THE ISLAMIC REPUBLIC OF PAKISTAN
CAPITAL DEVELOPMENT AUTHORITY

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

APPENDIX A
(METEOROLOGY AND HYDROLOGY)

APPENDIX B
(GEOLOGY AND GROUNDWATER)

FEBRUARY 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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APPENDIX A.

HYDROLOGY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

A.1. Meteorology

A.1.1. Climate

Climate can be classified into following major four seasons in the study area.

Table A-1-1. Climate Season

Season	Period
Cold Season	December - March
Hot Season	April - June
Monsoon	July - August some times mid September (fluctuating by year)
Post Monsoon	Mid September - November

The cold season lasts from December to March, characterized by moderate temperature and fine weather. However, depressions pass the area periodically from west, and bring widespread rains and low temperature meanwhile. Consequently, the diurnal range of temperature becomes large in this season. Although snow falls in the Murree and the Margala hills, most snow melts soon except at the high ranges around Murree because temperature rises after depression passing. The amount of rainfall, however, is not much as compared with that during the monsoon. In March and April the weather becomes progressively warmer with scarce spring time.

The hot season lasts from April to June, characterized by the continentality with hot and dry climate. May and June are usually hotest and dusty with the maximum temperature rising up to 45°C, and mean relative humidity becomes below 50 percent during these two months.

<u>The monsoon</u> (southwest monsoon) generally reaches the area towards the beginning of July and lasts up to the end of August or the mid September. During this period, the monsoon brings much rainfall of about 60 percent of annual rainfall, and the high floods are occasionally caused by a series of tropical depressions. The beginning and termination of monsoon varies by year, accordingly severe drought is caused when the monsoon reaches the area late. In case of such drought, serious difficulties are brought on water supply and irrigation.

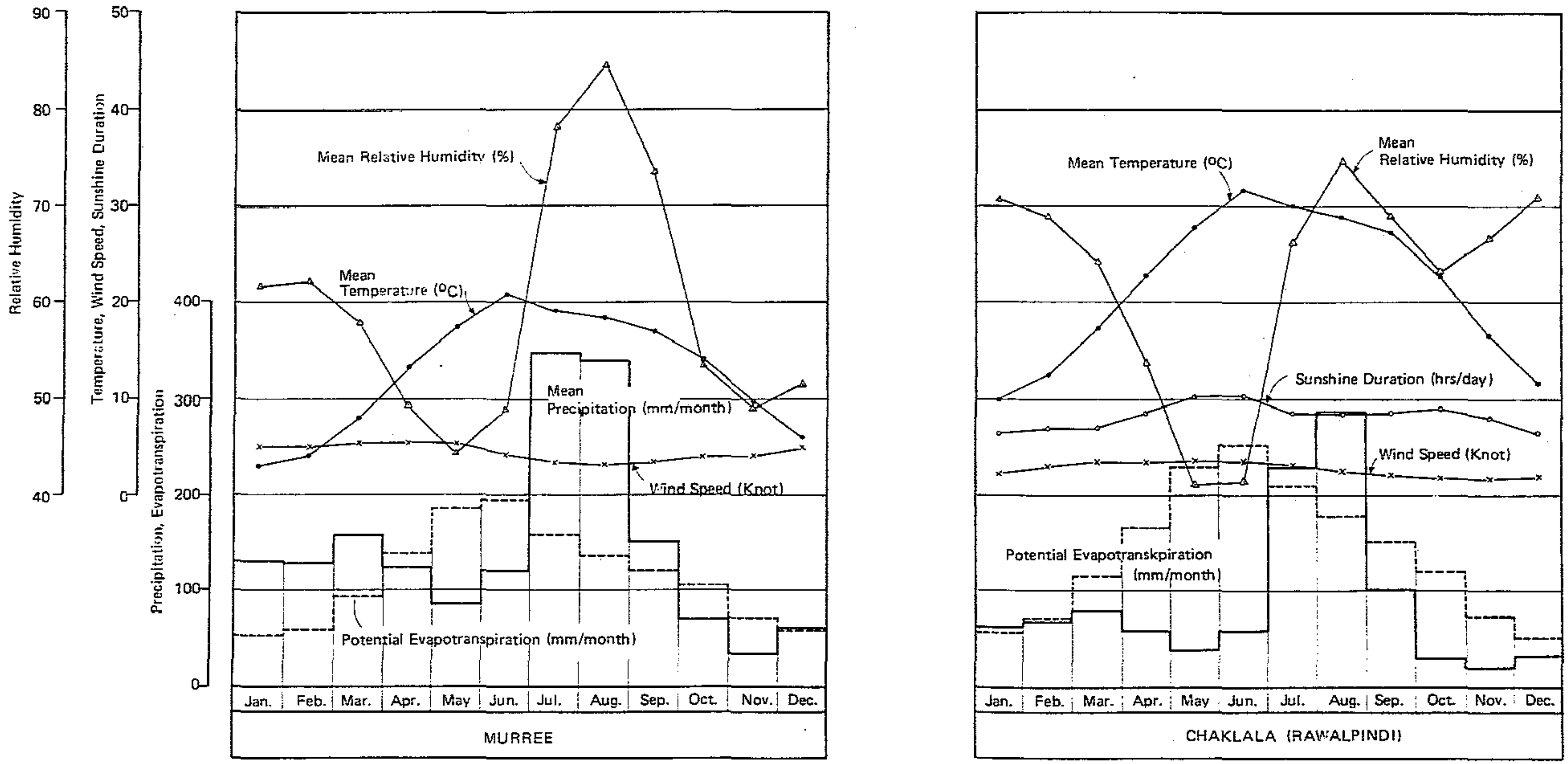
<u>The post monsoon</u> lasts from mid September to November, and it is the most pleasant season in a year. During this season, it is fine weather and the temperature goes down toward the cold season.

Table A-1-2 and Figure A-1-1 show the major climatic elements at Chaklala and Murree which are the representative meteorological stations in the study area. There is much deference on the climates at Chaklala and Murree, and it is mentioned in Section 2.3. in Main Report.

Table A-1-2 Climatic Elements at Murree and Chaklala (Rawalpindi)

Climatic Element		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual	Period
Murree (El. 7,236 ft = 2,205m)															
Precipitation	(mm)														
Max		257.1	60.5	15.7	209.0	160.9	200.6	523.5	263.4	221.5	254.1	57.5	65.9	2,289.7	1977
Mean		131.7	128.9	157.9	124.5	85.7	120.7	347.8	338.3	150.1	69.3	34.3	60.1	1,749.5	1952-86
Min		42.9	103.4	113.5	116.9	110.9	55.1	219.8	220.0	95.7	193.3	23.6	0.0	1,295.1	1969
Mean Temperature	(°C)	3.0	4.0	8.0	13.2	17.4	20.7	19.0	18.3	16.9	14.1	9.7	6.0	12.5	1954-86
Mean Relative Humidity	(%)	61.4	61.9	57.8	49.4	44.4	48.9	78.2	84.7	73.3	53.4	49.0	51.5	59.5	1954-86
Mean Wind Speed	(knot)	5.0	4.9	5.4	5.4	5.3	4.2	3.4	3.2	3.4	3.9	4.0	4.9	4.4	1954-86
Potential Evapotranspiration															
	(mm/day)	1.7	2.1	3.0	4.6	6.0	6.5	5.1	4.4	4.0	3.4	2.4	1.9	3.8	computed
	(mm)	53	59	93	138	186	195	158	136	120	105	72	59	1,374	computed
Chaklala (El. 1,670ft = 510m)															
Precipitation	(mm)														
Max		159.8	73.4	176.5	131.6	109.6	19.4	580.2	338.2	131.3	10.0	5.0	0.0	1,735.1	1981
Mean		62.3	67.8	78.2	57.2	37.8	57.3	254.0	287.6	101.5	30.3	19.6	32.2	1,085.8	1952-86
Min		143.3	13.6	20.6	44.1	45.7	24.7	263.7	91.9	47.0	0.0	1.8	12.5	708.9	1964
Mean Temperature	(°C)	10.0	12.3	17.2	22.7	27.7	31.6	29.9	28.8	27.3	22.6	16.5	11.6	21.5	1954-86
Mean Relative Humidity	(%)	70.7	68.8	64.1	53.6	41.0	41.3	66.1	74.7	68.9	63.0	66.5	70.8	62.5	1954-86
Mean Wind Speed	(knot)	2.2	3.0	3.4	3.4	3.5	3.4	3.1	2.4	2.0	1.7	1.6	1.7	2.6	1954-86
Mean Sunshine duration	(hrs/day)	6.4	6.8	6.8	8.5	10.1	10.2	8.5	8.5	8.6	9.0	8.1	6.5	8.2	1957-86
Pan-Evaporation	(mm)	61.0	82.6	152.4	208.8	309.1	347.7	268.7	208.8	171.2	139.7	85.9	58.9	2,093.7	1966-73
Potential Evapotranspiration															
	(mm/day)	1.8	2.5	3.7	5.5	7.4	8.4	6.7	5.7	5.0	3.8	2.4	1.6	4.6	computed
	(mm)	56	70	115	165	229	252	208	177	150	118	72	50	1,662	computed

FIGURE A–1–1 MONTHLY CLIMATIC ELEMENTS AT MURREE AND CHAKLALA (RAWALPINDI)



A.1.2. Evapotranspiration

Evapotranspiration is one of important factors in meteorology. Petential evapotranspiration is calculated by the Modified Penman Method. The original Pernman equation (1948) predicted losses from an open water surface (Eo). Experimentally determined crop coefficients are ranging from 0.6 in winter months to 0.8 in summer months related Eo to grass evapotranspiration for the climate in England. The Penman equation consisted to two terms: the energy (radiation) term and the aerodynamic (wind and humidity) term. The relative importance of each term varies with climatic conditions. Under calm weather conditions the aerodynamic term is usually less important than the energy term. In such conditions the original Penman Eo equation using a crop coefficient of 0.8 has been shown to predict ETo closely, not only in cool, humid regions but also in very hot, and semi-arid regions. It is under windy conditions and particularly in the more arid regions that the aerodynamic term becomes relatively more important and thus errors can result in predicting ETo when using 0.8 Eo.

A modified Penman equation is suggested to determined ETo, involving a revised wind function term and an adjustment on day and night time weather conditions.

$$ETo = C\,[\underbrace{W \cdot Rn}_{\text{radiation term}} + \underbrace{(1 - W) \cdot f(u) \cdot (es - ea)}_{\text{aerodynamic term}}]$$

where;

ETo = reference crop evapotranspiration in mm/day.

W = temperature-related weighting factor.

Rn = net radiation in equivalent evaporation in mm/day.

f(u)= wind-related function.

(es - ea)= difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air in mbar.

C = adjusted factor to compensate for the effect of day and night weather conditions.

Wind function f(u)

$$f(u) = 0.27\ (1 + u/100)$$

where;

u = wind run in km/day at 2 meters height

when wind (Uz) at different at Z meters, wind at 2 meters (U_2) is;

$$U_2 = Uz\ (\frac{2}{z})^{0.2}$$

Weighting factor (1 - W)

(1 - W) is a weighting factor for the effect of wind and humidity on ETo.

$$W = \Delta/(\Delta + \gamma)$$

where;

Δ = slope of saturation vapour pressure-temperature curve in mbar/°C = $33.86[0.05904(0.00738T + 0.8072)^7 - 0.0000342]$

γ = psychrometric constant = $cp \cdot p/(0.622\lambda)$

cp = 0.240

p = atmospheric pressure in mbar = 1013 - 0.1055EL

EL = elevation from sea level in meters

λ = latent heat of water in cal/g = 595.9 - 0.55T

T = air temperature in °C

Vapour pressure (es - ea)

(es - ea) is the difference between the mean saturated vapour pressure (es) and the mean actual vapour pressure (ea) in mbar. es can be obtained by temperature (T°C) in Table A-1-5, and ea is calculated by relative humidity (RH) thus ea = es*RH.

Net radiation (Rn)

Net radiation (Rn) is the difference between all incoming and outgoing radiation in mm/day. Rn can be calculated from solar radiation or sunshine hours (or degree of cloud cover), temperature and humidity data.

$Rn = Rns - Rn\ell$

where;

Rns = net shortwave solar radiation in mm/day

$Rn\ell$ = net longwave solar radiation in mm/day

$Rns = (1 - \alpha)\ Rs$

where;

α = reflection depending on the nature of the surface cover and being approximately 0.25.

Rs = solar radiation being dependent on Ra (amount of radiation received at top of the atmosphere) and transmission through the atmosphere, which is largely dependent on cloud cover.

$Rs = (a + b\ n/N)\ Ra$

where;

n = actual sunshine hours per day

N = maximum possible sunshine hours per day, N for a given month and latitude is given in Table A-1-6.

a,b = constant by regions, 0.25 and 0.50 can be used respectively for practical purposes.

Ra = Extra-terrestrial radiation, Ra for a given month and latitude is given Table A-1-7.

$Rn\ell = f(T) f(ea) f(n/N)$

where;

$Rn\ell$ respresents net energy loss, since outgoing is greater than incoming.

$f(T)$ = effect of temperature = σTK^4

$= 1.98 \times 10^{-9}(T + 273)^4$

$f(ea)$ = effect of vapour pressure = $0.34 - 0.044 \cdot ea^{0.5}$

$f(n/N)$ = effect of the ratio actual and maximum bright sunshine hours = $0.1 + 0.9\ n/N$

Adjustment factor (c)

Adjustment factor (c) is given in Table A-1-8, to adjust calculated ETo to weather conditions by relative humidity, U day/U night, U day and Rs.

Table A-1-3 and A-1-4 are showing the evapotranspiration by the modified Penman equation at Murree and Chaklala, and sample calculation is presented in Table A-1-9.

Table A-1-3 Potential Evapotranspiration at Chaklala (Rawalpindi) by Modified Penman

(Latitude: 33°35' Longitude: 73°03' Altitude: 510m)

Factors		Jan.*	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual	Remarks
Tmean	(°C)	10.0	12.3	17.2	22.7	27.7	31.6	29.9	28.8	27.3	22.6	16.5	11.6	21.5	Given data
RHmean	(%)	70.7	68.8	64.1	53.6	41.0	41.3	66.1	74.7	68.9	63.0	66.5	70.8	62.5	"
U_2	(knot)	2.2	3.0	3.4	3.4	3.5	3.4	3.1	2.4	2.0	1.7	1.6	1.7	2.6	"
n	(hours/day)	6.4	6.8	6.8	8.5	10.1	10.2	8.5	8.5	8.6	9.0	8.1	6.5	8.2	"
Ra	(mm/day)	8.38	9.88	12.5	14.8	16.5	18.0	16.8	15.5	13.4	10.9	8.61	7.33		Table A-1-7
N	(hours/day)	10.2	11.0	11.9	13.0	13.9	14.4	14.2	13.4	12.4	11.4	10.4	9.9		Table A-1-6
U day	(m/sec)	1.13	1.55	1.75	1.75	1.80	1.75	1.60	1.24	1.03	0.88	0.82	0.88		
Rs	(mm/day)	4.72	5.52	6.69	8.56	10.1	10.9	9.23	8.80	8.02	7.01	5.51	4.24		
(1) (1-W)f(U)	(es-ea)	0.83	1.13	1.61	2.39	3.44	3.62	1.92	1.22	1.33	1.33	1.01	0.77		
(2) W·Rn		1.00	1.44	2.27	3.36	4.28	5.07	4.57	4.30	3.55	2.41	1.35	0.80		
(3) = (1) + (2)		1.83	2.57	3.88	5.75	7.72	8.69	6.49	5.52	4.88	3.74	2.36	1.57		
C		0.98	0.96	0.95	0.98	0.96	0.97	1.03	1.04	1.02	1.01	1.0	0.99		
ETo = C * (3)	(mm/day)	1.8	2.5	3.7	5.5	7.4	8.4	6.7	5.7	5.0	3.8	2.4	1.6		
ETo	(mm/month)	56	70	115	165	229	252	208	177	150	118	72	50	1,662	

Note) 1) Wind speed is given at 2m height.

2) for estimating adjustment factor (C), assuming U day/U night = 1.0.

3) * sample computation is presented in Table A-1-8.

Table A-1-4 Potential Evapotranspiration at Murree by Modified Penman

(Latitude: 33°54' Longitude: 73°24' Altitude: 2,205m)

Factors		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual	Remarks
Tmean	(°C)	3.0	4.0	8.0	13.2	17.4	20.7	19.0	18.3	16.9	14.1	9.7	6.0	12.5	Given data
RHmean	(%)	61.4	61.9	57.8	49.4	44.4	48.9	78.2	84.7	73.3	53.4	49.0	51.5	59.5	"
U_2	(knots)	5.0	4.9	5.4	5.4	5.3	4.2	3.4	3.2	3.4	3.9	4.0	4.9	4.4	"
n	(hours/day)	6.4	6.8	6.8	8.5	10.1	10.2	8.5	8.5	8.6	9.0	8.1	6.5	8.2	(*) "
Ra	(mm/day)	7.92	9.82	12.4	14.5	16.5	17.1	16.8	15.5	13.4	10.8	8.53	7.23		Table A-1-7
N	(hours/day)	10.1	11.0	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3	10.3	9.8		Table A-1-6
U day	(m/sec)	2.58	2.52	2.78	2.78	2.73	2.16	1.75	1.65	1.75	2.01	2.06	2.52		
Rs	(mm/day)	4.49	5.49	6.65	8.35	10.1	10.3	9.19	8.75	8.00	7.01	5.49	4.21		
(1) (1-W)f(U)	(es-ea)	1.23	1.24	1.69	2.40	2.89	2.46	0.88	0.59	1.03	1.82	1.78	1.69		
(2) W·Rn		0.77	1.21	1.92	2.82	3.80	4.24	3.97	3.67	2.98	1.98	1.06	0.63		
(3) = (1) + (2)		2.00	2.45	3.61	5.22	6.69	6.70	4.85	4.26	4.01	3.80	2.84	2.32		
C		0.84	0.87	0.84	0.89	0.89	0.97	1.04	1.04	0.99	0.90	0.84	0.80		
ETo = C * (3)	(mm/day)	1.7	2.1	3.0	4.6	6.0	6.5	5.1	4.4	4.0	3.4	2.4	1.9		
ETo	(mm/month)	53	59	93	138	186	195	158	136	120	105	72	59	1,374	

Note) 1) Wind speed is given at 2m height.

2) for estimating adjustment factor (C), assuming U day/U night = 1.0.

3) * using data at Chaklala.

Table A-1-5 Saturation Vapour Pressure (es) in mbar as Function of Mean Air Temperature (T) in °C

T (°C)	es (mbar)	T (°C)	es (mbar)	T (°C)	es (mbar)	T (°C)	es (mbar)
0	6.1	10	12.5	20	23.4	30	42.4
1	6.6	11	13.1	21	24.9	31	44.9
2	7.1	12	14.0	22	26.4	32	47.6
3	7.6	13	15.0	23	28.1	33	50.3
4	8.1	14	16.1	24	29.8	34	53.2
5	8.7	15	17.0	25	31.7	35	56.2
6	9.3	16	18.2	26	33.6	36	59.4
7	10.0	17	19.4	27	35.7	37	62.8
8	10.7	18	20.6	28	37.8	38	66.3
9	11.5	19	22.0	29	40.1	39	69.9

Data Source: HY-1

Table A-1-6 Mean Daily Duration of Maximum Possible Sunshine Hours (N) for Different Months and Latitudes

Northern Lats	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Southern Lats	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
50°	8.5	10.1	11.8	13.8	15.4	16.3	15.9	14.5	12.7	10.8	9.1	8.1
48	8.8	10.2	11.8	13.6	15.2	16.0	15.6	14.3	12.6	10.9	9.3	8.3
46	9.1	10.4	11.9	13.5	14.9	15.7	15.4	14.2	12.6	10.9	9.5	8.7
44	9.3	10.5	11.9	13.4	14.7	15.4	15.2	14.0	12.6	11.0	9.7	8.9
42	9.4	10.6	11.9	13.4	14.6	15.2	14.9	13.9	12.6	11.1	9.8	9.1
40	9.6	10.7	11.9	13.3	14.4	15.0	14.7	13.7	12.5	11.2	10.0	9.3
35	10.1	11.0	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3	10.3	9.8
30	10.4	11.1	12.0	12.9	13.6	14.0	13.9*	13.2	12.4	11.5	10.6	10.2
25	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
20	11.0	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
15	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	11.8	11.4	11.2
10	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
5	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8
0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0

Data Source: HY-1

Table A-1-7 Extra-terrestrial Radiation (Ra) expressed in equivalent evaporation in mm/day

Northern Hemisphere													Southern Hemisphere												
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Lat	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
3.8	6.1	9.4	12.7	15.8	17.1	16.4	14.1	10.9	7.4	4.5	3.2	50°	17.5	14.7	10.9	7.0	4.2	3.1	3.5	5.5	8.9	12.9	16.5	18.2
4.3	6.6	9.8	13.0	15.9	17.2	16.5	14.3	11.2	7.8	5.0	3.7	48	17.6	14.9	11.2	7.5	4.7	3.5	4.0	6.0	9.3	13.2	16.6	18.2
4.9	7.1	10.2	13.3	16.0	17.2	16.6	14.5	11.5	8.3	5.5	4.3	46	17.7	15.1	11.5	7.9	5.2	4.0	4.4	6.5	9.7	13.4	16.7	18.3
5.3	7.6	10.6	13.7	16.1	17.2	16.6	14.7	11.9	8.7	6.0	4.7	44	17.8	15.3	11.9	8.4	5.7	4.4	4.9	6.9	10.2	13.7	16.7	18.3
5.9	8.1	11.0	14.0	16.2	17.3	16.7	15.0	12.2	9.1	6.5	5.2	42	17.8	15.5	12.2	8.8	6.1	4.9	5.4	7.4	10.6	14.0	16.8	18.3
6.4	8.6	11.4	14.3	16.4	17.3	16.7	15.2	12.5	9.6	7.0	5.7	40	17.9	15.7	12.5	9.2	6.6	5.3	5.9	7.9	11.0	14.2	16.9	18.3
6.9	9.0	11.8	14.5	16.4	17.2	16.7	15.3	12.8	10.0	7.5	6.1	38	17.9	15.8	12.8	9.6	7.1	5.8	6.3	8.3	11.4	14.4	17.0	18.3
7.4	9.4	12.1	14.7	16.4	17.2	16.7	15.4	13.1	10.6	8.0	6.6	36	17.9	16.0	13.2	10.1	7.5	6.3	6.8	8.8	11.7	14.6	17.0	18.2
7.9	9.8	12.4	14.8	16.5	17.1	16.8	15.5	13.4	10.8	8.5	7.2	34	17.8	16.1	13.5	10.5	8.0	6.8	7.2	9.2	12.0	14.9	17.1	18.2
8.3	10.2	12.8	15.0	16.5	17.0	16.8	15.6	13.6	11.2	9.0	7.8	32	17.8	16.2	13.8	10.9	8.5	7.3	7.7	9.6	12.4	15.1	17.2	18.1
8.8	10.7	13.1	15.2	16.5	17.0	16.8*	15.7	13.9	11.6	9.5	8.3	30	17.8	16.4	14.0	11.3	8.9	7.8	8.1	10.1	12.7	15.3	17.3	18.1
9.3	11.1	13.4	15.3	16.5	16.8	16.7	15.7	14.1	12.0	9.9	8.8	28	17.7	16.4	14.3	11.6	9.3	8.2	8.6	10.4	13.0	15.4	17.2	17.9
9.8	11.5	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.3	9.3	26	17.6	16.4	14.4	12.0	9.7	8.7	9.1	10.9	13.2	15.5	17.2	17.8
10.2	11.9	13.9	15.4	16.4	16.6	16.5	15.8	14.5	12.6	10.7	9.7	24	17.5	16.5	14.6	12.3	10.2	9.1	9.5	11.2	13.4	15.6	17.1	17.7
10.7	12.3	14.2	15.5	16.3	16.4	16.4	15.8	14.6	13.0	11.1	10.2	22	17.4	16.5	14.8	12.6	10.6	9.6	10.0	11.6	13.7	15.7	17.0	17.5
11.2	12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7	20	17.3	16.5	15.0	13.0	11.0	10.0	10.4	12.0	13.9	15.8	17.0	17.4
11.6	13.0	14.6	15.6	16.1	16.1	16.1	15.8	14.9	13.6	12.0	11.1	18	17.1	16.5	15.1	13.2	11.4	10.4	10.8	12.3	14.1	15.8	16.8	17.1
12.0	13.3	14.7	15.6	16.0	15.9	15.9	15.7	15.0	13.9	12.4	11.6	16	16.9	16.4	15.2	13.5	11.7	10.8	11.2	12.6	14.3	15.8	16.7	16.8
12.4	13.6	14.9	15.7	15.8	15.7	15.7	15.7	15.1	14.1	12.8	12.0	14	16.7	16.4	15.3	13.7	12.1	11.2	11.6	12.9	14.5	15.8	16.5	16.6
12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5	12	16.6	16.3	15.4	14.0	12.5	11.6	12.0	13.2	14.7	15.8	16.4	16.5
13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9	10	16.4	16.3	15.5	14.2	12.8	12.0	12.4	13.5	14.8	15.9	16.2	16.2
13.6	14.5	15.3	15.6	15.3	15.0	15.1	15.4	15.3	14.8	13.9	13.3	8	16.1	16.1	15.5	14.4	13.1	12.4	12.7	13.7	14.9	15.8	16.0	16.0
13.9	14.8	15.4	15.4	15.1	14.7	14.9	15.2	15.3	15.0	14.2	13.7	6	15.8	16.0	15.6	14.7	13.4	12.8	13.1	14.0	15.0	15.7	15.8	15.7
14.3	15.0	15.5	15.5	14.9	14.4	14.6	15.1	15.3	15.1	14.5	14.1	4	15.5	15.8	15.6	14.9	13.8	13.2	13.4	14.3	15.1	15.6	15.5	15.4
14.7	15.3	15.6	15.3	14.6	14.2	14.3	14.9	15.3	15.3	14.8	14.4	2	15.3	15.7	15.7	15.1	14.1	13.5	13.7	14.5	15.2	15.5	15.3	15.1
15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8	0	15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8

Data Source: HY-1

Table A-1-8 Adjustment Factor (C) in Penman Equation

	RHmax = 30%				RHmax = 60%				RHmax = 90%			
Rs mm/day	3	6	9	12	3	6	9	12	3	6	9	12
Uday m/sec	Uday/Unight = 4.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.79	.84	.92	.97	.92	1.00	1.11	1.19	.99	1.10	1.27	1.32
6	.68	.77	.87	.93	.85	.96	1.11	1.19	.94	1.10	1.26	1.33
9	.55	.65	.78	.90	.76	.88	1.02	1.14	.88	1.01	1.16	1.27
	Uday/Unight = 3.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.76	.81	.88	.94	.87	.96	1.06	1.12	.94	1.04	1.18	1.28
6	.61	.68	.81	.88	.77	.88	1.02	1.10	.86	1.01	1.15	1.22
9	.46	.56	.72	.82	.67	.79	.88	1.05	.78	.92	1.06	1.18
	Uday/Unight = 2.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.69	.76	.85	.92	.83	.91	.99*	1.05*	.89	.98	1.10*	1.14*
6	.53	.61	.74	.84	.70	.80	.94	1.02	.79	.92	1.05	1.12
9	.37	.48	.65	.76	.59	.70	.84	.95	.71	.81	.96	1.06
	Uday/Unight = 1.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.64	.71	.82	.89	.78	.86	.94*	.99*	.85	.92	1.01*	1.05*
6	.43	.53	.68	.79	.62	.70	.84	.93	.72	.82	.95	1.00
9	.27	.41	.59	.70	.50	.60	.75	.87	.62	.72	.87	.96

Data Source: HY-1

Table A-1-9 Sample Calculation by Modified Penman

Location : Chaklala (Rawalpindi)
Latitude : 33°35'N
Altitude : EL 510m MSL
Wind Measurement: 2 meters in height
Period : January
U day/U night : 1.0

Data		Calculation
T mean	10.0 °C	es = 12.3 mbar (Table A-1-5)
RH mean	70.7 %	ea = es x 0.707 = 8.70 mbar (es - ea) = 12.3 - 8.70 = 3.60 mbar
U_2	2.2 knot	u = 1.13 m/s = 97.9 km/day f(u) = 0.27(1 + u/100) = 0.27(1 + 97.9/100) = 0.534
T mean Altitude	10.0 °C, EL 510 m	$\Delta = 33.86[0.05904(0.00738 * T\,mean + 0.8072)^7 - 0.0000342] = 0.822$ mbar/°C $\lambda = 595.9 - 0.55\ T\,mean = 590$ °C $\gamma = 0.24(1013 - 0.1055EL)/(0.622\lambda) = 0.627$ $W = \Delta/(\Delta + \gamma) = 0.567$ (1 - W) = 0.433 (1 - W)f(u)(es - ea) = 0.83 mm/day
Ra		Ra = 16.7mm/day(January at latitude 33°35'N) (Table A-1-7)
n		n = 6.4 hr/day (data)
N		N = 10.2 hr/day (January at Latitude 33°35'N) (Table A-1-6) n/N = 0.627 Rs = (0.25 + 0.50 n/N)Ra = 4.72 mm/day
$\alpha = 0.25$		Rns = $(1 - \alpha)$ Rs = 3.54 mm/day
$\delta = 1.98 \times 10^{-9}$		$f(T) = \delta(T\,mean + 273)^4 = 4.72$
ea = 8.70 mbar		$f(ea) = 0.34 - 0.044\ ea^{0.5} = 0.210$
n/N = 0.547		f(n/N) = 0.1 + 0.9 n/N = 0.665 $Rn\ell = f(T)f(ea)f(n/N) = 1.77$ mm/day $Rn = Rns - Rn\ell = 3.54 - 1.77 = 1.77$ mm/day
W = 0.738		W·Rn = 1.00 mm/day W·Rn + (1 - W)f(u)(es - ea) = 1.00 + 0.83 = 1.83
U day/U night = 1.0 RH max = 90% Rs = 4.72 mm/day U day = 1.13 m/s		C = 0.98 (Table A-1-8) ETo = C[W·Rn + (1 - W)f(u)(es - ea] = 0.98 x 1.83 = 1.8 mm/day

A.1.3. Reliability of Meteorological and Precipitation Data

The reliability is judged to be sufficiently high on data at the synoptic stations belonging to RMC and WAPDA (Chaklala, Murree, Barkot, Rawal dam). For this study, the data at Chaklala and Murree have been used considering the length of observation period and the representativeness for areas at the alluvial plain and at the mountains. The observation period is for 33 years from 1954 to 1986 excepting few observation items at the selected two representative stations.

Table A-1-10. Meteorological Stations and Data for the Study

Observation Items	Station and Observation Period	
	Chaklala	Murree
(Altitude) MSL	510 m(1,670 ft)	2,205 m(7,236 ft)
Mean Temperature	1954 - 86	1954 - 86
Relative Humidity	1954 - 86	1954 - 86
Wind Velocity	1954 - 86	1954 - 86
Sunshine Duration	1957 - 86	not observed
Pan Evaporation	1966 - 73	not observed

On the other hand, precipitation data are judged to contain lower reliable data at some stations. For evaluating the reliability of data, isohyet has been prepared using annual precipitation data as shown in Figure A-1-2. Omitting such stations to differ from other stations on their annual precipitation amount in the Figure, following thirteen (13) key rain gauge stations have been selected to represent the study area. The study estimates areal precipitation using those 13 key rain gauge stations.

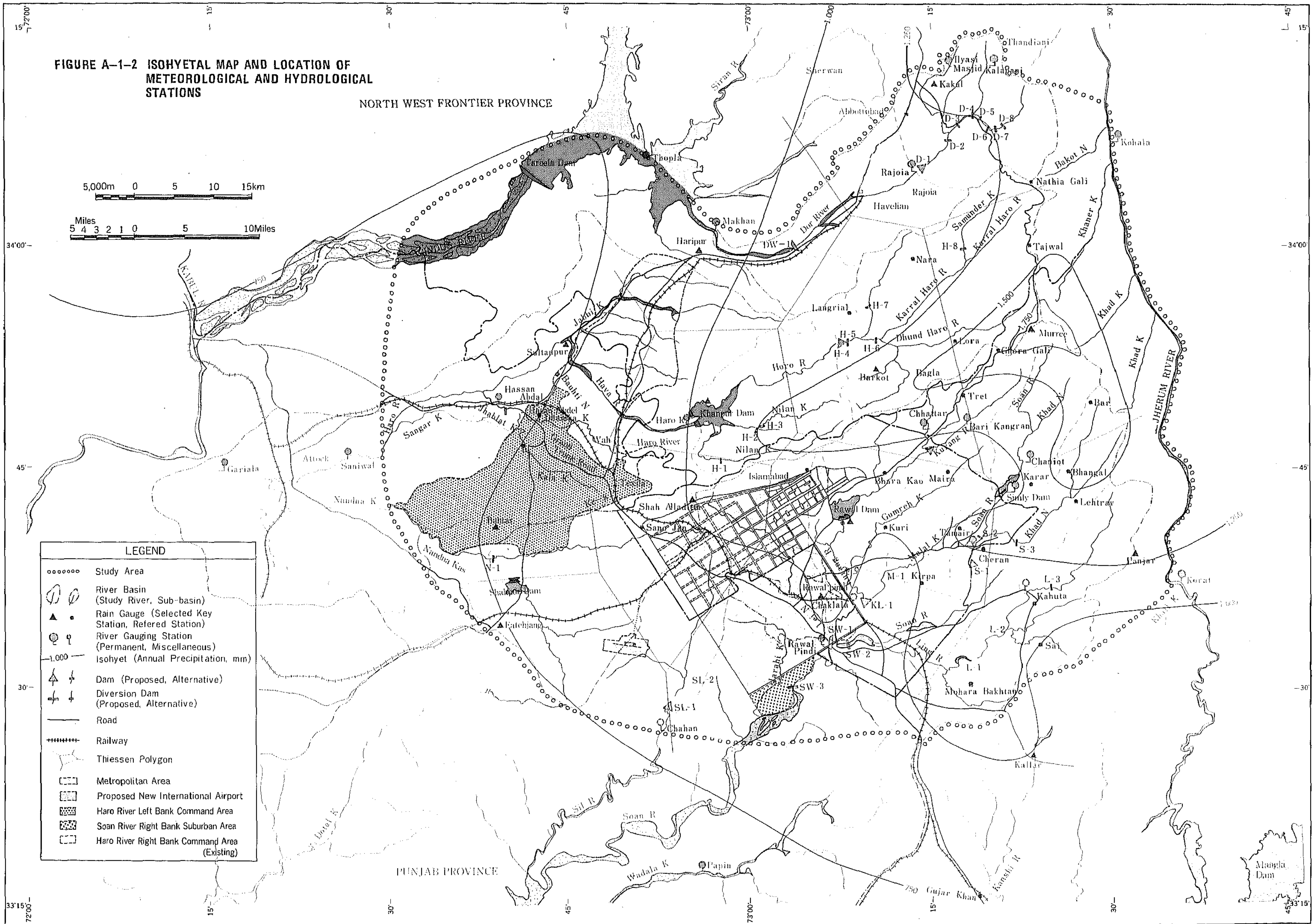


FIGURE A-1-2 ISOHYETAL MAP AND LOCATION OF METEOROLOGICAL AND HYDROLOGICAL STATIONS

Table A-1-11. Key Rain Gauge Stations

Rain Gauge Station	Data Period	Basis	Data Missing	Annual Precipitation (mm)	Agency
Bahtar	Sep.1952 - 68	Monthly	some	759	RMC
Barkot *	Oct.1962 - 79	Daily	no	1,364	WAPDA
Chaklala *	1952 - 86	Daily	no	1,086	RMC
Fateh Jang	1948 - Apr.86	Monthly	1980-83	743	Forest(P)
Haripur	1952 - 83	Monthly	some	820	RMC
Kakul *	1953 - 86	Daily	no	1,039	RMC
Kallar *	Jul.1960 - 80	Daily	no	938	WAPDA
Khanpur	Aug.1954 - 86	Monthly	some	1,064	RMC
Murree *	1952 - 86	Daily	some	1,750	RMC
Panjar	Aug.1952 - 68	Monthly	some	1,300	RMC
Rawal Dam *	1963 - 79	Daily	some	1,231	WAPDA
Shah Alladitta	1953 - 68	Monthly	many	1,036	RMC
Sultanpur	Sep.1952 - 68	Monthly	some	699	RMC

Among above 13 key rain gauge stations, six (6) stations marked with * have been used for runoff analysis of the study rivers, because daily precipitation records are available at these six stations.

A.1.4. Interpolation of Daily Precipitation Data

Interpolation has been made for the daily precipitation data of Barkot, Murree and Rawal dam using adjacent stations such as Kakul and Chaklala. Table A-1-12 shows methodology of the interpolation.

Table A-1-12. Interpolation of Daily Precipitation Record

Station	Interpolated Period	Method
Barkot	Jan.1960-26 Oct.'62, 1980	Y = 0.797 X -0.066 (r = 0.847) Y: Precipitation at Barkot (mm/day) X: Precipitation at Murree (mm/day) Regression equation is derived by corelation on monthly basis.
Murree	Aug. 1961, Dec.'68, Jan.-May'70, Jan.-14 Apr.'71, May'85	Since monthly records are available in these periods at Murree, monthly precipitation is provided to paticular days in accordance with the daily records at Kakul.
	Jan.-12 Jun. 1972	Since monthly records are not available in this period, daily records at Kakul are applied without any revision.
Rawal Dam	Jan. 1960-Dec. 1972, 19-31 Jan. 1964, 1980	Y = 1.054 X -0.366 (r = 0.924) Y: Precipitation at Rawal Dam (mm/day) X: Precipitation at Chaklala (mm/day) Regression equation is derived by corelation on monthly basis.

A.1.5. Seasonal Fluctuation of Precipitation

As mentioned above, most rainfall of about 60 percent of annual rainfall is brought by the southwest monsoon from July to the mid September with the highest amount of rainfall in August. (see Table A-1-2) On the other hand, the depressions also bring rainfall during the cold season, but the amount of rainfall is only about 20 percent of annual rainfall, less as compared with that during the monsoon.

Consequently, the amount of rainfall varies by season, and such variation of rainfall is one of major obstructions on agricultural development in the area. Furthermore, annual amount of rainfall also greatly varies by year, and droughts occasionally bring difficulties on water supply and damages on agricultural products.

A.1.6. Areal Distribution of Precipitation

As seeing the isohyetal map in Figure A-1-2, annual amount of rainfall remarkably differs by area. Annual rainfall ranges from 700 mm to 1,000 mm in the western alluvial plain, and increases toward the eastern mountainous area and reaches 1,750 mm at Murree. Abundant rainfall is observed in the Margala and the Murree hills which are the uppermost river basins of the Haro, the Kurang and the Soan rivers. On the other hand, the river basins of the Dor and the Ling rivers receive relatively less rainfall as compared with above three river basins.

Mean annual rainfall of each river basin has been estimated by Thiessen method, and it may be highest as 1,413 mm in the Soan river basin and least as 837 mm in the Nandna Kas basin. Mean annual rainfall of the whole study area is estimated around at 1,000 mm. Table V-1-13 shows mean annual rainfalls of various river basins estimated by Thiessen method.

Table A-1-13. Mean Annual Areal Rainfall

River Basin	Mean Annual Rainfall (mm)	Point	Catchment Area (sq.km)	Remarks
Dor River	1,269	Dw-1 Site	517.7	
Haro River	1,403	Khanpur Dam	778.0	
Kurang River	1,309	Soan Junction	580.3	
Soan River	1,413	Sw-1 Site	487.9	Excluding the Kurang, the Ling
Ling River	1,129	Soan Junction	404.6	
Jabbi Kas	(820)	Haro Junction	304.0	
Bauhti Nala	(820)	Bauhti Village	12.8	
Jhablat Kas	857	Hassan Abdal SGS	248.6	
Nandna Kas	837	N-1 Site	462.0	
Lei Nala	1,009	Soan Junction	211.2	
Sil River	1,009	SL-1 Site	237.6	
Whole Study Basin	(1,000)		6,800	

Note: see weight of station in Table A-1-16.

A.1.7. *Long Term Fluctuation of Annual Precipitation*

Figure A-1-3 shows the long term fluctuation of annual rainfall by 5 years moving average at Chaklala, and Murree where rainfall is observed for a long period. As seeing the Figure, two stations show similar pattern of fluctuation, the long term fluctuation of annual rainfall of the study area can be studied by the record at Chaklala where the longest observation record is available. According to the record at Chaklala, followings can be stated;

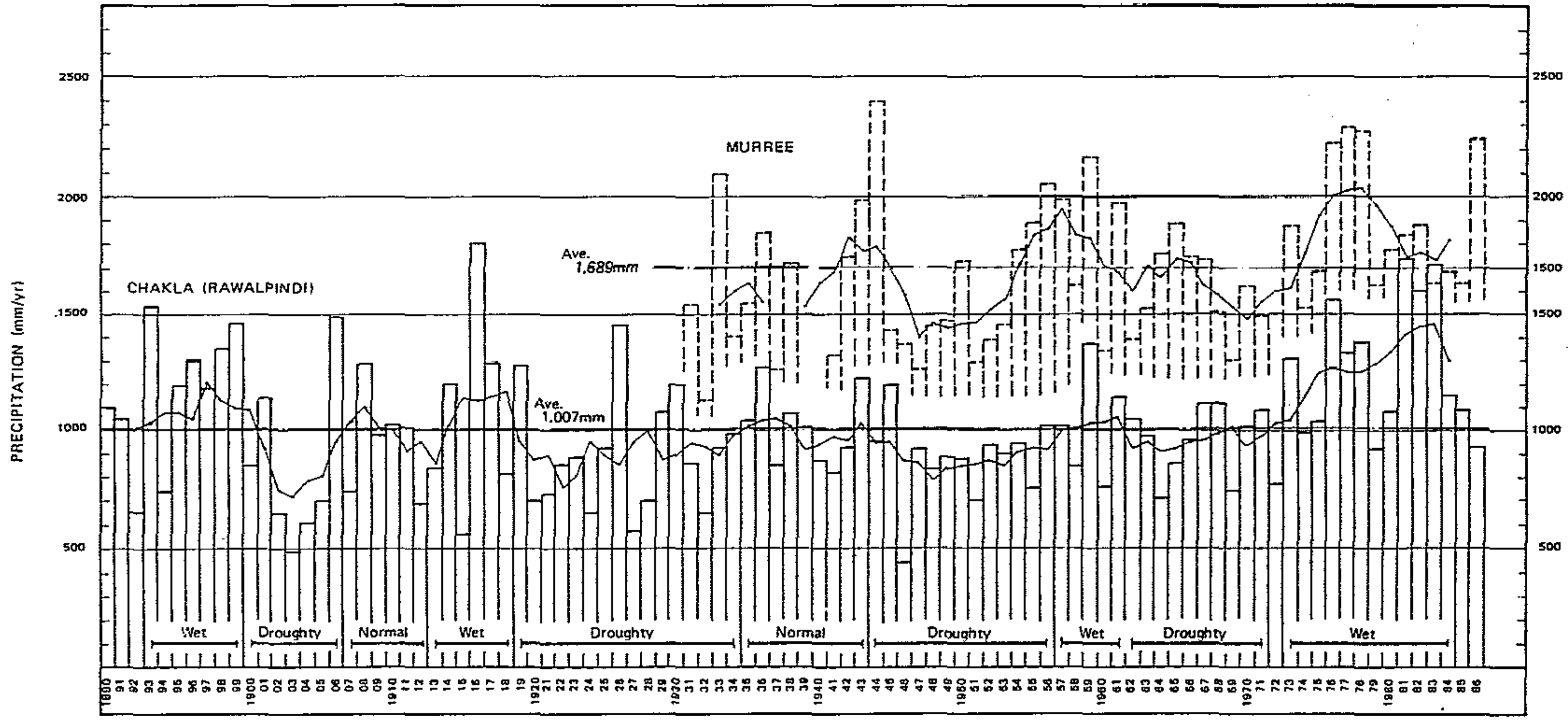
Although the cycle of wet and droughty periods is not clear, but there are clear periods of wet and drought, and they last for certain years. This fact suggests the necessity to consider not only the particular drought year on planning the water resources development but also the certain years before and behind the particular drought year in case of the development by dams. Table A-1-14 shows the distinguinshable periods of wet and drought years.

Although there were a few short wet periods in the years from the 1920s to the 1960s, this 50 years was the drought term with less rainfall. On the other hand, it was wet term after 1973.

Table A-1-14. Wet and Droughty Periods by Annual Rainfall

Period	Duration	Wet/Droughty	
1893 - 1899	7 years	Wet	Period
1900 - 1906	7	Droughty	"
1913 - 1918	6	Wet	"
1919 - 1934	16	Droughty	"
1944 - 1956	13	Droughty	"
1957 - 1961	5	Wet	"
1962 - 1971	10	Droughty	"
1973 - 1986	14	Wet	"

FIGURE A-1-3 MOVING AVERAGED ANNUAL PRECIPITATION



A.1.8. Probable Drought and Wet Years by Annual Precipitation

The drought year and the wet year have been studied using the weighted annual rainfall by the data at Chaklala, Kakul and Murree where reliable long term observation records are available. (weight 2:1:1, period 1952-86, see Figure A-1-4) The weighted annual rainfall can be considered to be approximate annual areal rainfall in the Margala and the Murree hills. Probable 1/10 drought year (once in ten years) is close to the years of 1953 and 1972. And, the years of 1960 and 1969 were considerably droughty and equivalent to 1/30 drought year approximately.

Table A-1-15. Probable Drought and Wet Years by Precipitation

Mean Annual Weighted Rainfall	1,306 mm (100%)	1952-86
Maximum Annual Rainfall	1,748 mm (134%)	1976
Minimum Annual Rainfall	971 mm (74%)	1969

Return Period	Drought Year: Probable Rainfall (mm)	Drought Year: Years Corresponding	Wet Year: Probable Rainfall (mm)	Wet Year: Years Corresponding
2 yrs	1,287	1956, 67, 68, 75, 80, 85	1,287	1956, 67, 68, 75, 80, 85
5 "	1,129	1958, 63, 64, 74, 79	1,472	1961, 73, 86
10 "	1,057	1953, 72	1,581	1959, 83
15 "	1,023	-	1,640	1977, 78, 81, 82
20 "	1,002	-	1,679	-
30 "	974	1960, 69	1,733	1976

Figure A-1-4 Annual Areal Precipitation from 1952 to 1986

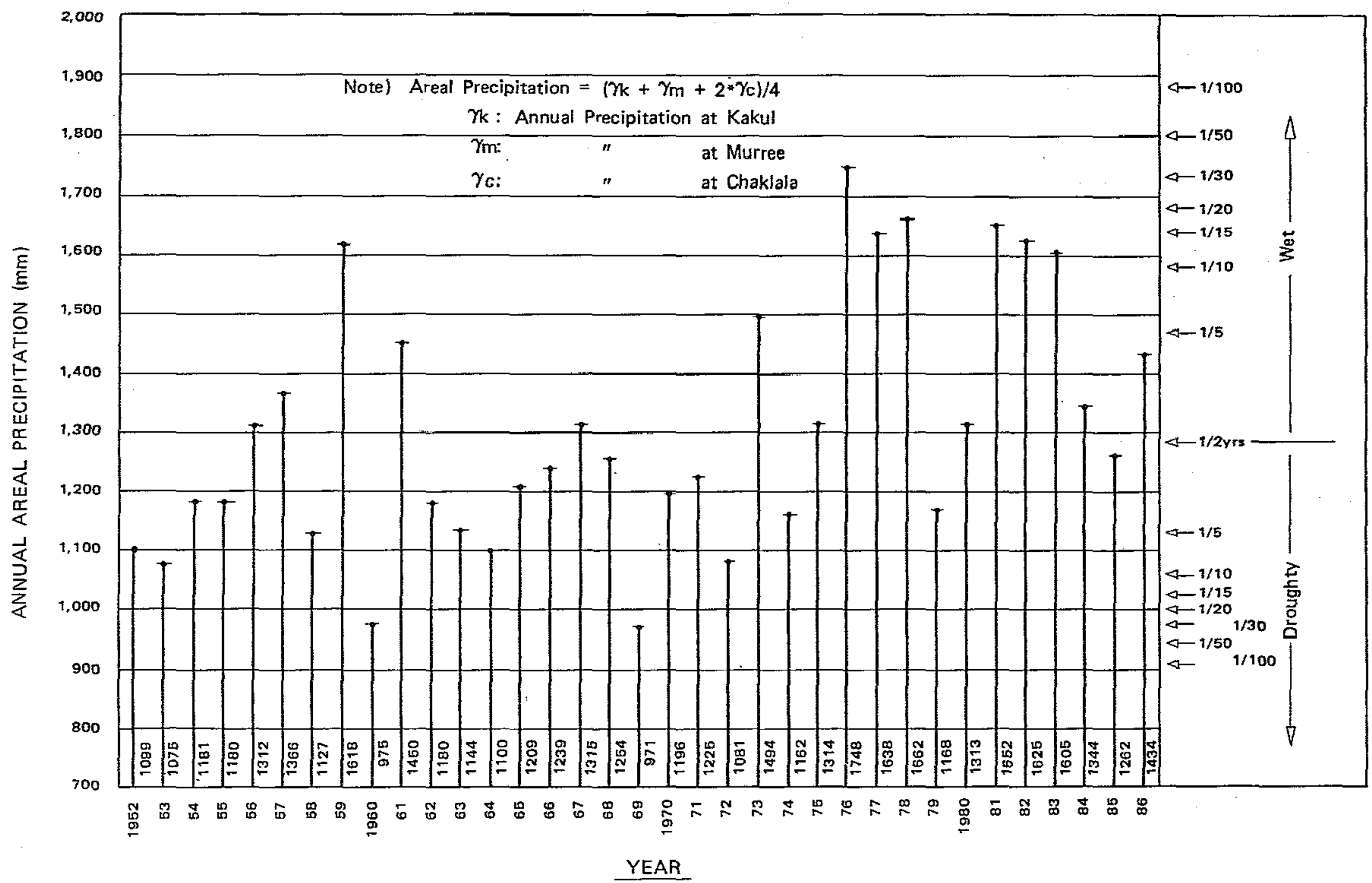


Table A-1-16 Weight for Computing Annual Areal Precipitation

Basin	D.A. (km^2)	Annual Rainfall (mm/yr)	Weight of Station (%)
Dor River			
D-1	292.3	1,309	Kakul (100)
Dw-1	517.7	1,269	Kakul (83), Barkot (8), Haripur (9)
Haro River			
H-4	498.5	1,539	Kakul (5), Murree (46), Barkot (49)
Khanpur Dam	778.0	1,403	Kakul (3), Murree (29), Barkot (44), Rawal Dam (1), Khanpur (20), Shah Alladitta (3)
Jhablat Kas			
Hasan Abdal	248.6	857	Khanpur (4), Shah Alladitta (35), Sultanpur (24), Bahtar (37)
Nandna Kas			
N-1	462.0	837	Shah Alladitta (31), Bahtar (19), Fateh Jang (50)
Soan River			
Kurang			
Rawal Dam	275.0	1,417	Murree (25), Barkot (42), Rawal Dam (33)
Gumreh Kas	129.3	1,276	Murree (8), Barkot (6), Rawal Dam (83), Chaklala (3)
M-1	82.8	1,231	Rawal Dam (100)
KL-1	283.7*	1,219	Barkot (2.6), Chaklala (22.6), Murree (3.4), Rawal Dam (71.4)
Whole Kurang	580.3	1,309	Murree (13), Barkot (21), Rawal Dam (54), Chaklala (12)
Soan River			
Cherah	326.3	1,530	Murree (52), Panjar (42), Rawal Dam (6)
S-1	341.1	"	- ditto -
Soan at Sw-1	(excluding Kurang and Ling river basins) 487.9	1,413	Murree (36), Panjar (35), Rawal Dam (9), Chaklala (20)
Ling River			
Kahuta	145.0	1,300	Panjar (100)
L-1	285.0	1,188	Panjar (69), Kallar (31)
Whole Ling	404.6	1,129	Panjar (49), Chaklala (9), Kallar (42)
Sil River			
SL-1	237.6	1,009	Shah Alladitta (62), Chaklala (24), Bahtar (14)
Chahan	241.0	"	- ditto -

Note) 1) Weight of station is computed by Thiessen polygon as shown in Figure A-1-2.
2) Mean annual precipitation before interpolation is applied for Barkot and Rawal dam.
3) * excluding the catchment area of Rawal dam.

A.2. River and River Regime

A.2.1. Rivers

As seeing in Figure A-2-1, the Study area is composed of three major river basins of the Dor, the Haro and the Soan, and bounded by the Indus and the Jhelum. Table A-2-11 is showing the drainage area at the key sites for the study.

(1) Dor River

The profile of the Dor river and its important tributaries on the left and right banks are shown in Figure A-2-2.

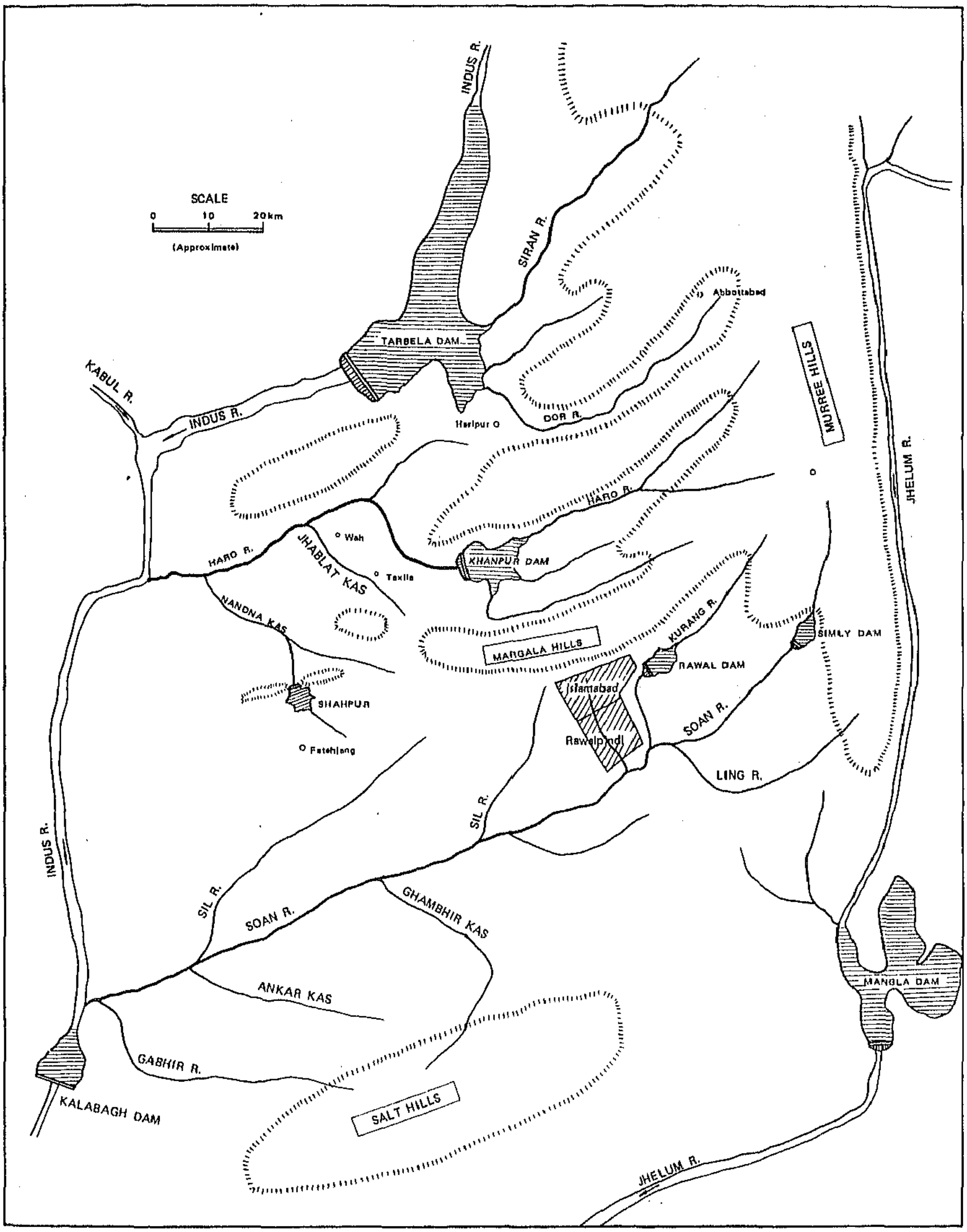
The Dor river is a left bank tributary of the Siran river and it joins the Indus river also. The confluence with the Siran river has been submerged in the Tarbela reservoir since construction of Tarbela dam in 1974. The characteristics of the Dor river, as may be seen from the above figure, are similar to those of the Haro river in that it falls rapidly in the first 10 km and then runs with a gentler slope. The left bank tributaries are longer and steeper than those on the right.

(2) Haro River

The profile of the Haro river and all the important tributaries on its left and right banks important tributaries on its left and right banks are shown in Figure A-2-3.

The Haro river is a left bank tributary of the Indus river. As may be seen from the above figure, the left bank tributaries are longer and steeper than the right bank tributaries. It may also be seen that the Haro river, like the Dor river, falls very rapidly in the first 10 km or so and then runs with a gentler slope.

FIGURE A-2-1 GENERAL VIEW OF RIVER SYSTEM



- Nandna Kas

The Nandna Kas is a major tributary of the Haro river and its length is about 68 km. It joins the Haro river on left bank at 10 km upstream from the confluence of the Indus. It drains the area of 912 sq.km and its slope is 1/70 in upstream and 1/140 in downstream at the confluence of the Bahudra Kas.

- Jhablat Kas

The Jhablat Kas is a tributary flowing into the left bank of the Haro river. It originates from Pind Bahadur Khan Village located between Fatehjang-Hassanabdal road and joins the Haro river at a point some 5 km of the downstream of Hassanabdal. The Kas runs through the high ridge near Hassanabdal.

(3) Soan river

The profile of the Soan river and the major tributaries on its left and right banks are shown in Figure A-2-4.

The Soan river is a left bank tributary of the Indus river. It rises in the south-western range of Murree hills, and after flowing through various hills and gorges enters the plains near Cherah.

Flowing in a south-western direction a distance of about 240 km through the plains, it joins the Indus river about 16 km upstream of Kalabagh.

- Malal Kas

The Malal Kas is a tributary with length of 24.8 km joining the Kurang river which drains into the Soan river at 216 km upstream from the Indus. It drains the area of 92.3 km^2 with a bed slope of 1/90.

- Ling River

The Ling river is a major tributary of the Soan river on left bank. It originates in the Lehtrar hills with altitude of 1,850 m and drains the area of 427 km^2 into the Soan river at 225 km upstream from the Indus at Kahuta where altitude is 470 m. It flows in the mountainous area and its bed slope is about 1/40.

- Sil River

The Sil river is a major tributary of the Soan river and it is also called as the Fateh Jang Kas. It originates near Bodia Rustam Khan with altitude of 560 m and drains the area of 595 sq.km into the Soan river at altitude of 338 m near Balawal. The length of the Sil river is 71 km and the bed slope is about 1/300.

Table A-2-1 shows the summary of channel morphology of each river.

Table A-2-1. Channel Morphology

Name of River	Drainage Area	Length of River	Average Width of Basin	Coefficient of Shape	Average Slope	Elevation
	A (km^2)	L (km)	W (km)	F		(m)
Dor R.	608	64.4	9.4	0.147	1:30	2,690-390
Haro R.	3,095	144.8	21.4	0.148	1:60	2,740-270
Nandna Kas	912	68	13.4	0.197	1:320	550-335
Soan R.	11,228	273.5	41.1	0.150	1:120	2,440-240
Malal Kas	92.3	24.8	3.7	0.150	1:90	760-470
Ling R.	427	58	7.4	0.127	1:40	1,850-470
Sil. R.	596	71	8.4	0.118	1:300	560-338

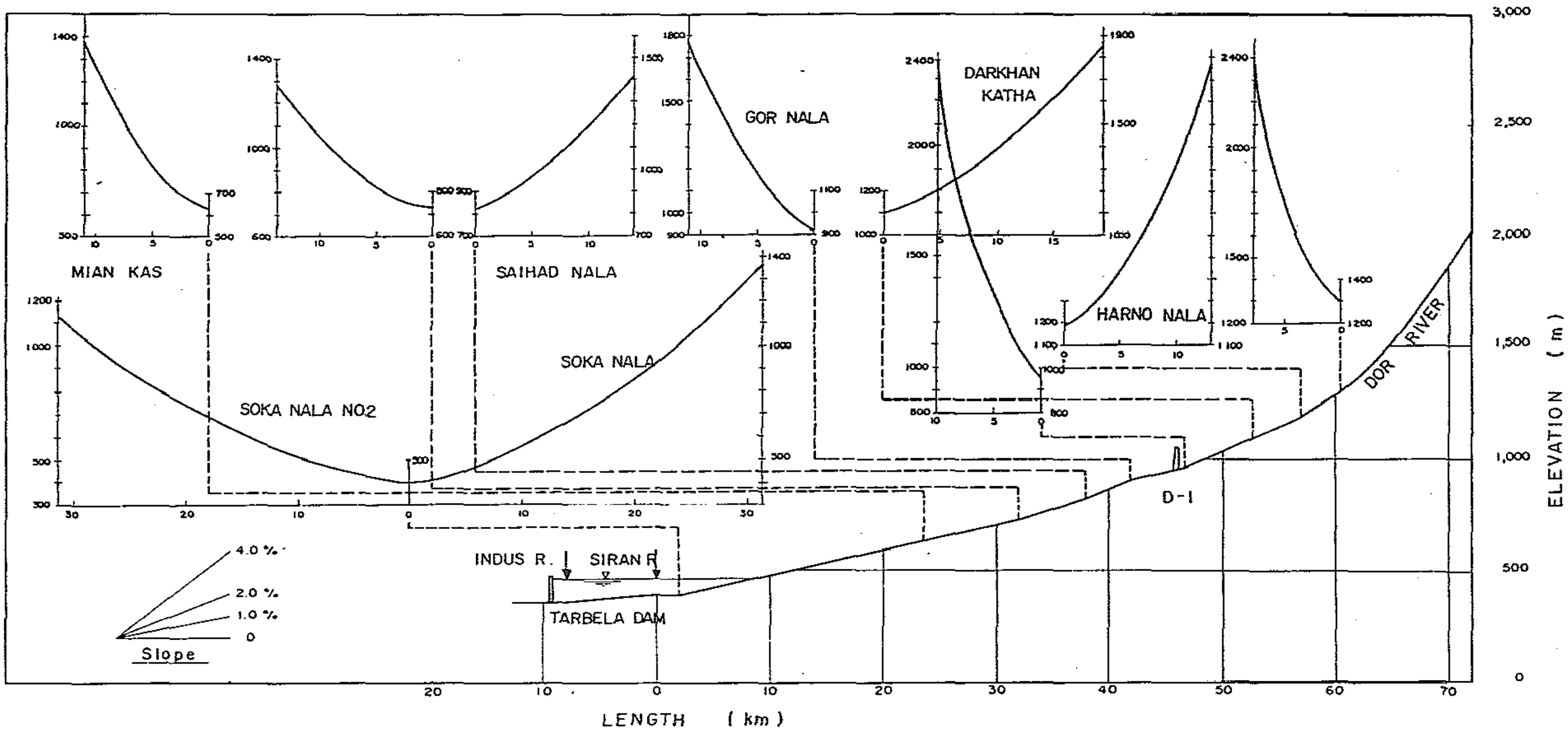


Figure A-2-2. Profile of the Dor Basin.

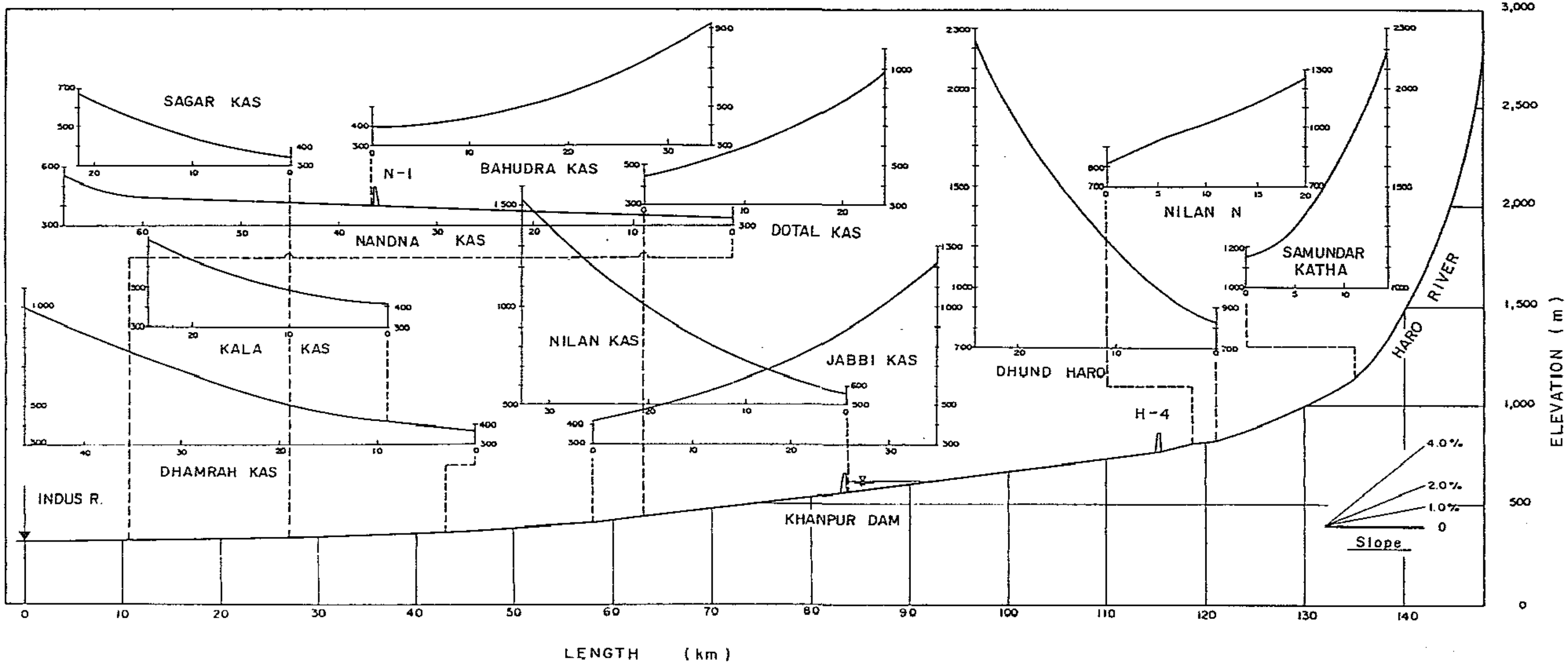


Figure A-2-3. Profile of the Haro Basin

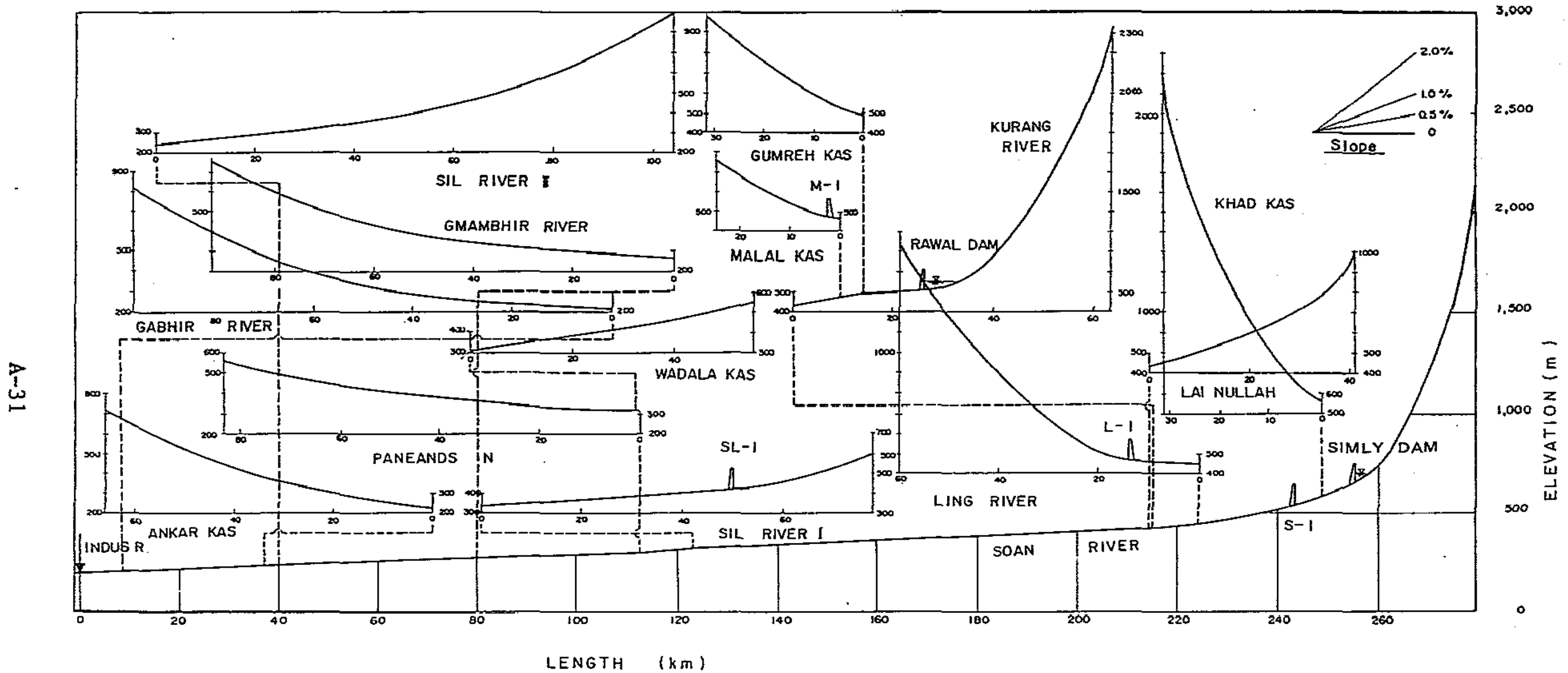


Figure A-2-4. Profile of the Soan Basin

A.2.2. Types of Rivers

The rivers in the study area flow through various types of physiographic zones and take on a variety of characteristics. The study area is divided into an upstream mountainous region and a middle or downstream plain.

In order to understand the behavior of the three rivers they have been characterized into the following broad categories:

1. Meandering alluvial plain rivers
2. Mountain rivers
3. Hill torrents

The predominant characteristics of these rivers, in terms of lateral shifting and vertical processes, are summarized in Table A-2-2.

(1) Meandering Alluvial Plain Rivers

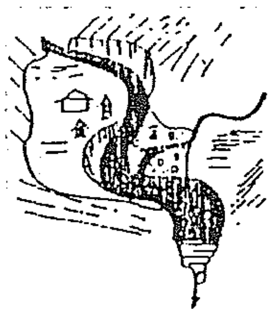
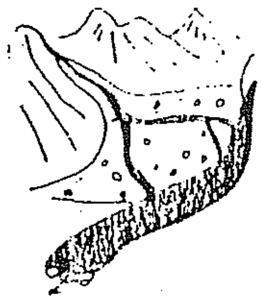
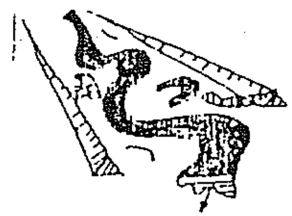
These rivers have enclosed channels exhibiting regular meander patterns (sine-wave) with a few cutoffs an oxbow lakes. The rivers appear relatively stable compared to others and generally aggrade slowly. Parts of the upper middle of the Soan River are like this. This type of river has a well defined meander belt within which most of the channel activity takes place. River widths are reasonably constant and beds generally consist of sandy soil. The rivers are capable of flowing down flood safely with the erosion in alluvial terraces.

(2) Mountain Rivers

Mountain rivers are characterized by frequent bedrock outcrops on their beds or banks which control their lateral activity and slopes.

At locations where the river valley widens, terraces and flood plains have been built up and these are usually under attack by the

Table A-2-2. Characteristics of Rivers

	Mountain River	Hill Torrents	Alluvial Plans Meandering
Lateral Shifting	Erosion of terraces, frequent lateral control by bedrock, channel pattern irregular.	Radiating Alluvial fan. channels switch frequently during flood.	Meandering Within meander belt, some bund erosion, natural cut offs, ox bows.
Vertical Processes	Degradation, scour holes at obstructions, aggradation within wide valleys.	Aggradation over alluvial fun	Accelerated aggradation after bund construction. possible short term degradation below barages.
Main Type Flood Control	Local bank protection, short bunds, also spurs to deflect flow.	Channelize main flow into several channels, control switching of channels by weirs small dams to reduce peak flows.	Bunds outside meander belt spurs to protect bunds at selected points, also breach sections in bund
SKETCH			

rivers. The rivers are in a process of long-term downcutting (degradation) and are generally able to move most of the sediment supplied form local tributaries and terrace erosion. The rivers are capable of flowing down flood safely by rising the water level within the channel. Most of the upstream areas of the three rivers can be classified as mountain rivers.

(3) Hill Torrents

"Hill torrents" mainly refers to channels flowing over their own massive alluvial deposits, usually alluvial fans. The channels switch frequently and sweep across the fans depositing sediment and aggrading their beds. The channels flow into the rivers and their main tributaries can be categorized into those types described above.

A.2.3. Water Rights

(1) River Act and Other Regulations

It appears that there are no regulations which would correspond to the Japanese River Act or other government river controls. It also appears that water rights are not recognized in Pakistan and that there are no laws or government controls to protect rights already acquired. However, in the planning of new water utilization projects it is of course necessary to know the state of water utilization up and down stream of the site proposed.

(2) Protection of Existing Water Utilization

The protection of existing rights to water usage downstream is the principle to be followed in the establishment of water utilization projects.

(3) Outline of Water Usage

Existing water usage for the three rivers in the study area is shown in Table A-2-3 and Supplement.

Table A-2-3. Existing Water Right and or Water Usage (Surface Water)

River	Tehsil	Remarks
Dor	Abbottabad	About 225 ha irrigated from main Dor between Havelian and Tehsil boundary. All private. No domestic water directly from the Dor.
	Haripur	Ditto about 3,600 has between Tehsil boundary and Tarbela Lake. Some private, some under Irrigation Dept. NWFP.
Haro	Haripur	Existing intakes from main Haro are all unauthorised since the area treated by the Khanpur Project.
	Rawalpindi	Seems no intake facilities authorized.
	Attock	Ditto but Sanjwal Cantt. (Population 6,200 in '81) taking water from the Haro.
Soan	Murree	None from the main Soan
	Islamabad	See Table D-4-1, Appendix D.
	Rawalpindi	Simly Dam. Refer to Table D-4-2, Appendix D.
	Chakwal	None from the main Soan
	Pindi Gheb	Ditto
	Talagang	Ditto

Note; Refer to Supplement for details.

(4) Minimum Regulated River Flow

The future development of water resources in the study area must be considered allowing for water demands above and beyond the new demands for urban water, irrigation water and water for the new international airport. The grand total of such water demands will be regarded as the "minimum regulated river flow" that will preserve the natural functions of the river downstream of surface water development facilities.

The following items are taken into account in the determination of the minimum regulated river flow.

a. The amount of flow necessary to preserve the natural functions of the river.

b. Already acquired water rights (permitted or customary).

c. Other development projects.

Note: Other than its two major functions (water supply, flood control) a river also has such functions as fishing, water quality preservation (deterioration prevention), underground water maintenance (preventing decreases in the water level), etc.

Basic policies are proposed based on field studies and preparatory investigations.

(a) Amount of Flow Necessary to Maintain the Natural Functions of Rivers

The amount of flow necessary to maintain the natural functions of a river is considered to be the amount of possible discharge 355 days per year. This is not to be less than the actual amount of discharge for a 355 day period.

This value observed at the following gauging stations will be the value used for the above mentioned discharge.

Dor River:	Havelian Gauging Station
Haro River:	Khanpur Gauging Station
Soan River:	Rawalpindi Gauging Station

(b) Water Rights

The amount of discharge necessary to compensate for present water use in the dry season is included in the discharge described in item (a). This is for the following reasons.

i) It was discovered in the field reconnaissance that no water rights have been granted on the three main rivers. However, there have been several granted in connection with the S.D.O. program on tributaries. However, these tributaries join the main rivers downstream of the base gauging stations listed above and the proposed weirs. Therefore, the water rights on the tributaries have not been included in this study.

ii) There are customary water rights at Havelian and Haripur where to DW-1 diversion dam has been proposed. Crops, from an agricultural stand point, can endure a one week water shortage, so it is recommended that water would be supplied for 355 days. Surface water will be supplied in the future to the area downstream of Khanpur Dam from the left bank irrigation program.

iii) Future Water Demands of Other Projects
The future water demands of other projects should also be considered. The program considered for the study area is already in P.C.I. form and gauging stations are positioned upstream.

SUPPLEMENT: WATER RIGHT

1. Existing Water Right and Water Use

In the course of the study, almost all the members of the team have suffered in lack of information about existing water right and water usage in the study area.

Therefore, study trips to all concerned Tehsils were made to inquire the actual conditions of their water usage. The followings are informations by officers of these Tehsils.

The team wishes to acknowledge with gratitude the kindness of concerned Tehsilder and Naib Tehsildar who have answered and furnished data to us.

1.1. Abbottabad

In Tehsil Abbottabad, although no water taxes are paid to the Government, extensive water usage exists. All along the river Dor, people use the water for drinking and irrigation purposes.

The villages being effected are, Joal, Rajoia, Babda Bozar, Bandi Atai Khan, Havelian, Lari, Langla, Sultanpur, Wazira, Nowshera, Kalumera Khorian and Doronimera. The approximate total area covered by irrigation from Dor river is about 400 - 600 acres (200 - 250 ha).

In the monsoons no intake from the river is necessary as water is available in sufficient quantities, but acute shortage is faced in the dry season and almost all the irrigation requirements are from the river Dor by constructing temporary diversion and weirs. The vegetables grown in the dry season are cauliflower, potato, onions, radish, spinach, tomato.

Informed by Mr. Mushtaq Ahmad
Tehsildar Abbottabad
29th Feb. 1987

1.2. Haripur

Extensive Water right and usage can be seen in Haripur Tehsil. River Dor flows through this Tehsil and many villages are irrigated in the process. There are 51 villages in this Tehsil having a total area of 21,024 acres (8,500 ha), out of which 8,870 acres (3590 ha) is irrigated.

Table D-5-1 is the detail of the area.

Informed by Mr. Sarang Khan
Naib Tehsildar Hripur
1st & 10th Feb. 1987

1.3. Attock

Scarce water right and usage exist in Tehsil Attock. River Haro flows through the tehsil and entered into the Indus at Bagh Nilab (village Dhok Haja). Enroute, one major usage of water from the river Haro is the water supply scheme for the Sanjwal Ordinance Factory at Sanjwal.

According to the 1981 population census. Sanjwal Cantonment has a population of 6,191. Very few people use the water of the river Haro downstream of Jhablat for drinking purposes at the Nullah Jhablat which carries the sewerage and industrial waste from Wah, Hassan Abdal and Rawalpindi enter into the Haro at Jhablat.

As far as usage for irrigation purpose are concerned, only Jhablat, Kacha and Burhan with approximate irrigated areas 194, 110 and 100 acres (80,45 and 50 ha) respectively have water right and usage. The rest of the villages in Tehsil Attock have other sources for irrigation such as tubewells, persian wheel etc.

Informed by Mr. Abdul Ghaffar
Tehsildar Attock
3rd Feb. 1987

1.4. Pindi Gheb and Talagag

No water right and water usage exist downstream side of the river Soan and Nullah Sil in Tehsil Pindi Gheb and Talagang.

However, the river Soan passes through the following villages in Tehsil Pindi Gheb namely Gandoko, Mallowala, Kot Malarian, Dhk Malarian, Purani.

Informed by Mr. Sultan Fayaz Kiani
Tehsilder Pindi Gheb
24 th Jan. 1987

1.5. Chakwal

Almost no water right or usage exist in Tehsil Chakwal. some perennial Nullahs do exist but they are of no relevance with respect to water right or usage. There are 38 villages in Chakwal Tehsil and 58 villages in Chakwal District.

Informed by Mr. Farasat Ali Khan
Naib Tehsildar Chakwal
28th Feb. 1987

Table S-1. List of Villages Irrigated by the River Dor

S.I.O.	Name of Village	Area Irrigated (Acres)	Aria Unirrigated (Acres)	Total Area (Acres)	Remarks
1.	Chohar	471	-	471	
2.	Fhewa	-	-	-	
3.	Qazian	355	-	355	
4.	Padhana	150	-	150	
5.	Chak Sikandarpur	82	-	82	
6.	Mathan	353	84	440	
7.	Bajeeda	366	226	592	
8.	Dobanai	255	-	255	
9.	Jama	51	-	51	
10.	Dhaenda	316	496	712	
11.	Jagal	90	585	675	
12.	Kalas	317	-	317	
13.	Panian	12	-	12	
14.	Kakka	120	154	274	
15.	Pharhala	108	450	558	
16.	Mohrahuhamau	77	56	133	
17.	Manakrai	367	1045	1412	
18.	Akhun Bandi	118	127	245	
19.	Thanda Choha	26	83	109	
20.	Maqsood	82	188	270	
21.	Kalawan	101	216	317	
22.	Nikapah	71	43	114	
23.	Nohri	176	266	442	
21.	Maira Toot.	43	8	51	
25.	Gheba	45	176	221	
26.	Doian Abi	162	218	380	
27.	Meelaz	161	570	731	
28.	Alam	71	181	252	
29.	Bhand	10	90	100	
30.	Darwesh	429	850	1279	

Continued

31.	Haripur	198	250	448
32.	Sikandarpur	117	111	528
33.	Malkiar	732	118	850
34.	Dheri.	351	251	602
35.	Serai Saleh	364	1229	1593
36.	Bhori Lahanbandi	290	715	1005
37.	Gir	85	1	86
38.	Pholian	150	610	760
39.	Dobandi	26	154	180
40.	Pandak	181	246	427
41.	GherKhn	200	224	424
42.	Ali Khan	127	333	460
43.	Shah Mohd	183	-	183
44.	Murad Abad	160	358	518
45.	Moonon	60	344	404
46.	Chak Shah Mohd	20	-	20
47.	Bagra	205	579	784
48.	Shorag.	34	193	227
49.	Ratta Bana	11	59	70
50.	Karwala	84	144	228
51.	Balaher.	4	128	132
	Total	8870	12154	21024

A.2.4. Coefficient of River Regime

As seeing in Table A-2-4, the coefficient of river regime extremely differs by rivers. And the Figure A-2-5 shows the discharge-duration curves at the several key sites in the study area.

(1) The Dor and the Haro Rivers

The coefficients of river regime of the Dor and the Haro rivers are so small as more or less than 100 that the flow of these rivers is relatively steady. The geology of these two river basins is composed of calcareous layers. As many cavities can be seen, their permeability might be judged to be considerably high. In these rivers, the base flow is fed mainly with groundwater, consequently the river flow becomes so steady. Furthermore, hydrographs of these rivers are relatively gentle (see Figures A-8-3-5 and A-8-3-6), because the interflow has a large portion in total runoff and the groundwater recharge is also large. The Jhablat Kas, a tributary of the Haro river, which flows through the alluvial plain has a particularly small coefficient of river regime. This river is extremely steady in its flow. (refer to discharge-duration curve at Hassan Abdal in Figure A-2-4) In the Jhablat Kas basin, there exist many springs where abundant groundwater outflow erupts. As the Jhablat Kas is gaining the groundwater outflow in its base flow, its river flow is so steady. The Bauhti Nala, adjacent to the Jhablat Kas on north, has also steady flow due to same natural conditions as the Jhablat Kas. According to the geological study, the groundwater in these basins is recharged not only by rainfall but also from the upper reach of the Haro river beyond watershed boundary. This fact will be discussed in Section A-3 in more detail.

(2) The Soan River

On the other hand, the river basin of the Soan river and its tributaries, the Kurang river and the Ling river, is composed of alternation of sandstone and shale. Consequently, the base flow of these rivers is scarcely fed with the groundwater. Therefore, the river flow of these rivers is not steady and their coefficients of river regime are so large. Groundwater recharge is relatively small in the basin as comparing in the Dor and the Haro river basins. And the surface runoff has a large portion in total runoff. As the result of these facts, the runoff increases sharply when raining and decreases also sharply after raining in the Soan river and its tributaries. The hydrograph of these rivers, therefore, is very sharp and the discharge sharply drops to the level close to the base flow after rain. (see Figure A-8-3-7 and A-8-3-8) However, the lower reaches of the Kurang river below the Rawal dam has a good quantity of base flow, because the Kurang river flows through the groundwater basin which has higher groundwater table than river bed of the Kurang river. The Sohan Nala, a small stream, flowing through the National Park and draining into the Kurang river, has also a good quantity of base flow due to same reason. This fact will be also discussed in Section A.3. The Soan river at the GT road bridge nearby Rawalpindi after confluence with the Kurang river gains much increase of base flow mainly from the Kurang river and the coefficient of its river regime becomes small.

(3) Tributaries in the Alluvial Plain

The Haro river and the Soan river at their downstream have many tributaries flowing through the alluvial plain. These tributaries except the Jhablat Kas and the Bauhti Nala have relatively large coefficients of river regime but less than those in the upstream basin of the Soan river. The hydrographs of the tributaries are also sharp (see Figure A-8-3-9). However, there exists perennial flow in the tributaries which have a certain extent of basin area

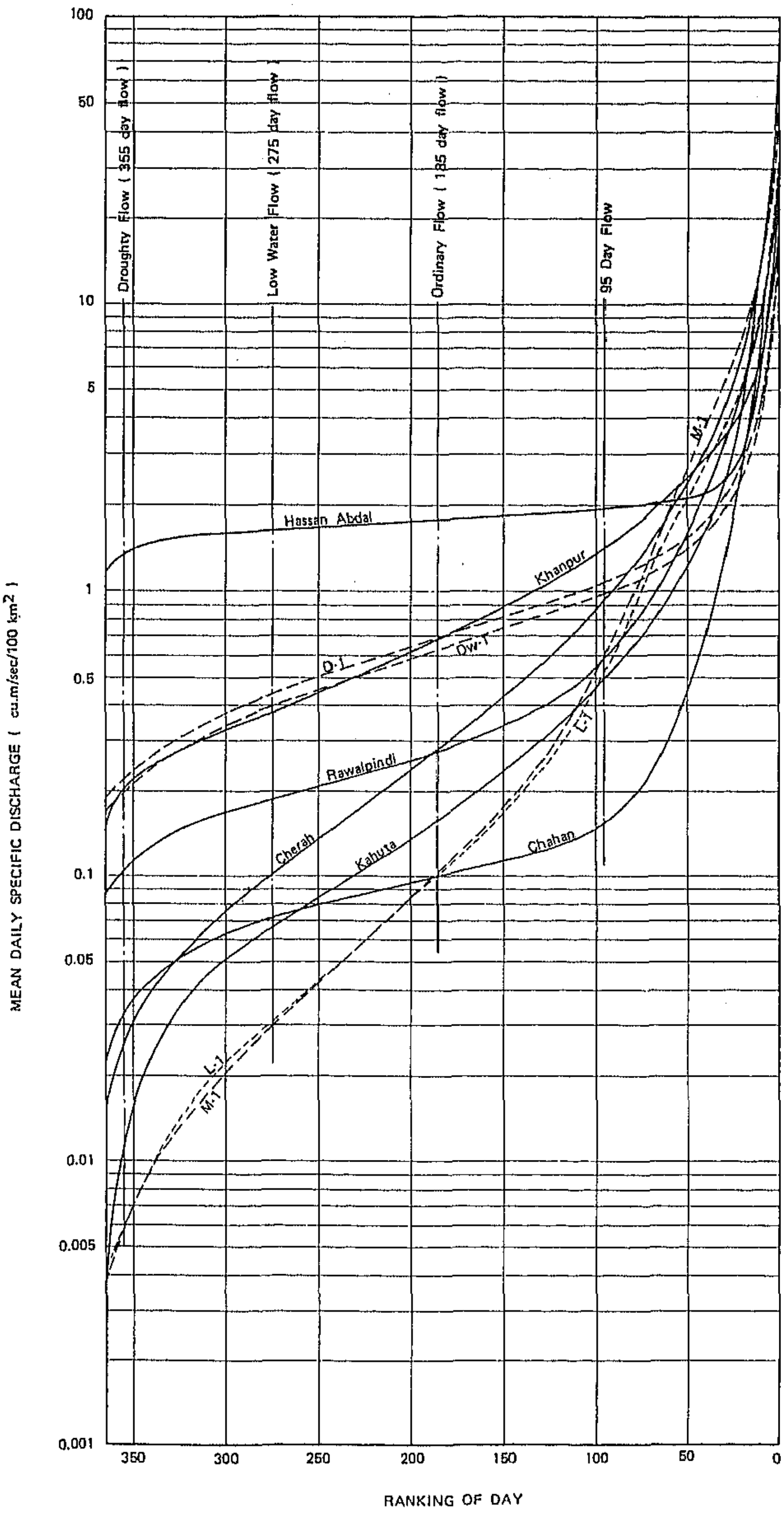
Table A-2-4. River Regime

River	Gauging Station or Development Site	Catchment Area	Discharge (cu.m/sec)						Coefficient of River Regime
			Minimum	Droughty	Low	Ordinary	95 Days	High	
		(km^2)		(355 days)	(275 days)	(185 days)	(95 days)		
Dor	D-1	292.3	0.561	0.65	1.30	2.03	3.27	46.6	83.1
	Dw-1	517.7	0.893	1.03	2.10	3.28	5.30	75.8	84.9
Haro	Khanpur	778.0	1.19	1.57	2.95	5.29	11.17	156.1	131.0
Jhablat Kas	Hasanabdal	248.6	2.90	3.39	4.08	4.41	4.89	61.7	21.3
Soan	Cherah	326.3	0.051	0.083	0.33	0.91	3.04	235.0	4,626.0
	Rawalpindi	1,684	1.46	1.78	3.15	4.71	10.3	667.0	457.0
Ling	Kahuta	145.0	0.005	0.018	0.095	0.225	0.72	93.4	18,680.0
	L-1	285.0	0.012	0.017	0.090	0.297	1.45	87.9	7,325.0
Malal Kas	M-1	82.8	0.003	0.004	0.024	0.084	0.48	37.1	12,367.0
Sil	Chahan	241.0	0.055	0.084	0.17	0.24	0.38	80.5	1,464.0

Remarks 1) Average observed discharge at gauging stations, Average computed discharge at prospect dams.

2) Coefficient of river regime = High flow/Minimum flow

FIGURE A-2-5 DISCHARGE-DURATION CURVE



(e.g. the Sil river at the Chahan Station: 241 sq.km, the Nandna Kas at the Shahpur dam: 203.9 sq.km), but base flow is relatively small as about 35 litres/sec/100 sq.km.

A.2.5. Runoff Pattern

As seeing in Figure A-2-6, the rivers in the study area have two peaks of runoff in March and August, because runoff by rainfall is dominant. However the runoff of March is less than that of August. On the other hand, since snowmelt is dominant in runoff of the Indus and the Jhelum rivers, they have only one peak of runoff in June for the Jhelum and in July for the Indus.

A.2.6. Annual Runoff

According to the analysis on precipitation and runoff analysis, total runoff amount can be assumed annually at 2,040 MCM on average as below;

Drainage Area x Areal Precipitation x Runoff coefficient
= 6,800 km^2 x 1,000 mm/yr x 0.30 = 2,040 MCM/yr

On the other hand, Table A-2-5 shows the annual runoff at the key sites from 1960 to 1980.

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

Table A-2-5. Annual Runoff at Key Sites

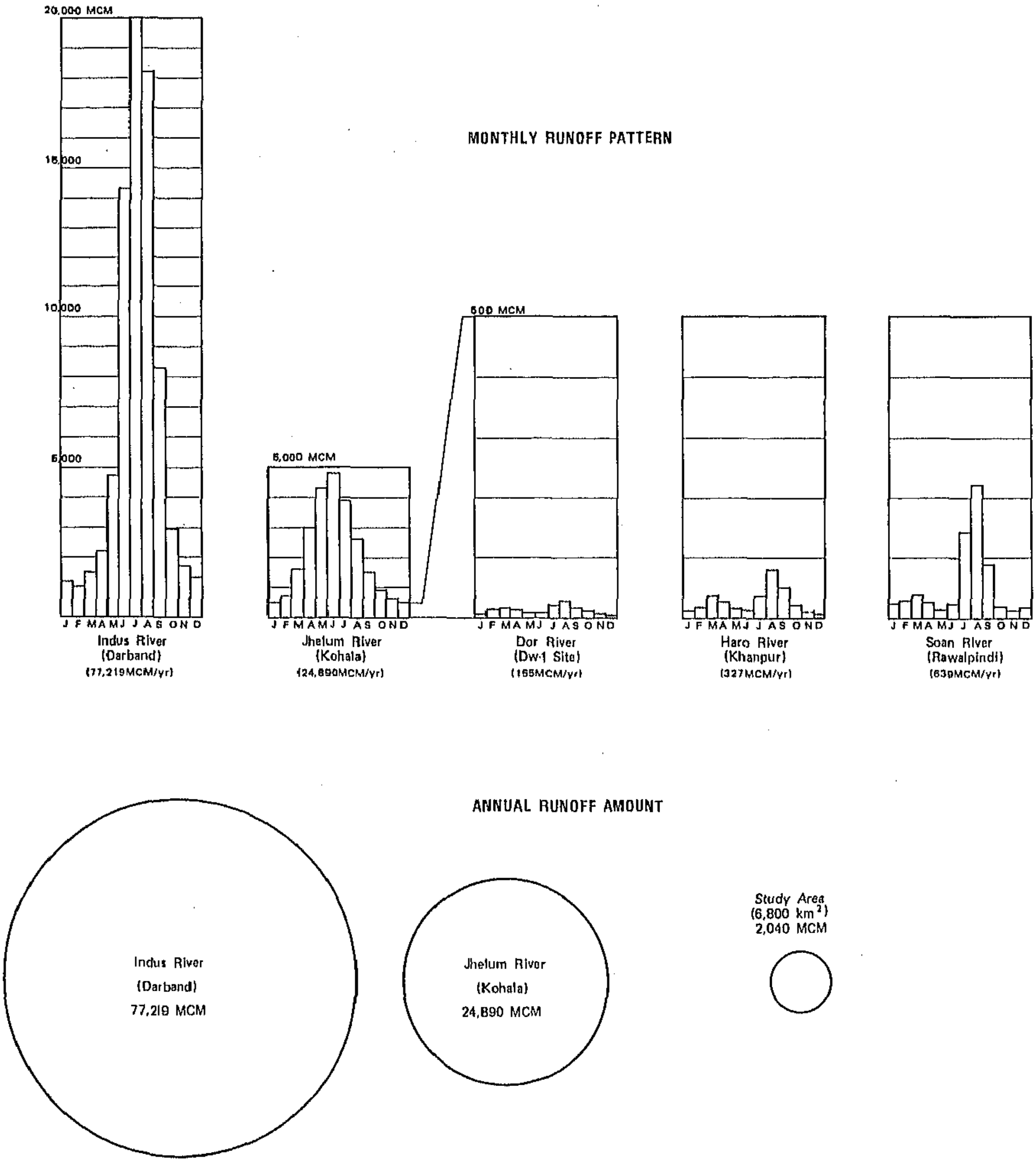
River	Site	Drainage Area (sq.km)	Annual Runoff (MCM)			Runoff Height (mm)			Ratio to Mean	
			Mean	Max.	Min.	Mean	Max.	Min.	Max.	Min.
Dor	Dw-1	517.7	155	240	112	299	464	216	1.55	0.72
Haro	Khanpur	778.0	327	629	127	420	808	163	1.92	0.39
Soan	Cherah	326.3	175	361	51.7	536	1,106	158	2.06	0.30
	Rawalpindi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

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

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

*5: Data Source: Upper Kurang Study

FIGURE A-2-6 COMPARISON OF RUNOFF PATTERN AND AMOUNT IN MAJOR RIVERS



On the other hand, seeing the mean annual runoff heights, the runoff height of the Jhelum reaches 1,000 mm in a year which is extremely higher than other rivers. This fact is because of existence of the heavy rain zone reaching the maximum annual precipitation more than 2,000 mm in Kashimir which covers almost of the uppermost river basin of the Jhelum. The Indus river, the other gigantic river, has less runoff height of 411 mm in a year than that of the Jhelum river, but the Indus river has extremely larger runoff amount than the Jhelum because of the huge river basin extending to the central area of the Himalayas.

In the study area, the Jhablat Kas has the highest runoff height reaching 686 mm in a year on average. As mentioned above, this river is a peculiar river receiving abundant outflow of the groundwater in its river basin and is much different from other rivers in the runoff mechanism. Among other rivers than the Jhablat Kas, mean annual runoff height is highest of 536 mm at Cherah in the upstream of the Soan river and least of 209 mm in the Sil river in the alluvial plain. Mean annual runoff height of the rivers in the study area, except the rivers having abundant outflow of the groundwater, ranges from 209 mm in the alluvial plain and to 536 mm in the uppermost of the study basin where much precipitation is received.

A.2.7. Probable Drought and Wet Years by Annual Runoff Amount

As seeing in Figure A-2-7, large fluctuation was observed in annual runoffs in the study area. Based on the probability analysis of data for 21 years from 1960 to 1980, the wet year and drought year differ by the rivers, as seeing Table A-2-6. According to Table A-2-6, these 7 years as 1960, 1962, 1963, 1969, 1972, 1974 and 1979 are corresponding to the drought year of return period of 10 years or more.

FIGURE A-2-7 FLUCTUATION OF ANNUAL RUNOFF AT KEY SITES

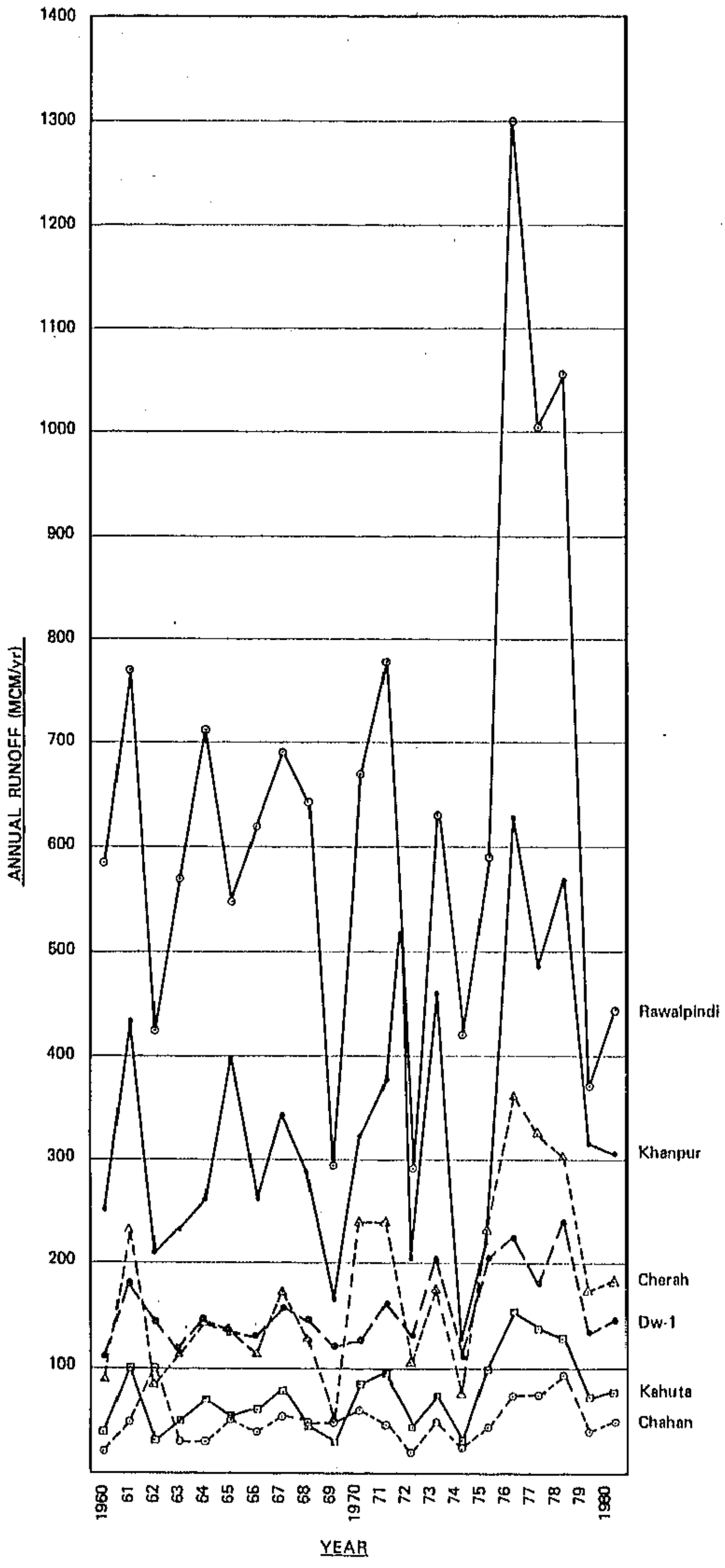


Table A-2-6. Probable Drought and Wet Years by River Basins

Rivers	Site	D.A (km^2)	Probable Annual Runoff (MCM/yr) Wet*	Normal	Droughty*	The Years Corresponding to the Given Return Period: Wet Year 10 yrs	Wet Year Over 10 yrs	Dourght Year 10 yrs	Dourght Year Over 10 yrs
Dor	Dw-1	517.7	203	147	116	1973,75	76,78	1963	60,74
Haro	Khanpur	778.0	505	305	180	1977	76,78	-	69,74
Soan	Cherah	326.3	295	158	80	1978	76,77	1962	69,74
	Kahuta	145.0	124	67	36	1978	76,77	1960	62,69,74
	Rawalpindi	1,684	969	602	360	1977	76,78	1979	69,72
Sil	Chahan	241.0	78	47	27	1977	62,78	1974	60,72

Note: 1) - : no particular year corresponding
2) detail computation is shown in Table A-2-9.
3) * .. 1/10 yrs.

Accordingly, these years of the whole study area have been analyzed using the synthetic runoff estimated as shown in Table A-2-7. As the result of probability analysis, the years of return period of 10 years are estimated at the year of 1977 as the wet year and at the year of 1974 as the drought year. And the normal year is at the year of 1968.

Table A-2-7. Probable Drought and Wet Years by the Synthetic Annual Runoff

Wet/Droughty	The Year Equivalent to the Return Period 10 Years	The Years exceeding the Period 10 Years
Wet Year	1977	1976, 78
Normal Year	1968 (note: Return Period 2 years)	
Drought Year	1974	1969, 72

Table A-2-8. The Synthetic Annual Runoff in the Study Area

River	D.A. (sq.km)	Mean Annual Runoff (MCM)	Point
Dor	517.7	155	Dw-1 Site
Haro	778.0	327	Khanpur Station
Soan	1,680.0	639	Rawalpindi Station
Sil	441.5	92	Total basin area at SL-1 (237.6 sq.km) and Shahpur dam (203.9 sq.km)
Total	3,417.2	1,213	

Return Period	Probable Annual Runoff (MCM) Wet	Normal	Droughty
2 years		1,139	
5 "	1,515		869
10 "	1,767		759
15 "	1,911		711
20 "	2,011		682
30 "	2,153		646

Note) Drainage area has been considered at the potential water resources development sites.

Figure A-2-8 shows a series of the synthetic annual runoff. The following facts can be recognized in this figure.

- *Wet years continuing from 1976 to 1978.*
- Drought years frequently occurring from 1969 to 1974.

Table A-2-9 Probability Analysis of Annual Runoff

(Unit: MCM/yr)

	Dor River	Haro River	Soan River			Sil River	Synthetic
THOMAS PLOT F=1-(I/(N+1)) %	Dw-1 Site DATA	Khanpur DATA	Cherah DATA	Kahuta DATA	Rawalpindi DATA	Chahan DATA	Runoff DATA
95.45	240.365	629.388	360.919	153.788	1301.292	99.544	2290.343
90.91	224.5	569.409	324.362	138.215	1055.719	84.36	2020.841
86.36	204.946	484.25	302.192	128.769	1004.459	74.664	1803.638
81.82	204.578	459.625	239.316	99.811	777.722	73.779	1473.984
77.27	182.381	433.16	238.617	98.968	770.031	61.596	1409.508
72.73	178.145	402.428	232.279	94.177	712.545	58.948	1403.804
68.18	161.697	383.452	232.235	85.834	691.279	55.061	1291.4
63.64	156.547	342.702	182.978	78.767	671.108	51.578	1235.859
59.09	145.353	323.923	175.682	77.985	642.727	49.522	1178.449
54.55	145.124	312.869	173.228	74.877	631.24	49.187	1174.197
50.	144.872	304.576	172.614	73.831	618.938	48.26	1162.87
45.45	143.871	286.557	142.393	69.902	591.017	48.162	1100.397
40.91	135.642	261.736	134.005	62.353	584.654	47.291	1081.333
36.36	134.959	260.714	128.648	55.566	570.131	44.767	986.173
31.82	129.579	249.144	113.969	49.281	546.571	40.081	983.861
27.27	129.096	233.914	113.954	45.012	443.25	39.863	978.18
22.73	127.984	222.789	104.456	44.525	423.683	31.445	961.552
18.18	118.396	210.632	89.091	37.989	420.38	31.15	893.653
13.64	116.528	203.567	84.49	32.587	371.714	25.418	705.455
9.09	112.556	164.165	76.41	31.754	294.346	21.746	667.631
4.55	111.617	126.892	51.671	31.289	291.37	19.947	660.859

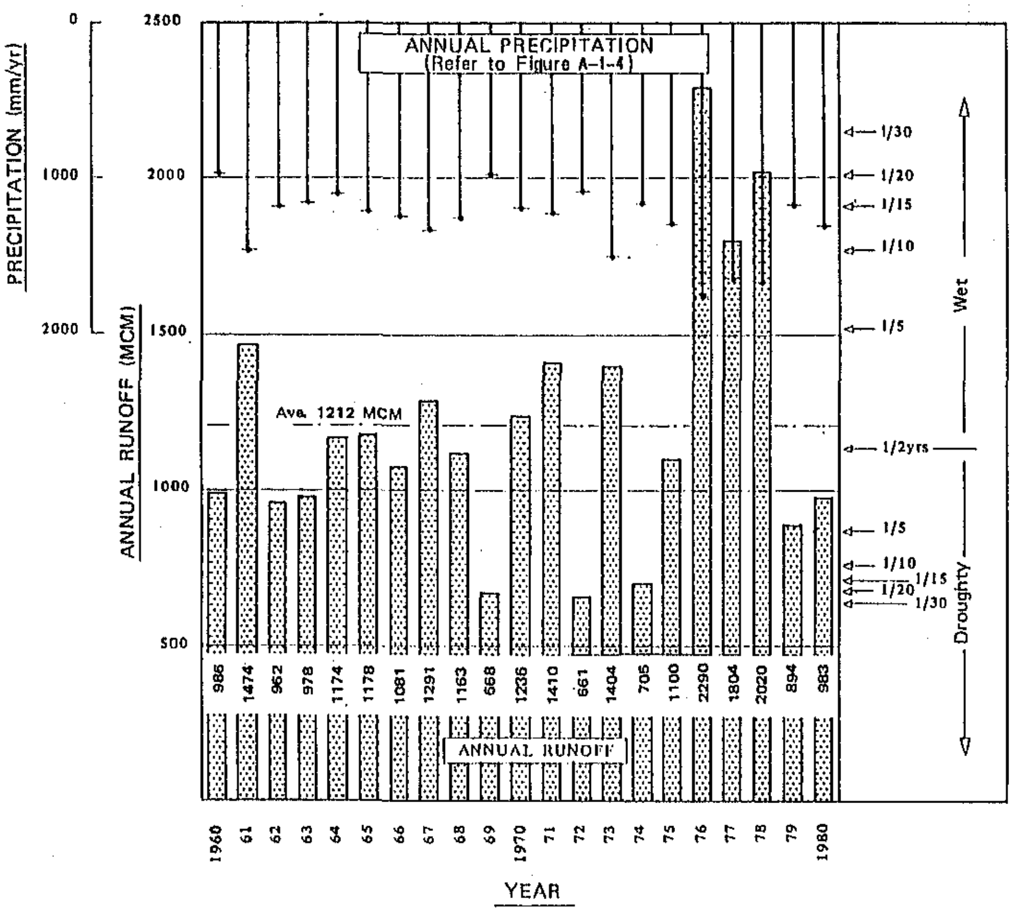
	Dw-1 Site	Khanpur	Cherah	Kahuta	Rawalpindi	Chahan	Synthetic Runoff
X0=	150.7730001	302.8719162	155.3164932	66.93816311	595.2885464	46.34121033	1150.1201
B=	-76.27080315	32.53016425	23.17731475	-1.961632935	105.930215	14.67877916	-179.9468853
XX0=	1.850418671	2.52870088	2.258038999	1.811178435	2.849871034	1.792356828	2.981789698
XX2=	3.4614593	6.418000929	5.133368424	3.324873566	8.140836214	3.230276022	8.91886789
1/A=	0.28028751	2.22963E-01	2.69665E-01	3.05717E-01	2.00124E-01	1.92974E-01	2.41611E-01

RETRN PERIOD / PRBBL. AMOUNT

UNEXCEEDANCE	Dw-1 Site	Khanpur	Cherah	Kahuta	Rawalpindi	Chahan	Synthetic Runoff
2.	147.1416623	305.2439102	157.9729608	66.70248859	601.8053744	47.3162442	1138.883051
5.	124.5423877	216.3062344	102.0102266	44.54559134	432.063326	32.91140755	868.6100595
10.	115.7628928	179.5657676	88.0199531	36.17039478	360.2119518	26.76724614	759.1642973
15.	111.9996304	163.3175498	70.53919954	32.62995532	328.0391759	24.00538064	711.25145
20.	109.7325138	153.3608932	64.80960634	30.51314646	308.1980567	22.29781521	682.0533893
30.	106.966893	141.8254272	57.80009015	27.94854777	283.4463861	20.1650722	646.861185
50.	104.0401931	127.7206653	50.35611379	25.25738931	256.5552071	17.84171496	607.4804382

EXCEEDANCE	Dw-1 Site	Khanpur	Cherah	Kahuta	Rawalpindi	Chahan	Synthetic Runoff
2.	147.1416623	305.2439102	157.9729608	66.70248859	601.8053744	47.3162442	1138.883051
5.	180.3229775	425.9617716	238.952782	100.3878607	825.1026441	66.08120914	1515.227475
10.	203.4577466	505.3726906	294.8100023	124.4851668	968.6124899	78.05346461	1767.534811
15.	216.8563091	549.990609	326.9789259	138.6296364	1048.27484	84.67418692	1910.702897
20.	226.3830726	581.1848342	349.7806423	148.7622085	1103.59688	89.26218639	2011.348515
30.	239.9105193	624.7941844	382.064399	163.2496664	1180.458499	95.62426654	2152.764647
50.	257.1611298	679.353548	423.0880503	181.8818864	1275.889949	103.5046318	2330.792271

Figure A-2-8. Synthetic Annual Runoff and Its Probability



A.2.8. Floods

According to the flood records in the study area, high floods generally occur during the monsoon centering in August. The specific runoff of the maximum recorded flood reached 8.35 cu.m/sec/sq.km in the study area. This specific runoff is equivalent approximately to c = 75 in the Creager equation as seeing in Figure A-2-9. Table A-2-10 shows the maximum floods recorded at major gauging stations in the study area.

Table A-2-10. The Maximum Recorded Floods in the Study Area

River	Station	D.A. (sq.km)	Discharge (cusecs)	Discharge (m^3/s)	Discharge ($m^3/s/km^2$)	Date
Dor	Kalapani*		1,477	41.8		30 Jun.'77(1971-78)
	Ilyasi Masjid*		570	16.1		2 Aug.'76(1971-78)
	Rajoia*	292.3	3,186	90.2	0.31	9 Aug.'71(1971-78)
	Havelian	357.5				
	Makhan*	605.9	1,624	46.0	0.076	2 Aug.'76(1971-77)
Haro	Khanpur	778	28,800	816	1.05	23 Jun.'71(1960-75)
	Sanjwal	1,800	55,300	1,566	0.87	2 Sep.'61(1960-75)
	Gariala	3,056	64,900	1,838	0.60	26 Aug.'70(1969-75)
Soan						
Kurang	Bari Kangran*	45.4				
	Chhattar*	29.7				
	Rawal Dam	272.0				
	Dok Khana	321.1				
	Lohi Bher	558.8				
Ling	Kahuta	145.0	39,800	1,127	7.77	31 Aug.'70(1961-70)
Soan	Chaniot*	126.4				
	Cherah	326.3	96,200	2,724	8.35	20 Aug.'75(1960-75)
	Rawalpindi	1,684	107,000	3,030	1.80	13 Aug.'70(1953-75)
	Dhok Pathan	6,475	209,000	5,919	0.91	30 Jul.'67(1964-75)
Sil	Chahan	240.9	31,400	889	3.69	20 Aug.'75(1962-75)
Wadala Kas	Papin					
Siran	Phulra	1,057	25,500	722	0.68	1 Sep.'70(1970-75)
	Thapla	2,797	56,800	1,609	0.58	8 Sep.'61(1960-70,72-73)
Kanshi	Palote	1,111	53,700	1,521	1.37	23 Jun.'71(1970-75)
	Jhangi	1,197	33,800	957	0.80	11 Jul.'60(1960-67)

Note) *: daily discharge basis

FIGURE A-2-9 MAXIMUM RECORDED DISCHARGE AND ENVELOPE:

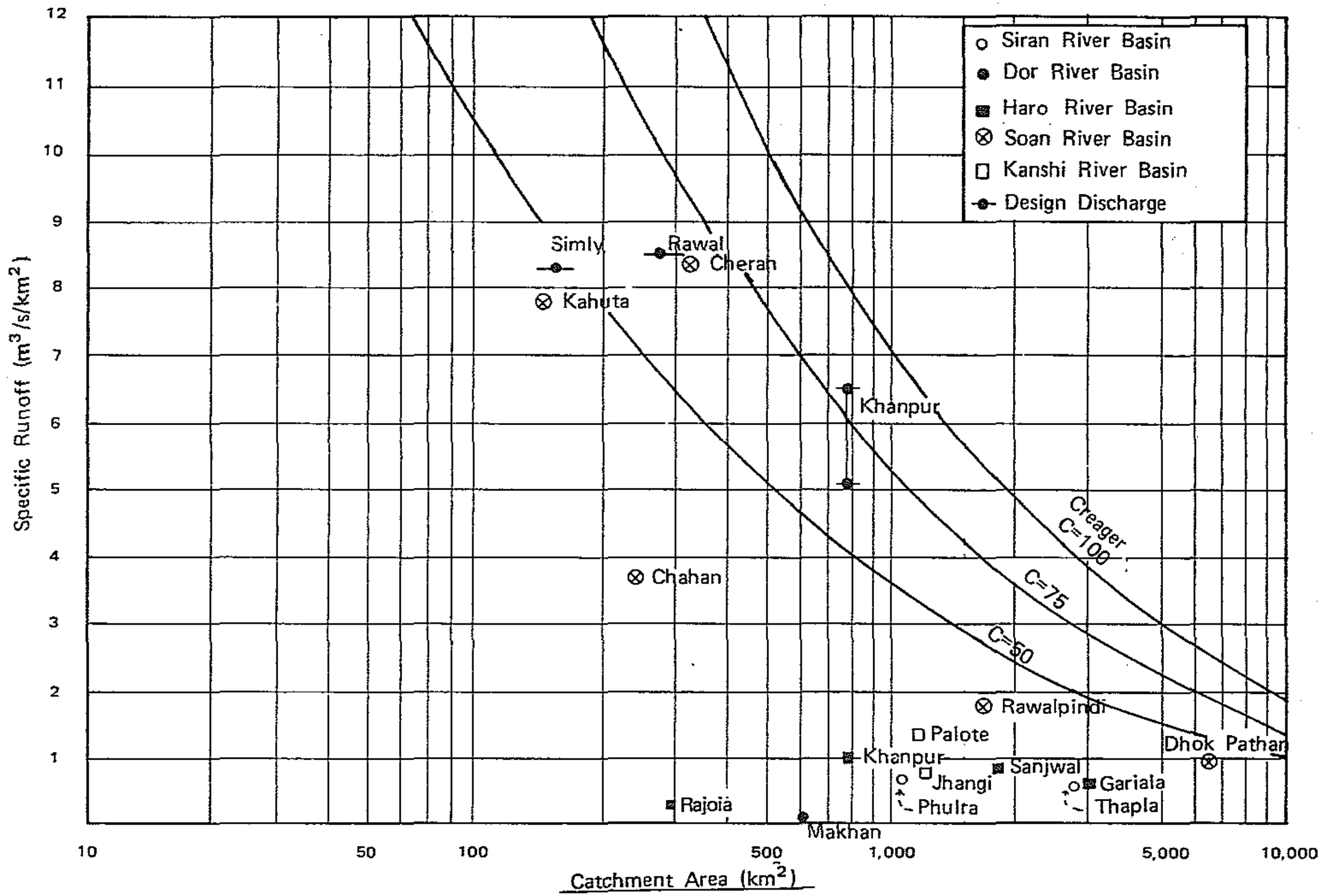


Table A-2-11 List of Drainage Area of Key Sites in the Study Area

List of Drainage Area of Key Sites in the Study Area

Dor River Basin

Site	Drainage Area (km^2)
Harno Nala	
Kalapani S.G.S.	
Darkhan Katha	
Ilyasi Masjid S.G.S.	
Dor River	
D-8	51.6
D-7	77.8
D-6	105.9
D-5	113.6
D-4	149.1
D-3	158.6
D-2	246.5
D-1	292.3
Rojoia S.G.S.	292.3
Havelian S.G.S.	414.5
Dw-1	517.7
Makhan S.G.S.	605.9
to Tarbela Reservoir	608.1

Haro River Basin

Site	Drainage Area (km^2)
Samundar Katha	
H-8	61.6
Nilan Nala	
H-7	56.7
Haro River	
H-6	407.9
H-5	488.9
H-4	498.5
Nilan Kas (Right)	
H-3	41.8
H-2	49.7
Nilan Kas (Left)	
H-1	41.3
Confluence to Haro River	134.9
Haro River	
Khanpur Dam	778.0
Khanpur S.G.S.	778.0
Hw-2	800.7
Hw-1	817.3
Highway Bridge	910.9
Confluence with Jabbi Kas	
Confluence with Jhablat Kas	
Jhablat Kas	
Hassan Abdal S.G.S.	248.6
Confluence to Haro River	
Jw-1	244.9
Nandna Kas	
Shapur Dam	203.9
N-1	462.0
Confluence to Haro River	
Haro River	
Sanjwal S.G.S.	1,800
Confluence with Nandna Kas	
Gariala S.G.S.	3,056
to Indus River	3,095

Soan River Basin – Kurang River

Site	Drainage Area (km^2)
Kurang River	
Bari Kangran S.G.S.	45.4
K-1	2.3
K-2	137.0
Chhattar S.G.S.	29.7
Bharakao	158.8
Shahdara	24.3
Nurpur	4.8
Rawal Dam	275.1
Rawal Dam S.G.S.	272.0(?)
Kc-1	300.0
Dhok Khanna S.G.S.	321.1
Confluence to Gumreh Kas	326.9
After Gumreh Kas	456.2
Confluence to Malal Kas	467.7
After Malal Kas	555.4
Lohi Bher S.G.S.	558.8
Confluence to Soan River	580.3
Gumreh Kas	
Dhok Khanna S.G.S.	125.0
Gc-2	125.0
Confluence to Kurang River	129.3
Malal Kas	
M-1	82.8
Confluence to Kurang River	87.7

Soan River Basin – Soan River

Site	Drainage Area (km^2)
Soan River	
Chaniot S.G.S.	126.4
Simly Dam	152.8
Confluence to Khad Nala	174.8
Khad Nala	
S-3	115.1
Confluence to Soan River	149.1
Soan River	
After Khad Nala	323.9
S-2	324.6
Cherah S.G.S.	326.3
S-1	341.1
Confluence to Ling River	451.7
After Ling River	856.3
Confluence to Kurang River	892.5
After Kurang River	1,472.8
Sw-1	1,472.8
Lai Nala	
Confluence to Soan River	211.2
Soan River	
After Lai Nala	1,684.0
Rawalpindi S.G.S.	1,684.0
Sil River (Upper)	
SL-2	196.7
SL-1	237.6
Chahan	241.0
Soan River	
Dhok Pathan S.G.S.	6,475
Makhad S.G.S.	10,749
to Indus River	11,228

Soan River Basin – Ling River

Site	Drainage Area (km^2)
Ling River	
L-3	115.3
Kahuta	145.0
L-2	240.3
L-1	285.0
Confluence to Soan River	404.6

Jhelum River Basin

Site	Drainage Area (km^2)
Jhelum River	
Kohala S.G.S.	24,890
Karot S.G.S.	26,677
Mangla Dam	33,333
Jhelum Right Bank	
Total of Tributaries	1,311

Indus River Basin

Site	Drainage Area (km^2)
Talbra Dam	168,350

Note) S.G.S. : Stream Gauging Station

A.3. Runoff Analysis

A.3.1. Introduction

Runoff analysis has been made in order to estimate runoff at the prospective water resources development sites.

Taking into account the fact that design drought year is set in once in ten years, runoff analysis must be returned for at least 20 years. Observation period of runoff gauging differs by stations. Since fairly good rating daily basis data during the period from 1960 to 1980 are collected, runoff analysis can be returned for the period of 21 years from 1960 to 1980.

Considering the minimum regulated river flow to be released to maintain the rivers healthy and the water resources development by diversion dams, runoff analysis has been made basically in daily basis, but in 10 days' basis in some rivers.

Runoff analysis has been made by using the correlation analysis between gauging stations (10 days' basis), the tank model analysis (daily basis) and the conversion by catchment area ratio. Runoff analysis has been proceeded in three steps. In the first step, appropriate hydrological stations are selected taking their reliability into account, and in the second step the gauging records have been interpolated to prepare complete data for 21 years from 1960 to 1980 at Khanpur, Cherah, Kahuta and Chahan gauging station. However, interpolation of the data at Hassan Abdal gauging station was not able to be achieved due to no available daily rainfall record nearby this station. And, using complete data at gauging stations, runoff analysis has been made to estimate runoff at the prospective development sites in the third step.

A.3.2. Hydrological Data

Hydrological observation is conducted by WAPDA, the Irrigation Department and the Capital Development Authority (CDA) in the study area. Although the observation accuracy and period vary at the stream gauging stations, all of the rivers have or had been observed in the study area. All of these observation records have been obtained in this study, at 32 stations in the study rivers and 4 stations in the adjacent rivers. The WAPDA stations are observing not only water level and discharge but also suspended sediment and water quality.

The following table shows the summary of collected hydrological data;

Table A-3-1. Stream Gauging Stations

Observation Institute	Study Rivers						Adjacent Rivers			Grand Total
	Indus	Dor	Haro	Soan	Jhelum	Total	Siran	Kanshi	Total	
WAPDA	1	1	7	9	3	21	2	2	4	25
Irri.Dept(F)	-	4	-	-	-	4	-	-	-	4
" " (P)	-	-	-	5	-	5	-	-	-	5
CDA	-	-	-	2	-	2	-	-	-	2
Total	1	5	7	16	3	32	2	2	4	36

Note: (F): Frontier Province, (P): Punjab Province
List of stations are shown in Table A-8-3-1.

A.3.3. Selection of the Appropriate Hydrological Stations

The data of WAPDA is judged to be most reliable among available hydrological data. WAPDA has set own criteria as shown in the table below for evaluating the accuracy of discharge measurement, and discharge measurement is evaluated at each WAPDA station every year.

Table A-3-2. Accuracy of Discharge Measurement by WAPDA

Accuracy Evaluation	Measurement Error
Excellent	Within ± 2%
Good	± 2% - ± 5%
Fair	± 5% - ± 8%
Poor	more than ± 8%

Accuracy of discharge measurement is not known at other stations than WAPDA, because there is no such criterion as WAPDA at those stations. The accuracy is judged, however, to be fairly low, because of inexpedience in the measurement and no rating curves at those stations.

Consequently, this study is using only the data of WAPDA in hydrological study. Following are summary of evaluation of major hydrological stations concerned with the study.

(1) Indus River

Gauging station (Darband) WAPDA

- ° Accuracy : Good (1960 - Apr. 1974)
- ° Catchment area: 166,019 km^2
- ° Annual runoff : 77,219 MCM (runoff height 465 mm)

The amount of inflow to Talbera dam can be estimated by the above annual runoff. However, it must be considered that runoff from the Siran river and Dor river also flows into the Talbera.

(2) Jhelum River

Gauging station (Kohala) WAPDA

- ° Accuracy : Fair (1965 - 80)
- ° Catchment area: 24,890 km^2
- ° Annual runoff : 24,890 MCM (runoff height 1,000 mm)

Gauging station (Karot): WAPDA

- ° Accuracy : Fair (Apr. 1969 - 79)
- ° Catchment area : 26,677 km^2
- ° Annual runoff : 24,160 MCM (runoff height 906 mm)

Gauging station (Mangla) WAPDA

- ° Accuracy : Good (1960 - 1980 no data in 1978)
- ° Catchment area : 33,411 km^2
- ° Annual runoff : not computed in the study

Mangla gauging station, located at just downstream of Mangla dam, has observed spill from the dam, so to speak, controlled runoff since 1967. Runoff at Karot and Kohala stations is fair enough in rating to be applied to the study. However, a care must be taken about the application of data because Karot gauging station at downstream observes less runoff than Kohala station at upstream.

(3) Dor River

Gauging station (Kala Pani) IRR (Frontier)

- ° Accuracy : unknown (1971 - 1986)
- ° Catchment area : "
- ° Annual runoff : not computed in the study

This station, located in the Harno river which is a right bank branch of the Dor river, can not be applied to runoff analysis due to the fact that its location was not clear during the field survey.

Gauging station (Ilyasi Masjid) IRR (Frontier)

- ° Accuracy : unknown (1971 - 1986)
- ° Catchment area : "
- ° annual runoff : not computed in the study

This station, located in the Dorkhan Khata which is a right bank branch of the Dor river, can not be applied to runoff analysis due to the same reason mentioned above.

Gauging station (Rajoia) IRR (Frontier)

- ° Accuracy : unknown (1971 - 1986, lack of data included)
- ° Catchment area : 292.3 km^2
- ° Annual runoff : 143 MCM (runoff height 490 mm)

This station is located at just downstream of D-1 site in the Dor river. No water use is observed in upstream. Daily basis hydrograph shows that recorded runoff does not correspond with rainfall and the hydrograph is unreliable shape. It must be considered that rating is poor because water level is converted to runoff by using Manning Formula. Therefore, the runoff data of this station can not be applied to runoff analysis.

Taking into account the advantage that this station is located at a gorge of the river where sediment deposit is less in the river bed, it is desirable to measure actual discharge by a current meter from now on.

Gauging station (Havelian) WAPDA

- ° Accuracy : unknown (Apr. 1970 - June. 1974)
- ° Catchment area : 414.5 km^2
- ° Annual runoff : unknown because of few observation in a year

This station was set temporarily as a miscellaneous station, and made measurements seven or eight days a year, so that runoff data can not be applied to runoff analysis. These actual gauged data are considered to be fairly good in rating.

Gauging station (Makhan) IRR (Frontier)

- ° Accuracy : unknown (Apr. 1971 - Nov. 1977)
- ° Catchment area : 605.9 km^2
- ° Annual runoff : 182 MCM (runoff height 300 mm)

Gauged data can not be applied to runoff analysis because of their poor rating. No flows are oftenly observed in May and June during irrigation period because irrigation water is taken at upstream. This data is fairly precious to know how the river is presently utilized.

(4) Haro River

Gauging station (Khanpur) WAPDA

- ° Accuracy : Fair (1960 - 1980)
- ° Catchment area : 778 km^2
- ° Annual runoff : 327 MCM (runoff height 420 mm)

Gauged data does not include the intake from the left bank, so that the data have been revised by adding the intake. The amount of this division was estimated in the previous study (Khanpur-Islamabad Conduction). The revised data is good enough to be applied to this study.

Gauging station (Sanjwal) WAPDA

- ° Accuracy : Good (1969 - 1979)
- ° Catchment area : 1,800 km^2
- ° Annual runoff : 546 MCM (runoff height 304 mm)

Gauging station (Gariala) WAPDA

- ° Accuracy : Good (1969 - 1979)
- ° Catchment area : 3,056 km^2
- ° Annual runoff : 737 MCM (runoff height 253 mm)

These two stations are located at upstream and at downstream of the junction of the Haro river and the Nandna Kas respectively. The gauged data are good enough for estimating the runoff of the Nandna Kas.

Gauging station (Hassan Abdal) WAPDA

- Accuracy : Good (Sep. 1961 - June 1965)
- Catchment area : 248.6 km^2
- Annual runoff : 170 MCM (runoff height 686 mm)

This station was located in the Jhablat Kas running in the alluvial plain on the left bank of the Haro river and closed in 1965. Runoff height is much higher than that in other river basins because there are a lot of spring in the basin and a part of the basin is irrigated. The collected data does not make it clear whether those springs are brought by irrigation, but abundant groundwater is prospected judging from the fact that these springs have been reported since ancient time. River flow is so stable that some runoff have been utilized for irrigation (22 cusecs = 0.62 m^3/s in observation period). The basin is so unique that the data can not be applied to other alluvial basins.

(5) Soan River

Gauging station (Chiniot) DHF (Punjab), CDA

- Accuracy : unknown (Apr. 1963 - 1981)
- Catchment area : 126.4 km^2
- Annual runoff : not computed in the study

Gauging station (Simly) CDA

- Accuracy : unknown (Apr. 1963 - Sep. 1982)
- Catchment area : 152.8 km^2
- Annual runoff : 238,800 Aft = 295 MCM (runoff height 1,931 mm)
  (Khanpur Conduction F/S)

Runoff height at the Simly station is so high that the runoff exceeds the rainfall studied on the Khanpur conduction F/S. The data are unapplicable for runoff analysis. Since runoff at Chiniot station (DHF) is not converted to discharge, those data are not applied to the study. CDA's runoff data are not applied to the study by the same reason as Simly Station.

Gauging station (Cherah) WAPDA

- ° Accuracy : Good (Apr. 1960 - 1980)
- ° Catchment area : 326.3 km^2
- ° Annual runoff : 175 MCM (runoff height 536 mm)

This data are good enough in rating and long enough in observation period for runoff analysis.

Gauging station (Rawalpindi) WAPDA

- ° Accuracy : Good (1960 - 1980)
- ° Catchment area : 1,684 km^2
- ° Annual runoff : 639 MCM (runoff height 379 mm)

This station is located at downstream of the junction of the Kurang river and the Ling river. The data are good enough in rating and long enough in observation period to make it possible to evaluate the out come of runoff from the Kurang, Soan and Ling rivers.

Gauging station (Dhok Pathan) WAPDA

- ° Accuracy : Fair

Gauging station (Makhan) DHF (Punjab)

- ° Accuracy : unknown

(6) Kurang River, Gumreh Kas

Data gauged at six stations are so poor in rating and short in observation period that data are not applied to the study.

(7) Ling River

Gauging Station (Kahuta) WAPDA

- ° Accuracy : Good (18 Jul.1961 - 10 Jul.1971)
- ° Catchment area : 145.0 km^2
- ° Annual runoff : 58.3 MCM (runoff height 402 mm)
- ° No intake at up and down stream

Rating is fair but observation period is not enough only about 10 years.

(8) Sil River

Gauging Station (Chahan) WAPDA

- ° Accuracy : Good (3 Mar. 1962 - 1980)
- ° Catchment area : 241.0 km^2
- ° Annual runoff : 52.0 MCM (runoff height 216 mm)

Data are good enough in rating, fairly long in gauging period, and are not affected by irrigation or intake. The data re considered to be applicable to rivers in the alluvial plain.

A.3.4. Runoff Analysis at the Gauging Stations

At the gauging stations where data are not available for long period and are considered to be applied to other river basins, runoff analysis has been returned by the tank model or the correlation from 1960 to 1980.

Daily rainfall data applicable for the tank model analysis are available only at the following six stations, so that the areal rainfall has been modified, referring to the isohyetal map when needed. Computed runoff can not be adjusted exactly to the observed runoff especially when flood, because the precise areal rainfall can not be computed by the data only at 6 stations.

Therefore, in due consideration that computed runoff is adjusted to the total amount of observed runoff in long term basis and to the observed recession, the structure of tank has been determined.

Rainfall Stations applied to the Tank Model

° Rainfall stations where gauging period is long enough

Kakul, Murree, Chaklala (1960 - 80)

° Rainfall stations where gauging period is not long enough

Barkot (Oct. 1962 - 79)

Kallar (Jul. 1960 - 80)

Rawal Dam (1963 - 79)

Following Table A-3-3 showing the summary of result of runoff analysis at the gauging stations.

Table A-3-3. Runoff Analysis at the Gauging Stations

(unit: mm)

Station	Analized Period	Annual Average Areal Rainfall	Analysis by Tank Model: Actual Runoff	Computed: Runoff	Computed: Evapotrans.	Computed: Grand Water	Analysis by Correlation	Interpolation
Khanpur	'63-'75	1,318	363 (0.275)	381 (0.289)	711 (0.540)	226 (0.171)		
Cherah	'63-'75	1,318	453 (0.344)	459 (0.348)	704 (0.534)	156 (0.118)	Rawalpindi Correlation Coefficient r = 0.887 (Apr.1960-1980)	by correlation Jan.-Mar. 1960
Kahuta	'62-'70	1,258	391 (0.311)	401 (0.319)	714 (0.567)	143 (0.114)	Cherah Correlation Coefficient r = 0.911 (20 Jul.1960-10 Jul.'71)	by correlation 1960-20 Jul. 1961 11 Jul. 1971-1980
Chahan	'63-'80	981	204 (0.208)	211 (0.215)	605 (0.617)	159 (0.162)		by tank model 1960-2 Mar. 1962

Remarks: ( ) ratio to rainfall

Regression equations for estimating runoff at Cherah and Kahuta are as follows;

Cherah Station

$$Y = 0.2722X + 0.0106$$

where Y: 10 day runoff at Cherah Station (MCM)
X: 10 day runoff at Rawalpindi (MCM)

Kahuta Station

$$Y = 0.4258X + 0.0008$$

where Y: 10 day runoff at Kahuta Station (MCM)
Y: 10 day runoff at Cherah Station (MCM)

Structure of tank models is presented in Figure A-8-3-1 for Khanpur, in Figure A-8-3-2 for Cherah, in Figure A-8-3-3 for Kahuta and in Figure A-8-3-4 for Chahan. Sample output of each tank model is shown in Figure A-8-3-5 to 9 to see applicability of tank model for the study. Although applicability is relatively low for estimating flood peak discharge, developed tank models are explaining the characteristics of river regime mentioned in Section A.2.4 and will be able to be applicable for estimating the water resouces on the whole.

As the result of above study, runoff coefficients are estimated approximately at 0.21 in the alluvial plain, at 0.28 in the Dor and the Haro river basins and at 0.31 to 0.34 in the Soan river basin. Groundwater recharge rate is lower in the Soan river basin as 0.11 to 0.12 to annual rainfall, and higher in the alluvial plain and the Dor and the Haro river basins as 0.16 to 0.17. These facts are expressed in Table A-3-3. From this table, it is also understood that evapotranspiration has large portion in hydrological balance in the area.

Appling above study, interpolation has been conducted to extend the runoff records at the gauging stations. These results are shown in Table A-8-3-11 to 13.

A.3.5. Runoff Analysis at the Prospective Development Sites

Considering the analogy of river basins, runoff at the prospective development sites has been computed with the interpolated gauging data by applying the catchment area ratio and the tank models developed at the gauging stations.

Runoff analysis of the Dor river basin has been made by applying the tank model at Khanpur station because the Dor river basin is similar to the Haro river basin on geology and morphology. The Soan river basin has been analyzed with the tank model developed at Cherah and Kahuta. The tributaries in the alluvial plain have been analyzed using the tank model developed at Chahan in the Sil river.

The results of above analysis are summarized in Table A-3-4. And, the derived runoffs are presented in Tables A-8-3-14 to 19.

Table A-3-4. Runoff Analysis at the Prospective Development Sites

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

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

A.3.6. Water Balance in the Jhablat Kas Basin

As seeing hydrographs of the Jhablat Kas in Figures A-8-3-10(1) to 10(5), abundant steady baseflow is available through the year. Comparing with the discharge computed by the tank model developed at Chahan, baseflow of the Jhablat Kas is much higher than the computed discharge. This difference of discharge might be outflow of groundwater.

Using the discharge record at Hassan Abdal Station which was located at the lowermost of the Jhablat Kas and the observation of the Bauhti Nala by the study team, total runoff of both rivers is estimated at about 208 MCM in a year on average as of the years from 1961 to 1965. Out of total runoff of 208 MCM, 162 MCM was bone by outflow of groundwater.

Average Annual Runoff from the Jhablat Kas and the Bauthi Nala
(as of 1961 - 65)

Jhablat Kas	170.43 MCM/yr	(recorded from 1961 - 65)
Bauhti Nala	37.47 "	(1.12 m^3/sec: observed Aug.1987)
Total	207.90 MCM/yr	

Note: no particular water usage in the Bauhti Nala.

Taking above amount and the tank model results into consideration, hydrological water balance has been preliminarily analyzed for the said years and for the year of 1987. The results of this analysis are presented in Figure A-3-2. According to the results, groundwater recharge from out side of the basin was assumed at 175 MCM/yr in the years from 1961 to 1965, and at 195.2 MCM/yr at present increased by 20 MCM/yr after Khanpur dam construction. Figure A-3-1 shows the general view of flow diagram in surrounding areas.

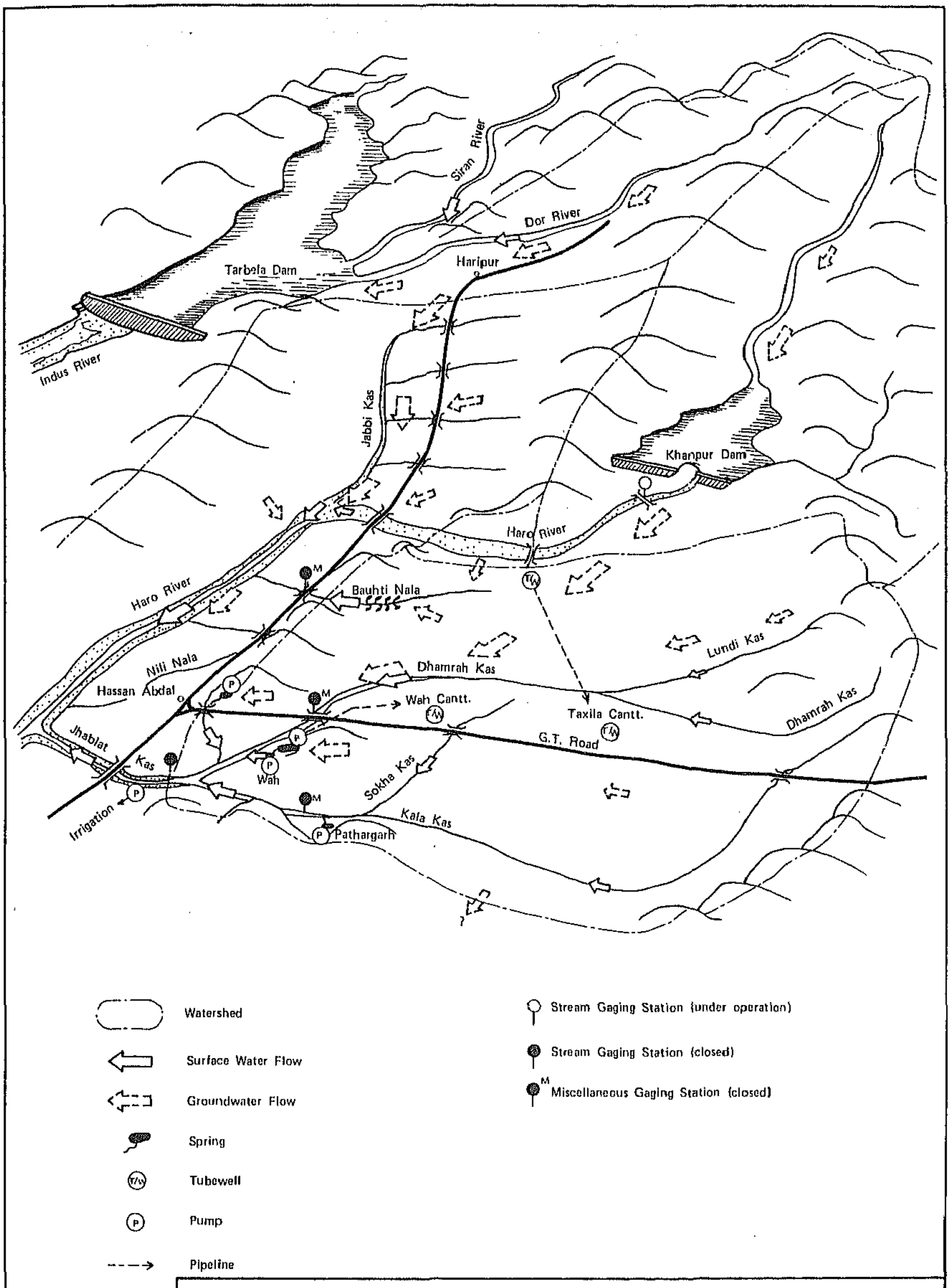
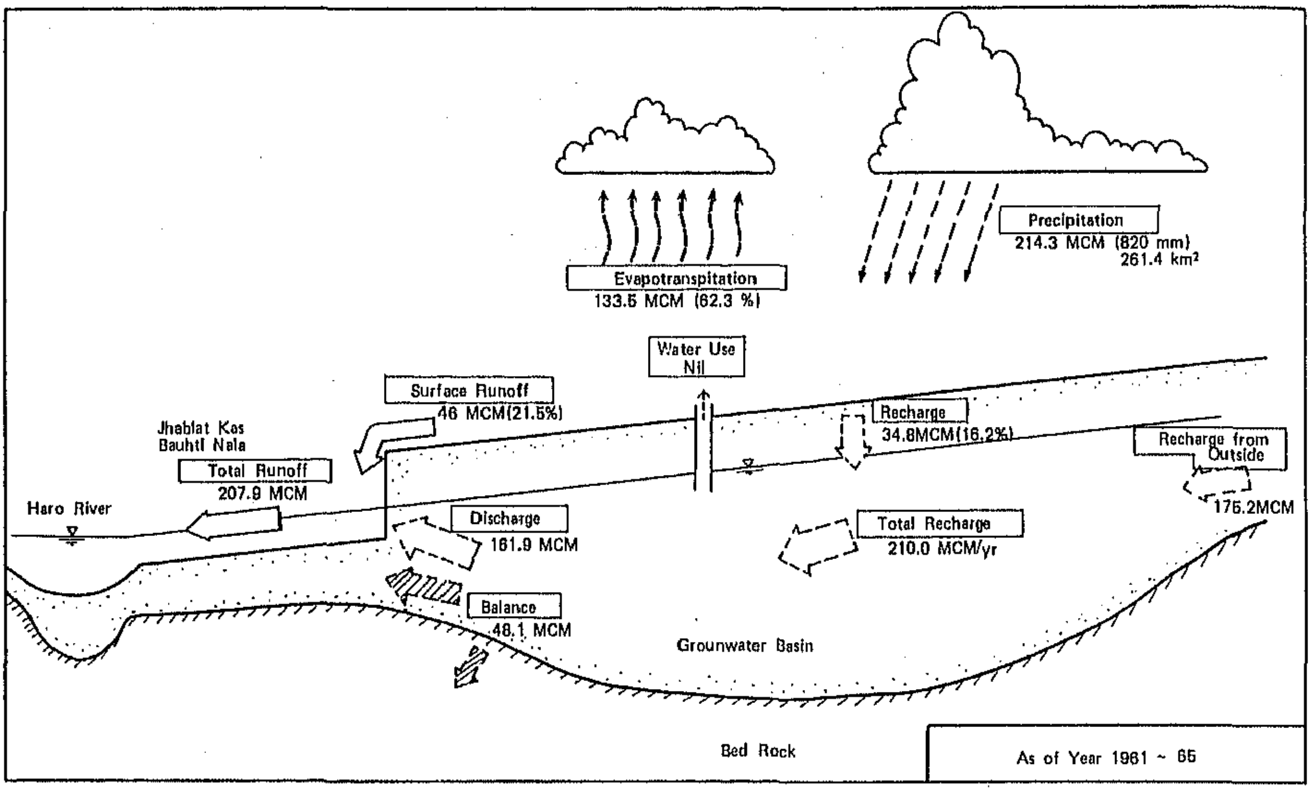
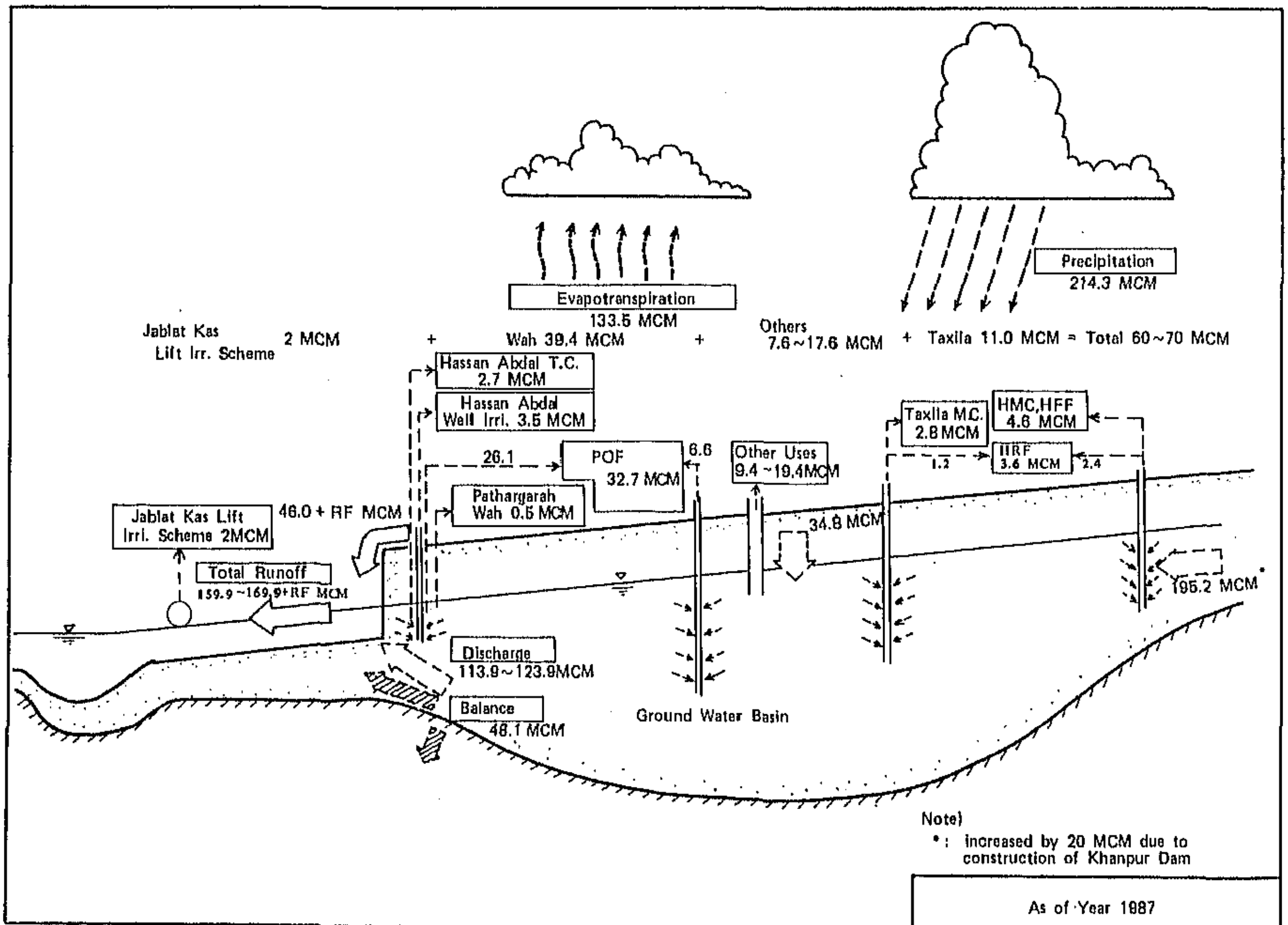


FIGURE A-3-1 WATER FLOW DIAGRAM INTO AND IN THE JHABLAT KAS BASIN

FIGURE A-3-2 PRELIMINARY STUDY ON HYDROLOGICAL WATER BALANCE IN THE JHABLAT KAS AND THE BAUHTI NALA BASINS



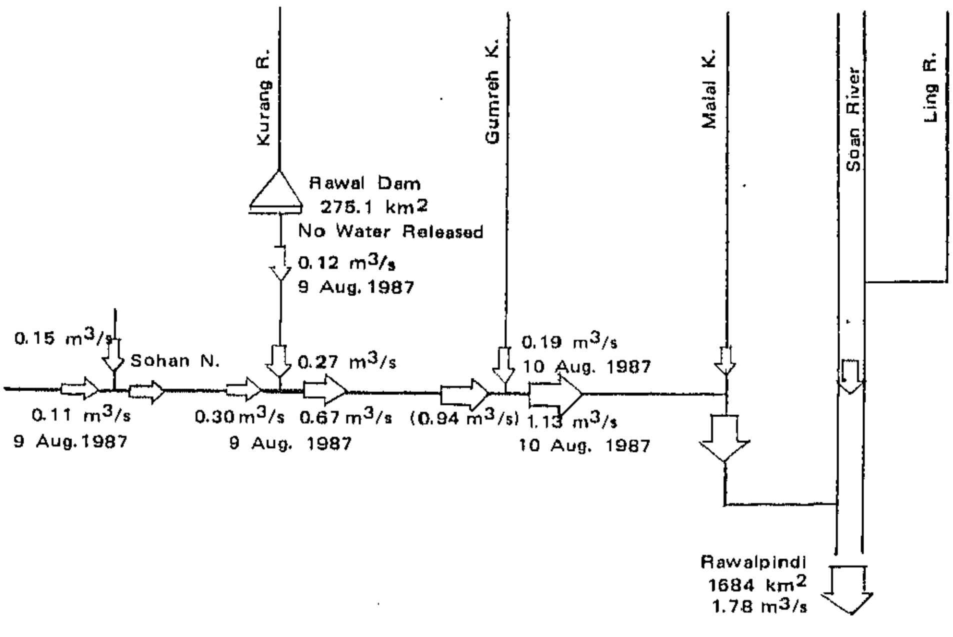


A.3.7. Base Flow in the Lower Reaches of the Kurang River

As mentioned in Section A.2.4., steady and relatively good quantity of base flow is available in the lower reaches of the Kurang river. However, since appropriate observation record is not available in this river, exact amount of base flow is not known. Therefore, discharge observation was conducted by the study team to know the amount. Fortunately, monsoon reached the area very late, base flow was able to be observed in time. Results of the observation is shown in Figure A-3-3.

According to the observation, total base flow discharge was 1.13 m^3/sec in the lower reaches after confluence of the Gumreh Kas. Below this site base flow does not increase so much, because base rock appears out in the river bed. Therefore, base flow can be assumed at about 1.0 m^3/sec in the lower reaches of the Kurang river.

FIGURE A-3-3 BASE FLOW DIAGRAM IN THE LOWER REACHES OF THE KURANG RIVER



Note) Date meaning the date observed

A.4. Analysis on the Development Potential of the River Basins

A.4.1. Introduction

From the view points of construction difficulty, socio economic, geography and hydrology, water resources Potential sites (27 dam sites, 4 diversion dam sites) are squeezed to several prospective water resources development sites. Available water resources are simulated at these prospective development sites. The prospective sites are finally squeezed to 9 sites of dams, 1 site for heightening the existing dam and 3 sites for diversion dams as shown in Table A-4-1.

Available water resources have been simulated in accordance with the size of dams or diversions to secure 1/10 years drought. Economically available water resources have been analyzed on the basis of unit water cost of the developed water resources in Chapter 7 in the Main Report.

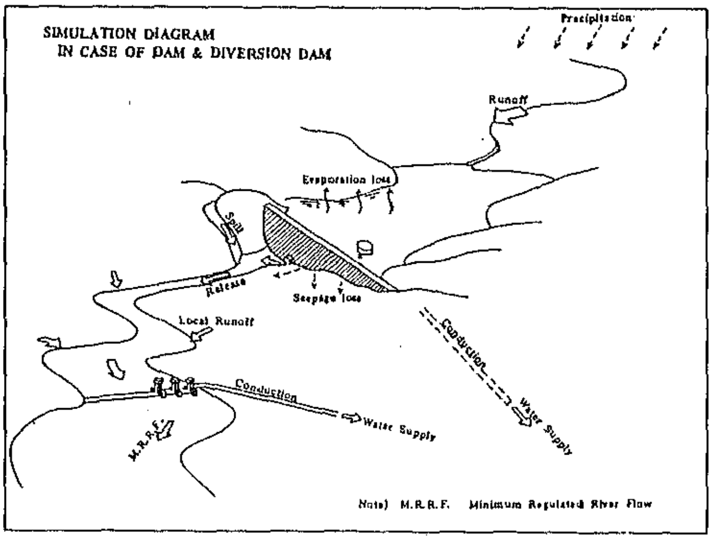
Table A-4-1. Prospective Water Resources Development Sites

River	Points	Area (km^2)	Type
Dor River	D-1	292.3	Dam
	Dw-1	517.7	Diversion Dam
Haro River	K-4	498.5	Dam
Jhablat Kas	Jw-1	244.9	Diversion Dam
Nandna Kas	N-1	462.0	Dam
	Shahpur	203.9	Heightening Existing Dam
Soan River	S-1	341.1	Dam
	Chaniot	126.4	Dam (Upper Simly)
	SW-1	1,472.8	Diversion Dam
Kurang River	KL-1	558.8	Dam
Malal Kas	M-1	82.8	Dam
Ling River	L-1	285.0	Dam
Sil River	SL-1	237.6	Dam

A.4.2. Simulation Scheme of Available Water Resources

Available water resources are simulated by computer on the basis of 10 days' runoff at each development site from 1960 to 1980. The results of simulation of each site including the Khanpur and the Simly dams are shown in Tables A-4-9 to 22.

Figure A-4-1. Typical Simulation Diagram for Water Balance



A.4.3. Simulation Premises

(1) Runoff

Runoff has been derived from runoff analysis, and 10 days' basis runoff for 21 years from 1960 to 1980 is applied to the simulation. Table A-8-3-14 to 19 show the monthly runoff data summarized from 10 day's basis data.

(2) Lake Evaporation Loss

Lake evaporation has been estimated at 80 percent of potential evapotranspiration at Chaklala, and water loss by lake evaporation is balance with precipitation at each development site. The values of lake evaporation loss are presented in Table A-4-2.

Table A-4-2 Lake Evaporation

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Potential Evapotranspiration*1 (mm)	56	70	115	165	229	252	208	177	150	118	72	50	1,662
N-1, SL-1, Shahpur													
Precipitation*2 (mm)	33.5	46.5	62.0	32.5	24.4	36.8	174.5	221.6	46.2	21.1	13.5	26.4	738.6
Lake Evaporation													
(mm)	22.5	23.5	53.0	132.5	204.6	215.2	33.5	0	103.8	96.9	58.5	23.6	
(mm/day)	0.73	0.84	1.71	4.42	6.60	7.17	1.08	0	3.46	3.13	1.95	0.76	
D-1, Khanpur, Chaniot, Simly, S-1, M-1, KL-1, L-1													
Precipitation*3 (mm)	62.3	67.8	78.2	57.2	37.8	57.3	254.0	287.6	101.5	30.3	19.6	32.2	1,085.8
Lake Evaporation													
(mm)	0	2.2	36.8	107.8	191.2	194.7	0	0	48.5	87.7	52.4	17.7	739.0
(mm/day)	0	0.08	1.19	3.59	6.17	6.49	0	0	1.62	2.83	1.75	0.57	

Note) *1 ... Potential Evapotranspiration at Chaklala

*2 ... Precipitation at Fateh Jang

*3 ... Precipitation at Chaklala

(3) Sediment

Sediment at each water resources development site is estimated on the basis of specific sediment and project life of dam (100 years). Only sediment discharge from direct catchment area is considered in the case that dam is located upstream.

Specific sediment in every river basis in estimated as follows.

Dor river basin	500	m^3/km^2/year
Haro river basin	400	"
Soan river basin	900	"

Table A-4-3 shows the estimated sediment at proposed dam site considering above specific sediment and direct catchment area.

Table A-4-3. Reservoir Sedimentation

Reservoir	Drainage Area Total	Drainage Area Direct	Unit Sediment Rate	Sediment in 100 Years	Remarks
	(km^2)	(km^2)	(m^3/km^2/yr)	(MCM)	
D-1	292.3	292.3	500	14.62	
H-4	498.5	498.5	400	19.94	
N-1	462.0	258.1	400	10.32	Shahpur Dam: 203.9 km^2
S-1	341.1	188.3	900	16.95	Simly Dam: 152.9 km^2
M-1	82.8	82.8	900	7.45	
L-1	285.0	285.0	900	25.65	
SL-1	237.6	237.6	900	21.38	
KL-1	558.8	283.7	900	25.53	Rawal Dam: 275.1 km^2

(4) Seepage Loss

Seepage loss is composed of losses from reservoir bed and through dam body. This study, however, does not count such seepage loss in water balance, considering most of seepage loss to appear in downstream and to feed minimum regulated river flow to be released from the development sites.

(5) Minimum Regulated River Flow

Minimum regulated river flow is released from dam or diversion dam to ensure 355 days flow (droughty flow) for downstream water utilization or for maintaining rivers in healthy condition at the fixed gauging station. Minimum regulated river flow at each development site is shown in Table A-4-4.

(6) H-A, H-V Curve

H-A, H-V curves of proposed damsites are prepared by survey or using topographical maps of 1:50,000 scale.

Dead water level has been set to equal to sediment amount described in Table A-4-3.

Table A-4-4. Minimum Regulated River Flow

Site	Drainage Area	Minimum Regulated River Flow: Specific Runoff	Discharge	Annual Release	Regulated Site	Regulated Flow
	(km^2)	($m^3/sec/100km^2$)	(m^3/sec)	(MCM)		(m^3/sec)
Dor River						
D-1	292.3	-	-	-		
Dw-1	517.7	0.199	1.03	32.48	Dw-1	1.03
Haro River						
H-4	398.5	-	-	-		
Khanpur Dam	778.0	0.202	1.57	49.51	Khampur Dam	1.57
Hw-2	800.7					
Nandna Kas						
Shahpur Dam	203.9	-	-	-		
N-1	462.0	0.0347	0.160	5.05	N-1	0.160
Soan River						
Malal Kas						
M-1	82.8	0.106	0.0878	2.78	Rawalpindi S.G.S.(1684km^2)	1.78
Soan River						
Simly Dam	152.8	-	-	-		
S-1	341.1	0.106	0.362	11.42	Rawalpindi S.G.S.(1684km^2)	1.78
Sw-1	1,472.8	0.106	1.561	49.23	Rawalpindi S.G.S.(1684km^2)	1.78
Ling River						
L-1	285.0	0.106	0.302	9.52	Rawalpindi S.G.S.(1684km^2)	1.78
KL-1	283.7	0.067	0.190	6.00		
Sil River						
SL-1	237.6	0.0347	0.0824	2.60	SL-1	0.0824

(7) Initial Storage Capacity

Simulation of water balance has been made from January 1960 to December 1980. Average storage capacity in the end of December from 1960 to 1980 is considered to be initial storage capacity in January 1960. Initial storage capacity is at about 70 percent of effective storage capacity in case that effective storage capacity is small comparing annual runoff.

(8) Water Demand

For urban water the following monthly fluctuation of water demand is applied in water balance simulation. Peak water demand occurs in June and least water demand appears in January.

Monthly Fluctuation of Urban Water Demand

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

For irrigation water requirement, 10 days irrigation water requirement from 1960 to 1980 is used for the simulation.

Average irrigation water requirement per 1,000 ha from 1960 to 1980 is 6.158 MCM/yr as shown below. This table shows that peak irrigation water requirement to appear in June.

Monthly Fluctuation of Irrigation Water Requirement

Irrigation Water Requirement in MCM per 1,000 ha, 1960-80
Cropping Intensity 140%

Jan.	0.349	May	0.757	Sep.	0.474		
Feb.	0.401	Jun.	0.961	Oct.	0.478		
Mar.	0.570	Jul.	0.456	Nov.	0.477		
Apr.	0.611	Aug.	0.285	Dec.	0.330	Annual	6.158 MCM

(9) Safe Water Utilization Ratio

Safe water utilization ratio is to be designed to allow water shortage to occur once in 10 years. In the simulation of water balance, therefore, water shortage is allowed to occur twice in 21 years. Water shortages less than 5 percent of water demand are not considered as water shortage, because such minor water shortages are to be patient.

A.4.4. Development Potential of the Dor River Basin

(1) General

The Dor river is not yet fully developed, however some of its flow has been utilized by farmers for irrigation below Havelian. The irrigation area is estimated at 3,800 ha in this river basin. Therefore, a large amount of water resources remains for further water use in this basin and it will be able to be conducted to the metropolitan area through the Khanpur reservoir.

On above considerations, the D-1 dam is proposed at Rajoia in upstream and the Dw-1 diversion dam in downstream.

(2) Water Balance Simulation

Water balance has been simulated on various sizes of the D-1 dam to estimate the available water resources in the Dor river basin. The Figure A-4-3 shows the available water resources at the Dw-1 diversion damsite. Table A-4-9 shows the results of simulation on selected size of the D-1 at V= 60 MCM. Conduction capacity from the Dw-1 to the Khanpur reservoir is set at 5 m^3/sec by the study on optimizing the conduction capacity. However it will be necessary to re-examine the conduction capacity in the feasibility study.

(3) Available Water Resources

From the results of water balance simulation in the Dor river basin shown in Figure A-4-3, water resources will be developed upto 109 MCM annually out of total runoff of 155 MCM at the Dw-1 diversion damsite when large storage capacity is given to the D-1. However, water resources will not increase so efficiently beyond 100 MCM/year. The optimum development size of the D-1 dam has been studied from a economic viewpoint of unit cost of water developed by the D-1 and the Dw-1. And the optimum water resources development has been finalized at 107.1 MCM in a year on average with the live storage capacity of 60 MCM (dam height H = 85 m) for the D-1 dam as shown in Figure VII-3-1 in the Main Report.

As extra water resources, some amount of water can be expected other than above. This extra water will be borne by flood water from the residual basin below the D-1 damsite, and it is estimated at 7.8 MCM/year in a year on average when conduction capacity is set at 5 m^3/sec. However, for utilizing this extra water effectively, it is necessary to control this extra water in the Khanpur reservoir without spilling. This fact has been examined in a simulation combining the Dor river basin and the Haro river basin. However, none of the extra water will not be able to be controlled and utilized due to less capacity of the Khanpur reservoir and almost of the extra water will spill from the Khanpur dam.

Table A-4-5. Available Water Resources in the Dor River Basin

Site	D.A.	Average Annual Runoff	Live Storage Cap.	Annual Firm Water Resources	Unit Water Cost
	(km^2)	(MCM)	(MCM)	(MCM)	(Rs/m^3)
D-1	292.3	96.2	60.0		
Dw-1	517.7	154.7	0	107.1	0.60
Total	517.7	154.7	60.0	107.1	0.60

A.4.5. Development Potential of the Haro River Basin

(1) General

The Haro river and its tributaries as the Jhablat Kas have been utilized for agriculture in a traditional way since ancient time because of relatively steady flow through a year. The large scale development of water resources in this basin, however, has been started recently by constructing the Khanpur dam in the Haro river and the Shahpur dam in the Nandna Kas. On the other hand, the Jhablat Kas is utilized by many agencies for domestic water and agricultural water taking water by pumps from the outflows of springs or from the Jhablat Kas. Total present utilization of surface water including the springs is estimated at 31 MCM/year or equivalent to 0.98 cu.m/sec (see Table D-4-3 of Appendix D) in the Jhablat Kas basin.

However, present water resources development does not yet reach to the full scale development in the Haro river basin, and the considerable large potential of water resources development still remains in this basin. For evaluating such potential, following four potential sites have been studied in this basin.

H-4 dam: proposed at upstream of the Khanpur dam in the Haro river to control the spill of the Khanpur dam.

N-1 dam: proposed at downstream of the Shahpur dam in the Nandna Kas, but canceled due to submergence of the irrigation area of the Shahpur dam.

Shahpur dam heightening: proposed instead of the N-1 dam to utilize the runoff of the Nandna Kas fully.

Jw-1 diversion dam: proposed at the lower reaches of the Jhablat Kas.

Other than above potential sites, the Khanpur reservoir will be linked with the Dor river to introduce water from the Dor river after completion of the D-1 dam and the Dw-1 diversion dam.

(2) Water Balance Simulation

Water balance simulation has been made in the following manner to estimate the available water resources in the Haro river basin.

a. Haro River Main Stream Development

Case 1(H) ... Khanpur dam only

This case has been made to examine the firm water resources developed by the Khanpur dam under prospective safe water utilization to allow water shortage once in ten years. The MRRF is also given to the Khanpur dam as same as in other cases below. The MRRF is estimated at 49.5 MCM/yr equivalent to 1.57 cu.m/sec. In this simulation, the firm water resources by the Khanpur dam is estimated at 158.8 MCM/yr out of the total runoff of 327 MCM/yr. The result of simulation is shown in Table A-4-10.

Case 2 (H) ... Khanpur dam + H-4 dam

In this case, the H-4 dam is proposed in upstream of the Khanpur dam to minimize the spill of the Khanpur dam. And available amount of water resources has been examined on various sizes of the H-4 dam. The water resources can be developed upto around 250 MCM/year in this case. However, annual water resources will not increase so efficiently beyond 230 MCM as shown in Figure A-4-4. From the study of water cost, the optimum size of the H-4 dam has been set at 125 MCM of live storage (H = 117.5 m) as shown in Figure A-4-2. In case of this size, total available water resources will be at 241.4 MCM in a year. The result of simulation is shown in Table A-4-11 for selected size.

Case 3 (H) ... Khanpur dam + H-4 dam + Dor Link

In this simulation, the Dor river has been linked with the Khanpur reservoir by the conduction from the Dw-1 diversion dam. The possibility of extra utilization of water of the Dor river has been examined in this simulation, but none of extra water will be utilized due to less capacity of the Khanpur reservoir as explained in A.4.4. The result of simulation is shown in Table A-4-12.

b. Nandna Kas Development

Case 1 (N) ... N-1 dam

The Nandna Kas is one of major left bank tributaries of the Haro river, which flows beside the Haro River Left Bank Command Area. The N-1 dam is proposed on the Nandna Kas below the Shahpur dam which was completed construction recently. Though the direct catchment area of the N-1 dam is reduced to 258.1 km^2 from 462 km^2 due to the Shahpur dam, the N-1 dam has still large catchment area for development and some of runoff to the Shahpur dam can be expected as spill from the Shahpur dam. However the N-1 dam has been canceled due to submergence of the irrigation area of the Shahpur dam.

The N-1 dam has been simulated under the condition of spill from the Shahpur dam. Spill of the Shahpur dam is simulated in the same manner as shown in Table A-4-13, and spill has been given to the N-1 dam as inflow combining with direct runoff into the N-1 dam. The MRRF has been given to the N-1 dam by 5.05 MCM/yr equivalent to 0.160 m^3/sec.

In simulation of the Shahpur dam, conditions on water demand and capacity of the Shahpur dam have been taken from PCI report of the Shahpur dam. Those conditions are summarized as follows;

- Water Demand 10.67 MCM/year

Irrigation Water	7.35 MCM/year
	(5,959 Aft/year for 4,308 acres)
Domestic Water	3.32 MCM/year (2.0 MGD)

- Storage Capacity

Full Water Capacity	17.66 MCM
	(14,320 Aft at 1,458.25 ft)
Dead Water Capacity	12.63 MCM
	(10,241 Aft at 1,452.5 ft)
Effective Capacity	5.03 MCM

Mean annual inflow is estimated at 20.6 MCM (16,700 Aft) at the Shahpur damsite in PCI report, however it seems too small in our study. Therefore, mean annual inflow is revised to 43.0 MCM averaged from 1960 to 1980 in this study and simulation of the Shahpur dam has been made using the revised inflow. According to the result of Shahpur dam simulation, water shortage will occur five times in 21 years equivalent to once in four years.

Under above conditions, water balance simulation of the N-1 dam has been made as shown in Table A-4-14 and its result is presented in Figure A-4-5. As seeing in the figure, the N-1 dam will be able to develop the available water resources ultimately upto about 67 MCM/yr which will be able to cover the irrigation area of 10,900 ha. However this amount of water resources can not be expected due to cancellation of the N-1 dam.

Case 2 (N) ... Shahpur Dam Hightening

Instead of the N-1 dam, heightening of the Shahpur dam has been considered to utilize water fully at the Shahpur dam site. In this case, modification of the Shahpur dam is considered as follows;

Shahpur Dam Modification

(1) Lowering the DWL from 442.72 m (1,452.5 ft) to 440.44 m.
Dead Water Capacity = 7.18 MCM

(2) Raising the FWL from 444.47 m (1,458.25 ft) to 449.58 m.
Full water capacity = 47.26 MCM

(3) Effective Storage Capacity increased from 5.03 MCM to 40.08 MCM.

(4) MRRF is newly given to the Shahpur dam by 2.24 MCM/yr equivalent to 0.071 cu.m/sec.

Under above conditions, available amount of water resources has been estimated at 27.92 MCM/yr by heightening the Shahpur dam as shown in Table A-4-15. However, net available amount is only at 17.25 MCM, because prospective water demand to the existing Shahpur is at 10.67 MCM/yr out of 27.92 MCM/yr.

c. Jhablat Kas Development

The Jw-1 diversion dam has been proposed at the lower reaches of the Jhablat Kas for producing the irrigation water for the Haro River Left Bank Command Area. Water balance simulation of the Jw-1 has been made using the runoff data only limited in a short period from September 1961 to July 1965 due to difficulty to extend the runoff data in hydrological analysis. However, in this period, considerable droughty year 1964 in the alluvial plain is included, accordingly this simulation will be acceptable to estimate the available amount of water resources in the Jhablat Kas. The year 1964 is estimated at the droughty year approximately once in 20 years by the record at Chaklala.

In simulation of the Jw-1 diversion dam, the existing water right has been estimated at 2.0 cu.m/sec including the MRRF at the Jw-1 sites.

POF (Operation Capacity)	1.00 cu.m/sec	
Jhablat Kas Lift Irrigation	0.28 "	
MRRF and Other Water Use	0.72 "	(22.7 MCM/yr)
Total Water Right	2.00 cu.m/sec	

As the result of simulation, lifting capacity of pumps is set at 2.7 cu.m/sec at the Jw-1 site with providing the regulating ponds in the irrigation area of which total capacity is 8.0 MCM. The Jw-1 diversion dam will be able to produce irrigation water of 70.8 MCM in a year which will cover about 10,000 ha even in a droughty year once in 10 years.

(3) Available Water Resources

In the Haro river basin, total net water resources will be 170.65 MCM in a year by the development.

Table A-4-6. Available Water Resources in the Haro River Basin

	Prospective Water Resources					Annual Available Water Resources	
Site	D.A.	Ave. Annual Runoff	Live Storage Cap.	Annual Firm Water Resources	Unit Water Cost	Developed by Exist. Facil.	Net Production
	(km^2)	(MCM)	(MCM)	(MCM)	(Rs/m^3)	(MCM)	(MCM)
H-4	498.5	209.5	125.0	82.6	1.54	-	82.6
Khanpur	778.0	327.0	112.9	158.8	-	158.8	-
Shahpur	203.9	42.5	5.03	10.67	-	10.67	-
Heightening	203.9	42.5	40.0	17.25	0.27	-	17.25
N-1	462.0	84.3	105	60.0	1.66	-	-
Jw-1	248.6	170.4	0	70.8	0.77*	-	70.8
Total						169.47	170.65

Note: * cost including the regulating Ponds. (see Table VII-3-6 in Main Report)

A.4.6. Development Potential of the Soan River Basin

(1) General

The Soan river is composed of three major rivers in upstream, one is main stream of the Soan river and others are the Kurang river and the Ling river which are tributaries of the Soan river. In these three rivers, the Soan and the Kurang rivers have been developed by the Simly dam and the Rawal dam respectively. On the other hand, the Ling river remains without any development on water resources. However, the Soan and the Kurang rivers are not yet reaching the ultimate development on water resources by said two dams. Furthermore, other tributaries like the Sil river still remains without development in the alluvial plain.

Considering above conditions, six dams and one diversion dam have been considered in this basin.

Upper Simly dam: proposed at Chaniot in the Soan river at upstream of the Simly dam to minimize spill of the Simly dam and to increase the availability of water resources in the uppermost of the basin. However this dam is canceled due to extreme higher water cost than that by the S-1 dam (see Table D-3-4, Appendix D), and the S-1 dam will develop the water resources including these by the Upper Simly dam with cheaper water cost.

S-1 dam: proposed in the Soan river at downstream of the Simly dam to develop the water resources in the residual area below the Simly dam and spill of it.

M-1 dam: proposed in the Malal Kas which is a lower most tributary of the Kurang river, but canceled due to higher water cost than the KL-1 dam which is proposed at downstream of the M-1 dam and the dam construction is not feasible technically.

KL-1 dam: proposed at the most downstream of the Kurang river to develop the residual area below the Rawal dam.

L-1 dam: proposed in the Ling river

SL-1 dam: proposed in the Sil river

Sw-1 diversion dam: proposed at just upstream of the GT road bridge in the Soan river, but canceled due to following reasons clarified by the hydrological study;

- The Soan river is relatively unsteady in its flow for developing by diversion dam.

- Almost of base flow at the Sw-1 site is fed by the Kurang river, and this base flow will be developed in the Kurang river basin in future.

(2) Water Balance Simulation

In the Soan river basin, water balance simulation has been made individually on each development site, and the results are shown in Tables A-4-16 to 22 and in Figure A-4-7 to 12. Following conditions are given to the simulation;

Conditions on Simulation

Development Site	Related Existing Structure	MRRF MCM/yr (cu.m/sec)	D.A. (km^2)	Remarks
Upper Simly dam	Simly Dam	-	126.4	MRRF is not considered for this dam.
Simly dam	-	-	152.8	Simulated under Second Phase Development.
S-1 dam	Simly Dam	11.42 (0.362)*1	341.1	
M-1 dam	-	2.78 (0.088)*1	82.8	
KL-1 dam	Rawal Dam	6.00 (0.190)*2	283.7	Considering only the residual area below Rawal dam.
L-1 dam	-	9.52 (0.302)*1	285.0	
SL-1 dam	-	2.60 (0.082)	237.6	

Note: *1: To feed 1.78 cu.m/sec of flow at the Rawalpindi Station in accordance with the drainage area.
*2: This flow will be utilized by development of the Kurang river below Rawal dam.

In connection with simulation of the S-1 dam and the Upper Simly dam, the Simly dam has been also examined on its water resources availability and spill from the Simly dam, because spill from the Simly dam will flow into the S-1 reservoir. Water balance of the Simly dam has been examined under its second phase development which is under execution to increase water supply by raising storage water level. In second phase, it is proposed to increase water supply to 49 MGD, however, it is grasped in simulation that only 65 percent of 49 MGD (equivalent to 31.85 MGD = 52.8 MCM/yr) can be developed with safe water utilization ratio of once in 10 years in second phase development. The simulation of the S-1 dam has been made under water supply of 31.85 MGD by the Simly dam.

The Upper Simly dam has been analyzed in combined operation with the Simly dam. The effectiveness of the Upper Simly dam is to minimize spill of the Simly dam, accordingly the available amount of water resources of the Upper Simly dam is only the amount increase from 52.8 MCM/yr which is already developed by the Simly dam.

(3) Available Water Resources

Table A-4-7 shows the optimum development scale at each prospective site from a economic point of view taking unit water cost into consideration. The Upper Simly dam will produce the most expensive water and the M-1 will follow it in this basin. The water resources produced by these two dams can be also developed with lower cost by other dams such as the S-1 dam and the KL-1 dam in the lower reaches. Therefore, it is recommended to develop four dams, namely S-1, KL-1, L-1 and SL-1, and they will produce the available water resources of 203.8 MCM in a year in this basin.

Table A-4-7 Available Water Resources in the Soan River Basin

Site	Prospective Water Resources D.A.	Ave. Annual Runoff	Live Storage Cap.	Firm Water Resources	Unit Water Cost	Annual Available Water Resrouces Developed by Exist. Facil.	Net Production
	(km^2)	(MCM)	(MCM)	(MCM)	(Rs/m^3)	(MCM)	(MCM)
Upper Simly	126.4	69.0	30.0	9.6	7.01	-	-
Simly dam	152.8	83.4	40.09	52.8	-	52.8	-
S-1 dam	341.1	130.9	66.0	60.0	0.43	-	60.0
M-1 dam	82.8	38.0	20.0	22.5	2.05	-	-
KL-1 dam	283.7	102.7	16.3	34.0	0.46	-	34.0
L-1 dam	285.0	107.1	91.0	69.8	1.55	-	69.8
SL-1 dam	237.6	50.1	62.0	40.0	0.51	-	40.0
Total						52.8	203.8

A.4.7. Comprehensive Evaluation of the Development Potential

Simulation on available water resources under respective safe water utilization ratio at the prospective development sites is summarized in Figure A-4-2. The figure shows the relation of the live storage capacity to the available water resources.

In the figure, setting the live storage capacity on abscissa and water resources on ordinate, the relation between available water resources and live storage is indicated on a curve connecting respective safe water utilization of 2 years shortage in 21 years from 1960 to 1980. Therefore this curve indicates the firm water resources under respective safe water utilization ratio. Within a range where curve has steep gradient, available water resources effectively increase with the size of storage capacity of dam, however, available water resources will not increase as much as storage capacity increases in a range with gentle gradient. The marked point on a curve means a point of the lowest unit water cost of developed water.

Table A-4-8 shows the potential development selected from a point of economic view. And, the table reveals the following facts.

1. Total live storage capacity of dams (including Khanpur dam) will be 573 MCM, and, in this case, average utility ratio will be 1.89 to the total inflow 1,085 MCM.

2. Total net available water resources is prospected at 482 MCM, and development ratio at 0.444 to the total inflow 1,085 MCM.

3. Total MRRF will be 133 MCM, which will be 12.3 percent of the total inflow 1,085 MCM.

4. The total of the net available water resources development and the MRRF will be 614 MCM, and that is 56.6 percent of the total inflow 1,085 MCM.

FIGURE A-4-2 RELATION BETWEEN THE FIRM WATER RESOURES AND THE SIZE OF LIVE STORAGE CAPACITY

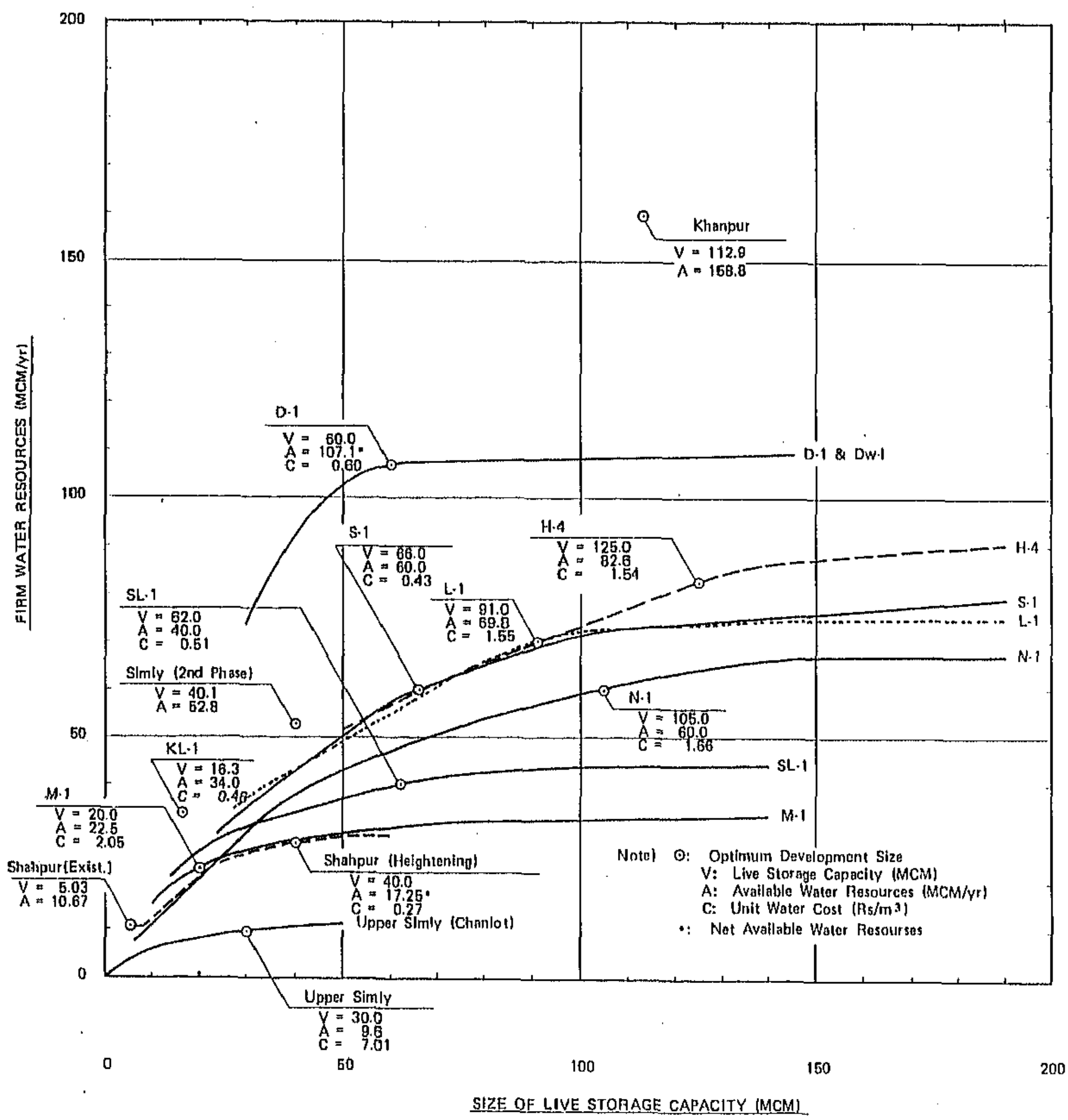


Table A-4-8 Potential Water Resources in the Study Area

Development Site	D.A. (km^2)	(1) Ave. Annual Runoff (MCM/yr)	(2) Live Storage (MCM)	Utility Ratio (1)/(2)	(3) Potential Water Resources (MCM/yr)	(4) Water Resources developed by Existing Facil. (MCM/yr)	(5) Net Water Resources Development (3) - (4) (MCM/yr)	Development Ratio (5)/(1)	Evp. Loss (MCM/yr)	M.R.R.F. (MCM/yr)	Spill (MCM/yr)	Years in Shortage
Dor River												
D-1	292.3	96.2	60.0	1.60		0						
Dw-1	517.7	58.5	0	-		0				32.5	10.9	
Sub-Total	517.7	154.7	60.0	-	107.1	0	107.1	0.692	1.6	32.5	10.9	1966, 70
Haro River												
H-4	498.5	209.5	125.0	1.68		0						
Khanpur Dam	778.0	117.5	112.9	1.04		158.8				49.5	36.6	
Total	778.0	327.0	237.9	1.37	241.4	158.8	82.6	0.253	5.3	49.5	36.6	1970, 75
Dor-Haro Link (Conduction Capacity 5.0 cu.m/sec.)												
H-4		209.5	125.0	1.68		0						
Khanpur Dam		228.2	112.9	2.02		158.8				49.5		
Total		437.2	237.9	1.84	348.5	158.8	189.7	0.434	5.3	49.5	40.4	1970, 75
Shahpur Dam	203.9	42.5	40.0	1.06	27.92	10.67	17.25	0.406	6.6	2.2	5.9	1973, 75
Jw-1	248.6	170.4	0	-	101.80	31.0	70.8	0.415	-	22.7	45.9	
Sub-Total	1230.5	539.9	277.9	1.94	371.12	200.47	170.65	0.316	11.9	74.4	88.4	1970,73,75
Soan River												
S-1	341.1	130.9	66.0	1.98	60.0	0	60.0	0.458	4.5	11.4	55.0	1970, 75
L-1	285.0	107.1	91.0	1.18	69.8	0	69.8	0.652	5.5	9.5	22.3	1970, 75
KL-1	283.7	102.7	16.3	6.30	34.0	0	34.0	0.331	6.8	2.3	59.6	1962. 74
SL-1	257.6	50.1	62.0	0.81	40.0	0	40.0	0.798	4.4	2.6	3.1	1962, 75
Sub-Total	1147.4	390.8	235.3	1.66	203.8	0	203.8	0.521	21.2	25.8	140.0	1962,70,74,75
Total	2895.6	1085.4	573.2	1.89	682.02	200.47	481.55	0.444	34.7	132.7	239.3	1962,70,73,74,75

FIGURE A-4-3 WATER RESOURCES DEVELOPMENT OF DOR RIVER (D-1 & Dw-1)

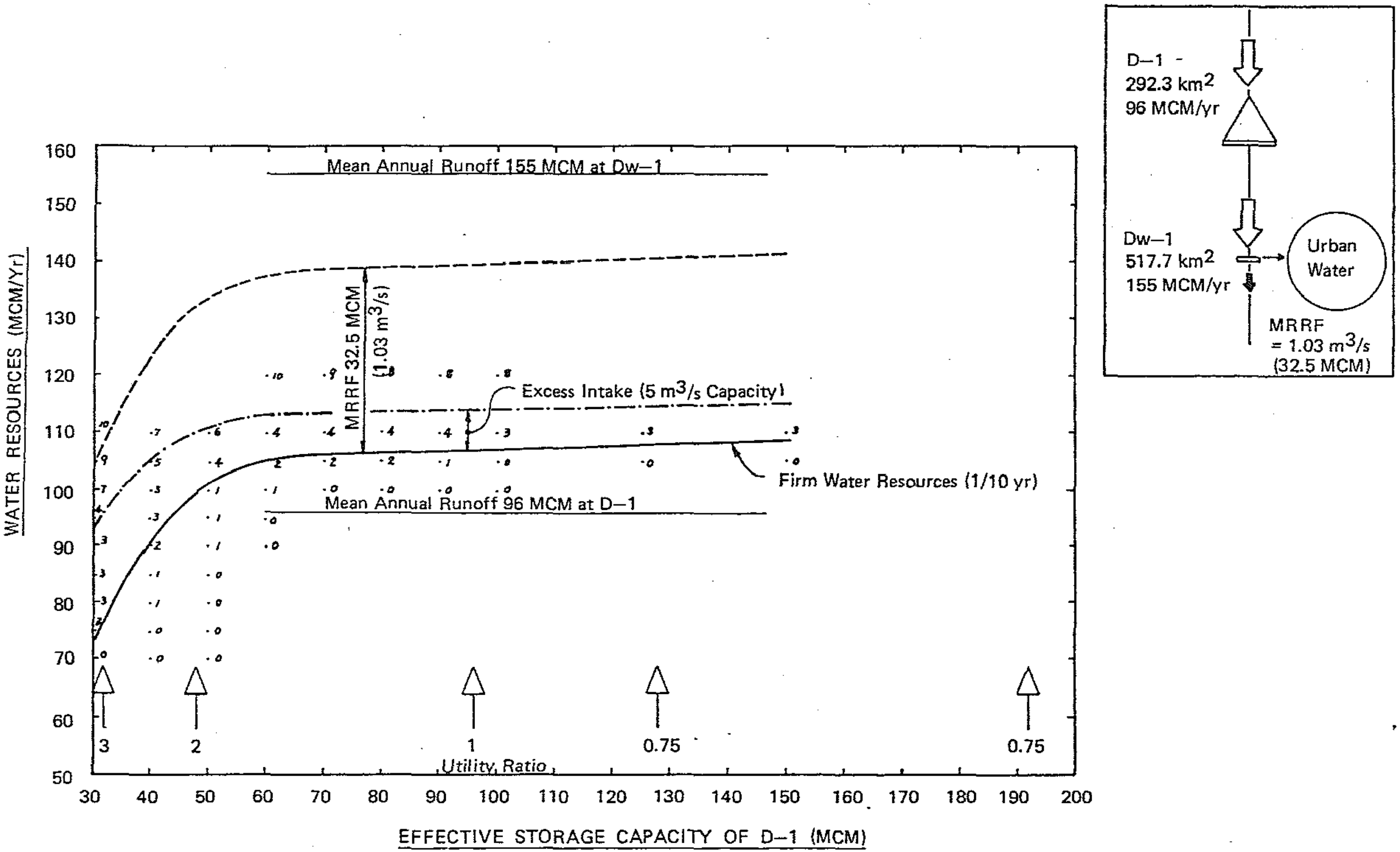
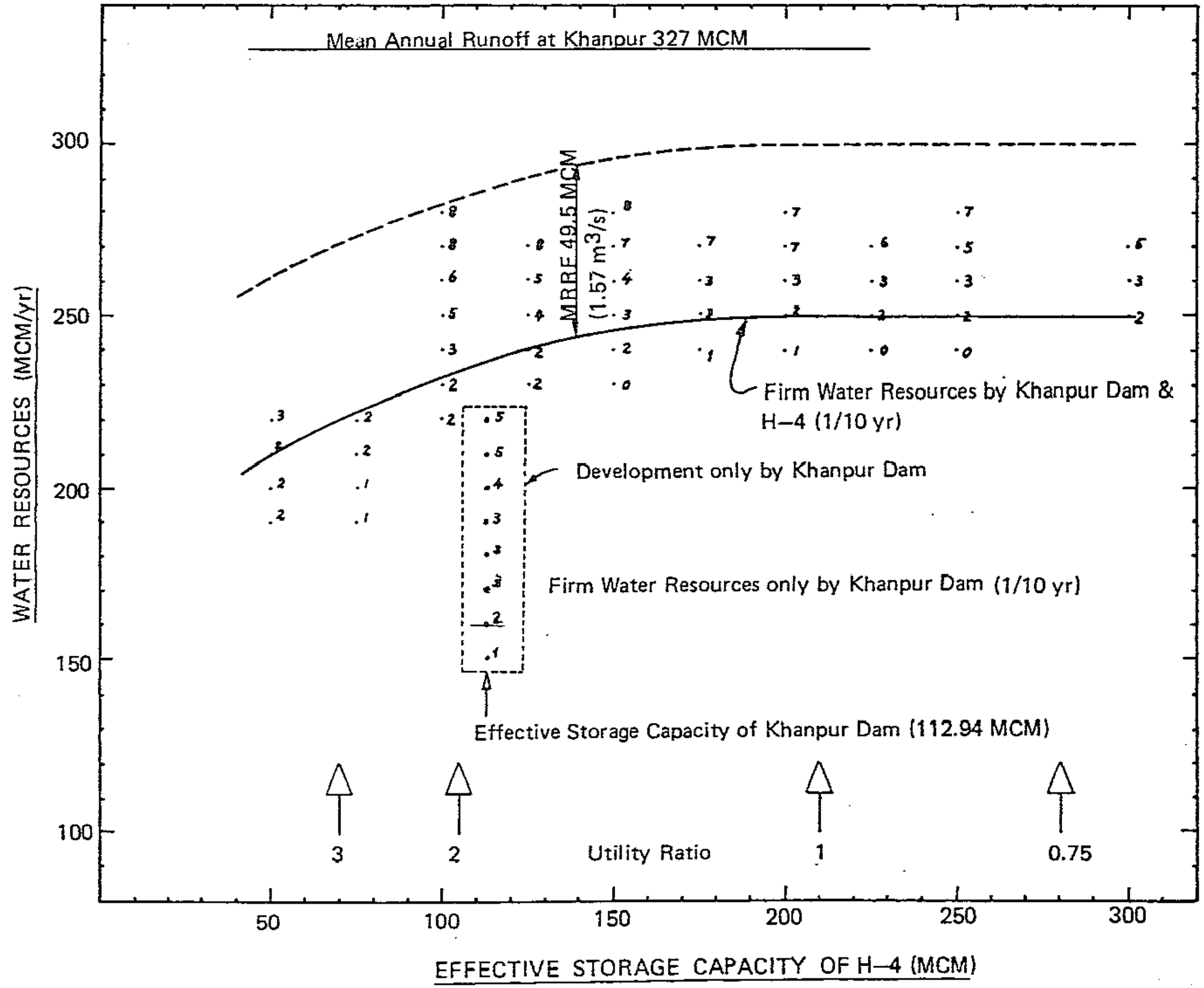


FIGURE A-4-4 WATER RESOURCES DEVELOPMENT OF HARO RIVER (KHANPUR DAM & H-4)



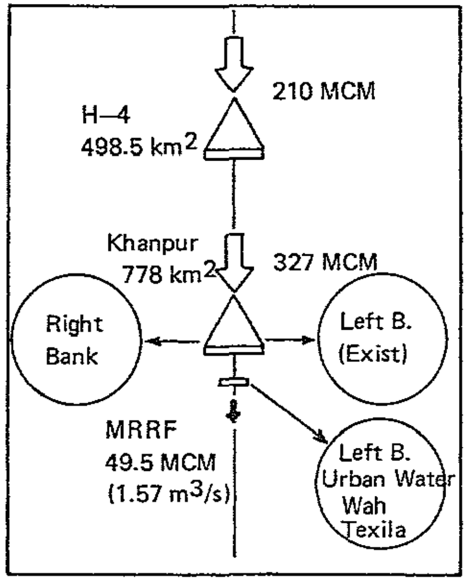
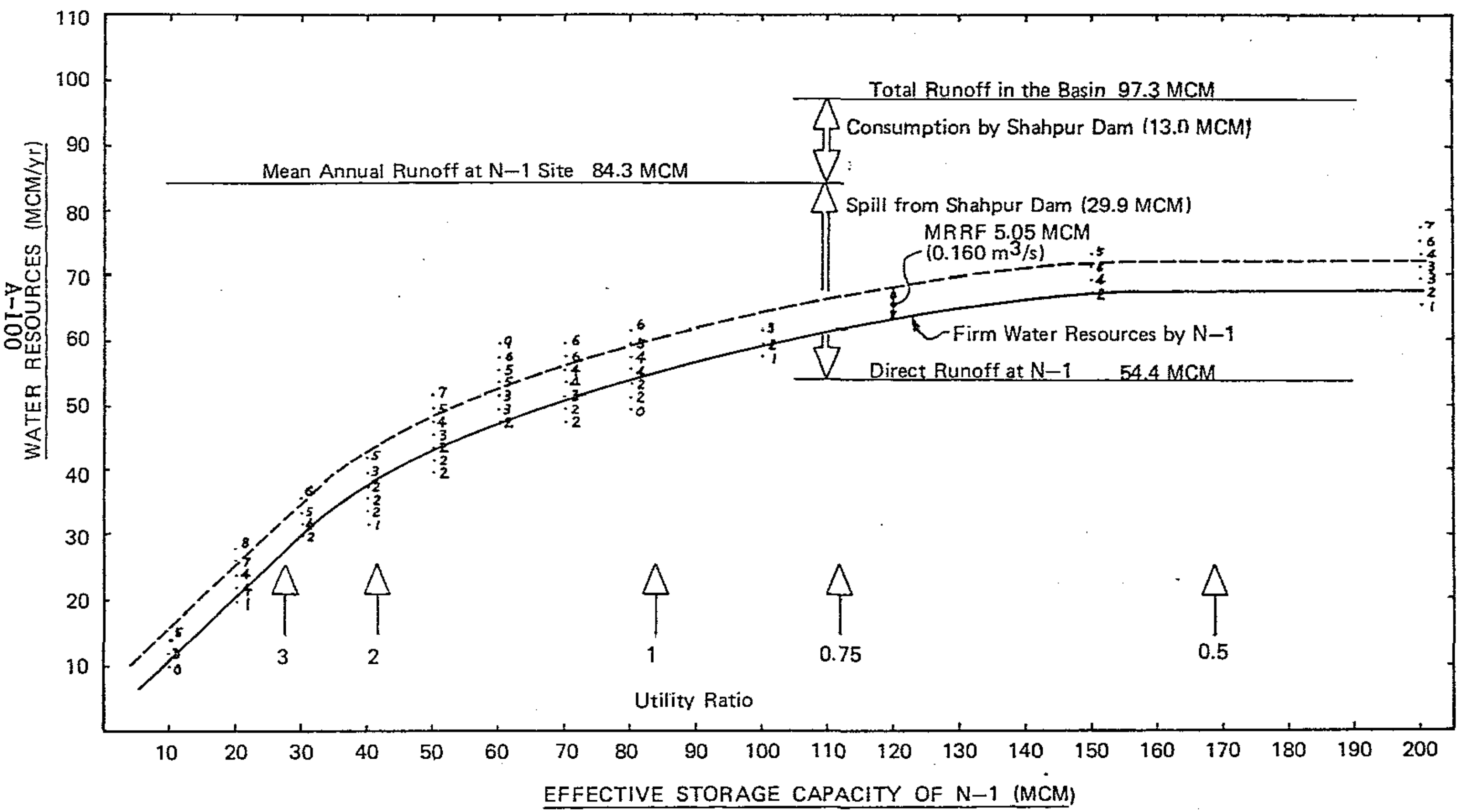


FIGURE A-4-5 WATER RESOURCES DEVELOPMENT OF NANDNA KAS (N-1)



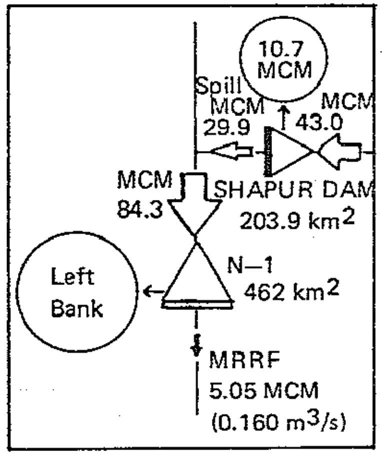
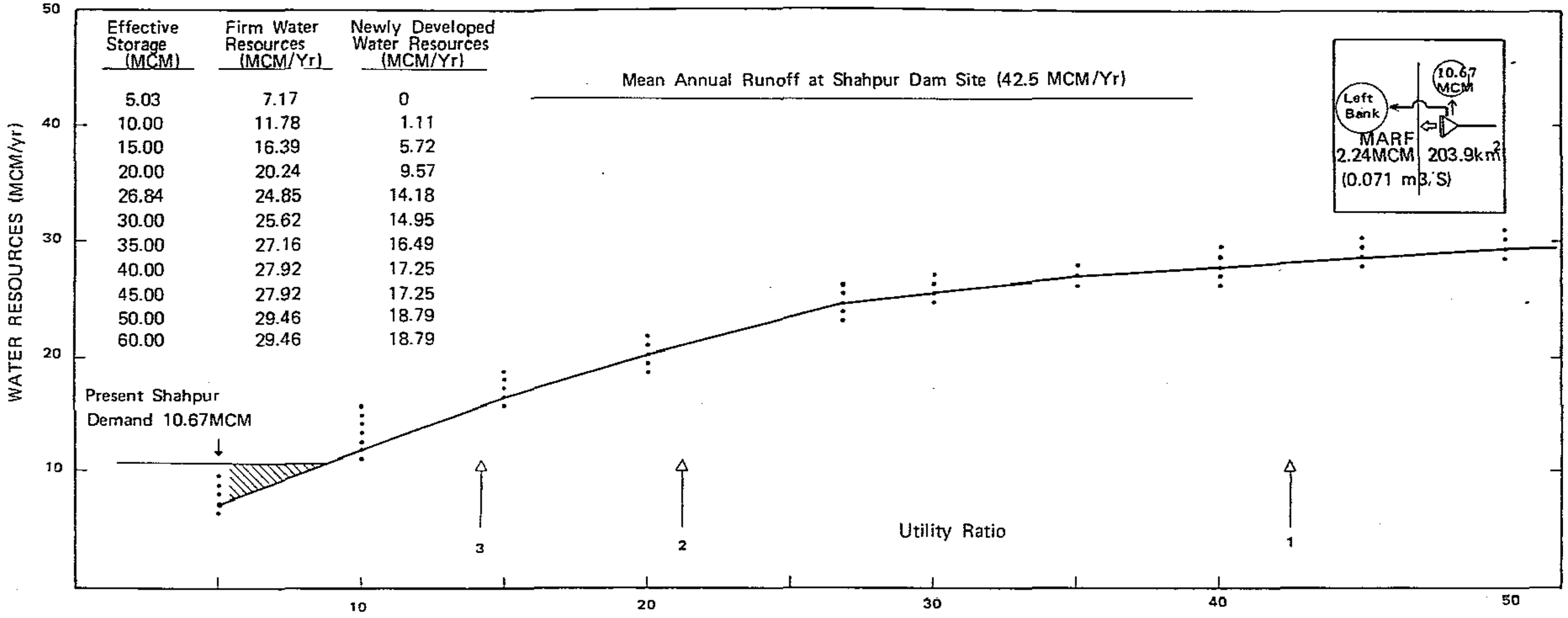


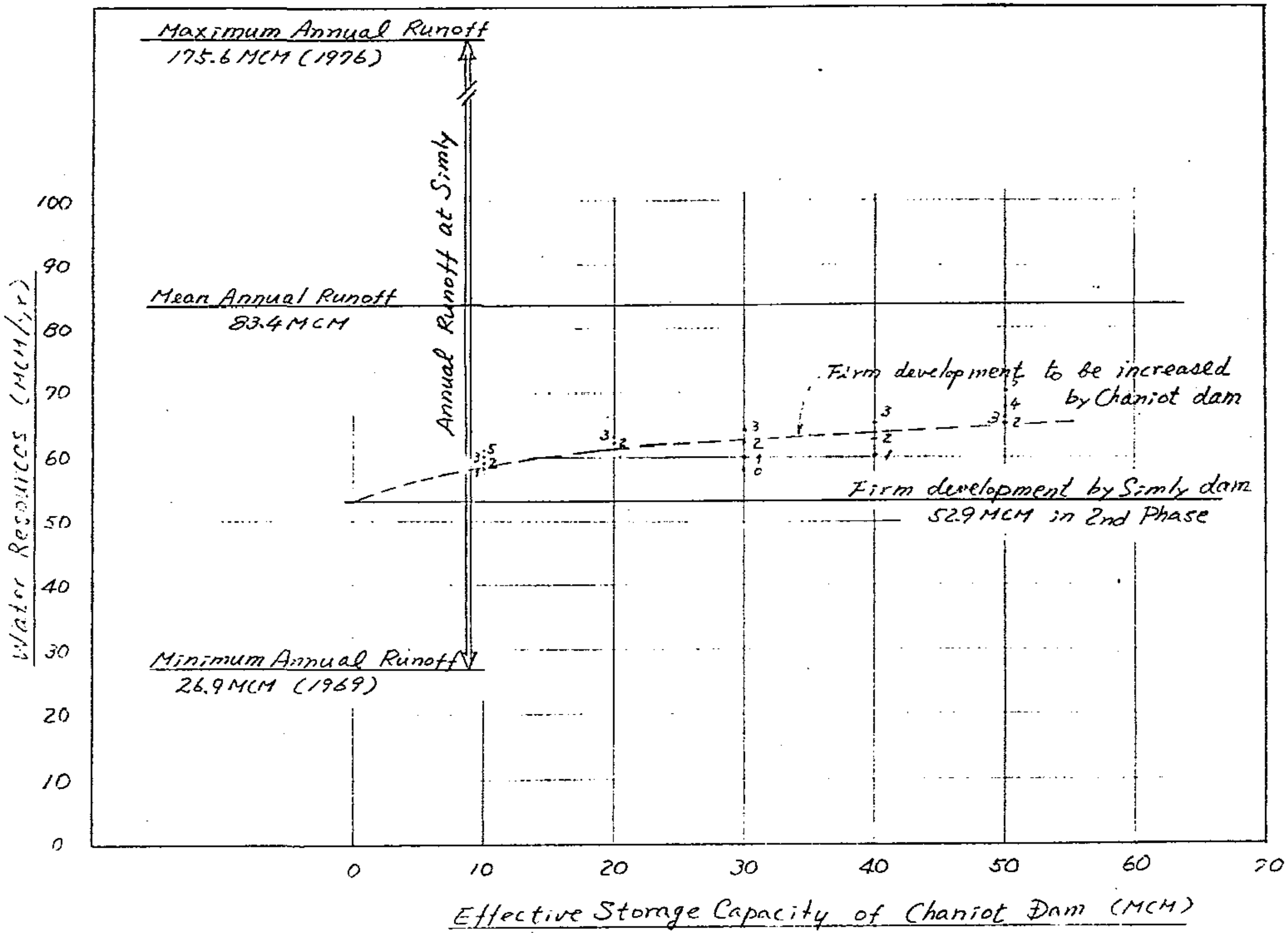
FIGURE A–4–6 WATER RESOURCES DEVELOPMENT OF NANDNA KAS (SHAHPUR DAM)



Effective Storage (MCM)	Firm Water Resources (MCM/Yr)	Newly Developed Water Resources (MCM/Yr)
5.03	7.17	0
10.00	11.78	1.11
15.00	16.39	5.72
20.00	20.24	9.57
26.84	24.85	14.18
30.00	25.62	14.95
35.00	27.16	16.49
40.00	27.92	17.25
45.00	27.92	17.25
50.00	29.46	18.79
60.00	29.46	18.79

EFFECTIVE STORAGE CAPACITY OF SHAHPUR DAM (MCM)

FIGURE A-4-7 WATER RESOURCES DEVELOPMENT OF CHANIOT (UPPER SIMLY)



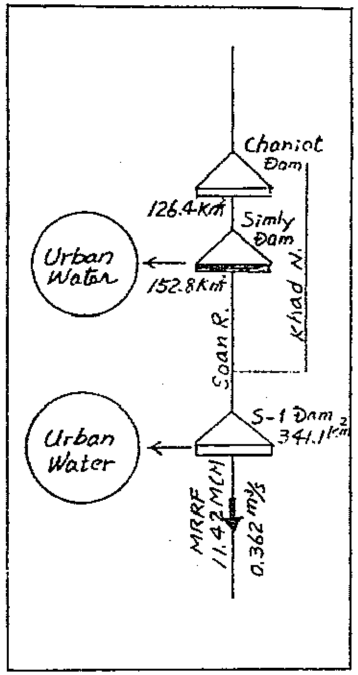
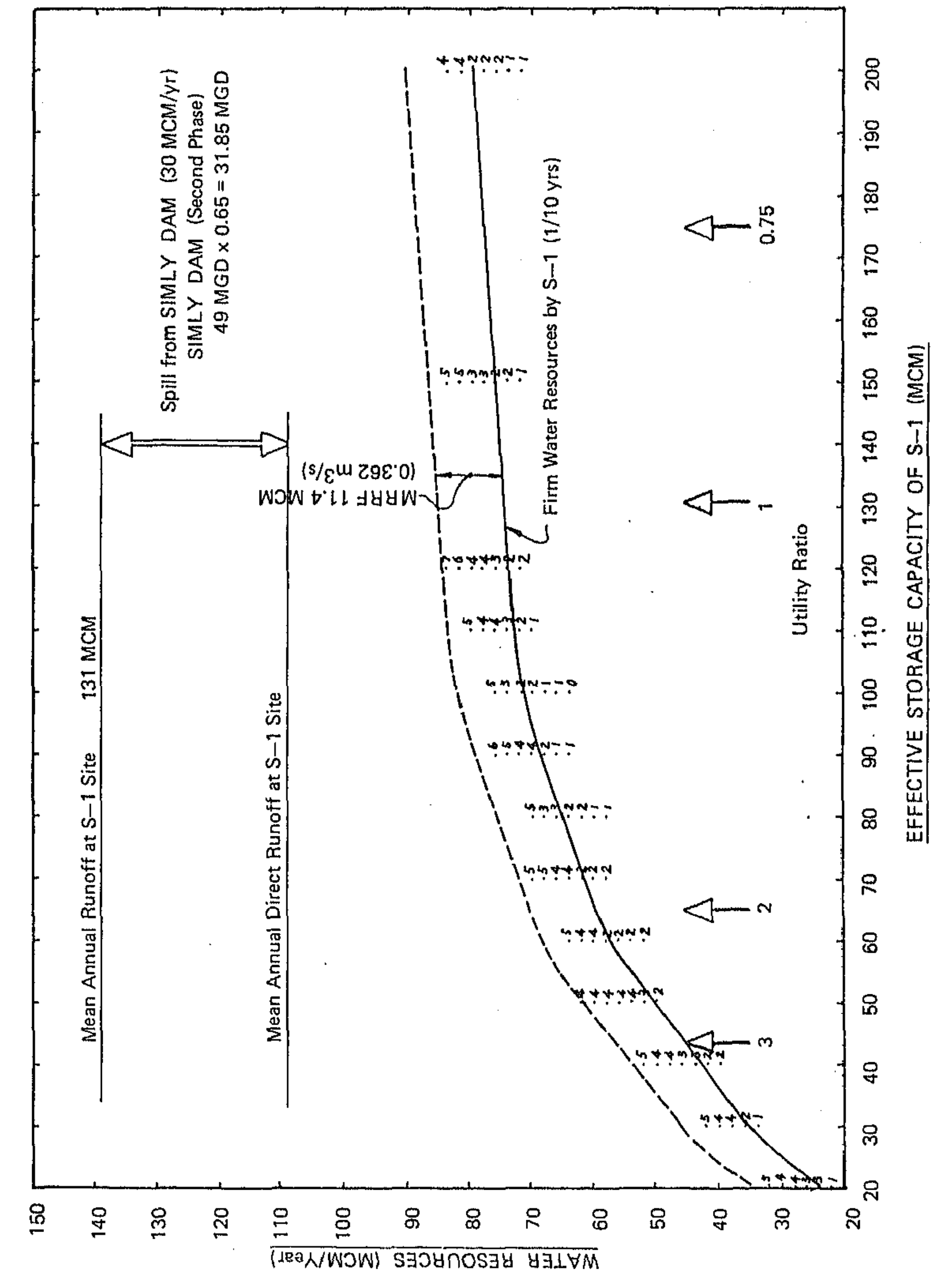


FIGURE A-4-8 WATER RESOURCES DEVELOPMENT OF SOAN RIVER (S-1)



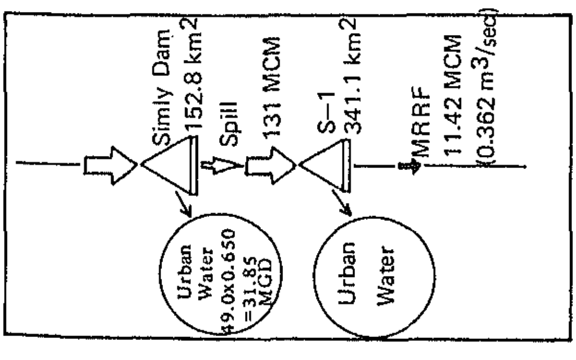
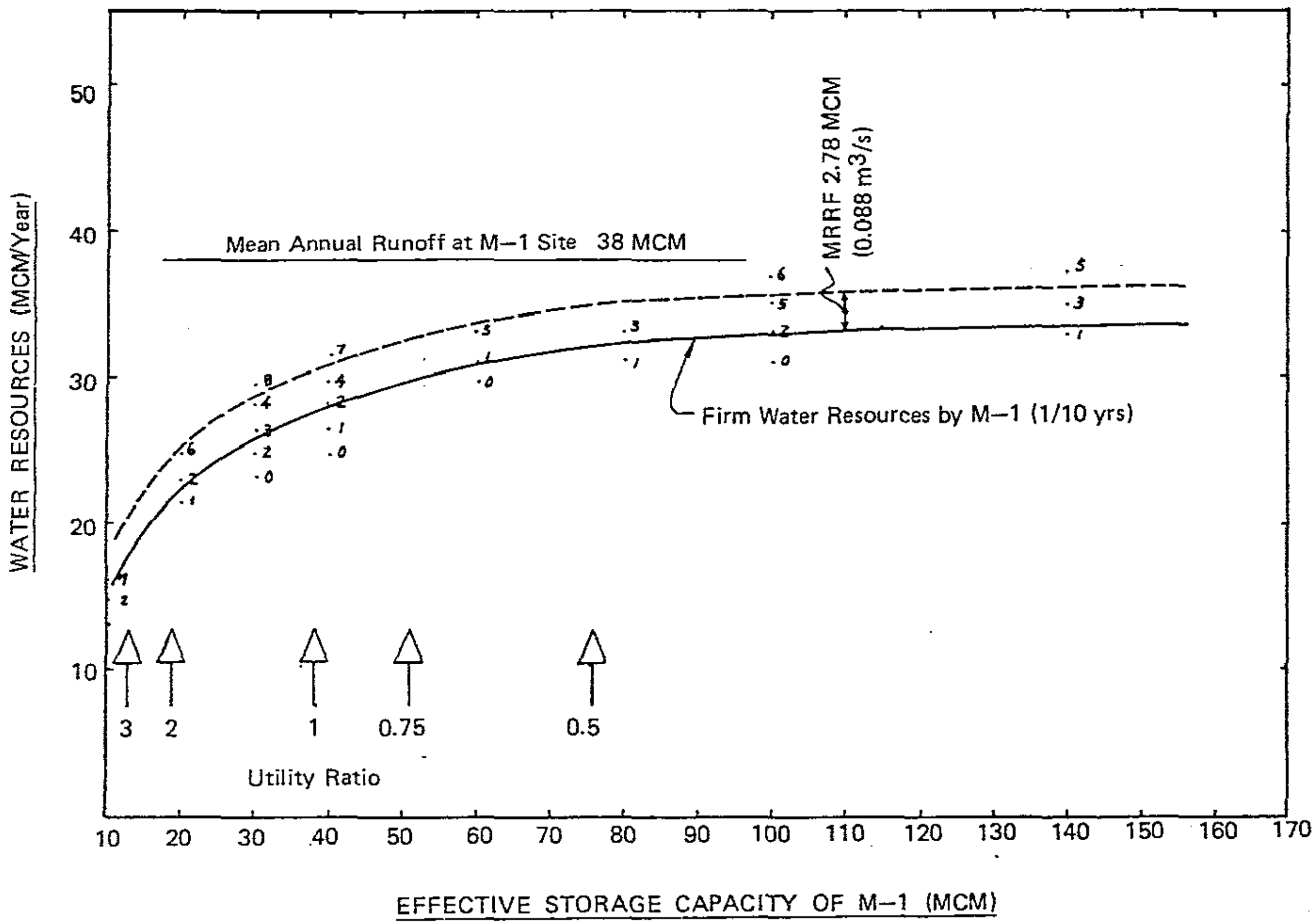


FIGURE A-4-9 WATER RESOURCES DEVELOPMENT OF MALAL KAS (M-1)



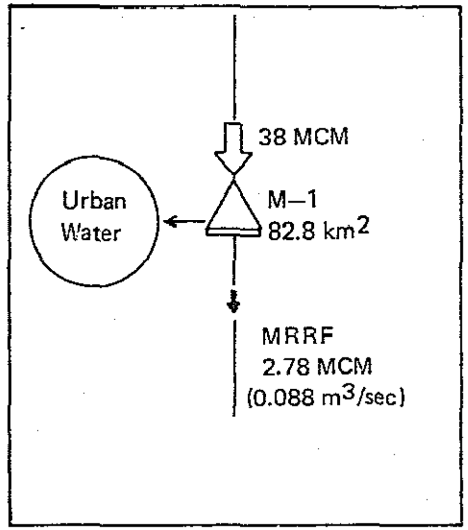
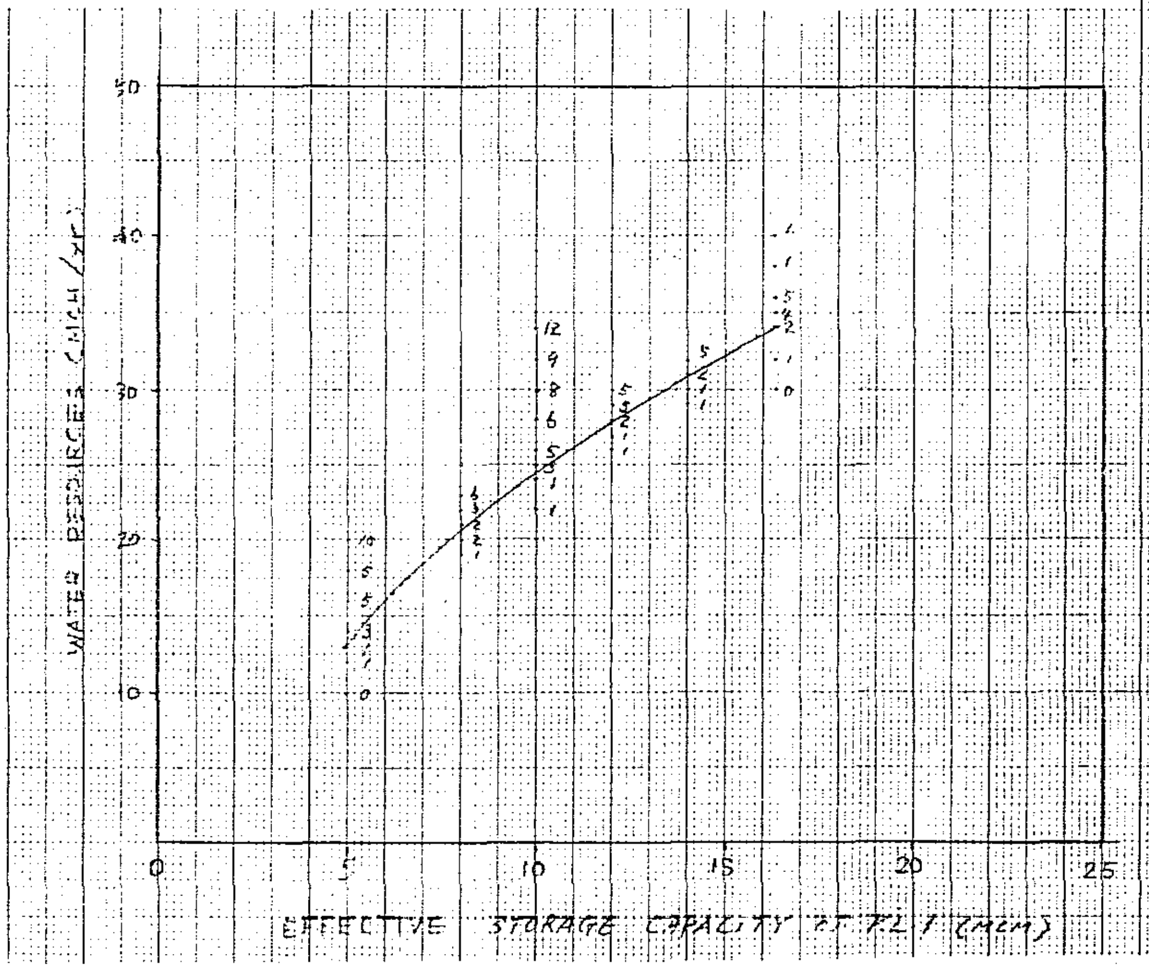


FIGURE A-4-10 WATER RESOURCES DEVELOPMENT OF KURANG RIVER (KL-1)



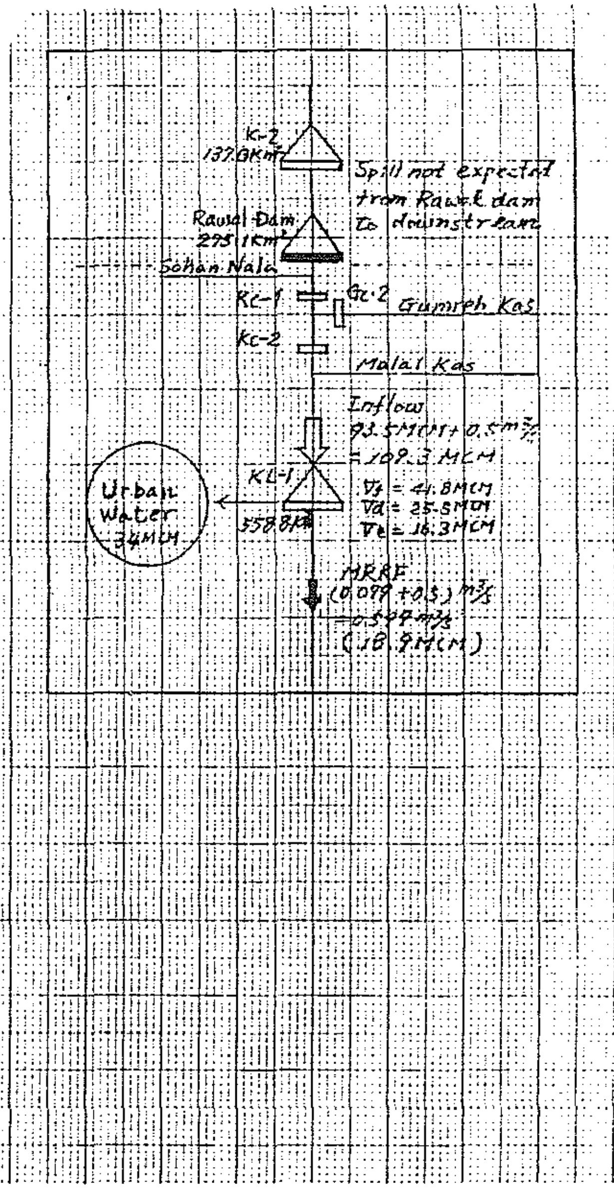
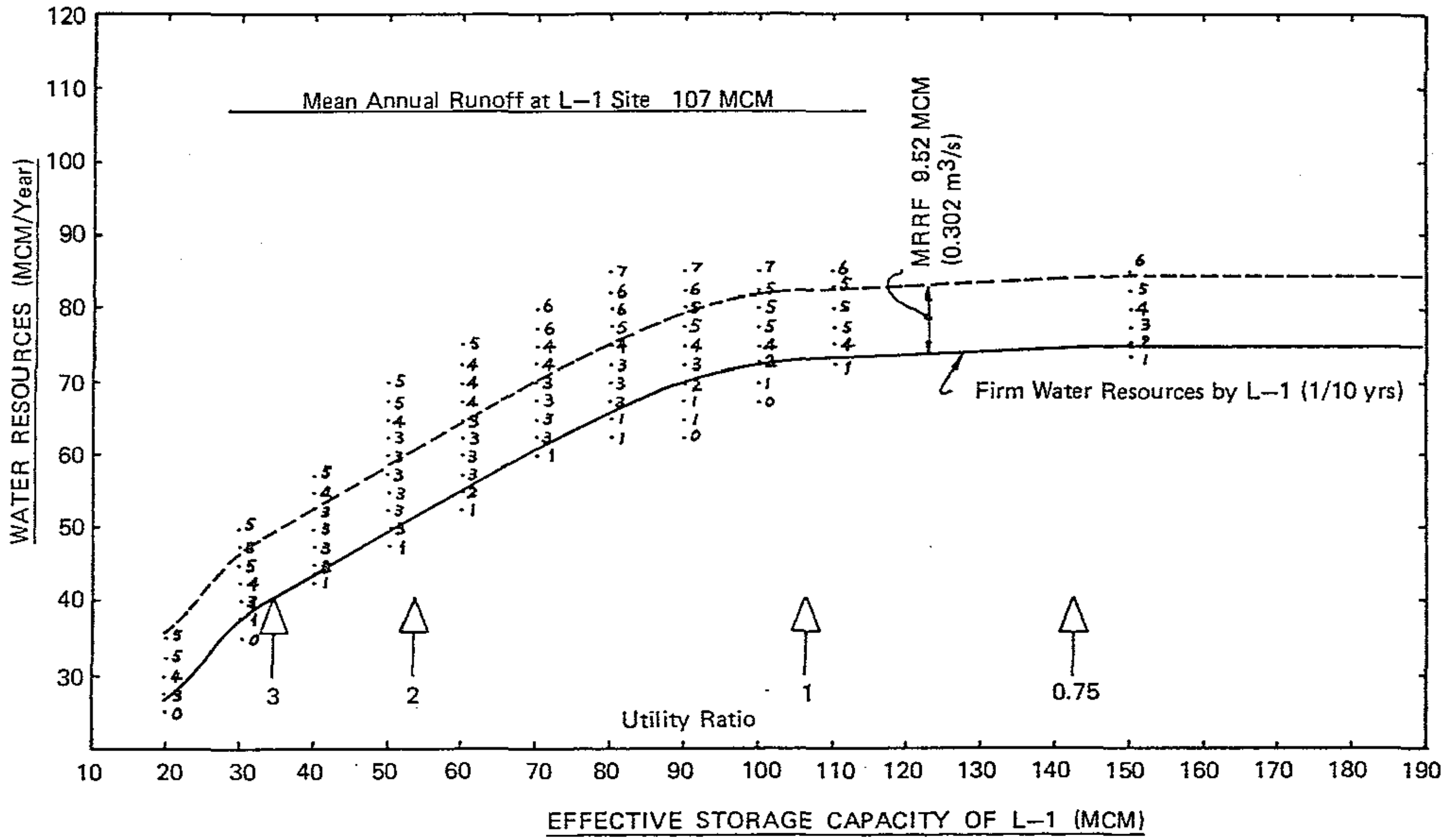


FIGURE A-4-11 WATER RESOURCES DEVELOPMENT OF LING RIVER (L-1)



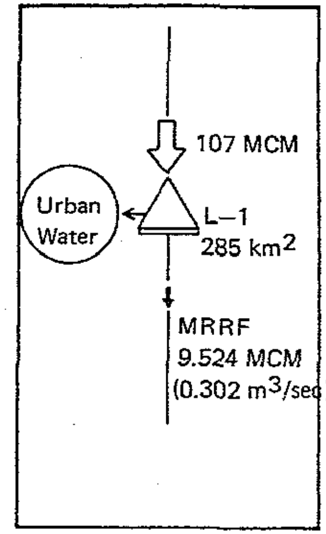
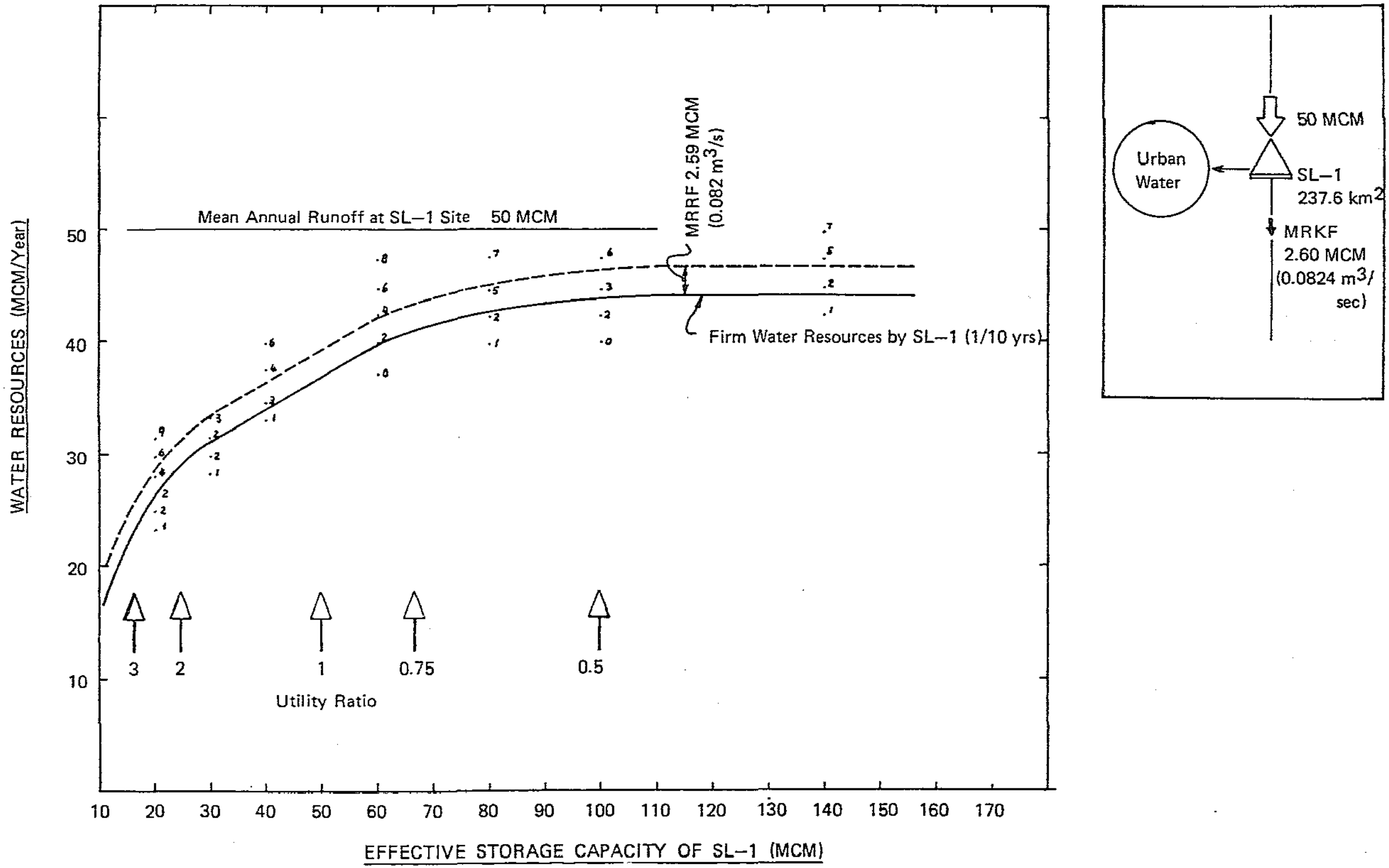


FIGURE A-4-12 WATER RESOURCES DEVELOPMENT OF SIL RIVER (SL-1)



SUMMARY OF D-1,DW-1 RESERVOIR OPERATION CASE = 1

PERIOD	D-1 RUNOFF (1)	DW-1 RUNOFF (2)	TOTAL RUNOFF (1)+(2)	TOTAL DEMAND (3)	INTAKE AT DW-1 (4)	INTAKE SURPLUS (4)-(3)	RELEASE AT DW-1	DEMAND TO D-1	RELEASE AT D-1	EVAPRTN AT D-1	SP.LOSS AT D-1	STORAGE OF D-1	SPILL D-1	SHORTGE
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	70.555	41.981	112.536	107.317	107.317	0.000	32.571	97.907	97.907	1.514	0.000	27.733	0.000	0.000
1961	113.449	68.932	182.381	107.068	109.948	5.812	33.774	74.790	74.790	1.642	0.000	64.750	0.000	0.000
1962	90.045	54.826	144.872	107.068	110.115	9.072	37.562	92.850	92.850	1.851	0.000	60.093	0.000	0.000
1963	73.117	43.412	116.529	107.068	107.068	0.000	32.482	96.138	96.138	1.744	0.000	35.328	0.000	0.000
1964	90.156	53.715	143.871	107.317	108.298	0.981	32.571	87.154	87.154	1.344	0.000	36.985	0.000	0.000
1965	83.776	51.183	134.959	107.068	108.120	1.052	32.482	89.419	89.419	1.921	0.000	29.420	0.000	0.000
1966	81.107	47.989	129.096	107.068	89.392	0.389	32.482	91.950	73.885	1.015	0.000	35.626	0.000	18.065
1967	97.429	59.118	156.547	107.068	110.252	5.178	32.898	84.032	84.032	1.742	0.000	47.281	0.000	0.000
1968	89.845	55.508	145.353	107.317	109.978	5.593	35.852	90.322	90.322	1.428	0.000	45.375	0.000	0.000
1969	73.587	44.810	118.396	107.068	107.502	0.434	32.482	95.175	95.175	1.296	0.000	22.491	0.000	0.000
1970	79.833	48.151	127.984	107.068	94.655	0.632	32.482	92.031	78.986	1.039	0.000	22.299	0.000	13.045
1971	99.751	61.946	161.697	107.068	107.556	9.610	38.673	86.516	84.284	1.199	0.000	36.567	0.000	2.232
1972	80.353	49.226	129.579	107.317	104.567	0.000	32.571	90.662	87.912	1.280	0.000	27.727	0.000	2.750
1973	127.394	77.553	204.947	107.068	118.359	17.888	48.881	68.782	89.688	1.719	0.000	63.714	20.906	0.000
1974	70.146	41.471	111.617	107.068	107.403	0.335	32.482	98.413	98.413	1.396	0.000	34.050	0.000	0.000
1975	126.324	78.255	204.578	107.068	118.524	20.546	51.382	70.086	91.651	1.701	0.000	67.021	21.566	0.000
1976	138.495	86.005	224.500	107.317	130.338	29.031	94.397	65.123	138.730	2.135	0.000	64.650	73.607	0.000
1977	111.850	66.295	178.145	107.068	117.992	13.856	53.264	75.982	104.961	1.994	0.000	69.545	28.979	0.000
1978	148.426	91.940	240.365	107.068	124.001	29.263	112.054	66.646	144.116	2.044	0.000	71.811	77.470	0.000
1979	84.191	51.451	135.641	107.068	115.959	8.891	43.778	90.128	108.287	2.047	0.000	45.667	18.158	0.000
1980	91.156	53.968	145.124	107.317	107.972	4.320	36.831	90.835	90.835	1.484	0.000	44.503	0.000	0.000
MEAN	96.237	58.463	154.701	107.139	110.253	7.756	43.426	85.473	95.216	1.597	0.000	45.364	11.461	1.719

***** SUMMARY OF SHORTAGE *****
5 % OF DEMAND (MCM) = 5.357
LESS THAN 5 % (YEAR) = 2
GREATER OR EQUAL TO 5 % (YEAR) = 2
TOTAL OF SHORTAGE (YEAR) = 4

Table A-4-9 Water Balance Simulation of the Dor River Basin (D-1 & Dw-1)

SUMMARY OF KHANPUR RESERVOIR OPERATION CASE = 2

PERIOD	INFLOW	WATER DEMAND: WATER SUPPLY ISLAMA	WATER SUPPLY RAWALP	INDUSTRIAL WAH	INDUSTRIAL TAXILA	AGRICULTURE RIGHT	AGRICULTURE LEFT	TOTAL	EVPO LOSS	SEEPAGE LOSS	RELEASE	STORAGE	SPILL	SHORT
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	249.145	17.845	37.511	8.111	7.278	94.124	0.000	164.870	4.797	0.000	75.010	102.666	25.363	0.000
1961	433.160	17.803	37.424	8.089	7.259	78.538	0.000	149.113	5.812	0.000	255.230	125.672	205.719	0.000
1962	210.632	17.803	37.424	8.089	7.259	88.634	0.000	159.209	5.175	0.000	65.274	106.645	15.763	0.000
1963	233.915	17.803	37.424	8.089	7.259	88.575	0.000	159.150	4.691	0.000	65.792	110.927	16.280	0.000
1964	260.715	17.845	37.511	8.111	7.278	105.283	0.000	176.029	5.256	0.000	89.010	101.347	39.363	0.000
1965	402.429	17.803	37.424	8.089	7.259	84.958	0.000	155.534	5.725	0.000	249.410	93.108	199.898	0.000
1966	261.737	17.803	37.424	8.089	7.259	85.696	0.000	156.272	4.829	0.000	77.717	116.027	28.205	0.000
1967	342.702	17.803	37.424	8.089	7.259	85.416	0.000	155.991	5.799	0.000	177.238	119.701	127.727	0.000
1968	286.558	17.845	37.511	8.111	7.278	81.091	0.000	151.837	5.523	0.000	145.270	103.628	95.623	0.000
1969	164.166	17.803	37.424	8.089	7.259	93.859	0.000	164.434	3.940	0.000	49.511	49.908	0.000	0.000
1970	323.924	17.803	37.424	8.089	7.259	85.593	0.000	156.168	3.399	0.000	105.263	111.876	55.752	2.875
1971	383.452	17.803	37.424	8.089	7.259	96.781	0.000	167.356	4.223	0.000	224.817	98.932	175.306	0.000
1972	203.367	17.845	37.511	8.111	7.278	81.992	0.000	152.738	5.039	0.000	49.647	94.875	0.000	0.000
1973	459.626	17.803	37.424	8.089	7.259	86.051	0.000	156.626	5.591	0.000	279.903	112.381	230.392	0.000
1974	126.892	17.803	37.424	8.089	7.259	108.117	0.000	178.692	3.235	0.000	48.463	19.140	0.000	11.306
1975	222.790	17.803	37.424	8.089	7.259	94.848	0.000	165.423	2.425	0.000	49.511	69.718	0.000	45.149
1976	629.388	17.845	37.511	8.111	7.278	74.582	0.000	145.328	5.809	0.000	429.772	118.196	380.125	0.000
1977	484.251	17.803	37.424	8.089	7.259	94.685	0.000	165.260	4.948	0.000	306.544	125.694	257.033	0.000
1978	569.409	17.803	37.424	8.089	7.259	80.501	0.000	151.076	5.504	0.000	414.395	124.128	364.884	0.000
1979	312.869	17.803	37.424	8.089	7.259	83.822	0.000	154.397	5.716	0.000	184.491	92.394	134.979	0.000
1980	304.576	17.845	37.511	8.111	7.278	78.287	0.000	149.033	5.580	0.000	136.331	106.026	86.684	0.000
MEAN	326.937	17.815	37.449	8.095	7.264	88.163	0.000	158.787	4.905	0.000	165.647	100.142	116.147	2.825

***** SUMMARY OF SHORTAGE *****
5 % OF DEMAND (MCM) = 7.939
LESS THAN 5 % (YEAR) = 1
GREATER OR EOUAL TO 5 % (YEAR) = 2
TOTAL OF SHORTAGE (YEAR) = 3

Table A-4-10 Water Balance Simulation of the Khanpur Dam (Existing)

SUMMARY OF H4,KANPR RESERVOIR OPERATION CASE = 1

PERIOD	H-4 RUNOFF (1)	KHANPUR RUNOFF (2)	CONDUCT ION DW1 (3)	TOTAL WATER (1+2+3)	TOTAL DEMAND	RELEASE KHANPUR	DEMAND TO H-4	RELEASE AT H-4	EVAPRTN (TOTAL)	SP.LOSS KHANPUR	STORAGE KHANPUR	SPILL KHANPUR	STORAGE H-4	SPILL H-4	SHORTGE
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	159.638	89.506	0.000	249.145	248.370	49.647	53.430	132.857	5.197	0.000	19.140	0.000	131.246	79.426	0.000
1961	277.545	155.615	0.000	433.160	230.330	89.278	106.587	260.836	5.644	0.000	111.736	39.767	145.000	154.249	0.000
1962	134.961	75.670	0.000	210.632	241.794	49.511	0.000	131.877	6.362	0.000	21.421	0.000	145.000	131.877	0.000
1963	149.880	84.035	0.000	233.915	241.727	49.511	206.490	206.490	4.049	0.000	19.140	0.000	85.908	0.000	0.000
1964	167.052	93.663	0.000	260.715	261.041	49.647	218.586	218.586	3.547	0.000	19.140	0.000	32.388	0.000	0.000
1965	257.855	144.575	0.000	402.429	237.621	49.511	39.445	143.499	5.858	0.000	19.140	0.000	143.934	108.585	4.532
1966	167.707	94.030	0.000	261.737	238.459	49.511	189.834	195.610	4.308	0.000	19.140	0.000	113.287	5.776	0.000
1967	219.585	123.118	0.000	342.702	238.140	49.511	34.833	184.806	5.913	0.000	33.772	0.000	145.000	149.974	0.000
1968	183.611	102.947	0.000	286.558	233.571	49.647	14.949	180.526	6.039	0.000	28.116	0.000	145.000	165.577	0.000
1969	105.188	58.977	0.000	164.166	247.727	49.511	229.614	228.012	3.736	0.000	19.140	0.000	20.000	1.232	2.833
1970	207.553	116.371	0.000	323.924	238.342	47.098	156.066	91.735	3.296	0.000	19.140	0.000	134.332	17.709	82.039
1971	245.696	137.757	0.000	383.452	251.046	61.808	122.603	232.900	4.716	0.000	72.909	12.296	145.000	110.297	0.000
1972	130.306	73.061	0.000	203.367	234.593	49.647	83.722	162.445	5.753	0.000	19.140	0.000	109.827	78.723	0.000
1973	294.503	165.123	0.000	459.626	238.861	104.117	72.560	256.350	5.736	0.000	92.979	54.606	145.000	183.790	0.000
1974	81.305	45.586	0.000	126.892	263.917	49.511	168.803	196.298	4.430	0.000	19.140	0.000	27.356	27.495	0.000
1975	142.751	80.038	0.000	222.790	248.850	49.511	219.907	137.720	2.716	0.000	19.140	0.000	31.255	0.000	82.187
1976	403.278	226.111	0.000	629.388	226.180	199.118	75.038	286.947	5.338	0.000	102.552	149.471	145.000	211.909	0.000
1977	310.281	173.970	0.000	484.251	248.666	213.493	0.000	307.198	6.733	0.000	114.261	163.982	145.000	307.198	0.000
1978	364.845	204.563	0.000	569.409	232.559	327.385	0.000	361.761	7.585	0.000	111.638	277.874	145.000	361.761	0.000
1979	200.470	112.400	0.000	312.869	236.330	120.784	0.000	197.386	8.233	0.000	54.011	71.272	145.000	197.386	0.000
1980	195.156	109.421	0.000	304.576	230.387	49.647	0.000	192.072	6.794	0.000	68.050	0.000	145.000	192.072	0.000
MEAN	209.484	117.454	0.000	326.937	241.357	86.067	94.879	205.043	5.332	0.000	47.754	36.632	115.454	118.335	8.171

***** SUMMARY OF SHORTAGE *****

5 % OF DEMAND (MCM) = 12.068

LESS THAN 5 % (YEAR) = 2

GREATER OR EQUAL TO 5 % (YEAR) = 2

TOTAL OF SHORTAGE (YEAR) = 4

Table A-4-11 Water Balance Simulation of the Haro River Basin (Khanpur + H-4)

SUMMARY OF DORHAROS RESERVOIR OPERATION CASE = 1

PERIOD	H-4 RUNOFF (1)	KHANPUR RUNOFF (2)	CONDUCTION DW1 (3)	TOTAL WATER (1+2+3)	TOTAL DEMAND	RELEASE KHANPUR	DEMAND TO H-4	RELEASE AT H-4	EVAPRTN (TOTAL)	SP.LOSS KHANPUR	STORAGE KHANPUR	SPILL KHANPUR	STORAGE H-4	SPILL H-4	SHORTGE
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	159.638	89.506	107.318	356.462	355.688	49.647	53.390	133.026	5.206	0.000	19.140	0.000	131.075	79.637	0.000
1961	277.545	155.615	109.948	543.109	337.411	91.770	105.060	260.649	5.671	0.000	111.910	42.258	145.000	155.589	0.000
1962	134.961	75.670	110.115	320.746	348.875	49.511	0.000	131.877	6.465	0.000	24.423	0.000	145.000	131.877	0.000
1963	149.880	84.035	107.069	340.983	348.808	49.511	202.699	203.501	4.101	0.000	19.140	0.000	88.845	0.802	0.000
1964	167.052	93.663	108.299	369.013	368.359	49.647	217.605	217.605	3.611	0.000	19.140	0.000	36.241	0.000	0.000
1965	257.855	144.575	108.121	510.550	344.702	49.511	36.969	147.017	5.879	0.000	19.140	0.000	144.259	110.048	0.000
1966	167.707	94.030	89.392	351.129	345.540	49.511	213.189	213.189	4.197	0.000	19.140	0.000	96.139	0.000	0.000
1967	219.585	123.118	110.253	452.955	345.222	49.511	57.418	167.673	5.378	0.000	20.950	0.000	145.000	110.255	0.000
1968	183.611	102.947	109.978	396.535	340.889	49.647	34.270	180.538	5.595	0.000	19.140	0.000	144.997	146.267	0.000
1969	105.188	58.977	107.503	271.668	354.808	49.511	239.400	228.153	3.591	0.000	19.140	0.000	20.000	0.000	11.247
1970	207.553	116.371	94.655	418.579	345.423	49.102	168.491	91.615	3.299	0.000	19.140	0.000	134.449	17.709	94.585
1971	245.696	137.757	107.557	491.009	358.127	62.308	123.578	233.016	4.719	0.000	73.000	12.796	145.000	109.438	0.000
1972	130.306	73.061	104.568	307.935	341.911	49.647	90.298	165.122	5.767	0.000	19.140	0.000	107.160	74.824	0.000
1973	294.503	165.123	118.359	577.985	345.942	112.035	72.206	253.691	5.727	0.000	93.682	62.523	145.000	181.485	0.000
1974	81.305	45.586	107.403	234.295	370.999	49.511	167.814	195.309	4.461	0.000	19.140	0.000	28.332	27.495	0.000
1975	142.751	80.038	118.524	341.313	355.931	49.511	208.481	128.725	2.771	0.000	19.140	0.000	41.187	0.000	79.756
1976	403.278	226.111	130.338	759.726	333.498	231.076	64.435	296.689	5.624	0.000	103.255	181.429	145.000	232.254	0.000
1977	310.281	173.970	117.992	602.243	355.747	224.752	0.000	307.198	6.780	0.000	114.522	175.240	145.000	307.198	0.000
1978	364.845	204.563	124.001	693.410	339.641	340.823	0.000	361.761	7.627	0.000	115.296	291.312	145.000	361.761	0.000
1979	200.470	112.400	115.959	428.828	343.412	132.489	0.000	197.386	8.259	0.000	54.789	82.978	145.000	197.386	0.000
1980	195.156	109.421	107.973	412.549	337.705	49.647	0.000	192.072	6.850	0.000	69.371	0.000	145.000	192.072	0.000
MEAN	209.484	117.454	110.253	437.190	348.506	89.937	97.872	205.038	5.313	0.000	47.225	40.407	115.366	116.005	8.838

***** SUMMARY OF SHORTAGE *****

5 % OF DEMAND (MCM) = 17.425

LESS THAN 5 % (YEAR) = 1

GREATER OR EQUAL TO 5 % (YEAR) = 2

TOTAL OF SHORTAGE (YEAR) = 3

Table A-4-12 Water Balance Simulation of the Haro River Basin (Dor Link)

SUMMARY OF SHAHPUR RESERVOIR OPERATION CASE = 1

PERIOD	INFLOW	WATER DEMAND: WATER SUPPLY ISLAMA	WATER SUPPLY RAWALP	INDUSTRIAL WAH	INDUSTRIAL TAXILA	AGRICULTURE RIGHT	AGRICULTURE LEFT	TOTAL	EVPO LOSS	SEEPAGE LOSS	RELEASE	STORAGE	SPILL	SHORT
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	18.399	0.000	3.328	0.000	0.000	0.000	7.880	11.207	2.816	0.000	5.760	15.515	5.760	0.750
1961	40.833	0.000	3.320	0.000	0.000	0.000	6.780	10.100	2.878	0.000	25.939	17.431	25.939	0.000
1962	84.224	0.000	3.320	0.000	0.000	0.000	7.323	10.643	2.849	0.000	71.791	16.372	71.791	0.000
1963	26.606	0.000	3.320	0.000	0.000	0.000	7.830	11.150	2.630	0.000	14.742	16.161	14.742	1.846
1964	26.356	0.000	3.328	0.000	0.000	0.000	8.624	11.952	2.782	0.000	13.686	14.915	13.686	0.818
1965	43.640	0.000	3.320	0.000	0.000	0.000	7.411	10.731	2.896	0.000	30.235	14.694	30.235	0.000
1966	33.051	0.000	3.320	0.000	0.000	0.000	7.207	10.527	2.881	0.000	18.903	15.435	18.903	0.000
1967	46.587	0.000	3.320	0.000	0.000	0.000	6.887	10.207	2.838	0.000	31.317	17.660	31.317	0.000
1968	40.750	0.000	3.328	0.000	0.000	0.000	6.704	10.031	2.854	0.000	28.183	17.341	28.183	0.000
1969	41.900	0.000	3.320	0.000	0.000	0.000	8.371	11.691	2.851	0.000	27.708	16.990	27.708	0.000
1970	52.116	0.000	3.320	0.000	0.000	0.000	6.758	10.077	2.852	0.000	39.960	16.217	39.960	0.000
1971	40.013	0.000	3.320	0.000	0.000	0.000	8.197	11.516	2.851	0.000	26.754	15.108	26.754	0.000
1972	16.877	0.000	3.328	0.000	0.000	0.000	7.182	10.509	2.850	0.000	2.329	16.297	2.329	0.000
1973	49.876	0.000	3.320	0.000	0.000	0.000	6.632	9.952	2.805	0.000	37.373	16.280	37.373	0.238
1974	21.506	0.000	3.320	0.000	0.000	0.000	8.810	12.130	2.295	0.000	10.939	14.749	10.939	2.758
1975	37.877	0.000	3.320	0.000	0.000	0.000	8.072	11.392	2.442	0.000	26.177	14.779	26.177	2.443
1976	62.425	0.000	3.328	0.000	0.000	0.000	6.227	9.555	2.877	0.000	47.780	16.992	47.780	0.000
1977	63.173	0.000	3.320	0.000	0.000	0.000	7.491	10.811	2.847	0.000	49.149	17.358	49.149	0.000
1978	71.377	0.000	3.320	0.000	0.000	0.000	6.798	10.118	2.862	0.000	58.094	17.660	58.094	0.000
1979	33.912	0.000	3.320	0.000	0.000	0.000	6.987	10.307	2.887	0.000	20.717	17.660	20.717	0.000
1980	41.617	0.000	3.328	0.000	0.000	0.000	6.197	9.525	2.891	0.000	29.201	17.660	29.201	0.000
MEAN	42.529	0.000	3.322	0.000	0.000	0.000	7.351	10.673	2.797	0.000	29.368	16.346	29.368	0.422

***** SUMMARY OF SHORTAGE *****

5 % OF DEMAND (MCM) = 0.534

LESS THAN 5 % (YEAR) = 1

GREATER OR EQUAL TO 5 % (YEAR) = 5

TOTAL OF SHORTAGE (YEAR) = 6

Table A-4-13 Water Balance Simulation of the Shahpur Dam (Existing)

SUMMARY OF N-1 DAM RESERVOIR OPERATION CASE = 1

PERIOD	INFLOW	WATER DEMAND: WATER SUPPLY- ISLAMA	WATER DEMAND: WATER SUPPLY- RAWALP	WATER DEMAND: INDUSTRIAL WAH	WATER DEMAND: INDUSTRIAL TAXILA	WATER DEMAND: AGRICULTURE RIGHT	WATER DEMAND: AGRICULTURE LEFT	WATER DEMAND: TOTAL	EVPO LOSS	SEEPAGE LOSS	RELEASE	STORAGE	SPILL	SHORT
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	29.050	0.000	0.000	0.000	0.000	0.000	64.321	64.321	5.053	0.000	5.060	28.615	0.000	0.000
1961	77.625	0.000	0.000	0.000	0.000	0.000	55.346	55.346	3.654	0.000	5.046	42.195	0.000	0.000
1962	178.402	0.000	0.000	0.000	0.000	0.000	59.775	59.775	4.512	0.000	61.017	100.066	56.110	4.917
1963	48.420	0.000	0.000	0.000	0.000	0.000	63.911	63.911	6.865	0.000	5.046	72.663	0.000	0.000
1964	47.048	0.000	0.000	0.000	0.000	0.000	70.399	70.399	4.966	0.000	5.060	39.286	0.000	0.000
1965	85.474	0.000	0.000	0.000	0.000	0.000	60.497	60.497	5.386	0.000	5.046	53.831	0.000	0.000
1966	60.739	0.000	0.000	0.000	0.000	0.000	58.829	58.829	4.495	0.000	5.046	46.200	0.000	0.000
1967	90.288	0.000	0.000	0.000	0.000	0.000	56.214	56.214	4.413	0.000	5.046	70.815	0.000	0.000
1968	79.766	0.000	0.000	0.000	0.000	0.000	54.721	54.721	6.216	0.000	5.060	84.584	0.000	0.000
1969	80.745	0.000	0.000	0.000	0.000	0.000	68.331	68.331	6.342	0.000	5.046	85.610	0.000	0.000
1970	105.929	0.000	0.000	0.000	0.000	0.000	55.160	55.160	7.294	0.000	27.629	101.456	22.583	0.000
1971	77.401	0.000	0.000	0.000	0.000	0.000	66.907	66.907	7.528	0.000	10.689	93.733	5.643	0.000
1972	23.691	0.000	0.000	0.000	0.000	0.000	58.624	58.624	6.616	0.000	5.060	47.124	0.000	0.000
1973	100.506	0.000	0.000	0.000	0.000	0.000	54.136	54.136	4.540	0.000	5.046	83.908	0.000	0.000
1974	38.162	0.000	0.000	0.000	0.000	0.000	71.911	71.911	5.050	0.000	5.046	40.062	0.000	0.000
1975	74.122	0.000	0.000	0.000	0.000	0.000	65.892	65.892	3.304	0.000	5.046	49.966	0.000	10.023
1976	126.798	0.000	0.000	0.000	0.000	0.000	50.829	50.829	5.603	0.000	22.117	98.214	17.058	0.000
1977	129.114	0.000	0.000	0.000	0.000	0.000	61.151	61.151	7.478	0.000	58.201	100.498	53.155	0.000
1978	148.444	0.000	0.000	0.000	0.000	0.000	55.492	55.492	7.688	0.000	72.672	113.089	67.627	0.000
1979	63.645	0.000	0.000	0.000	0.000	0.000	57.033	57.033	8.601	0.000	14.670	96.428	9.624	0.000
1980	81.881	0.000	0.000	0.000	0.000	0.000	50.585	50.585	8.235	0.000	18.414	101.075	13.354	0.000
MEAN	83.202	0.000	0.000	0.000	0.000	0.000	60.003	60.003	5.897	0.000	16.717	73.782	11.674	0.711

***** SUMMARY OF SHORTAGE *****

5 % OF DEMAND (MCM) = 3.000

LESS THAN 5 % (YEAR) = 0

GREATER OR EOUAL TO 5 % (YEAR) = 2

TOTAL OF SHORTAGE (YEAR) = 2

Table A-4-14 Water Balance Simulation of the Nandna Kas (N-1)

SUMMARY OF SHAHPUR RESERVOIR OPERATION CASE = 1

PERIOD	INFLOW	WATER DEMAND: WATER SUPPLY ISLAMA	WATER SUPPLY RAWALP	INDUSTRIAL WAH	INDUSTRIAL TAXILA	AGRICULTURE RIGHT	AGRICULTURE LEFT	TOTAL	EVPO LOSS	SEEPAGE LOSS	RELEASE	STORAGE	SPILL	SHORT
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	18.399	0.000	3.328	0.000	0.000	0.000	26.372	29.700	4.254	0.000	2.245	14.200	0.000	0.000
1961	40.833	0.000	3.320	0.000	0.000	0.000	22.692	26.012	3.514	0.000	2.239	23.267	0.000	0.000
1962	84.224	0.000	3.320	0.000	0.000	0.000	24.508	27.828	4.346	0.000	35.372	40.025	33.133	0.080
1963	26.606	0.000	3.320	0.000	0.000	0.000	26.204	29.524	5.733	0.000	2.239	29.135	0.000	0.000
1964	26.356	0.000	3.328	0.000	0.000	0.000	28.864	32.192	3.808	0.000	2.245	17.245	0.000	0.000
1965	43.640	0.000	3.320	0.000	0.000	0.000	24.804	28.124	5.042	0.000	2.239	25.480	0.000	0.000
1966	33.051	0.000	3.320	0.000	0.000	0.000	24.120	27.440	4.335	0.000	2.239	24.517	0.000	0.000
1967	46.587	0.000	3.320	0.000	0.000	0.000	23.048	26.368	4.515	0.000	2.239	37.982	0.000	0.000
1968	40.750	0.000	3.328	0.000	0.000	0.000	22.436	25.764	6.586	0.000	6.181	40.201	3.936	0.000
1969	41.900	0.000	3.320	0.000	0.000	0.000	28.016	31.336	6.371	0.000	2.844	41.550	0.605	0.000
1970	52.116	0.000	3.320	0.000	0.000	0.000	22.616	25.936	7.033	0.000	19.975	40.722	17.736	0.000
1971	40.013	0.000	3.320	0.000	0.000	0.000	27.432	30.752	6.554	0.000	6.436	36.993	4.197	0.000
1972	16.877	0.000	3.328	0.000	0.000	0.000	24.036	27.364	5.468	0.000	2.245	18.792	0.000	0.000
1973	49.876	0.000	3.320	0.000	0.000	0.000	22.196	25.516	3.862	0.000	2.333	38.986	0.155	2.189
1974	21.506	0.000	3.320	0.000	0.000	0.000	29.484	32.804	4.748	0.000	2.239	20.701	0.000	0.000
1975	37.877	0.000	3.320	0.000	0.000	0.000	27.016	30.336	3.527	0.000	2.239	26.082	0.000	3.607
1976	62.425	0.000	3.328	0.000	0.000	0.000	20.840	24.168	5.293	0.000	19.465	39.581	17.220	0.000
1977	63.173	0.000	3.320	0.000	0.000	0.000	25.072	28.392	6.419	0.000	27.201	40.741	24.962	0.000
1978	71.377	0.000	3.320	0.000	0.000	0.000	22.752	26.072	6.655	0.000	33.090	46.300	30.851	0.000
1979	33.912	0.000	3.320	0.000	0.000	0.000	23.384	26.704	7.491	0.000	6.480	39.537	4.241	0.000
1980	41.617	0.000	3.328	0.000	0.000	0.000	20.740	24.068	7.172	0.000	8.902	41.011	6.657	0.000
MEAN	42.529	0.000	3.322	0.000	0.000	0.000	24.601	27.924	5.368	0.000	9.080	32.526	6.843	0.280

***** SUMMARY OF SHORTAGE *****

5 % OF DEMAND (MCM) = 1.396

LESS THAN 5 % (YEAR) = 1

GREATER OR EQUAL TO 5 % (YEAR) = 2

TOTAL OF SHORTAGE (YEAR) = 3

Table A-4-15 Water Balance Simulation of the Shahpur Dam (Heightening)

SUMMARY OF SIMLYDAM RESERVOIR OPERATION CASE = 1

PERIOD	INFLOW	WATER DEMAND: WATER SUPPLY ISLAMA	WATER SUPPLY RAWALP	INDUSTRIAL WAH	INDUSTRIAL TAXILA	AGRICULTURE RIGHT	AGRICULTURE LEFT	TOTAL	EVPO LOSS	SEEPAGE LOSS	RELEASE	STORAGE	SPILL	SHORT
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	41.722	81.528	0.000	0.000	0.000	0.000	0.000	81.528	0.947	0.000	0.000	10.790	0.000	12.693
1961	108.746	81.339	0.000	0.000	0.000	0.000	0.000	81.339	0.905	0.000	12.537	37.371	12.537	12.615
1962	39.556	81.339	0.000	0.000	0.000	0.000	0.000	81.339	0.827	0.000	0.000	10.790	0.000	16.030
1963	53.355	81.339	0.000	0.000	0.000	0.000	0.000	81.339	0.662	0.000	0.000	17.393	0.000	35.365
1964	66.662	81.528	0.000	0.000	0.000	0.000	0.000	81.528	0.778	0.000	0.000	23.343	0.000	21.625
1965	62.738	81.339	0.000	0.000	0.000	0.000	0.000	81.339	0.999	0.000	0.000	10.790	0.000	7.047
1966	53.362	81.339	0.000	0.000	0.000	0.000	0.000	81.339	0.750	0.000	0.000	13.202	0.000	31.140
1967	80.814	81.339	0.000	0.000	0.000	0.000	0.000	81.339	0.966	0.000	0.000	18.812	0.000	7.100
1968	60.230	81.528	0.000	0.000	0.000	0.000	0.000	81.528	0.795	0.000	0.000	11.119	0.000	14.399
1969	26.852	81.339	0.000	0.000	0.000	0.000	0.000	81.339	0.627	0.000	0.000	10.790	0.000	54.785
1970	117.538	81.339	0.000	0.000	0.000	0.000	0.000	81.339	0.854	0.000	38.539	37.787	38.539	30.196
1971	117.864	81.339	0.000	0.000	0.000	0.000	0.000	81.339	1.114	0.000	41.779	31.419	41.779	0.000
1972	54.642	81.528	0.000	0.000	0.000	0.000	0.000	81.528	0.880	0.000	0.000	10.790	0.000	7.137
1973	88.141	81.339	0.000	0.000	0.000	0.000	0.000	81.339	0.962	0.000	0.000	23.849	0.000	7.219
1974	39.765	81.339	0.000	0.000	0.000	0.000	0.000	81.339	0.708	0.000	0.000	10.790	0.000	29.223
1975	113.584	81.339	0.000	0.000	0.000	0.000	0.000	81.339	0.847	0.000	43.783	33.345	43.783	34.940
1976	175.583	81.528	0.000	0.000	0.000	0.000	0.000	81.528	1.407	0.000	88.856	37.137	88.856	0.000
1977	158.098	81.339	0.000	0.000	0.000	0.000	0.000	81.339	1.029	0.000	70.391	43.299	70.391	0.823
1978	148.165	81.339	0.000	0.000	0.000	0.000	0.000	81.339	1.216	0.000	70.480	38.429	70.480	0.000
1979	88.313	81.339	0.000	0.000	0.000	0.000	0.000	81.339	1.365	0.000	19.375	24.663	19.375	0.000
1980	56.645	81.528	0.000	0.000	0.000	0.000	0.000	81.528	0.758	0.000	0.000	10.790	0.000	11.768
MEAN	83.446	81.393	0.000	0.000	0.000	0.000	0.000	81.393	0.924	0.000	18.368	22.224	18.368	15.910

***** SUMMARY OF SHORTAGE *****
5 % OF DEMAND (MCM) = 4.070
LESS THAN 5 % (YEAR) = 1
GREATER OR EQUAL TO 5 % (YEAR) = 16
TOTAL OF SHORTAGE (YEAR) = 17

Table A-4-16 (1) Water Balance Simulation of the Simly Dam (Second Phase)
Demand = 49 MGD = 81 MCM/yr

SUMMARY OF SIMLYDAM RESERVOIR OPERATION CASE = 1

PERIOD	INFLOW	WATER DEMAND: WATER SUPPLY ISLAMA	WATER SUPPLY RAWALP	INDUSTRIAL WAH	INDUSTRIAL TAXILA	AGRICULTURE RIGHT	AGRICULTURE LEFT	TOTAL	EVPO LOSS	SEEPAGE LOSS	RELEASE	STORAGE	SPILL	SHORT
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	41.722	52.993	0.000	0.000	0.000	0.000	0.000	52.993	1.243	0.000	0.000	26.336	0.000	0.000
1961	108.746	52.870	0.000	0.000	0.000	0.000	0.000	52.870	1.276	0.000	37.337	43.598	37.337	0.000
1962	39.556	52.870	0.000	0.000	0.000	0.000	0.000	52.870	1.204	0.000	0.000	29.079	0.000	0.000
1963	53.355	52.870	0.000	0.000	0.000	0.000	0.000	52.870	0.990	0.000	0.000	30.179	0.000	1.606
1964	66.662	52.993	0.000	0.000	0.000	0.000	0.000	52.993	1.126	0.000	2.622	40.100	2.622	0.000
1965	62.738	52.870	0.000	0.000	0.000	0.000	0.000	52.870	1.446	0.000	13.072	35.449	13.072	0.000
1966	53.362	52.870	0.000	0.000	0.000	0.000	0.000	52.870	1.182	0.000	0.000	34.758	0.000	0.000
1967	80.814	52.870	0.000	0.000	0.000	0.000	0.000	52.870	1.421	0.000	16.470	44.810	16.470	0.000
1968	60.230	52.993	0.000	0.000	0.000	0.000	0.000	52.993	1.418	0.000	13.342	37.287	13.342	0.000
1969	26.852	52.870	0.000	0.000	0.000	0.000	0.000	52.870	0.994	0.000	0.000	10.790	0.000	0.516
1970	117.538	52.870	0.000	0.000	0.000	0.000	0.000	52.870	0.866	0.000	46.241	44.539	46.241	16.194
1971	117.864	52.870	0.000	0.000	0.000	0.000	0.000	52.870	1.358	0.000	68.082	40.093	68.082	0.000
1972	54.642	52.993	0.000	0.000	0.000	0.000	0.000	52.993	1.329	0.000	0.000	40.413	0.000	0.000
1973	88.141	52.870	0.000	0.000	0.000	0.000	0.000	52.870	1.433	0.000	32.911	41.340	32.911	0.000
1974	39.765	52.870	0.000	0.000	0.000	0.000	0.000	52.870	1.142	0.000	0.000	27.093	0.000	0.000
1975	113.584	52.870	0.000	0.000	0.000	0.000	0.000	52.870	0.961	0.000	49.557	41.204	49.557	3.915
1976	175.583	52.993	0.000	0.000	0.000	0.000	0.000	52.993	1.456	0.000	118.973	43.364	118.973	0.000
1977	158.098	52.870	0.000	0.000	0.000	0.000	0.000	52.870	1.300	0.000	100.259	47.032	100.259	0.000
1978	148.165	52.870	0.000	0.000	0.000	0.000	0.000	52.870	1.402	0.000	95.572	45.353	95.572	0.000
1979	88.313	52.870	0.000	0.000	0.000	0.000	0.000	52.870	1.442	0.000	40.322	39.032	40.322	0.000
1980	56.645	52.993	0.000	0.000	0.000	0.000	0.000	52.993	1.305	0.000	0.000	41.379	0.000	0.000
MEAN	83.446	52.905	0.000	0.000	0.000	0.000	0.000	52.905	1.252	0.000	30.227	37.297	30.227	1.059

***** SUMMARY OF SHORTAGE *****
5 % OF DEMAND (MCM) = 2.645
LESS THAN 5 % (YEAR) = 2
GREATER OR EOUAL TO 5 % (YEAR) = 2
TOTAL OF SHORTAGE (YEAR) = 4

Table A-4-16 (2) Water Balance Simulation of the Simly Dam (Second Phase)
Demand = 31.85 MGD = 52.8 MCM/yr

SUMMARY OF UP SIMLY RESERVOIR OPERATION CASE = 1

PERIOD	CHANIOT RUNOFF (1)	SIMLY RUNOFF (2)	CONDUCTION (3)	TOTAL WATER (1+2+3)	TOTAL DEMAND	RELEASE SIMLY	DEMAND TO CHANIOT	RELEASE AT CHANIOT	EVAPRTN (TOTAL)	SP.LOSS SIMLY	STORAGE SIMLY	SPILL SIMLY	STORAGE CHANIOT	SPILL CHANIOT	SHORTGE
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	34.513	7.209	0.000	41.722	62.560	0.000	29.051	42.347	1.587	0.000	10.790	0.000	28.548	13.295	0.000
1961	89.957	18.789	0.000	108.746	62.415	1.057	28.997	76.222	1.705	0.000	41.079	1.057	41.380	47.225	0.000
1962	32.722	6.834	0.000	39.556	62.415	0.000	0.000	31.696	2.057	0.000	15.459	0.000	41.380	31.696	0.000
1963	44.137	9.218	0.000	53.355	62.415	0.000	36.683	49.380	1.364	0.000	10.790	0.000	35.232	12.696	0.000
1964	55.144	11.518	0.000	66.662	62.560	0.000	38.179	51.924	1.302	0.000	10.790	0.000	37.645	13.745	0.000
1965	51.898	10.840	0.000	62.738	62.415	0.000	19.318	53.008	1.795	0.000	10.790	0.000	35.518	33.690	0.000
1966	44.142	9.220	0.000	53.362	62.415	0.000	53.819	53.819	1.320	0.000	10.790	0.000	25.065	0.000	0.000
1967	66.851	13.963	0.000	80.814	62.415	0.000	35.503	49.626	1.480	0.000	11.103	0.000	41.380	14.124	0.000
1968	49.824	10.406	0.000	60.230	62.560	0.000	22.964	52.906	1.586	0.000	10.790	0.000	37.314	29.942	0.000
1969	22.213	4.639	0.000	26.852	62.415	0.000	58.400	47.557	1.086	0.000	10.790	0.000	11.380	0.000	10.843
1970	97.230	20.308	0.000	117.538	62.415	13.317	34.428	66.657	1.270	0.000	41.941	13.317	41.380	53.400	21.171
1971	97.500	20.364	0.000	117.864	62.415	57.295	0.000	96.474	2.280	0.000	36.559	57.295	41.380	96.474	0.000
1972	45.201	9.441	0.000	54.642	62.560	0.000	0.000	44.175	2.177	0.000	25.311	0.000	41.380	44.175	0.000
1973	72.912	15.229	0.000	88.141	62.415	9.378	0.000	71.887	2.276	0.000	38.130	9.378	41.380	71.887	0.000
1974	32.895	6.870	0.000	39.765	62.415	0.000	2.576	31.869	1.955	0.000	12.678	0.000	41.380	29.293	0.000
1975	93.959	19.624	0.000	113.584	62.415	23.752	30.560	93.113	1.619	0.000	37.994	23.752	41.380	62.554	0.000
1976	145.247	30.336	0.000	175.583	62.560	106.293	0.000	144.221	2.451	0.000	40.846	106.293	41.380	144.221	0.000
1977	130.783	27.315	0.000	158.098	62.415	87.515	0.000	129.757	2.217	0.000	45.604	87.515	41.380	129.757	0.000
1978	122.566	25.599	0.000	148.165	62.415	85.204	0.000	121.540	2.349	0.000	42.584	85.204	41.380	121.540	0.000
1979	73.055	15.258	0.000	88.313	62.415	29.754	0.000	72.029	2.431	0.000	34.890	29.754	41.380	72.029	0.000
1980	46.858	9.787	0.000	56.645	62.560	0.000	0.000	45.832	2.137	0.000	25.724	0.000	41.380	45.832	0.000
MEAN	69.029	14.417	0.000	83.446	62.456	19.694	18.594	67.907	1.831	0.000	25.021	19.694	37.620	50.837	1.524

***** SUMMARY OF SHORTAGE *****

5 % OF DEMAND (MCM) = 3.123

LESS THAN 5 % (YEAR) = 0

GREATER OR EQUAL TO 5 % (YEAR) = 2

TOTAL OF SHORTAGE (YEAR) = 2

Table A-4-17 Water Balance Simulation of the Chaniot (Upper Simly)

SUMMARY OF S-1 DAM RESERVOIR OPERATION CASE = 1

PERIOD	INFLOW	WATER DEMAND: WATER SUPPLY ISLAMA	WATER SUPPLY RAWALP	INDUSTRIAL WAH	INDUSTRIAL TAXILA	AGRICULTURE RIGHT	AGRICULTURE LEFT	TOTAL	EVPO LOSS	SEEPAGE LOSS	RELEASE	STORAGE	SPILL	SHORT
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	51.415	60.181	0.000	0.000	0.000	0.000	0.000	60.181	3.105	0.000	11.447	33.681	0.000	0.000
1961	171.385	60.041	0.000	0.000	0.000	0.000	0.000	60.041	3.109	0.000	69.830	72.086	58.414	0.000
1962	48.759	60.041	0.000	0.000	0.000	0.000	0.000	60.041	3.396	0.000	11.416	45.991	0.000	0.000
1963	65.763	60.041	0.000	0.000	0.000	0.000	0.000	60.041	2.439	0.000	11.416	37.858	0.000	0.000
1964	84.797	60.181	0.000	0.000	0.000	0.000	0.000	60.181	2.424	0.000	11.447	49.160	0.000	0.558
1965	90.407	60.041	0.000	0.000	0.000	0.000	0.000	60.041	3.848	0.000	14.528	61.150	3.112	0.000
1966	65.771	60.041	0.000	0.000	0.000	0.000	0.000	60.041	3.309	0.000	11.416	52.155	0.000	0.000
1967	116.086	60.041	0.000	0.000	0.000	0.000	0.000	60.041	3.852	0.000	31.022	73.326	19.606	0.000
1968	87.584	60.181	0.000	0.000	0.000	0.000	0.000	60.181	4.073	0.000	33.250	63.405	21.803	0.000
1969	29.819	60.041	0.000	0.000	0.000	0.000	0.000	60.041	2.748	0.000	11.416	19.019	0.000	0.000
1970	184.351	60.041	0.000	0.000	0.000	0.000	0.000	60.041	1.821	0.000	91.753	70.742	82.872	23.985
1971	205.787	60.041	0.000	0.000	0.000	0.000	0.000	60.041	3.768	0.000	148.247	64.471	136.831	0.000
1972	60.270	60.181	0.000	0.000	0.000	0.000	0.000	60.181	3.472	0.000	11.447	49.641	0.000	0.000
1973	134.297	60.041	0.000	0.000	0.000	0.000	0.000	60.041	3.876	0.000	53.271	66.749	41.855	0.000
1974	44.096	60.041	0.000	0.000	0.000	0.000	0.000	60.041	3.005	0.000	11.416	36.383	0.000	0.000
1975	183.580	60.041	0.000	0.000	0.000	0.000	0.000	60.041	2.205	0.000	101.892	66.606	91.542	11.980
1976	327.259	60.181	0.000	0.000	0.000	0.000	0.000	60.181	4.281	0.000	259.615	69.788	248.168	0.000
1977	287.449	60.041	0.000	0.000	0.000	0.000	0.000	60.041	3.621	0.000	217.708	75.866	206.292	0.000
1978	269.966	60.041	0.000	0.000	0.000	0.000	0.000	60.041	3.940	0.000	209.989	71.861	198.573	0.000
1979	140.290	60.041	0.000	0.000	0.000	0.000	0.000	60.041	4.216	0.000	85.576	62.318	74.160	0.000
1980	105.596	60.181	0.000	0.000	0.000	0.000	0.000	60.181	3.635	0.000	34.785	69.312	23.338	0.000
MEAN	131.177	60.081	0.000	0.000	0.000	0.000	0.000	60.081	3.340	0.000	68.709	57.694	57.455	1.739

***** SUMMARY OF SHORTAGE *****

5 % OF DEMAND (MCM) = 3.004

LESS THAN 5 % (YEAR) = 1

GREATER OR EQUAL TO 5 % (YEAR) = 2

TOTAL OF SHORTAGE (YEAR) = 3

Table A-4-18 Water Balance Simulation of the Soan River (S-1)

SUMMARY OF M-1 DAM RESERVOIR OPERATION CASE = 1

PERIOD	INFLOW	WATER DEMAND: WATER SUPPLY ISLAMA	RAWALP	INDUSTRIAL WAH	TAXILA	AGRICULTURE RIGHT	LEFT	TOTAL	EVPO LOSS	SEEPAGE LOSS	RELEASE	STORAGE	SPILL	SHORT
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	18.043	23.710	0.000	0.000	0.000	0.000	0.000	23.710	1.366	0.000	2.776	9.641	0.000	0.000
1961	37.433	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.427	0.000	2.769	19.224	0.000	0.000
1962	32.881	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.415	0.000	4.357	23.420	1.588	0.742
1963	54.689	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.619	0.000	29.877	22.957	27.108	0.000
1964	43.060	23.710	0.000	0.000	0.000	0.000	0.000	23.710	1.927	0.000	19.674	20.706	16.897	0.000
1965	22.368	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.987	0.000	2.769	14.663	0.000	0.000
1966	30.605	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.570	0.000	2.769	17.274	0.000	0.000
1967	35.307	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.656	0.000	2.769	24.500	0.000	0.000
1968	50.947	23.710	0.000	0.000	0.000	0.000	0.000	23.710	1.914	0.000	27.530	22.293	24.754	0.000
1969	20.811	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.527	0.000	2.769	15.153	0.000	0.000
1970	56.457	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.499	0.000	23.475	22.980	20.706	0.000
1971	46.500	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.699	0.000	23.012	21.114	20.243	0.000
1972	13.925	23.710	0.000	0.000	0.000	0.000	0.000	23.710	1.478	0.000	2.776	7.450	0.000	0.375
1973	33.404	23.655	0.000	0.000	0.000	0.000	0.000	23.655	0.993	0.000	2.534	18.020	0.000	4.704
1974	25.567	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.247	0.000	2.734	17.402	0.000	1.485
1975	32.234	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.414	0.000	4.161	20.935	1.393	0.529
1976	71.496	23.710	0.000	0.000	0.000	0.000	0.000	23.710	2.084	0.000	45.763	20.874	42.987	0.000
1977	54.034	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.570	0.000	29.834	19.849	27.065	0.000
1978	55.734	23.655	0.000	0.000	0.000	0.000	0.000	23.655	1.527	0.000	26.423	23.978	23.654	0.000
1979	34.552	23.655	0.000	0.000	0.000	0.000	0.000	23.655	2.028	0.000	12.164	20.684	9.395	0.000
1980	28.425	23.710	0.000	0.000	0.000	0.000	0.000	23.710	1.839	0.000	2.776	20.783	0.000	0.000
MEAN	38.022	23.670	0.000	0.000	0.000	0.000	0.000	23.670	1.609	0.000	13.034	19.233	10.276	0.373

***** SUMMARY OF SHORTAGE *****

5 % OF DEMAND (MCM) = 1.184

LESS THAN 5 % (YEAR) = 3

GREATER OR EQUAL TO 5 % (YEAR) = 2

TOTAL OF SHORTAGE (YEAR) = 5

Table A-4-19 Water Balance Simulation of the Malal Kas (M-1)

SUMMARY OF KL-1 RESERVOIR OPERATION CASE = 7

PERIOD	INFLOW	WATER DEMAND: WATER SUPPLY ISLAMA	WATER SUPPLY RAWALP	INDUSTRIAL WAH	INDUSTRIAL TAXILA	AGRICULTURE RIGHT	AGRICULTURE LEFT	TOTAL	EVPO LOSS	SEEPAGE LOSS	RELEASE	STORAGE	SPILL	SHORT
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	49.474	0.000	33.942	0.000	0.000	0.000	0.000	33.942	3.054	0.000	16.294	33.084	9.400	0.000
1961	103.922	0.000	33.863	0.000	0.000	0.000	0.000	33.863	3.250	0.000	62.494	37.397	55.619	0.000
1962	90.634	0.000	33.863	0.000	0.000	0.000	0.000	33.863	2.813	0.000	53.196	41.139	46.382	3.041
1963	136.580	0.000	33.863	0.000	0.000	0.000	0.000	33.863	2.939	0.000	103.417	39.206	96.600	1.765
1964	102.933	0.000	33.942	0.000	0.000	0.000	0.000	33.942	3.095	0.000	71.387	33.715	64.493	0.000
1965	62.986	0.000	33.863	0.000	0.000	0.000	0.000	33.863	3.340	0.000	28.886	30.611	22.011	0.000
1966	81.473	0.000	33.863	0.000	0.000	0.000	0.000	33.863	3.270	0.000	41.294	33.656	34.419	0.000
1967	99.359	0.000	33.863	0.000	0.000	0.000	0.000	33.863	3.216	0.000	54.169	41.767	47.294	0.000
1968	135.565	0.000	33.942	0.000	0.000	0.000	0.000	33.942	3.182	0.000	100.036	40.171	93.143	0.000
1969	58.019	0.000	33.863	0.000	0.000	0.000	0.000	33.863	3.141	0.000	23.870	37.315	16.995	0.000
1970	142.209	0.000	33.863	0.000	0.000	0.000	0.000	33.863	3.165	0.000	105.122	37.373	98.247	0.000
1971	123.802	0.000	33.863	0.000	0.000	0.000	0.000	33.863	3.002	0.000	89.715	34.593	82.840	0.000
1972	40.285	0.000	33.942	0.000	0.000	0.000	0.000	33.942	2.983	0.000	10.190	27.762	3.296	0.000
1973	101.280	0.000	33.863	0.000	0.000	0.000	0.000	33.863	3.167	0.000	57.385	34.627	50.510	0.000
1974	76.775	0.000	33.863	0.000	0.000	0.000	0.000	33.863	2.566	0.000	47.881	32.595	41.536	6.128
1975	93.815	0.000	33.863	0.000	0.000	0.000	0.000	33.863	2.817	0.000	57.061	34.124	50.354	1.624
1976	189.557	0.000	33.942	0.000	0.000	0.000	0.000	33.942	3.259	0.000	151.239	35.240	144.346	0.000
1977	128.544	0.000	33.863	0.000	0.000	0.000	0.000	33.863	3.019	0.000	88.739	38.162	81.864	0.000
1978	166.162	0.000	33.863	0.000	0.000	0.000	0.000	33.863	2.950	0.000	129.112	38.398	122.238	0.000
1979	93.196	0.000	33.863	0.000	0.000	0.000	0.000	33.863	3.199	0.000	59.294	35.237	52.420	0.000
1980	79.302	0.000	33.942	0.000	0.000	0.000	0.000	33.942	3.226	0.000	42.143	35.226	35.250	0.000
MEAN	102.660	0.000	33.886	0.000	0.000	0.000	0.000	33.886	3.079	0.000	66.330	35.781	59.488	0.598

***** SUMMARY OF SHORTAGE *****

5 % OF DEMAND (MCM) = 1.694

LESS THAN 5 % (YEAR) = 1

GREATER OR EQUAL TO 5 % (YEAR) = 3

TOTAL OF SHORTAGE (YEAR) = 4

Table A-4-20 Water Balance Simulation of the Kurang River (KL-1)

SUMMARY OF L-1 DAM RESERVOIR OPERATION CASE = 1

PERIOD	INFLOW	WATER DEMAND - WATER SUPPLY - ISLAMA	WATER SUPPLY - RAWALP	INDUSTRIAL - WAH	INDUSTRIAL - TAXILA	AGRICULTURE - RIGHT	AGRICULTURE - LEFT	TOTAL	EVPO LOSS	SEEPAGE LOSS	RELEASE	STORAGE	SPILL	SHORT
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	54.590	73.001	0.000	0.000	0.000	0.000	0.000	73.001	3.707	0.000	9.550	46.981	0.000	0.000
1961	143.428	72.831	0.000	0.000	0.000	0.000	0.000	72.831	3.652	0.000	10.731	103.196	1.207	0.000
1962	44.963	72.831	0.000	0.000	0.000	0.000	0.000	72.831	4.331	0.000	9.524	61.471	0.000	0.000
1963	70.817	72.831	0.000	0.000	0.000	0.000	0.000	72.831	2.401	0.000	9.524	50.855	0.000	3.323
1964	100.449	73.001	0.000	0.000	0.000	0.000	0.000	73.001	2.617	0.000	9.550	66.136	0.000	0.000
1965	79.848	72.831	0.000	0.000	0.000	0.000	0.000	72.831	4.252	0.000	9.524	59.377	0.000	0.000
1966	89.601	72.831	0.000	0.000	0.000	0.000	0.000	72.831	3.306	0.000	9.524	63.317	0.000	0.000
1967	113.189	72.831	0.000	0.000	0.000	0.000	0.000	72.831	4.566	0.000	9.524	89.584	0.000	0.000
1968	64.682	73.001	0.000	0.000	0.000	0.000	0.000	73.001	4.467	0.000	9.550	67.247	0.000	0.000
1969	45.632	72.831	0.000	0.000	0.000	0.000	0.000	72.831	2.451	0.000	9.524	28.073	0.000	0.000
1970	123.344	72.831	0.000	0.000	0.000	0.000	0.000	72.831	2.185	0.000	7.325	100.449	0.000	33.757
1971	135.332	72.831	0.000	0.000	0.000	0.000	0.000	72.831	4.798	0.000	63.411	94.741	53.887	0.000
1972	63.979	73.001	0.000	0.000	0.000	0.000	0.000	73.001	4.526	0.000	9.550	71.643	0.000	0.000
1973	107.598	72.831	0.000	0.000	0.000	0.000	0.000	72.831	4.643	0.000	9.524	92.242	0.000	0.000
1974	46.828	72.831	0.000	0.000	0.000	0.000	0.000	72.831	3.766	0.000	9.524	52.948	0.000	0.000
1975	142.217	72.831	0.000	0.000	0.000	0.000	0.000	72.831	2.653	0.000	31.415	97.218	22.153	9.221
1976	220.993	73.001	0.000	0.000	0.000	0.000	0.000	73.001	5.819	0.000	138.342	101.049	128.792	0.000
1977	198.615	72.831	0.000	0.000	0.000	0.000	0.000	72.831	4.869	0.000	113.753	108.211	104.229	0.000
1978	185.041	72.831	0.000	0.000	0.000	0.000	0.000	72.831	5.296	0.000	112.246	102.879	102.722	0.000
1979	106.095	72.831	0.000	0.000	0.000	0.000	0.000	72.831	5.719	0.000	39.498	90.925	29.974	0.000
1980	112.064	73.001	0.000	0.000	0.000	0.000	0.000	73.001	4.798	0.000	25.325	99.865	15.775	0.000
MEAN	107.110	72.879	0.000	0.000	0.000	0.000	0.000	72.879	4.039	0.000	31.259	78.496	21.845	2.205

***** SUMMARY OF SHORTAGE *****

5 % OF DEMAND (MCM) = 3.644

LESS THAN 5 % (YEAR) = 1

GREATER OR EQUAL TO 5 % (YEAR) = 2

TOTAL OF SHORTAGE (YEAR) = 3

Table A-4-21 Water Balance Simulation of the Ling River (L-1)

SUMMARY OF SL-1 DAM RESERVOIR OPERATION CASE = 1

PERIOD	INFLOW	WATER DEMAND: WATER SUPPLY ISLAMA	WATER SUPPLY RAWALP	INDUSTRIAL WAH	INDUSTRIAL TAXILA	AGRICULTURE RIGHT	AGRICULTURE LEFT	TOTAL	EVPO LOSS	SEEPAGE LOSS	RELEASE	STORAGE	SPILL	SHORT
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1960	19.712	39.932	0.000	0.000	0.000	0.000	0.000	39.932	3.716	0.000	2.606	26.839	0.000	0.000
1961	46.863	39.839	0.000	0.000	0.000	0.000	0.000	39.839	2.774	0.000	2.599	28.983	0.000	0.493
1962	99.352	39.839	0.000	0.000	0.000	0.000	0.000	39.839	3.388	0.000	22.463	72.514	20.255	10.495
1963	31.445	39.839	0.000	0.000	0.000	0.000	0.000	39.839	5.425	0.000	2.599	56.096	0.000	0.000
1964	31.150	39.932	0.000	0.000	0.000	0.000	0.000	39.932	4.142	0.000	2.606	40.565	0.000	0.000
1965	51.578	39.839	0.000	0.000	0.000	0.000	0.000	39.839	4.212	0.000	2.599	45.493	0.000	0.000
1966	39.063	39.839	0.000	0.000	0.000	0.000	0.000	39.839	3.730	0.000	2.599	38.388	0.000	0.000
1967	55.061	39.839	0.000	0.000	0.000	0.000	0.000	39.839	3.308	0.000	2.599	47.702	0.000	0.000
1968	48.162	39.932	0.000	0.000	0.000	0.000	0.000	39.932	3.980	0.000	2.606	49.346	0.000	0.000
1969	49.522	39.839	0.000	0.000	0.000	0.000	0.000	39.839	4.036	0.000	2.599	52.393	0.000	0.000
1970	61.596	39.839	0.000	0.000	0.000	0.000	0.000	39.839	4.737	0.000	2.599	66.814	0.000	0.000
1971	47.291	39.839	0.000	0.000	0.000	0.000	0.000	39.839	5.543	0.000	2.599	66.123	0.000	0.000
1972	19.947	39.932	0.000	0.000	0.000	0.000	0.000	39.932	4.810	0.000	2.606	38.722	0.000	0.000
1973	58.948	39.839	0.000	0.000	0.000	0.000	0.000	39.839	3.383	0.000	2.599	52.062	0.000	0.214
1974	25.418	39.839	0.000	0.000	0.000	0.000	0.000	39.839	3.607	0.000	2.599	31.435	0.000	0.000
1975	44.767	39.839	0.000	0.000	0.000	0.000	0.000	39.839	2.620	0.000	2.402	39.583	0.000	8.613
1976	73.779	39.932	0.000	0.000	0.000	0.000	0.000	39.932	3.919	0.000	2.606	66.906	0.000	0.000
1977	74.664	39.839	0.000	0.000	0.000	0.000	0.000	39.839	5.606	0.000	22.262	73.861	19.664	0.000
1978	84.360	39.839	0.000	0.000	0.000	0.000	0.000	39.839	6.126	0.000	33.840	78.415	31.242	0.000
1979	40.081	39.839	0.000	0.000	0.000	0.000	0.000	39.839	6.581	0.000	2.599	69.476	0.000	0.000
1980	49.187	39.932	0.000	0.000	0.000	0.000	0.000	39.932	5.898	0.000	2.606	70.227	0.000	0.000
MEAN	50.093	39.866	0.000	0.000	0.000	0.000	0.000	39.866	4.359	0.000	5.961	52.950	3.389	0.944

***** SUMMARY OF SHORTAGE *****

5 % OF DEMAND (MCM) = 1.993

LESS THAN 5 % (YEAR) = 2

GREATER OR EQUAL TO 5 % (YEAR) = 2

TOTAL OF SHORTAGE (YEAR) = 4

Table A-4-22 Water Balance Simulation of the Sil River (SL-1)