1900.00	900.	1119.00	1.767	3.669	6.972	678.028	80.228
K2	597.20	2000.00	-0.60	2000.00	900.	912.00	1.440	2.513	5.027	673.001	75.801
K3	614.00	2000.00	16.80	2000.07	800.	739.00	1.477	3.023	6.045	666.956	52.956
K4	597.20	2000.00	-16.80	2000.07	800.	686.00	1.372	2.634	5.268	661.688	64.488
K5	594.80	2000.00	-2.40	2000.00	700.	500.00	1.306	2.811	5.622	656.065	61.265
K6	588.00	2000.00	-6.80	2000.01	450.	192.00	1.215	4.115	8.230	647.835	59.835
H-13 (EP)	610.00	100.00	22.00	102.39	300.	84.00	1.197	6.423	0.658	647.177	37.177
K1	597.80									678.028	80.228
E-11 (EP)	588.70	100.00	-9.10	100.41	350.	171.00	1.788	11.294	1.134	676.894	88.194
K1	597.80									678.028	80.228
D-11 (EP)	607.00	100.00	9.20	100.42	150.	36.00	2.053	39.176	3.934	674.094	67.094
K2	597.20									673.001	75.801
E-12 (EP)	591.70	100.00	-5.50	100.15	250.	110.00	2.256	25.706	2.574	670.427	78.727
K2	597.20									673.001	75.801
D-12 (EP)	602.40	100.00	5.20	100.14	200.	63.00	2.020	27.176	2.721	670.280	67.880
K3	614.00									666.956	52.956
E-13 (EP)	610.00	100.00	-4.00	100.08	150.	38.00	2.167	43.297	4.333	662.623	52.623
K3	614.00									666.956	52.956
D-13 (EP)	617.60	100.00	3.60	100.06	100.	15.00	1.926	55.872	5.591	661.365	43.765
K4	597.20									661.688	64.488
F-12 (EP)	591.70	100.00	-5.50	100.15	250.	108.00	2.215	24.848	2.489	659.199	67.499
K4	597.20									661.688	64.488
F-13 (EP)	602.40	100.00	5.20	100.14	200.	78.00	2.500	40.344	4.040	657.648	55.248
K5	594.80									656.065	61.265
G-13 (EP)	594.80	100.00	0.0	100.00	300.	138.00	1.965	16.092	1.609	654.456	59.656
K5	594.80									656.065	61.265
G-12 (EP)	594.80	100.00	0.0	100.00	350.	170.00	1.778	11.172	1.117	654.948	60.148
K6	588.00									647.835	59.835

TABLE B.VI-4 HYDRAULIC CALCULATION

ORIGINAL PLAN (KHANPUR LOW ZONE)

POINT	G.LEVEL (M)	H.LENGTH (M)	HEIGHT (M)	P.LENGTH (M)	DIAMETER (MM)	DISCHARGE (L/S)	VELOCITY (M/S)	HYDR.GRAD. (M/1000M)	H.LOSS (M)	WATER LEVEL (M)	EFFEC.HEAD (M)
D.P	600.00									605.000	5.000
K7	564.30	2700.00	-35.70	2700.24	900.	873.00	1.379	2.318	0.626	604.374	40.074
K8	549.00	2000.00	-15.30	2000.06	800.	708.00	1.416	2.792	0.558	603.815	54.815
K9	549.00	2000.00	0.0	2000.00	700.	562.00	1.468	3.490	0.698	603.117	54.117
K10	539.90	2000.00	-9.10	2000.02	600.	430.00	1.529	4.506	0.901	602.216	62.316
K11	533.80	2000.00	-6.10	2000.01	400.	194.00	1.553	7.444	1.489	600.727	66.927
I-12 (EP)	549.00	100.00	15.20	101.15	400.	194.00	1.553	7.444	0.075	600.652	51.652
K7	564.30									604.374	40.074
F-11 (EP)	562.70	100.00	-1.60	100.01	400.	165.00	1.321	5.517	0.055	604.319	41.619
K8	549.00									603.815	54.815
G-11 (EP)	567.30	100.00	18.30	101.66	400.	146.00	1.169	4.400	0.045	603.771	36.470
K9	549.00									603.117	54.117
H-11 (EP)	556.60	100.00	7.60	100.29	300.	132.00	1.880	14.822	0.149	602.969	46.369
K10	539.90									602.216	62.316
I-11 (EP)	556.60	100.00	16.70	101.38	400.	236.00	1.889	10.697	0.108	602.108	45.508

TABLE B.VI-5 HYDRAULIC CALCULATION

ALTERNATIVE PLAN (SIMLY WEST ZONE)

POINT	G.LEVEL (M)	H.LENGTH (M)	HEIGHT (M)	P.LENGTH (M)	DIAMETER (MM)	DISCHARGE (L/S)	VELOCITY (M/S)	HYDR.GRAD. (M/1000M)	H.LOSS (M)	WATER LEVEL (M)	EFFEC.HEAD (M)
S.R	630.00									657.000	27.000
S3	597.80	1500.00	-32.20	1500.35	800.	784.00	1.567	3.372	0.506	656.494	58.694
S4	597.20	2000.00	-0.60	2000.00	700.	577.00	1.507	3.664	0.733	655.761	58.561
S5	614.00	2000.00	16.80	2000.07	350.	131.00	1.370	6.899	1.380	654.381	40.381
F-13 (EP)	602.40	2000.00	-11.60	2000.03	250.	78.00	1.600	13.609	2.722	651.659	49.259
S3	597.80									656.494	58.694
E-11 (EP)	588.70	100.00	-9.10	100.41	350.	171.00	1.788	11.294	0.113	656.380	67.680
S3	597.80									656.494	58.694
D-11 (EP)	607.00	100.00	9.20	100.42	150.	36.00	2.053	39.176	0.393	656.100	49.100
S4	597.20									655.761	58.561
E-12 (EP)	591.70	100.00	-5.50	100.15	300.	110.00	1.567	10.578	0.106	655.655	63.955
S4	597.20									655.761	58.561
S6	577.40	2000.00	-19.80	2000.10	450.	273.00	1.727	7.892	1.578	654.182	76.782
F-11 (EP)	562.70	100.00	-14.70	101.07	350.	165.00	1.726	10.572	0.107	654.075	91.375
S6	577.40									654.182	76.782
F-12 (EP)	591.70	100.00	14.30	101.02	300.	108.00	1.538	10.225	0.103	654.079	62.379
S4	597.20									655.761	58.561
D-12 (EP)	602.40	100.00	5.20	100.14	200.	63.00	2.020	27.176	0.272	655.489	53.089
S5	614.00									654.381	40.381
E-13 (EP)	610.00	100.00	-4.00	100.08	150.	38.00	2.167	43.297	0.433	653.948	43.948
S5	614.00									654.381	40.381
D-13 (EP)	617.80	100.00	3.80	100.07	100.	15.00	1.926	55.872	0.559	653.822	36.022

TABLE V.BI-6 HYDRAULIC CALCULATION

ALTERNATIVE PLAN (KHANPUR WEST ZONE)

POINT	G.LEVEL (M)	H.LENGTH (M)	HEIGHT (M)	P.LENGTH (M)	DIAMETER (MM)	DISCHARGE (L/S)	VELOCITY (M/S)	HYDR.GRAD. (M/1000M)	H.LOSS (M)	WATER LEVEL (M)	EFFEC.HEAD (M)
S.R	630.00									683.000	53.000
K5	549.00	4300.00	-81.00	4300.76	900.	972.00	1.535	2.828	12.162	670.838	121.838
K6	549.00	2000.00	0.0	2000.00	800.	826.00	1.651	3.714	7.427	663.411	114.411
K7	579.50	2000.00	30.50	2000.23	800.	694.00	1.388	2.691	5.382	658.029	78.529
K8	602.40	2000.00	22.90	2000.13	450.	222.00	1.404	5.383	10.767	647.261	44.862
H-13 (EP)	610.00	100.00	7.60	100.29	300.	84.00	1.197	6.423	0.644	646.617	36.617
K5	549.00									670.838	121.838
G-11 (EP)	567.30	100.00	18.30	101.66	300.	146.00	2.079	17.861	1.816	669.022	101.722
K6	549.00									663.411	114.411
H-11 (EP)	556.60	100.00	7.60	100.29	300.	132.00	1.880	14.822	1.486	661.925	105.324
K7	579.50									658.029	78.529
G-12 (EP)	594.80	100.00	15.30	101.16	350.	170.00	1.778	11.172	1.130	656.898	62.098
K7	579.50									658.029	78.529
H-12 (EP)	565.80	100.00	-13.70	100.93	300.	108.00	1.538	10.225	1.032	656.996	91.196
K7	579.50									658.029	78.529
I-12 (EP)	549.00	2000.00	-30.50	2000.23	350.	194.00	2.029	14.264	28.532	629.497	80.497
K8	602.40									647.261	44.862
G-13 (EP)	594.80	100.00	-7.60	100.29	300.	138.00	1.965	16.092	1.614	645.647	50.847

TABLE B.VI-7 HYDRAULIC CALCULATION

ALTERNATIVE PLAN (KHANPUR EAST ZONE)

POINT	G.LEVEL (M)	H.LENGTH (M)	HEIGHT (M)	P.LENGTH (M)	DIAMETER (MM)	DISCHARGE (L/S)	VELOCITY (M/S)	HYDR.GRAD. (M/1000M)	H.LOSS (M)	WATER LEVEL (M)	EFFEC.HEAD (M)
S.R	600.00									586.500	-13.500
K1	547.50	4600.00	-52.50	4600.30	1000.	1143.00	1.462	2.285	1.051	585.449	37.949
K2	530.70	2000.00	-16.80	2000.07	900.	907.00	1.433	2.488	0.498	584.951	54.251
K3	521.60	2000.00	-9.10	2000.02	700.	590.00	1.541	3.818	0.764	584.187	62.587
K4	518.50	2000.00	-3.10	2000.00	400.	236.00	1.889	10.697	2.139	582.048	63.548
I-11 (EP)	526.10	100.00	7.60	100.29	400.	236.00	1.889	10.697	0.107	581.940	55.840
K1	547.50									585.449	37.949
G-9 (EP)	546.00	100.00	-1.50	100.01	400.	158.00	1.265	5.092	0.051	585.398	39.398
K1	547.50									585.449	37.949
G-10 (EP)	549.00	100.00	1.50	100.01	300.	78.00	1.111	5.600	0.056	585.393	36.393
K2	530.70									584.951	54.251
H-9 (EP)	527.70	100.00	-3.00	100.04	300.	102.00	1.453	9.199	0.092	584.859	57.159
K2	530.70									584.951	54.251
H-10 (EP)	533.80	100.00	3.10	100.05	400.	215.00	1.721	9.003	0.090	584.861	51.061
K3	521.60									584.187	62.587
I-9 (EP)	518.50	100.00	-3.10	100.05	300.	134.00	1.908	15.240	0.152	584.035	65.535
K3	521.60									584.187	62.587
I-10 (EP)	524.60	100.00	3.00	100.04	400.	220.00	1.761	9.394	0.094	584.094	59.493

TABLE B.VI-8 FACILITIES SPECIFICATION AND COST

Facility	Original Plan: Specification	Original Plan: Cost	Alternative Plan: Specification	Alternative Plan: Cost
1. Pump	Simly High Zone	(Rs.1,000)	Simly West Zone	
	300 mm x 135 KW x 3 units		300 mm x 175 KW x 4 units	
	Khanpur High Zone		Simly East Zone	
	300 mm x 350 KW x 5 units	96,120	300 mm x 135 KW x 3 units	116,800
	Khanpur Low Zone		Khanpur West Zone	
	300 mm x 145 KW x 4 units		300 mm x 300 KW x 5 units	
			Khanpur East Zone	
			300 mm x 95 KW x 5 units	
2. Pipe Work	PRCC, 900 - 500 mm, 25.6 km	106,600	PRCC, 1,000 - 700 mm, 20.9 km	140,200
	FC, 800 - 100 mm, 11.1 km		FC, 800 - 100 mm, 19.9 km	
3. Service Reservoir	Simly, Flat slab type, 13,600 m^3		Simly, Flat slab type, 1,500 m^3	
	Simly, PC tank type, 6,500 m^3		Simly, PC tank type, 11,300 m^3	
	Khanpur, " 16,200 m^3	79,260	Simly, " 6,500 m^3	91,340
	Khanpur, " 12,600 m^3		Khanpur, " 16,500 m^3	
			Khanpur, " 14,000 m^3	
Total		281,980		348,340

APPENDIX - C

APPENDIX - C

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LIST OF FIGURES

CHAPTER I. PROJECT IMPLEMENTATION

CHAPTER I. PROJECT IMPLEMENTATION

1.1. Implementation Schedule

The whole project would be constructed over a 14 year period (refer to Table C.I-1). Phase I project would start in 1987 with construction of intake tower and No.2 tunnels (11,480 m long) that need a construction period of five years, and complete in early 1992. At the same time all construction works of Phase I should be completed, so that Phase I water supply would start in the both cities of Islamabad and Rawalpindi. Construction works of Phase II and III would be started in 1992 and 1998 respectively so as to meet the water demand prospected in 1996 and 2001, respectively.

1.2. Organization for Project Implementation

The Capital Development Authority (CDA), being the principal implementing agency, would be responsible for overall planning and coordination. Because of the involvement of many Government agencies in the implementation of the Project, special provision should be made for the coordination of their activities. A Project Coordination Committee, comprising representative from CDA, WAPDA, PHED, MES, RMC, CB, ID, POF and PIDC, would be established to coordinate their activities related to the Project.

The committee will concentrate in the planning and coordination of the construction programmes to be carried out by different agencies; in securing Government funds for financing these programmes; and in periodically reviewing their progress. Later the role of the committee will be expanded to include formation of plans for joint activities and adequate operation and maintenance of project works.

Responsibility for the construction of the project will be shared between CDA and PHED of Punjab, both of which have had considerable experience of constructing works of a similar nature. CDA would establish a Project Unit, headed by a qualified and experienced Director General under the Member of CDA to carry out the works described above. The organization structure of the Project is shown in Figure C.I-1.

FIGURE C.I –1 ORGANIZATIONAL STRUCTURE OF PROJECT IMPLEMENTATION

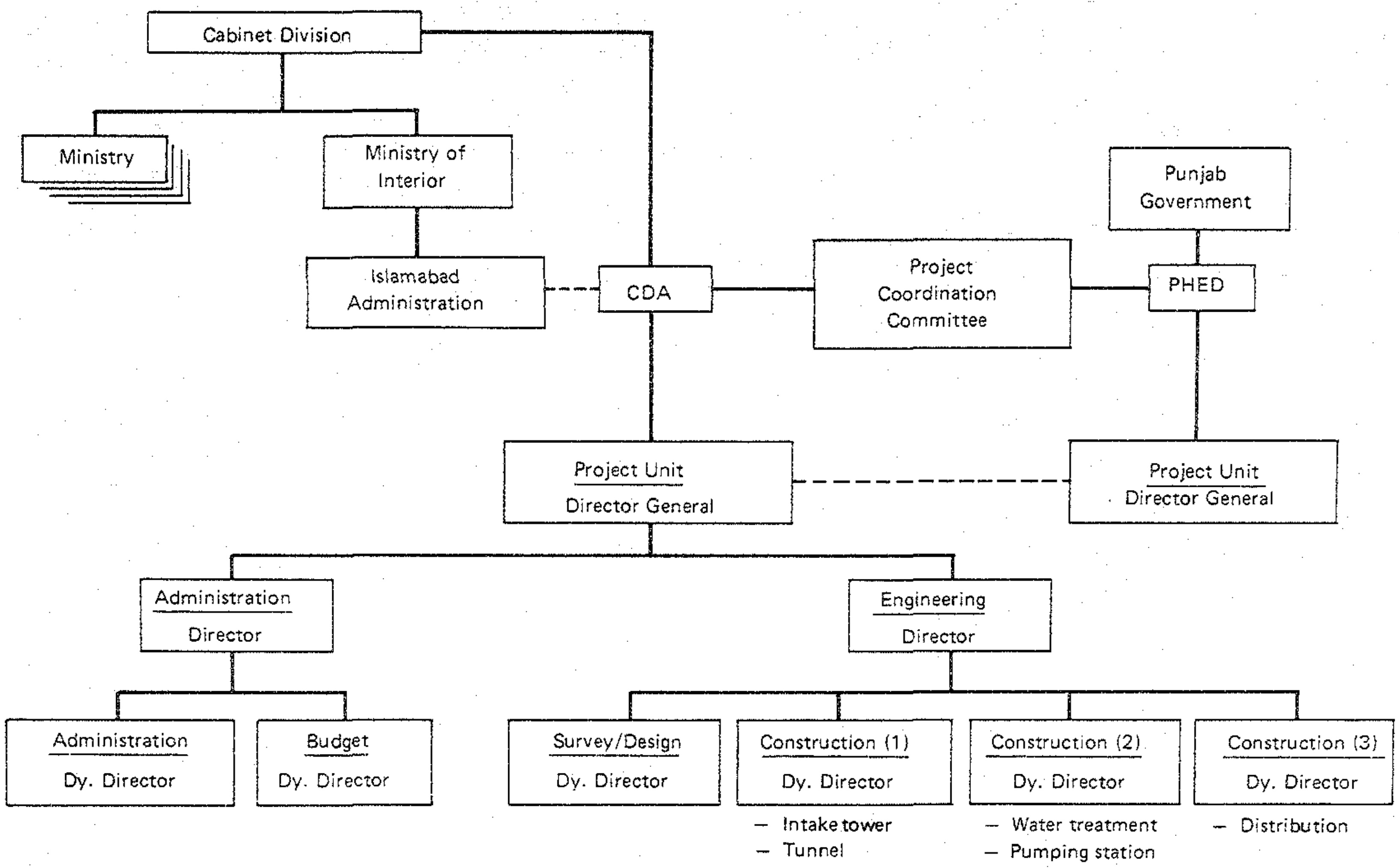
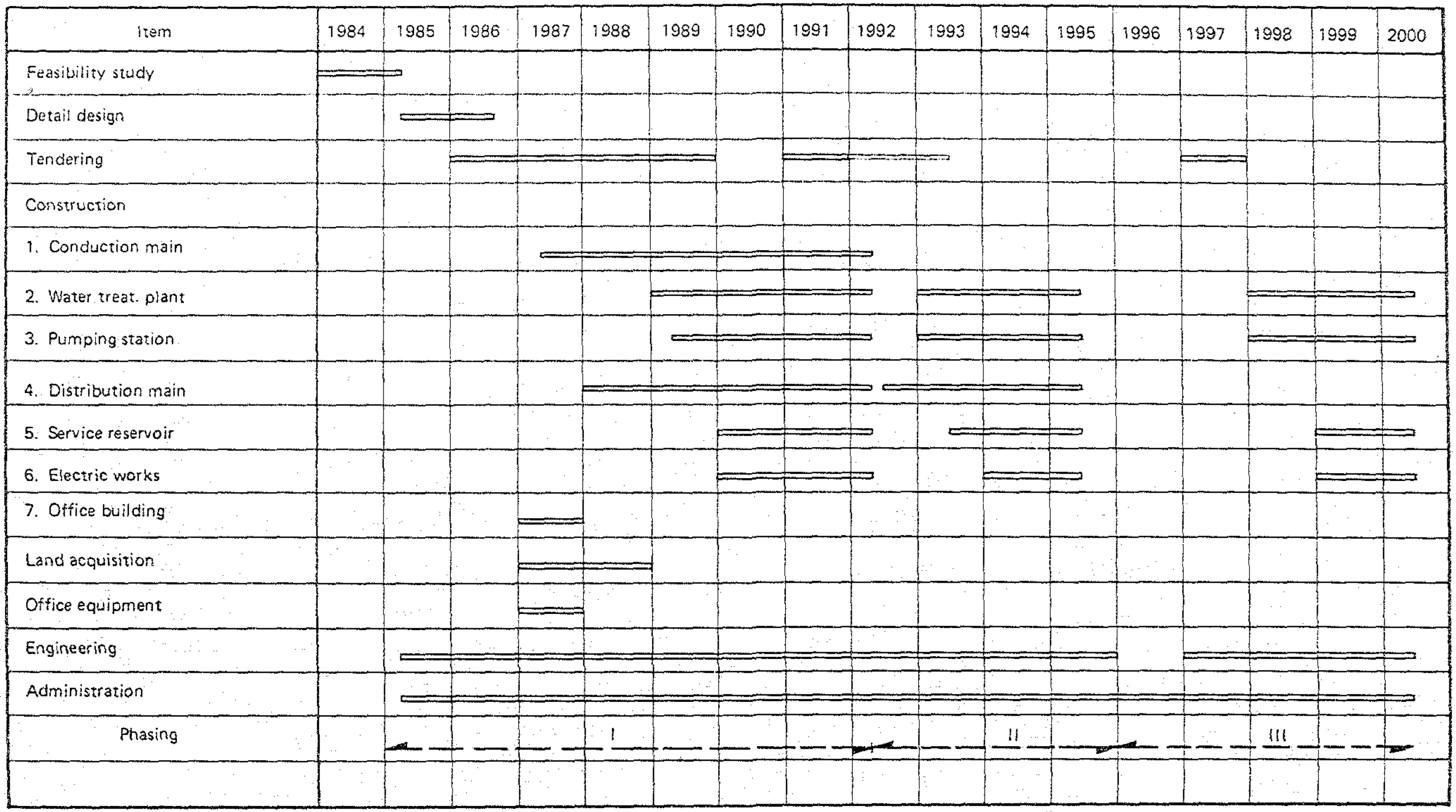


TABLE C.I-1 IMPLEMENTATION SCHEDULE



CHAPTER II. PROJECT COST ESTIMATE

CHAPTER II. PROJECT COST ESTIMATE

2.1. 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 (refer to Table C.II-1 - 16). Construction costs of civil works are based on detailed quantities and unit price estimate making reference to the schedule of rates, 1982 prepared by Public Works Department, and the following prevailing rate in CDA and WAPDA; (a) building and (b) electric power transmission lines.

The total project cost includes about Rs. 154 million of import duties and taxes to be levied on such equipment as large sized steel pipes and ductile iron pipes, water treatment plants, pumps and electric motors, sub-station, etc. Estimates were made in accordance with Pakistan Customs Tariff and Import Trade Guide. Electric power can be obtained at distribution voltage from the existing system. Costs for electric works are composed of transmission lines from K.T.M. Grid and sub-station and distribution system at the Golra water treatment plant including requirement for pumping station. Details of the major construction work items are shown Table C.II-17.

Engineering and administration costs amount to Rs. 183.2 million for detailed topographic surveys and geological investigation of construction sites including tunnel routes, detailed design, tendering, supervision and administration of the