Table 8.6

Estimated Return Periods of Selected Design Years
(in years)

(a) Regional Sub-Model

Planning Unit	1970	1971	1972	1973	1974	1985	1986	1987	1988	1989
8	4	–	*	8	(8)	(2)	(4)	(6)	11	*
12	(3)	–	*	5	12	(2)	(3)	16	(5)	(2)
13	4	–	*	(4)	(8)	(2)	(3)	22	8	(2)
14	4	–	*	(3)	(15)	(2)	*	9	21	*
15	5	–	*	(3)	10	*	*	(10)	39	*

(b) Gaibandha Model

Planning Unit	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
7 (a)	*	(2)	*	(2)	(3)	5	(2)	13	16	2
7 (b)	*	(2)	(2)	2	4	(8)	*	14	13	(2)
7 (c)	2	(2)	*	*	(3)	4	*	14	13	(4)
7 (d)	2	(2)	*	*	(4)	6	*	39	15	(4)

Notes: Values for years not selected as design years in the particular planning unit appear in parentheses.

An asterisk indicates a return period of less than 1.5 years.

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Table 8.7

Example output: Comparison of options for Level Exceedance-Duration

```
 !  DATA FILE      : REG-WITH.RDF          BOUNDARY FILE: R70-WITH.BSF     !
 !  RESULT FILE    : R70-WITH.RRF          CALCULATED : 29-SEP-1992, 14:48!
 !  DATA FILE      : REG-WOUT.RDF          BOUNDARY FILE: R70-WOUT.BSF     !
 !  RESULT FILE    : R70-WOUT.RRF          CALCULATED : 17-SEP-1992, 21:11!
MIKE-11 files      : ROO-F-AL.TXT,ROO-W-AL.TXT
This analysis file: F-ATROO3.17W
```

MAXIMUM LEVELS AND CHANGES FOR GIVEN DURATIONS

ATRAI (ATR) Chainage 3.170

	DURATION IN DAYS									
Year	1	3	5	10	15	20	30	45	60	90
First Run (F)										
1970	19.65	19.62	19.51	19.30	19.07	19.07	17.78	16.18	15.46	15.22
1972	19.50	19.27	18.70	17.03	16.36	16.36	15.23	15.02	14.97	14.54
1973	19.74	19.62	19.03	17.98	17.98	16.46	15.54	14.76	14.45	14.45
1974	19.34	19.29	18.98	18.86	18.79	18.03	16.08	15.96	14.72	14.72
1985	19.11	19.09	19.04	18.26	17.27	17.27	15.98	15.30	14.73	14.64
1986	18.70	18.27	17.71	16.53	16.50	16.33	15.69	15.36	15.36	14.78
1987	19.30	19.28	19.26	19.07	18.29	16.98	16.98	16.00	16.00	15.86
1988	19.31	19.27	19.15	18.50	17.59	17.59	15.94	15.46	15.19	15.09
1989	19.04	18.91	18.50	17.38	16.95	16.95	16.80	16.00	15.81	15.39
max.	19.74	19.62	19.51	19.30	19.07	19.07	17.78	16.18	16.00	15.86
mean	19.30	19.18	18.88	18.10	17.64	17.22	16.22	15.56	15.19	14.97
min.	18.70	18.27	17.71	16.53	16.36	16.33	15.23	14.76	14.45	14.45
Second Run (W)										
1970	19.64	19.61	19.50	19.30	19.05	19.05	17.75	16.16	15.44	15.25
1972	19.49	19.27	18.70	17.00	16.34	16.34	15.22	15.02	14.97	14.54
1973	19.74	19.62	19.03	17.95	17.95	16.40	15.54	14.78	14.46	14.46
1974	19.32	19.28	18.96	18.84	18.78	18.00	15.99	15.93	14.74	14.74
1985	19.10	19.08	19.03	18.25	17.23	17.23	15.89	15.29	14.75	14.67
1986	18.69	18.25	17.70	16.51	16.48	16.29	15.65	15.34	15.34	14.77
1987	19.28	19.27	19.25	19.05	18.26	16.89	16.89	16.00	16.00	15.82
1988	19.30	19.26	19.13	18.48	17.54	17.54	15.88	15.48	15.20	15.11
1989	19.03	18.91	18.48	17.35	16.91	16.91	16.76	15.98	15.81	15.37
max.	19.74	19.62	19.50	19.30	19.05	19.05	17.75	16.16	16.00	15.82
mean	19.29	19.17	18.86	18.08	17.62	17.18	16.18	15.55	15.19	14.97
min.	18.69	18.25	17.70	16.51	16.34	16.29	15.22	14.78	14.46	14.46
Difference										
1970	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.03	-0.01	-0.03	0.02
1972	0.00	0.00	0.00	-0.03	-0.02	-0.02	-0.01	0.00	0.00	0.00
1973	-0.01	0.00	0.00	-0.03	-0.03	-0.07	0.00	0.02	0.01	0.01
1974	-0.02	-0.01	-0.02	-0.02	-0.01	-0.03	-0.09	-0.03	0.02	0.02
1985	-0.01	-0.01	-0.01	-0.01	-0.04	-0.04	-0.09	-0.01	0.02	0.03
1986	-0.01	-0.02	-0.01	-0.02	-0.02	-0.04	-0.03	-0.01	-0.01	0.00
1987	-0.01	-0.01	-0.01	-0.01	-0.03	-0.08	-0.08	-0.01	-0.01	-0.04
1988	-0.01	-0.01	-0.01	-0.02	-0.05	-0.05	-0.05	0.02	0.00	0.01
1989	-0.01	-0.01	-0.02	-0.04	-0.04	-0.04	-0.04	-0.02	-0.01	-0.02
max.	0.00	0.00	0.00	-0.01	-0.01	-0.01	0.00	0.02	0.02	0.03
mean	-0.01	-0.01	-0.01	-0.02	-0.03	-0.04	-0.05	-0.01	0.00	0.00
min.	-0.02	-0.02	-0.02	-0.04	-0.05	-0.08	-0.09	-0.03	-0.03	-0.04

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Table 8.8

Example Output: Comparison of Options for 10-Day Time Series

```
!  DATA FILE      : REGSUB-P.RDF       BOUNDARY FILE: R8589M-P.BSF      !
!  RESULT FILE    : R85-89-P.RRF       CALCULATED : 26-APR-1992, 17:34!
!  DATA FILE      :   REG-C1.RDF       BOUNDARY FILE: R8589-C1.BSF      !
!  RESULT FILE    : R8589-C1.RRF       CALCULATED : 19-AUG-1992, 13:11!
MIKE-11 files     : R00-P-BL.TXT,R00-C-BL.TXT
This analysis file: PLATR110.42C
```

10-DAY MEAN LEVELS AND CHANGES
ATRAI (ATR) Chainage 110.420

		1985			1986		
		Run P	Run C	Diff	Run P	Run C	Diff
Apr	1	6.23	6.21	-0.02	6.25	6.26	0.02
	2	6.18	6.19	0.01	6.24	6.26	0.02
	3	6.32	6.33	0.01	6.36	6.37	0.01
May	1	6.60	6.59	-0.01	6.83	6.86	0.03
	2	6.75	6.72	-0.03	6.98	6.96	-0.02
	3	7.06	6.95	-0.11	7.21	7.27	0.06
Jun	1	8.31	8.29	-0.02	7.00	6.94	-0.06
	2	8.72	8.81	0.10	7.03	6.97	-0.06
	3	8.83	8.91	0.08	7.89	7.92	0.04
Jul	1	9.33	9.43	0.11	9.07	9.18	0.12
	2	10.02	10.20	0.18	9.67	9.95	0.28
	3	10.57	10.86	0.28	10.02	10.23	0.20
Aug	1	11.09	11.46	0.38	10.25	10.46	0.21
	2	11.09	11.30	0.21	10.44	10.66	0.22
	3	10.84	10.89	0.05	10.36	10.44	0.08
Sep	1	10.78	10.86	0.08	10.34	10.46	0.12
	2	10.94	11.07	0.13	10.44	10.61	0.17
	3	11.05	11.17	0.12	10.75	10.95	0.19
Oct	1	11.08	11.16	0.08	11.17	11.23	0.05
	2	10.91	10.93	0.02	11.48	11.58	0.10
	3	10.83	10.91	0.07	11.44	11.55	0.11
Nov	1	10.71	10.79	0.08	11.08	11.11	0.02
	2	10.39	10.29	-0.10	10.67	10.60	-0.07
	3	9.95	9.70	-0.26	10.26	10.04	-0.21
Dec	1	9.45	9.06	-0.39	9.81	9.48	-0.33
	2	8.80	8.16	-0.65	9.36	8.89	-0.47
	3	7.96	7.45	-0.51	8.80	8.07	-0.73
Jan	1	7.34	7.08	-0.26	8.08	7.49	-0.59
	2	6.95	6.96	0.01	7.60	7.14	-0.46
	3	6.77	6.83	0.06	7.08	6.97	-0.12
Feb	1	6.61	6.66	0.05	6.65	6.72	0.07
	2	6.52	6.57	0.04	6.47	6.57	0.09
	3	6.47	6.51	0.04	6.41	6.48	0.07
Mar	1	6.41	6.44	0.04	6.35	6.41	0.05
	2	6.35	6.39	0.04	6.37	6.41	0.04
	3	6.27	6.30	0.03	6.32	6.36	0.04

(Remaining years would be on additional pages)

Table 8.8

Example Output: Comparison of Options for 10 Day Time Series

```
!  DATA FILE      : REG-WITH.RDF          BOUNDARY FILE: R70-WITH.BSF     !
!  RESULT FILE    : R70-WITH.RRF          CALCULATED : 29-SEP-1992, 14:48!
!  DATA FILE      : REG-WOUT.RDF          BOUNDARY FILE: R70-WOUT.BSF     !
!  RESULT FILE    : R70-WOUT.RRF          CALCULATED : 17-SEP-1992, 21:11!
MIKE-11 files       : R00-F-AL.TXT,R00-W-AL.TXT
This analysis file: FLATR003.17W
```

10-DAY MEAN LEVELS AND CHANGES

ATRAI (ATR) Chainage 3.170

		1970			1972		
		Run F	Run W	Diff	Run F	Run W	Diff
Apr	1	13.65	13.65	0.00	13.49	13.44	-0.04
	2	13.62	13.62	0.00	13.44	13.42	-0.03
	3	13.69	13.69	0.00	13.42	13.44	0.02
May	1	13.80	13.80	0.00	13.44	13.40	-0.05
	2	13.65	13.65	0.00	13.40	13.38	-0.01
	3	13.78	13.71	-0.07	13.38	13.43	0.05
Jun	1	13.57	14.47	0.90	13.43	13.63	0.20
	2	14.47	14.59	0.12	13.63	13.82	0.19
	3	14.60	15.69	1.09	13.82	14.95	1.13
Jul	1	15.73	15.82	0.09	14.95	14.87	-0.08
	2	15.85	17.59	1.74	14.87	14.54	-0.33
	3	17.62	19.06	1.44	14.56	16.55	1.99
Aug	1	19.21	19.24	0.03	16.74	18.04	1.30
	2	19.25	19.02	-0.23	18.06	15.82	-2.24
	3	18.88	16.43	-2.44	15.79	15.44	-0.35
Sep	1	16.36	15.55	-0.82	15.46	16.35	0.88
	2	15.53	16.12	0.59	16.35	15.61	-0.74
	3	16.11	16.72	0.61	15.63	15.47	-0.16
Oct	1	16.73	16.34	-0.39	15.47	15.58	0.11
	2	16.36	14.99	-1.36	15.59	14.72	-0.88
	3	14.95	14.30	-0.65	14.69	14.33	-0.37
Nov	1	14.30	14.01	-0.29	14.31	14.18	-0.13
	2	14.03	13.82	-0.21	14.18	14.05	-0.13
	3	13.83	13.73	-0.10	14.05	13.99	-0.07
Dec	1	13.73	13.65	-0.08	13.99	13.93	-0.05
	2	13.65	13.59	-0.06	13.93	13.89	-0.04
	3	13.59	13.63	0.03	13.89	13.86	-0.03
Jan	1	13.63	13.66	0.03	13.86	13.84	-0.02
	2	13.66	13.63	-0.03	13.84	13.81	-0.03
	3	13.62	13.61	-0.01	13.80	13.74	-0.06
Feb	1	13.61	13.52	-0.09	13.74	13.70	-0.03
	2	13.52	13.45	-0.07	13.70	13.65	-0.05
	3	13.45	13.42	-0.03	13.65	13.60	-0.05
Mar	1	13.43	13.41	-0.02	13.61	13.66	0.05
	2	13.41	13.37	-0.05	13.66	13.48	-0.17
	3	13.36	13.35	-0.02	13.48	13.42	-0.06

Table 8.9

Example Output: Comparison of Options over 25 Year run
(for Level Exceedance Duration)

```
  !  DATA FILE      : REG-WOUT.RDF           BOUNDARY FILE: R65-WO-M.BSF     !
  !  RESULT FILE    : R65-WO-M.RRF           CALCULATED : 20-SEP-1992, 18:20!
  !  DATA FILE      : REG-WITH.RDF           BOUNDARY FILE: R65-WITH.BSF     !
  !  RESULT FILE    : R65-WITH.RRF           CALCULATED : 29-SEP-1992, 17:34!
MIKE-11 files       : R65-W-AL.TXT,R65-F-AL.TXT   (also R70...., R75.... etc)
This analysis file: C-ATR026.17
```

CHANGE IN MAXIMUM LEVELS FOR GIVEN DURATIONS

ATRAI (ATR) Chainage 26.170

	DURATION IN DAYS									
Year	1	3	5	10	15	20	30	45	60	90
1965	0.14	0.14	0.15	0.16	0.19	0.20	0.23	0.06	0.07	0.14
1966	0.10	0.11	0.10	0.16	0.05	0.16	0.17	0.09	0.03	-0.23
1967	0.08	0.09	0.12	0.11	0.20	0.23	0.10	0.10	-0.02	-0.02
1968	0.13	0.15	0.15	0.15	0.25	0.18	0.19	0.29	-0.02	0.05
1969	0.11	0.13	0.14	0.10	0.22	0.18	0.10	0.14	0.03	0.00
1970	0.13	0.12	0.12	0.15	0.15	0.15	0.13	0.04	0.07	-0.15
1971										
1972	0.07	0.05	0.07	0.17	0.10	0.09	0.09	0.01	0.00	-0.03
1973	0.08	0.05	0.15	0.20	0.10	0.22	0.02	-0.10	0.00	-0.05
1974	0.15	0.15	0.16	0.17	0.14	0.18	0.09	0.14	0.06	-0.06
1975	0.11	0.17	0.16	0.10	0.18	0.18	0.11	0.11	-0.01	-0.10
1976	0.12	0.12	0.16	0.19	0.22	0.22	0.04	-0.09	0.01	-0.10
1977	0.11	0.09	0.07	0.23	0.15	0.12	-0.01	0.01	-0.06	-0.03
1978	0.10	0.12	0.07	0.30	0.30	0.19	0.11	0.18	0.08	-0.08
1979	0.08	0.09	0.12	0.10	0.22	0.17	0.11	-0.03	-0.03	-0.10
1980	0.14	0.15	0.13	0.14	0.14	0.18	0.14	0.12	0.02	0.02
1981	0.08	0.07	0.10	0.14	0.12	0.22	0.16	0.12	0.12	0.00
1982	0.10	0.10	0.07	0.14	0.17	0.11	0.11	0.04	0.00	-0.04
1983	0.11	0.12	0.14	0.16	0.20	0.12	0.09	0.09	0.07	-0.01
1984	0.12	0.12	0.14	0.15	0.19	0.19	0.19	0.00	0.08	-0.14
1985	0.13	0.14	0.15	0.24	0.17	0.17	0.18	0.08	-0.21	-0.26
1986	0.07	0.09	0.11	0.27	0.10	0.07	0.06	0.10	0.10	0.01
1987	0.15	0.14	0.13	0.11	0.15	0.27	0.27	0.01	0.01	0.22
1988	0.12	0.15	0.14	0.17	0.22	0.22	0.18	-0.07	-0.02	-0.08
1989	0.09	0.08	0.07	0.18	0.20	0.20	0.15	0.08	0.10	0.15
max.	0.15	0.17	0.16	0.30	0.30	0.27	0.27	0.29	0.12	0.22
mean	0.11	0.11	0.12	0.17	0.17	0.18	0.13	0.06	0.02	-0.04
min.	0.07	0.05	0.07	0.10	0.05	0.07	-0.01	-0.10	-0.21	-0.26
max yr	0.10	0.12	0.14	0.15	0.15	0.15	0.13	0.11	0.01	0.22
For return periods calculated by Blom formula (years)										
2	0.11	0.13	0.13	0.15	0.18	0.15	0.19	0.06	0.08	-0.03
5	0.10	0.10	0.13	0.15	0.14	0.23	0.13	0.13	0.02	-0.06
10	0.12	0.13	0.14	0.16	0.18	0.21	0.26	0.04	0.09	0.03
20	0.11	0.14	0.14	0.12	0.14	0.17	0.19	0.06	0.04	0.18
For return periods estimated by Gumbel Extreme Value Analysis (on upper half of points only)										
5	0.11	0.12	0.14	0.15	0.17	0.19	0.17	0.09	0.04	0.00
10	0.11	0.12	0.13	0.14	0.16	0.19	0.18	0.10	0.04	0.04
20	0.11	0.12	0.13	0.14	0.15	0.19	0.19	0.10	0.03	0.08
50	0.11	0.13	0.13	0.13	0.14	0.19	0.20	0.11	0.03	0.13
100	0.10	0.13	0.13	0.13	0.13	0.19	0.20	0.12	0.02	0.17

Table 8.10

Maximum Levels and Frequency Analysis for Present Condition

Station	Closest Node		Maximum Levels		Estimated Return Period Levels (model)			
	River	Ch'ge	Observed	Model	1-in 2	1-in 5	1-in 10	1-in-20
Nowhata	SIB	68.29	15.53	14.96	14.20	14.52	14.70	14.81
Mohadevpur	ATR	3.17	19.55	19.11	18.76	19.00	19.06	19.08
Naogaon	LJA	12.20	15.63	15.95	15.39	15.62	15.75	15.84
Atrai RB	ATR	54.00	14.31	14.27	13.70	13.94	13.99	14.13
Naldanga RB	SIB	114.99	13.94	13.65	13.12	13.40	13.48	13.55
Baral RB	BAR	106.62	12.70	12.34	10.65	11.08	11.61	11.84
Ullapara	BAN	205.78	13.17	11.57	10.46	10.97	11.25	11.40
Simulbari	BAN	54.96	19.22	18.33	17.01	17.48	18.18	18.25
Jafarganj	GHA	0.00	34.63	35.42	33.92	35.04	35.34	35.39
Gaibandha	GHA	154.56	22.19	22.65	21.31	21.77	22.07	22.34
Kaunia	TEE	0.00	30.46	30.81	30.28	30.53	30.61	30.75

Notes: Observed maxima refer to period of record at each station, model maxima to 25-year run.

The comparison is not strictly like-with-like because the Present Condition has the model configured in line with 1991 embankments which were not in identical conditions in previous years.The model considers BRE sealed which, actually, is not the present condition.

Comparison of observed and modelled maximum levels at flow stations is subject to the rating curves, the accuracy of which is doubtful at flood levels. (Flow stations are Mohadevpur, Naogaon, Jafarganj and Kaunia.)

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Table 8.11

Maximum Levels and Frequency Analysis for With-Project Condition

Station	Closest Node River	Closest Node Ch'ge	Maximum Level	Estimated Return Period Levels 1-in 2	1-in 5	1-in 10	1-in-20
Nowhata	SIB	68.29	16.15	15.62	16.03	16.14	16.17
Mohadevpur	ATR	3.17	19.74	19.12	19.54	19.66	19.70
Naogaon	LJA	12.20	16.43	15.69	15.99	16.05	16.27
Atrai RB	ATR	54.00	15.31	14.73	15.00	15.05	15.20
Naldanga RB	SIB	114.99	15.31	14.82	15.19	15.30	15.31
Baral RB	BAR	106.62	12.33	10.74	11.19	11.56	11.99
Ullapara	BAN	205.78	12.33	10.57	11.08	11.66	11.95
Simulbari	BAN	54.96	18.34	17.01	17.48	18.18	18.25
Jafarganj	GHA	0.00	33.88	32.98	33.25	33.38	33.77
Gaibandha	GHA	154.56	22.73	21.60	21.88	22.31	22.54
Kaunia	TEE	0.00	30.81	30.28	30.53	30.61	30.75

Table 8.12

Potential Changes in 5- and 20-Year Levels in Gaibandha Area

Model Node Code	Ch'ge	5-Year Event Present	5-Year Event Future	5-Year Event Change	20-Year Event Present	20-Year Event Future	20-Year Event Change
GHA	57.77	28.91	27.32	-1.59	29.48	27.96	-1.52
GHA	89.17	26.34	25.07	-1.27	26.94	25.77	-1.17
GHA	117.39	22.99	22.18	-0.81	23.59	22.62	-0.97
GHA	154.56	21.77	21.88	0.11	22.34	22.54	0.20
TEE	12.00	27.55	27.55	0.00	27.74	27.74	0.00
TEE	24.00	25.72	25.75	0.03	25.91	25.95	0.04
D1	10.00	22.51	22.35	-0.16	22.76	22.76	0.00
D1	30.00	21.81	21.80	-0.01	22.37	22.03	-0.34
D2	10.00	26.49	26.54	0.05	26.69	26.92	0.23
D2	30.00	25.61	24.93	-0.68	25.82	25.06	-0.76
D2	40.00	24.66	24.65	-0.01	25.00	25.94	0.94
D2	60.00	21.85	21.74	-0.11	22.39	22.02	-0.37
D2	80.00	21.79	21.72	-0.07	22.35	22.01	-0.34
D3	10.00	26.50	26.53	0.03	26.63	26.57	-0.06
D3	30.00	26.22	26.32	0.10	26.43	26.58	0.15
D5	10.00	25.06	24.62	-0.44	25.23	24.97	-0.26
D5	20.00	24.57	24.61	0.04	24.86	24.97	0.11
D5	30.00	22.64	22.46	-0.18	22.92	22.93	0.01
D5	50.00	22.53	22.46	-0.07	22.83	22.92	0.09
D6	10.00	22.60	23.04	0.44	22.89	23.48	0.59

Note: Present = Model Run – Present Condition

Future = Model Run – With Project

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13-Oct-92

Figure 2.1

Climatic Norms at Bogra

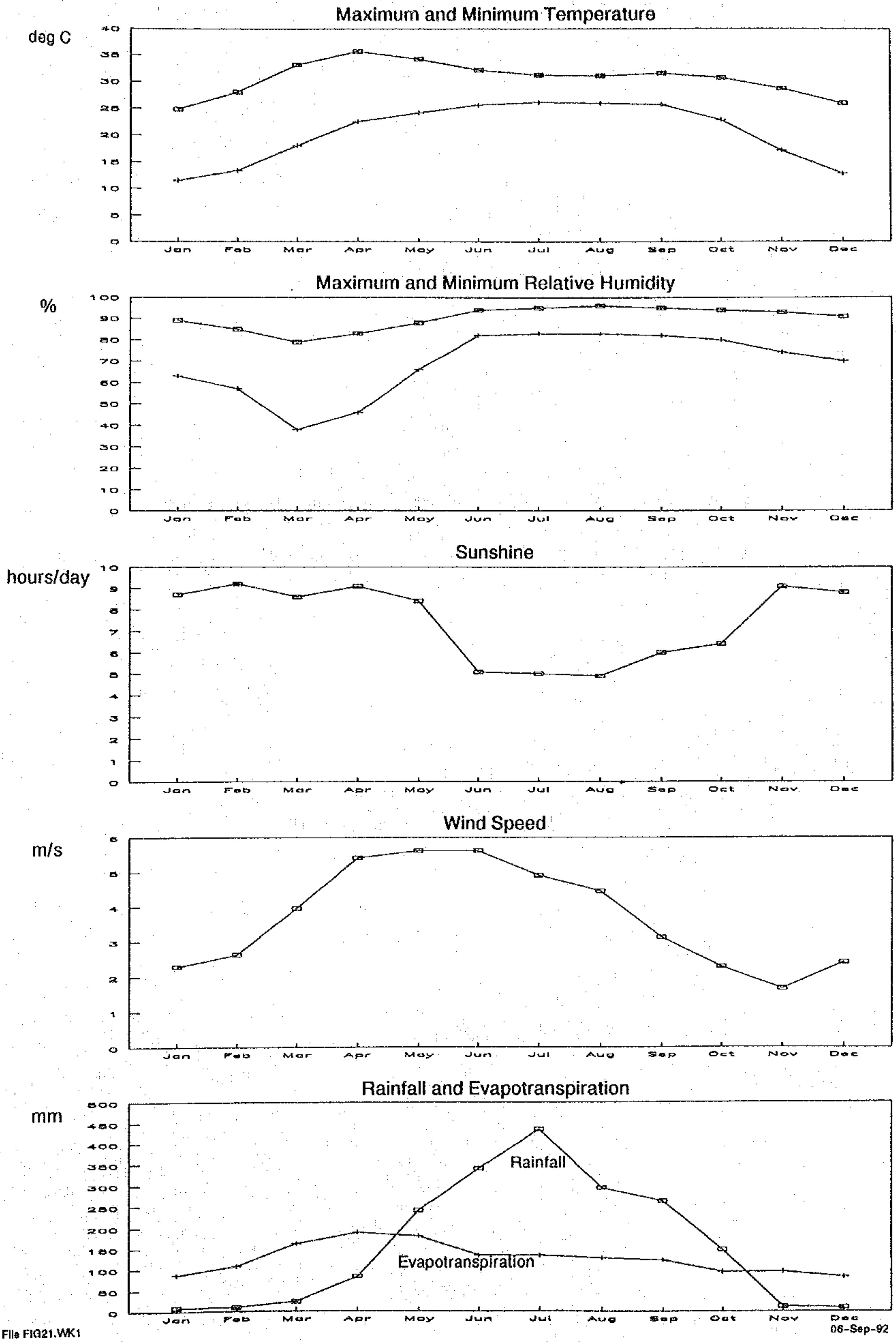


Figure 2.2

The Major Drainage Basins of Bangladesh

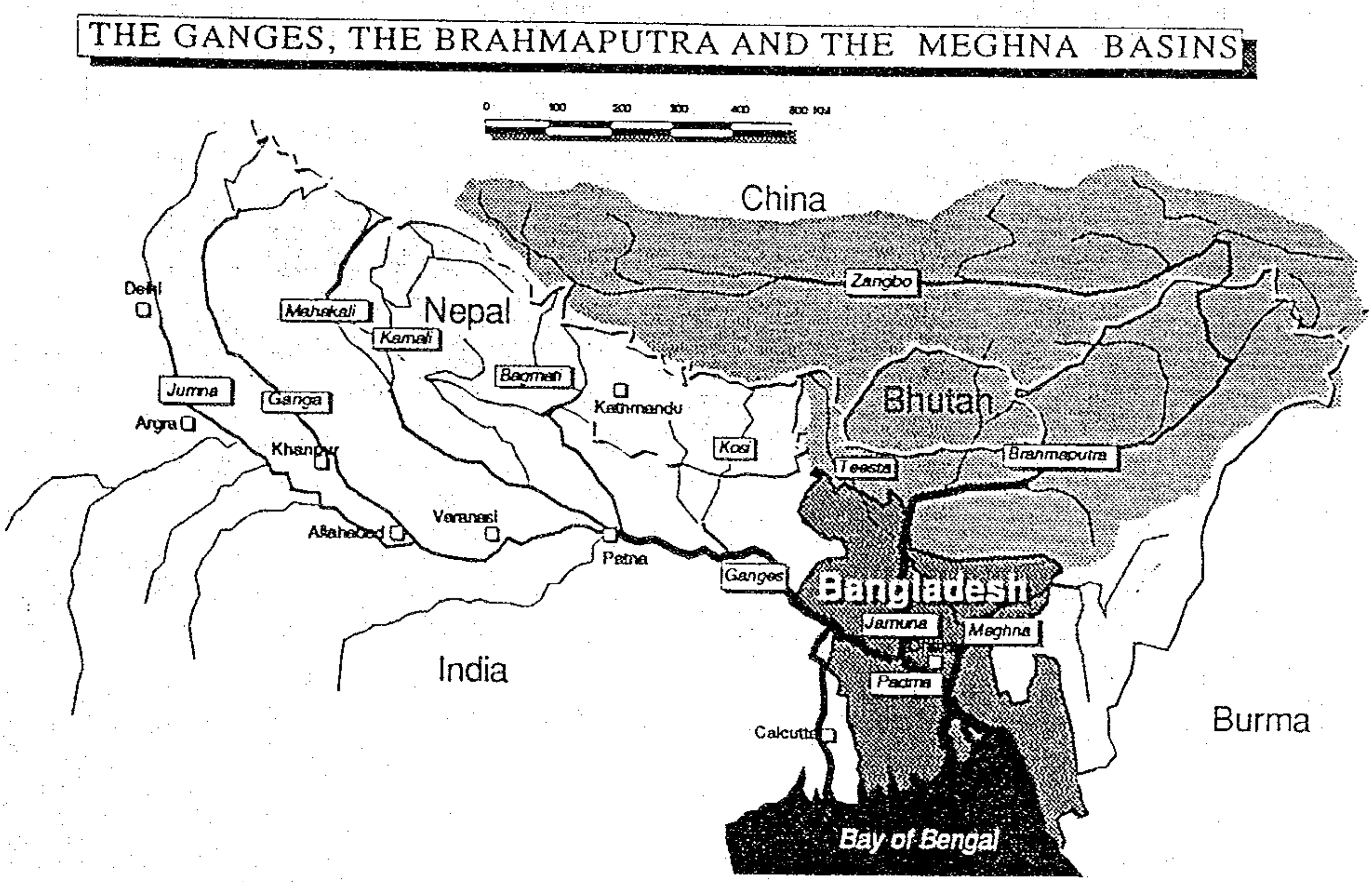
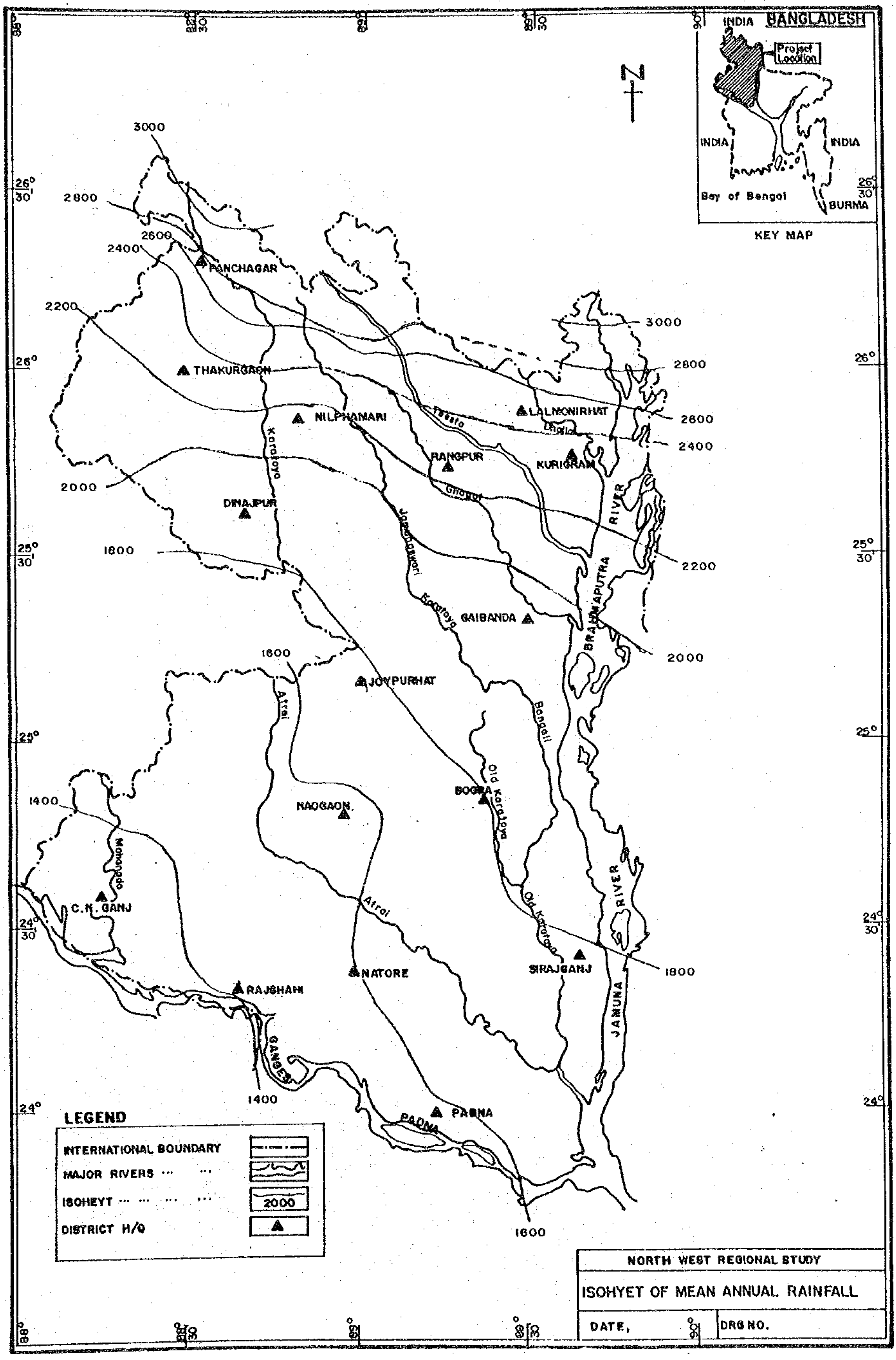


Figure 2.3



NORTH WEST REGIONAL STUDY

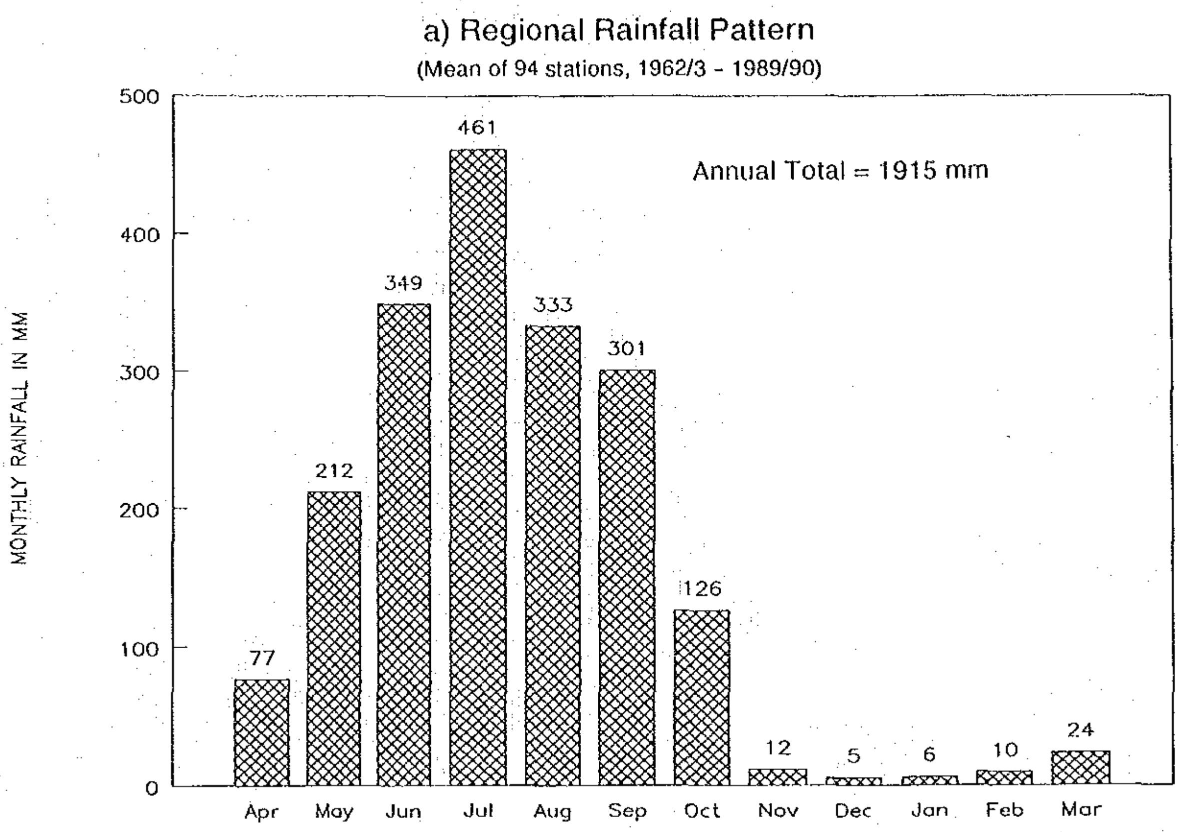
ISOHYET OF MEAN ANNUAL RAINFALL

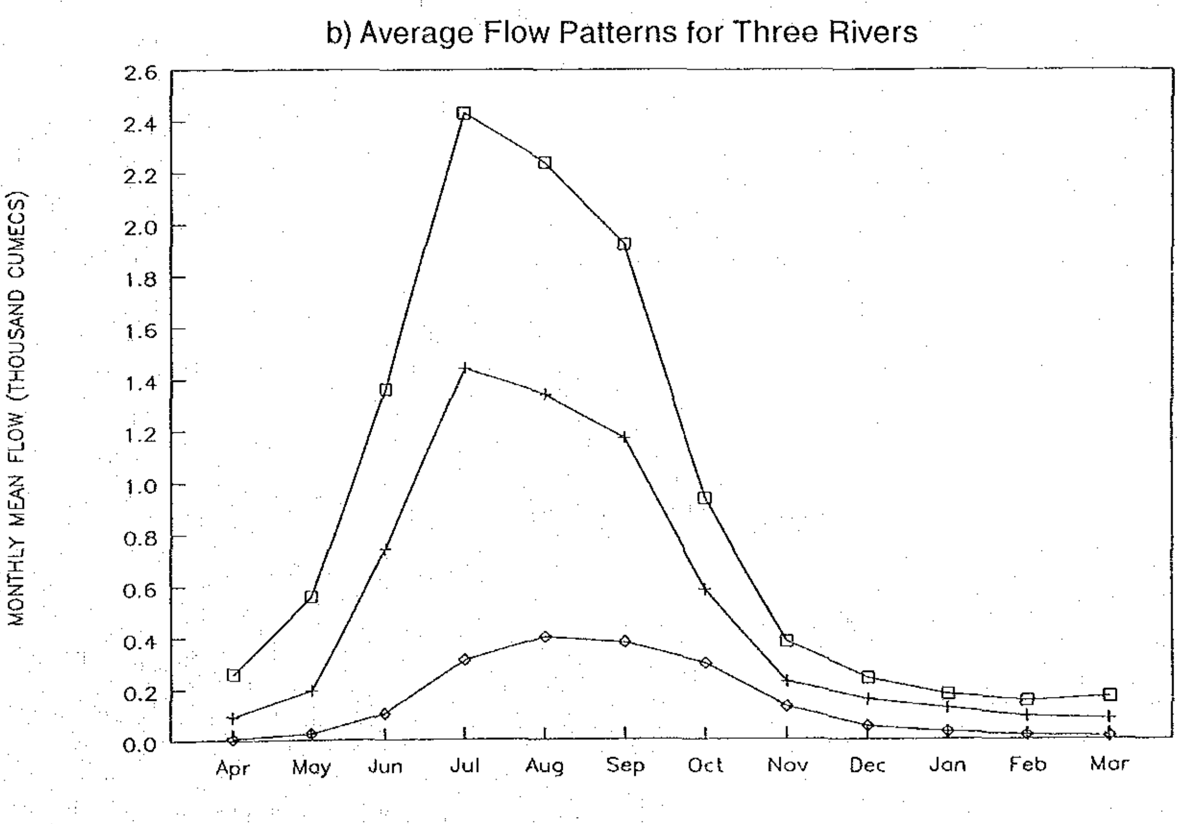
DATE, DRG NO.

10

Figure 2.4

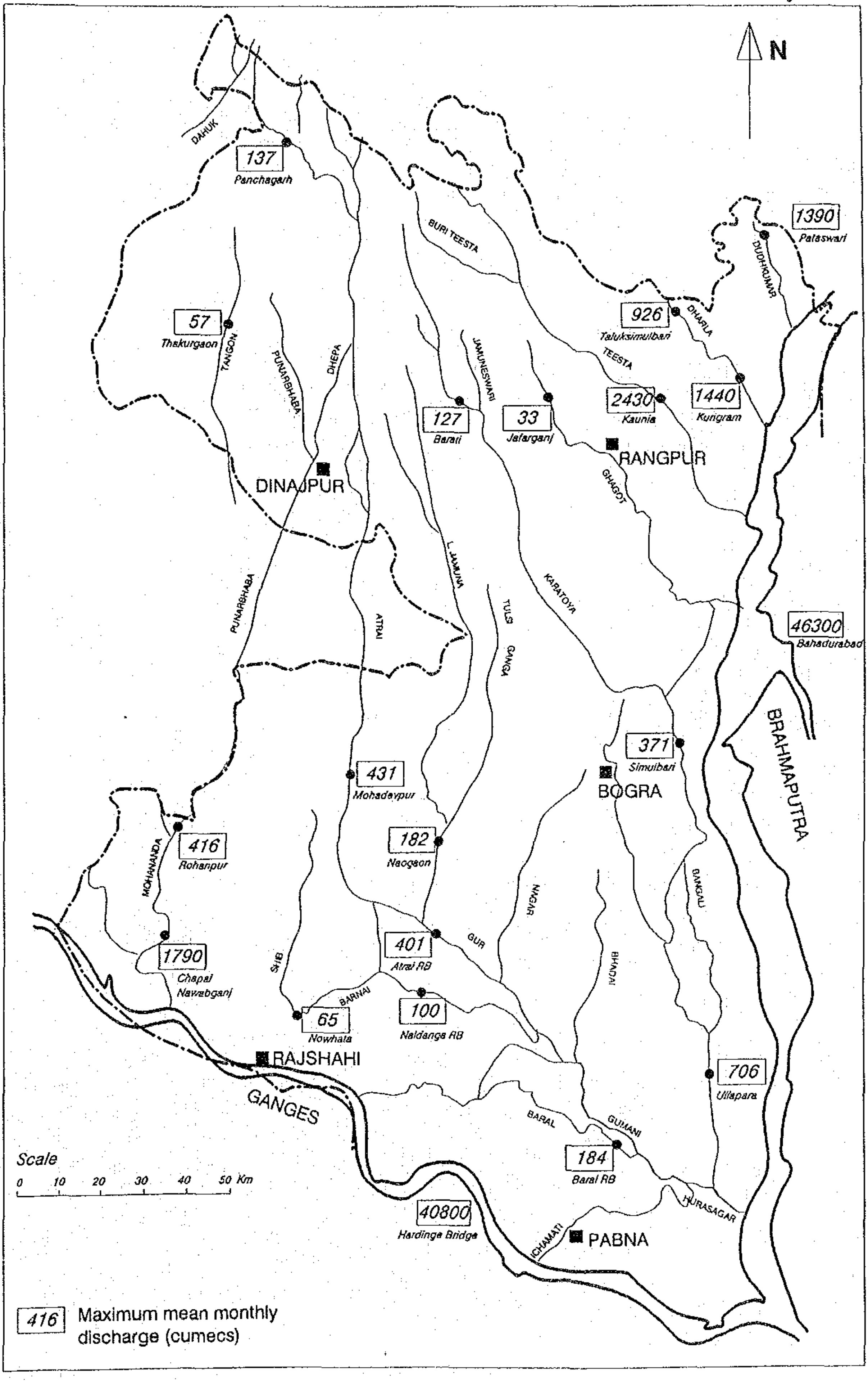
Monthly Rainfall and Runoff Patterns in the North West Region





C:\NWRS\FIG24.WK1 (FIG24A.PIC , FIG24B.PIC) 06-Sep-92

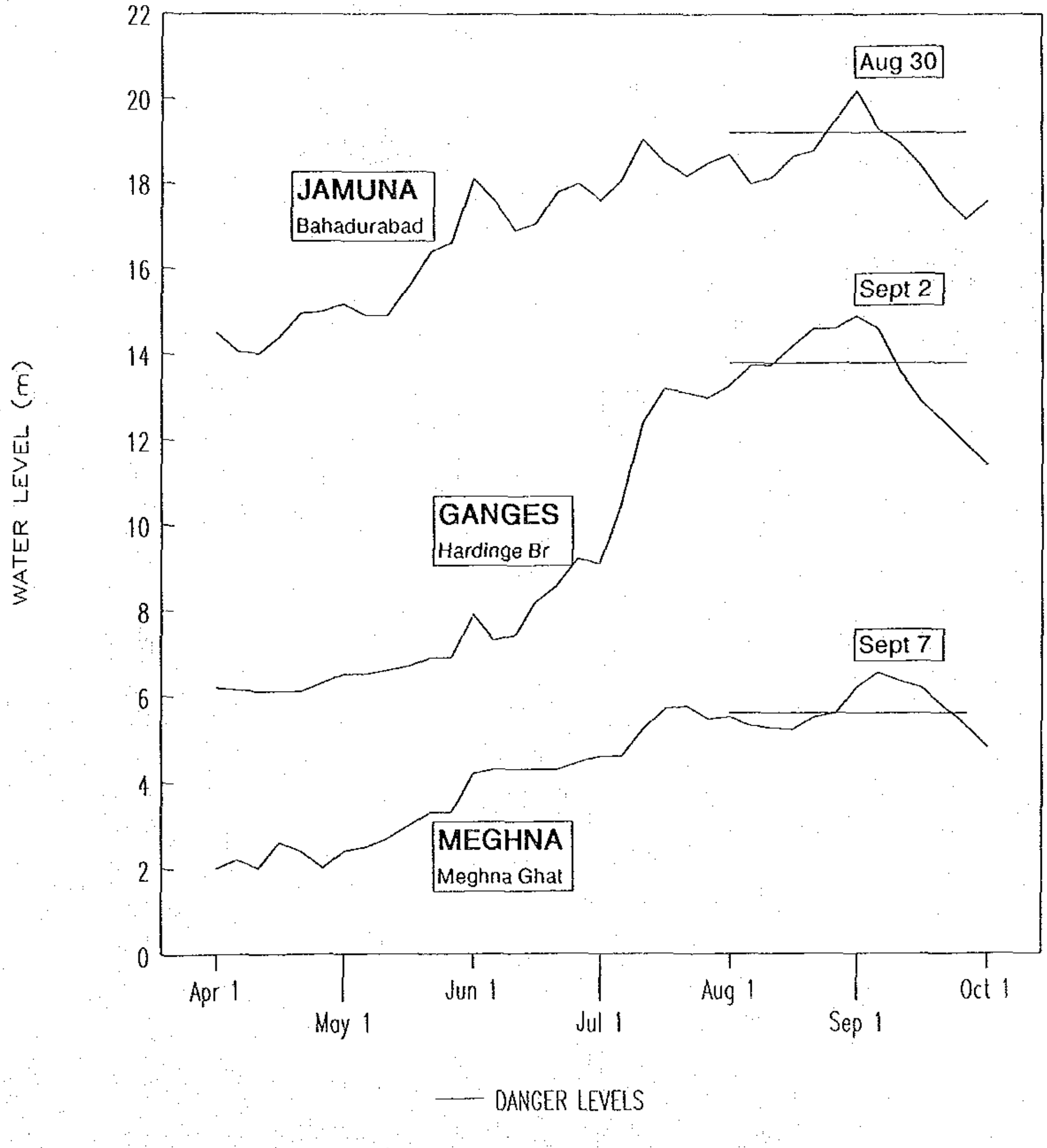
Figure 2.5
The River System



99

Figure 2.6

1988 Hydrographs of Major Rivers



Source: Bangladesh Flood Policy Study, UNDP, May 1989

C:\NWRS\FIG26.WK1/.PIC

07-Sep-92

Figure 2.7

Areas Flooded in 1988

1988 FLOOD EXTENT

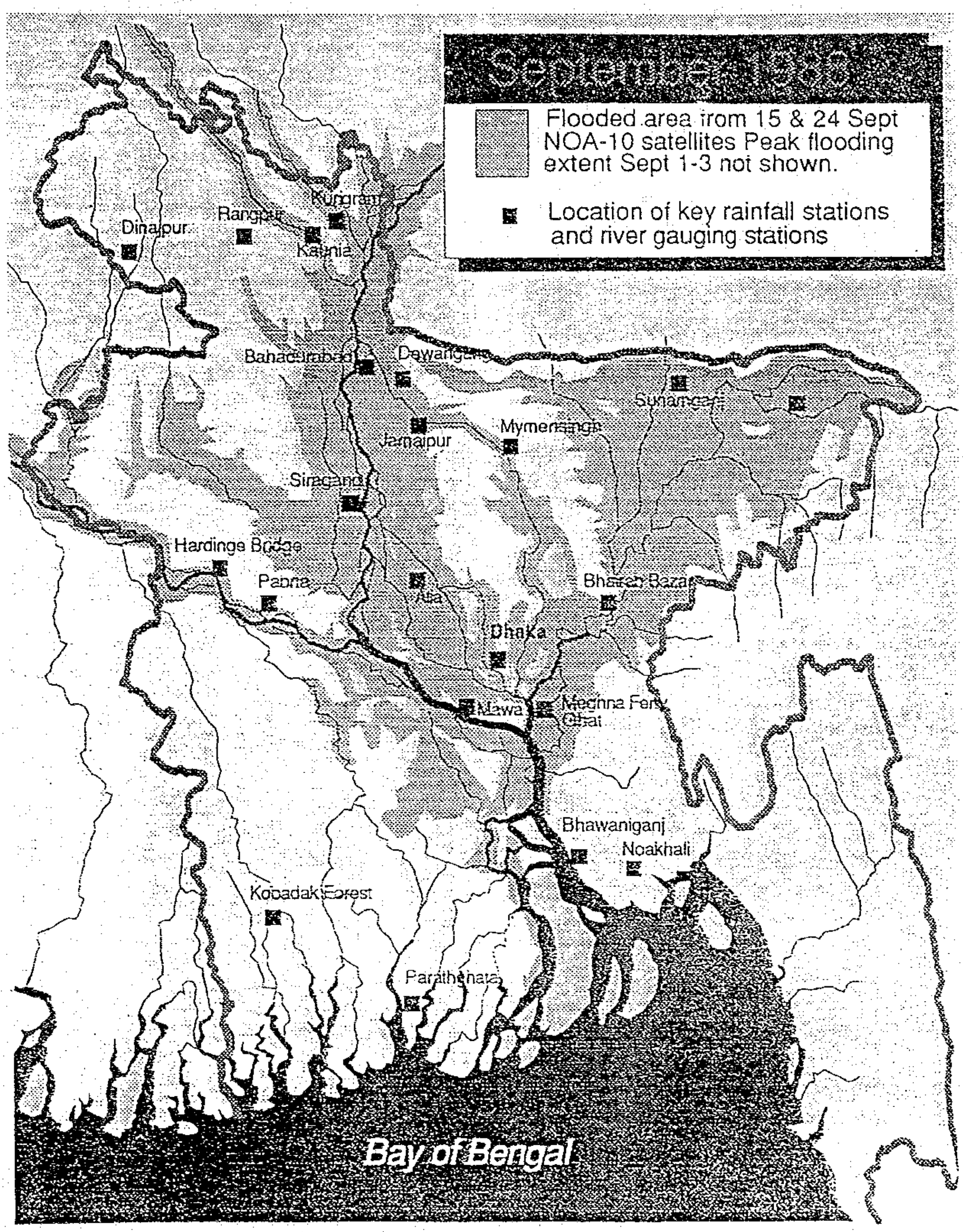


Figure 3.1

HYDROMETROLOGICAL STATION

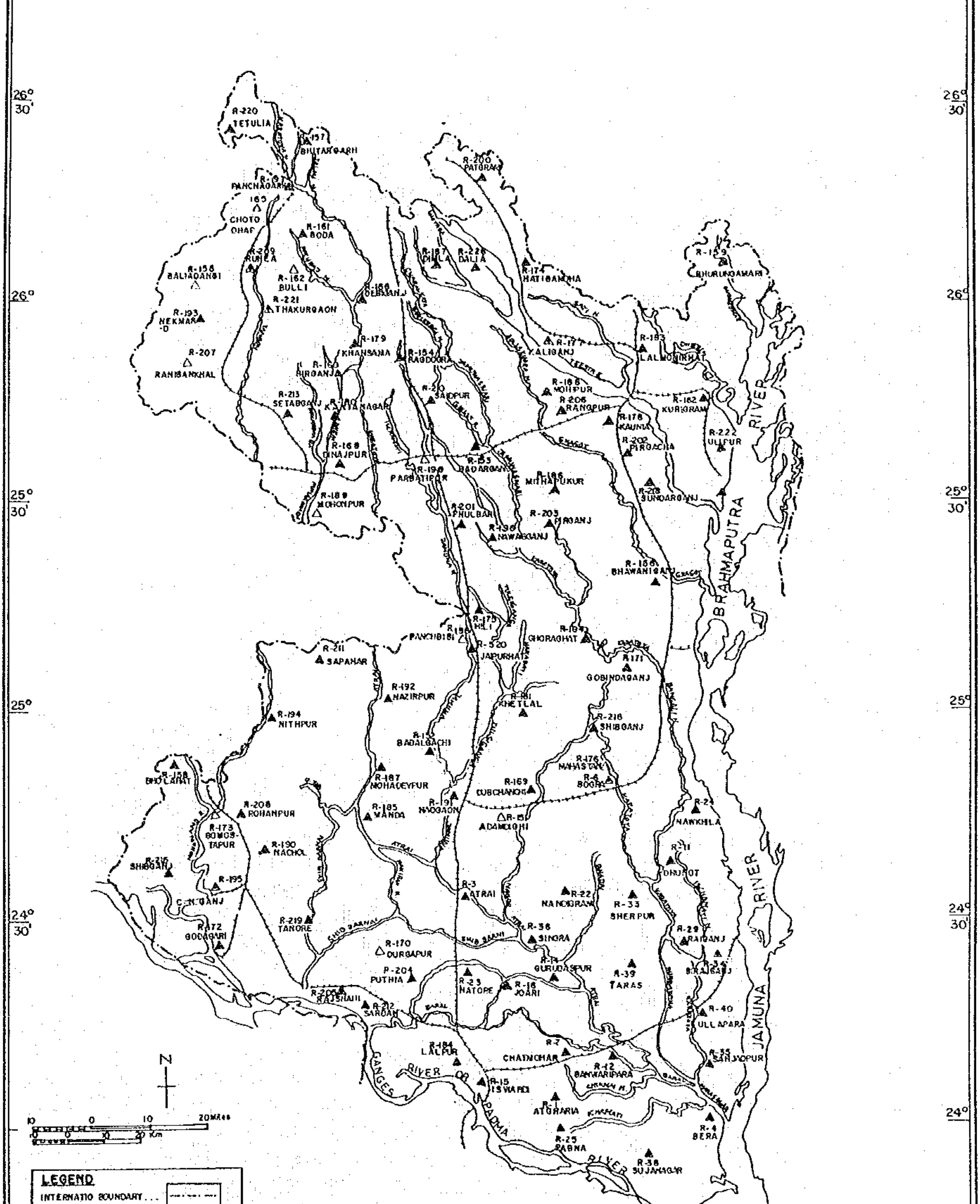
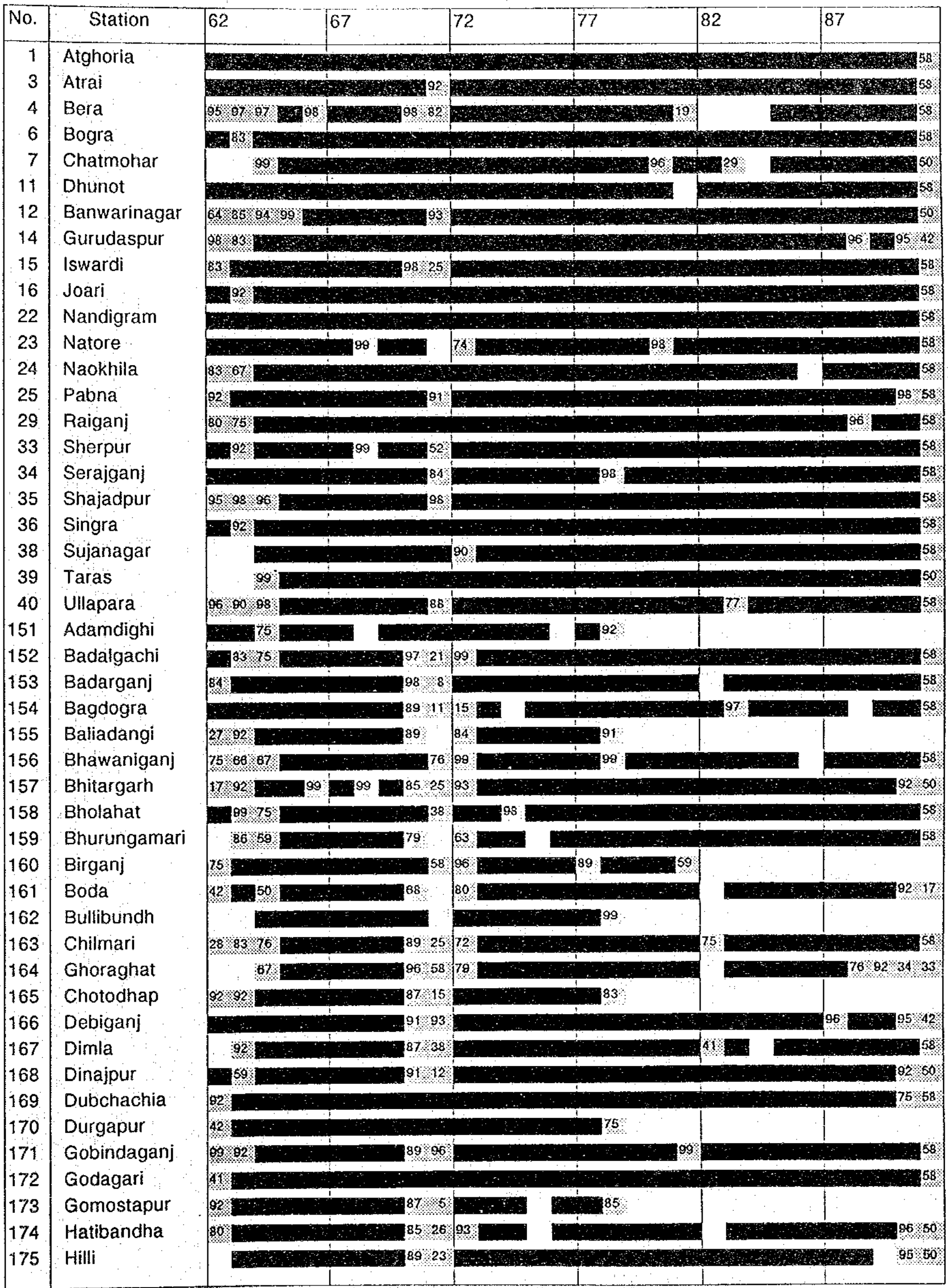


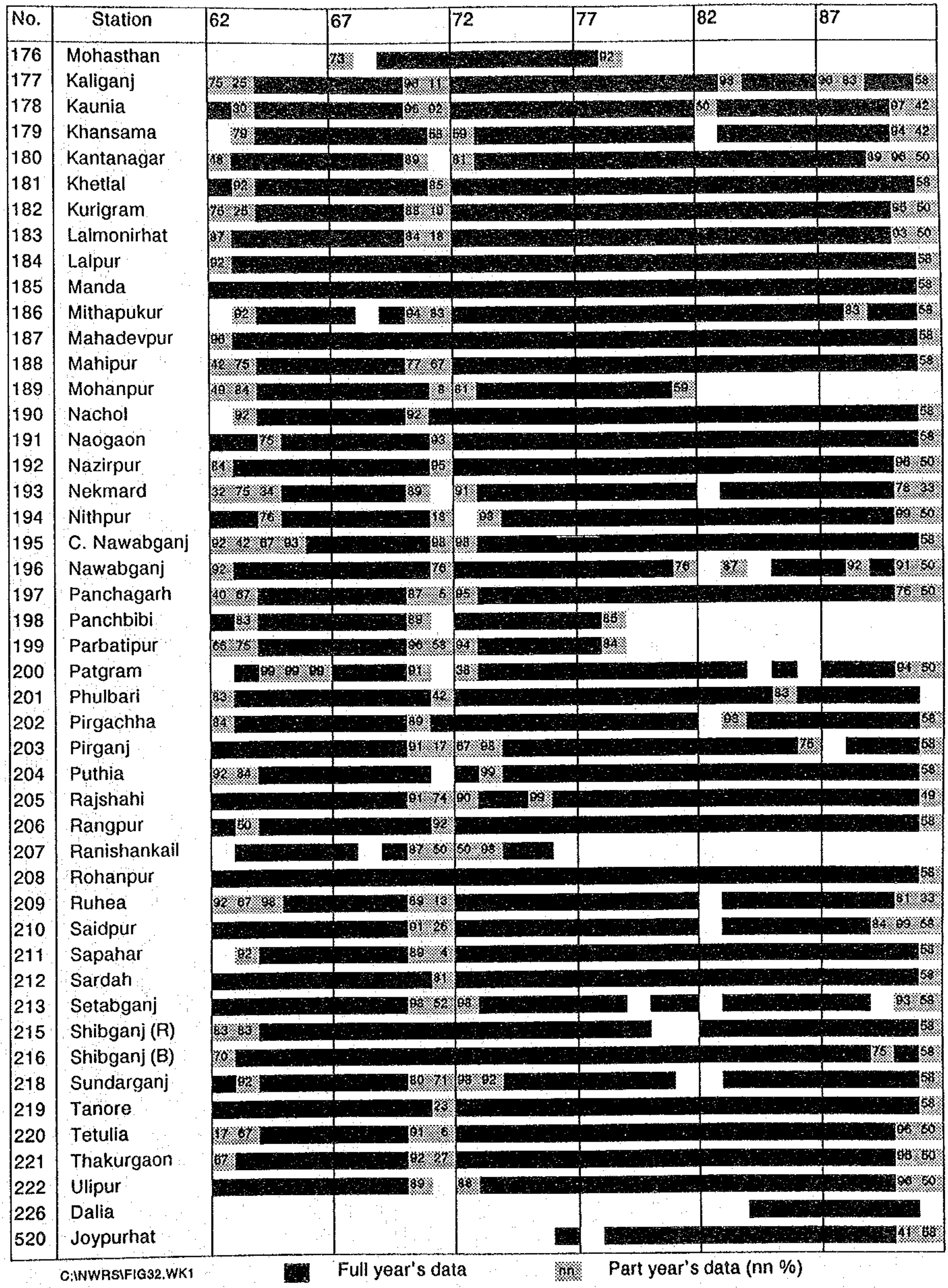
Figure 3.2 – Rainfall Data Availability 1962/3 to 1991/92



C:\NWRS\FIG32.WK1 ■ Full year's data nn Part year's data (nn %)

05

Figure 3.2 – Rainfall Data Availability 1962/3 to 1991/92



C:\NWRS\FIG32.WK1

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Figure 3.3

Average Rainfall Data Availability

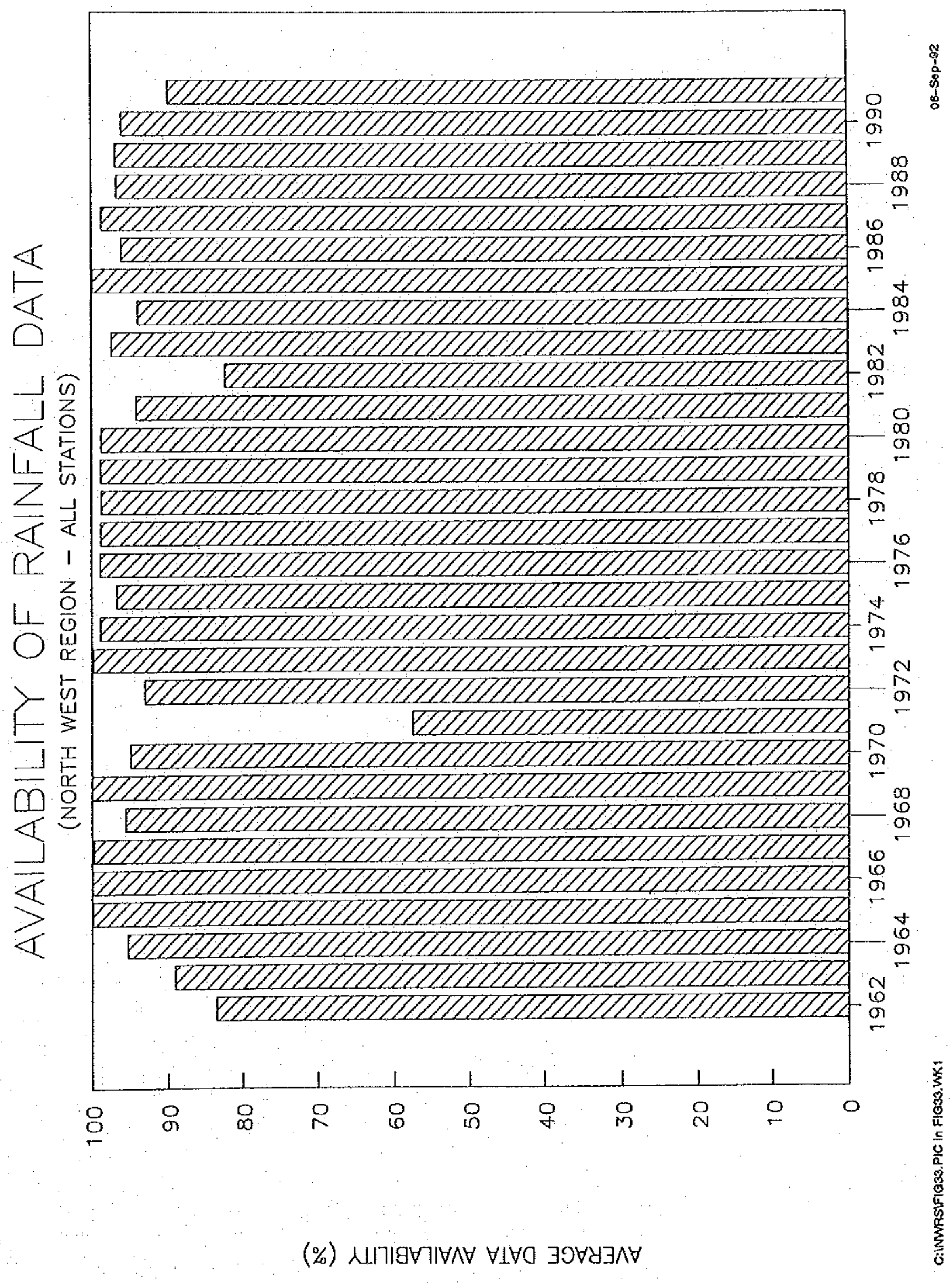
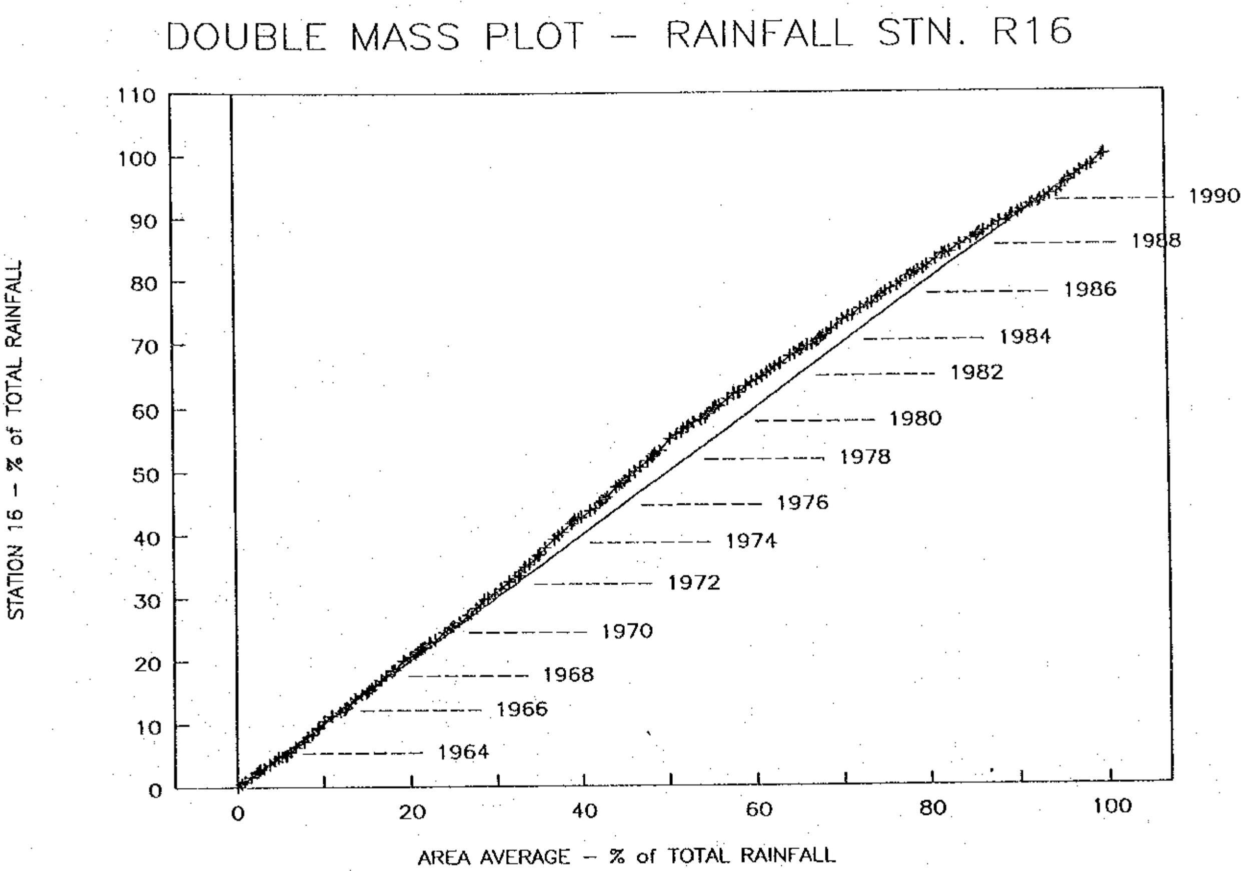
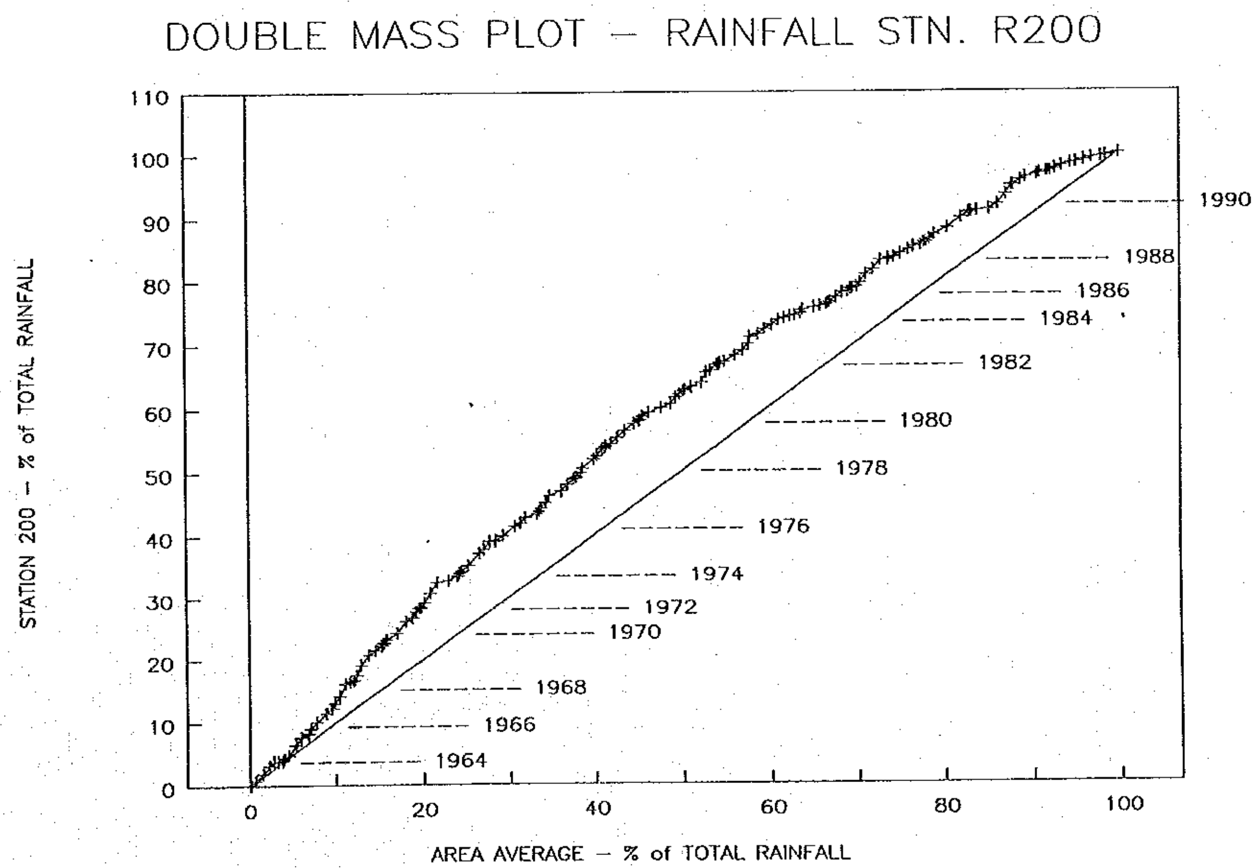


Figure 3.4

Example Double Mass Plots of Monthly Rainfall



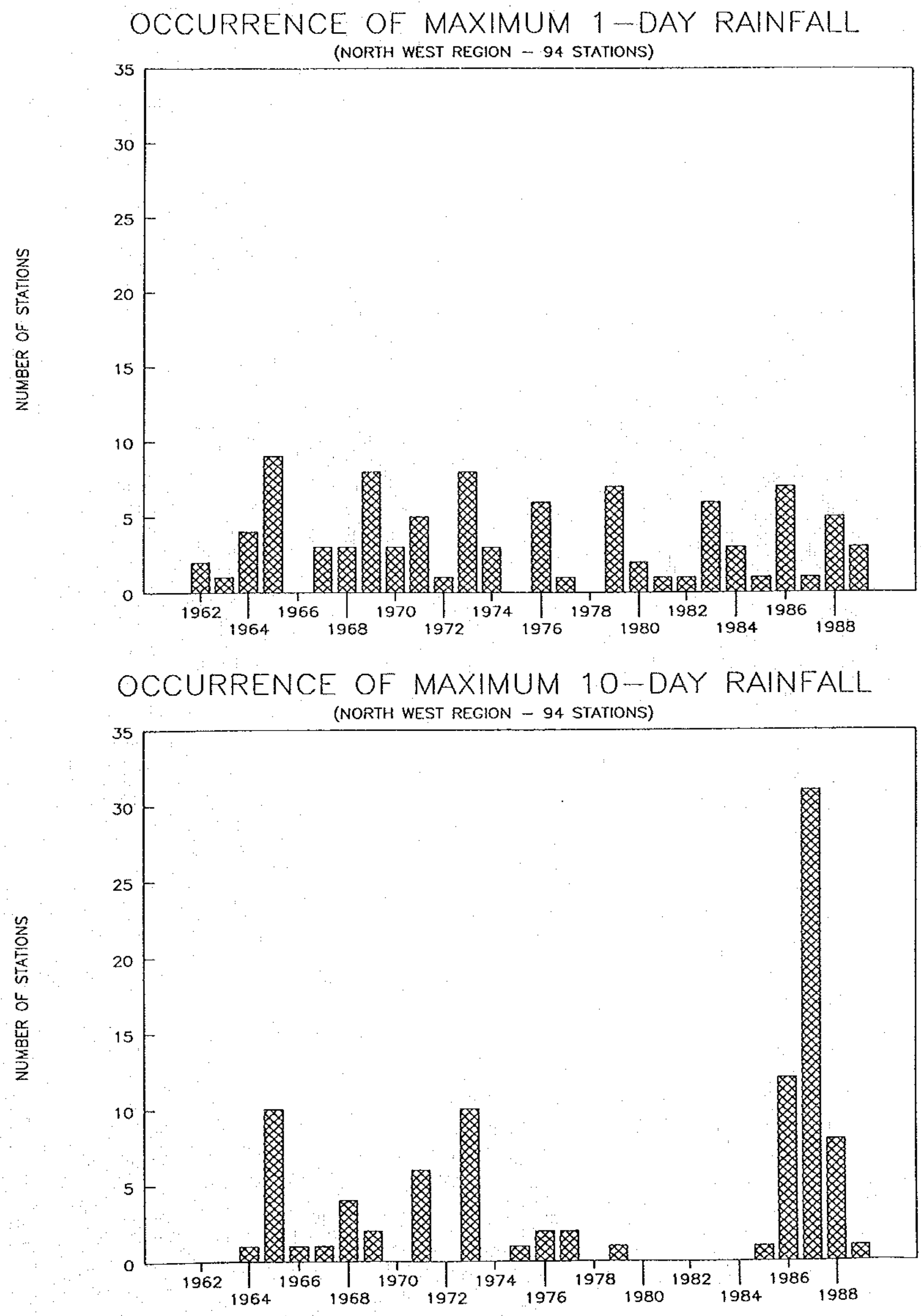


C:\NWRS\FIG34.WK1 (FIG34A.PIC , FIG34B.PIC)

08-Sep-92

Figure 3.5

Occurrence of Maximum Daily and 10-Day Rainfall

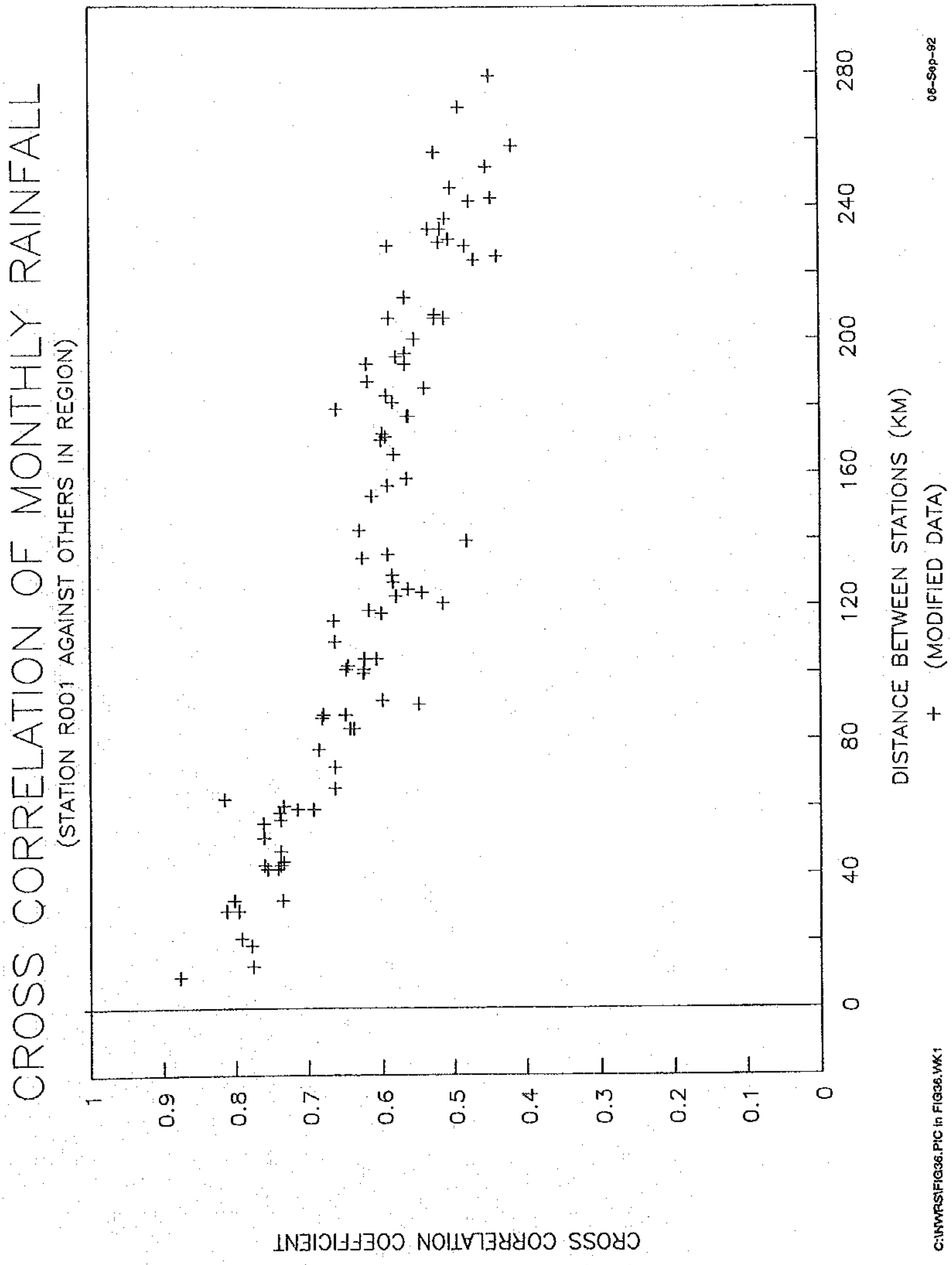


C:\NWRS\FIG35.WK1 (FIG35A.PIC, FIG35B.PIC)

06-Sep-92

Figure 3.6

Cross Correlation of Monthly Rainfall



90

Figure 3.7

Annual Rainfall Trends 1962–1990

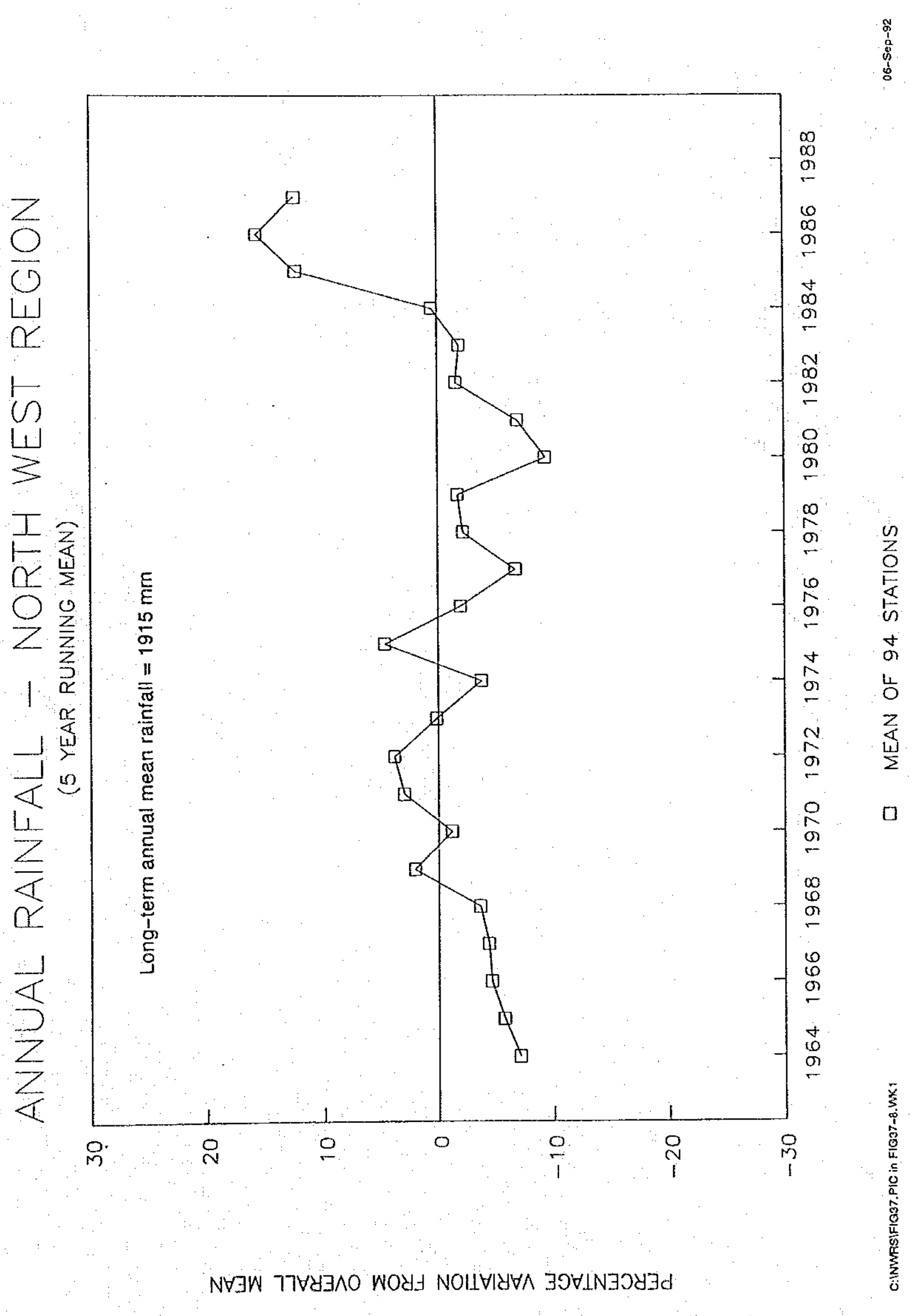
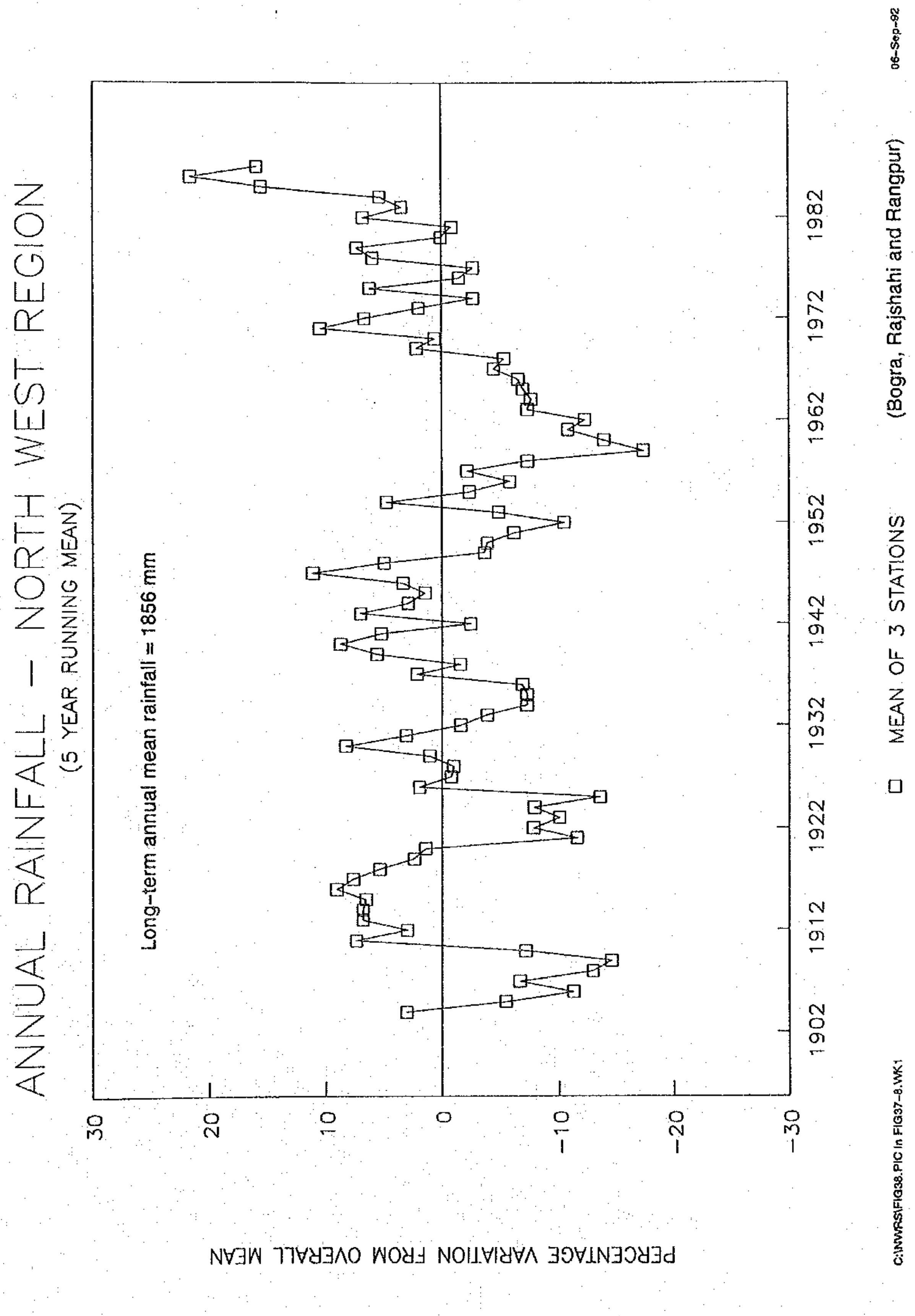


Figure 3.8

Annual Rainfall Trends 1902-1990



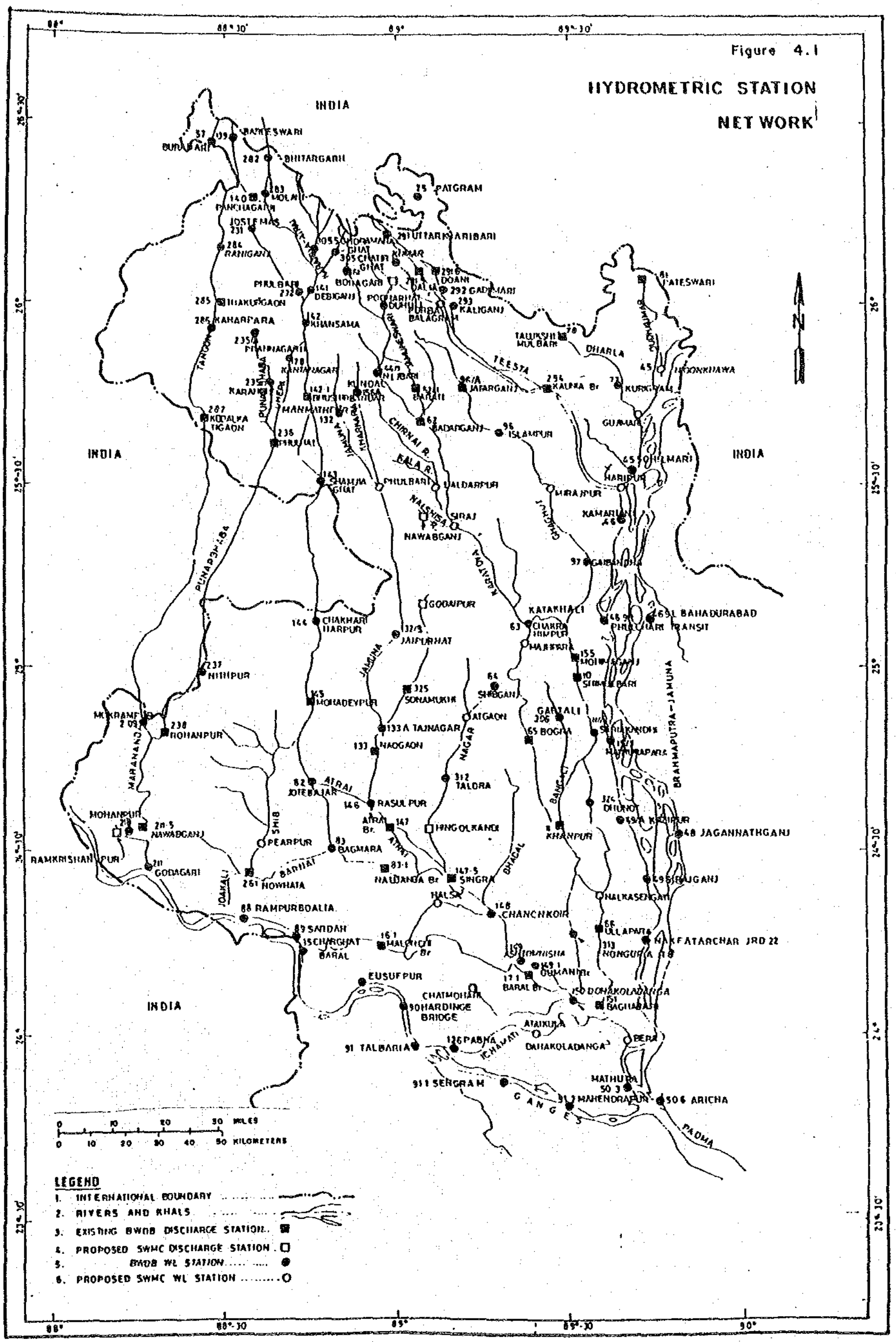


Figure 4.1

HYDROMETRIC STATION NETWORK

Figure 4.2 (page 1)

Water Level Stations and Data Availability

NO	STATION	RIVER	1960-69	1970-79	1980-89
10	Simulbari	Bangali			
11	Khanpur	Bangali			
11A	Sariakandi	Bangali			
15J	Mathurapara	Brahmaputra			
16.1	Malonchi	Baral			
17A	Baral Rly Br	Baral			
44.1	Nizbari	Burikhora			
45	Noonkhawa	Brahmaputra			
45.5	Chilmari	Brahmaputra			
46	Kamarjani	Brahmaputra			
46.9R	Phulchari	Brahmaputra			
46.9L	Bahadurabad	Brahmaputra			
49A	Kazipur	Brahmaputra			
61	Boragari	Deonai			
62	Badarganj	Jamuneswari			
63.1	Baratia	Deonai			
63	Chakrahimpur	Karatoa			
64	Shibganj	Karatoa			
65	Bogra	Karatoa			
66	Ullapara	Karatoa			
76	Taluksimulbari	Dharla			
77	Kurigram	Dharla			
78	Kantanagar	Dhepa			
81	Pateswari	Dudhkumar			
82	Jotebazar	Barnai			
83	Bagmara	Barnai			
83.1	Naldanga RB	Barnai			
88	Rampurboalia	Ganges			
89	Sardah	Ganges			
90	Hardinge Br	Ganges			
96	Islampur	Ghagot			
96a	Jafarganj	Ghagot			
97	Gaibandha	Ghagot			
132	Manmathpur	L.Jamuna			
132.5	Jaipurhat	L.Jamuna			
133	Naogaon	L.Jamuna			
133a	Tajnagar	L.Jamuna			
139	Baradeswari	Karatoa			
140	Panchagarh	Karatoa			

C:\NWRS\FIG42.WK1 07-Sep-92 Data collected

Figure 4.2 (page 2)

Water Level Stations and Data Availability

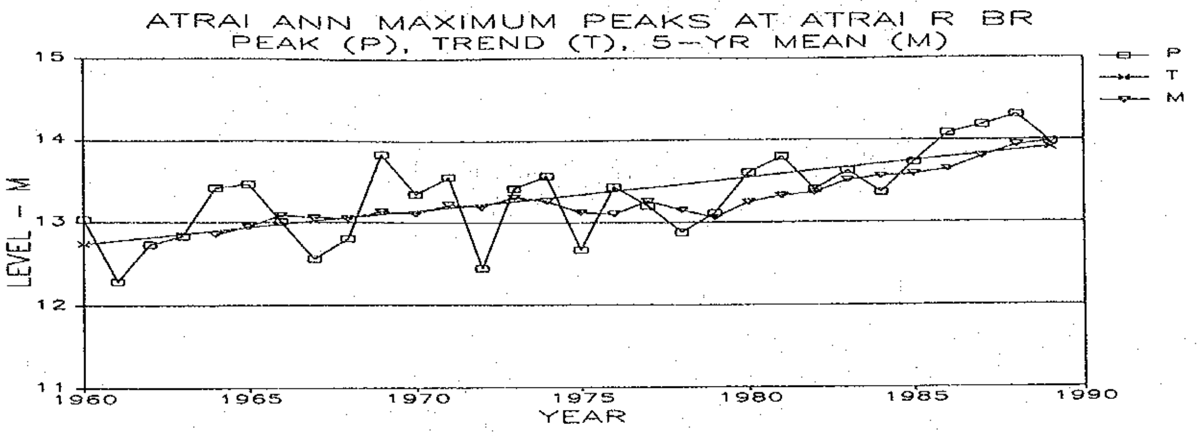
NO			1960-69	1970-79	1980-89
141	Debiganj	Karatoa			
142.1	Bhushirbandar	Karatoa			
142	Khansama	Karatoa			
143	Samjhiaghat	Atrai			
144	Chakhariharpur	Atrai			
145	Mahadebpur	Atrai			
146	Rasulpur	Atrai			
147	Atrai Rly Br	Atrai			
147.5	Singra	Gur			
148	Chanchkoir	Gur			
149	Astomonisha	Gumani			
149.1	Gumani Rly Br	Gumani			
150	Dohokoladanga	Baral			
151	Baghabari	Hurasagar			
155	Mohimaganj	Katakhali			
156A	Kundal	Kharkharia			
209	Mokrampur	Mohananda			
209A	Tetulia	Mohananda			
211	Godagari	Mohananda			
211.5	Chapai Nawabganj	Mohananda			
232	Phulbari	Pathraj			
235	Kaharole	Punarbhaba			
235A	Prannagar	Punarbhaba			
236	Phulhat	Punarbhaba			
238	Rohanpur	Punarbhaba			
261	Nowhata	Sib			
282	Bhitargarh	Talma			
283	Molani	Talma			
284	Raniganj	Tangon			
285	Thakurgaon	Tangon			
287	Kodalkatigaon	Tangon			
291.5L	Doani	Teesta			
291.5R	Dalia	Teesta			
293	Kaliganj	Teesta			
294	Kaunia	Teesta			
312	Talora	Nagor			
313	Nongura R B	Durgadaha			
324	Dhunot	Bangali (Old)			
325	Sonamukhi	Tulshiganga			

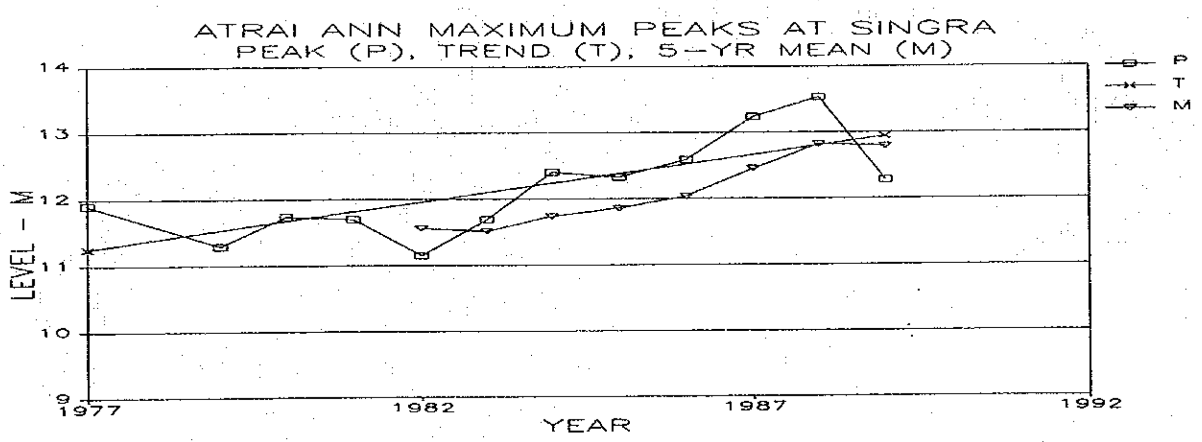
C:\NWRS\FIG42.WK1 07-Sep-92

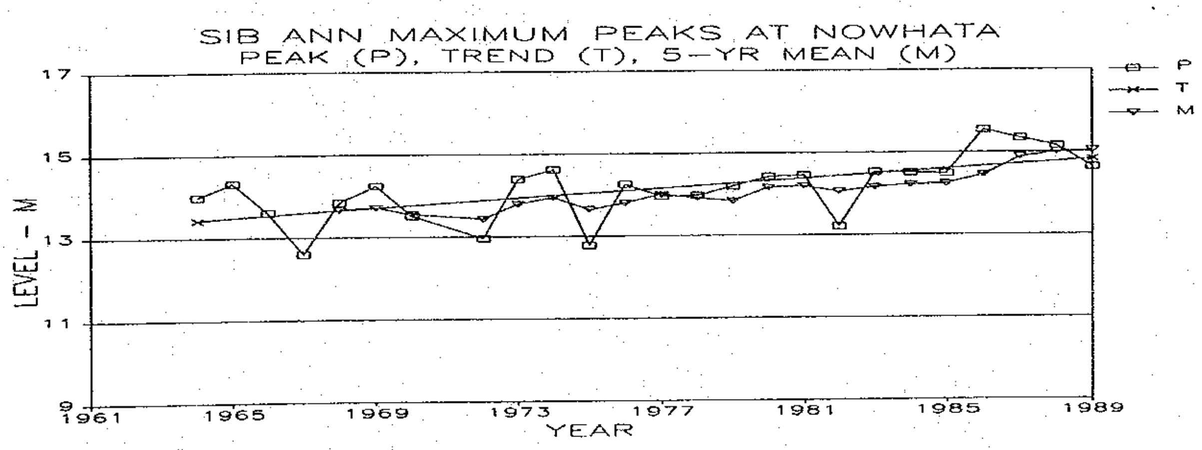
▯ Data collected

Figure 4.3

Examples of Water Level Trend Analysis







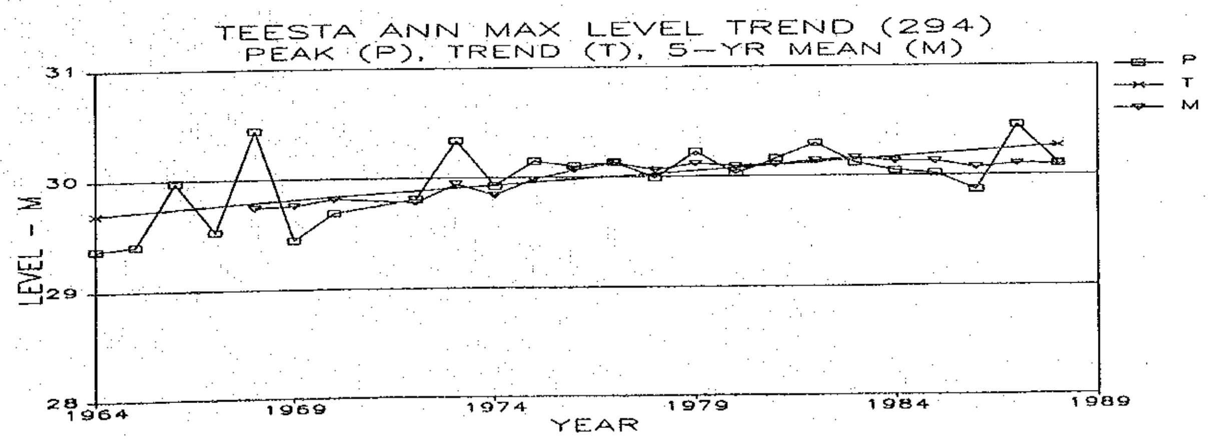


Figure 4.4

Trend Analysis of Annual Maximum Water Levels from Model

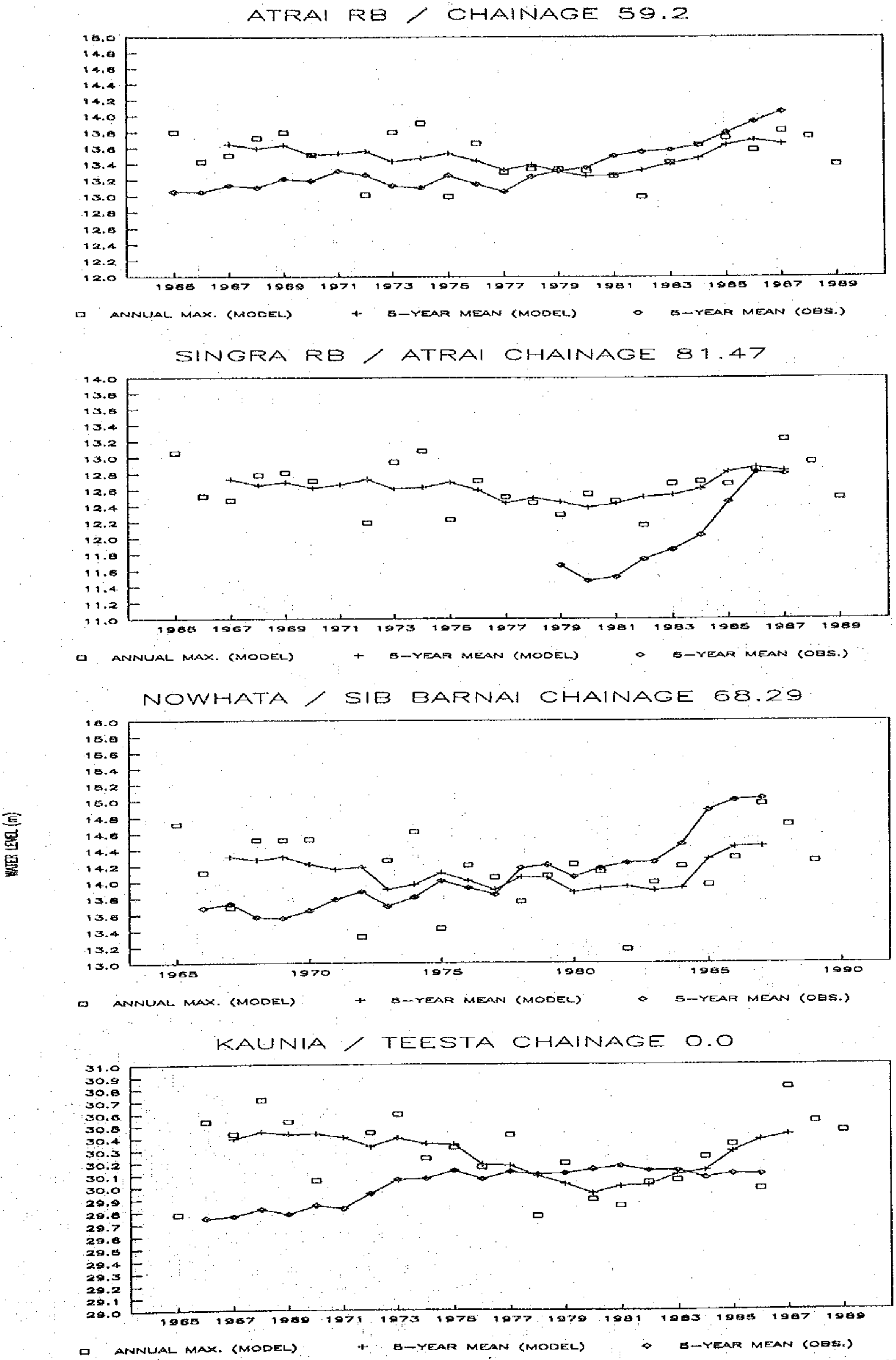


Figure 5.1

River Flow Stations and Data Availability

NO	STATION	RIVER	1960-69	1970-79	1980-89
10	Simulbari	Bangali		IIIIII	IIgIIIIIII
11	Khanpur	Bangali		IIIIIII	ggggIIIIgI
16.1	Malonchi	Baral	IIIIII	IIIIIIII	II IIIIIII
17A	Baral Rly Br	Baral	IIIIIII	IIIIIIII	I IIIIIII
44.1	Nizbari	Burikhora	IIIIII	IIIIII I	
46.9L	Bahadurabad	Brahmaputra	IIIIIIIIIII	IIIIIIII	IIIIIIIII
61	Boragari	Deonai			ggggg
62	Badarganj	Jamuneswari			ggggI
62.1	Baratia	Deonai	IIIIIII	IIIIIIII	III IIII
65	Bogra	Karatoa	IIIIIII	IIIIIIII	II IIgIII
66	Ullapara	Karatoa	IIIIIII	IIIIIIII	IIIIIIIIII
76	Taluksimulbari	Dharla	III	IIIIIII	I II
77	Kurigram	Dharla		IIIIIII	IIIIIIIIII
78	Kantanagar	Dhepa	IIIIII	IIIIIIII	
81	Pateswari	Dudhkumar	III	IIIIIIII	IIII IIII
83.1	Naldanga R B	Barnai	IIIIII	IIIIIIII	IIIIIIIIII
96A	Jafarganj	Ghagot	IIIIIII	IIIIIIII	I gggIg
133	Naogaon	L.Jamuna		IIIIIII	IIIIIIIIII
140	Panchagarh	Karatoa	IIIIIII	IIIIIII	IIIII IIII
142.1	Bhushirbandar	Karatoa	III III	IIII I I	I I I IIII
142	Khansama	Karatoa	IIII	IIIIIIII	I
145	Mahadevpur	Atrai		IIIIIII	IIIIIIIIII
146	Rasulpur	Atrai		IIIIIII	
147	Atrai Rly Br	Atrai	IIIIIII	I IIIIII	IIIIIIIIII
147.5	Singra	Gur			IIIIIII
149.1	Gumani Rly Br	Gumani	IIIIIII	IIIIIIII	I
151	Baghabari	Hurasagar			IIII
155	Mohimaganj	Katakhali	IIIIIII	IIIIIIII	IIIIIIIIII
211	Godagari	Mohananda	IIIII	IIIIIII	I
211.5	ChapaiNganj	Mohananda			IIIIIIII
235A	Prannagar	Punarbhaba	IIIII		I
236	Phulhat	Punarbhaba	IIIIII	IIIIIIII	IIIIIIIIII
238	Rohanpur	Punarbhaba	IIIII	IIIIIII	IIIIII III
261	Nowhata	Sib		IIIIIII	II IIIgIII
285	Thakurgaon	Tangon	IIII II	II IIIIII	IIIIIII I
287	Kodalkatigaon	Tangon		IIIIII	IIIIIII II
291.5R	Dalia	Teesta			IIIIIIIIII
291.5L	Doani	Teesta			IIIIIIIIII
294	Kaunia	Teesta	IIII IIIII	IIIIIIII	IIIIIIIIII
312	Talora	Nagor	IIIIIII	IIIIIIgg	gggggggggI
313	Nongura R B	Durgadaha	IIIIIII	IIIIIII	
325	Sonamukhi	Tulshiganga		IIIII	I IIIIgIII

C:\NWRS\FIG51.WK1

07-Sep-92

I Flow data collected   g Data generated from levels and DMs

Figure 6.1

Daily and Monthly Evapotranspiration for Dinajpur

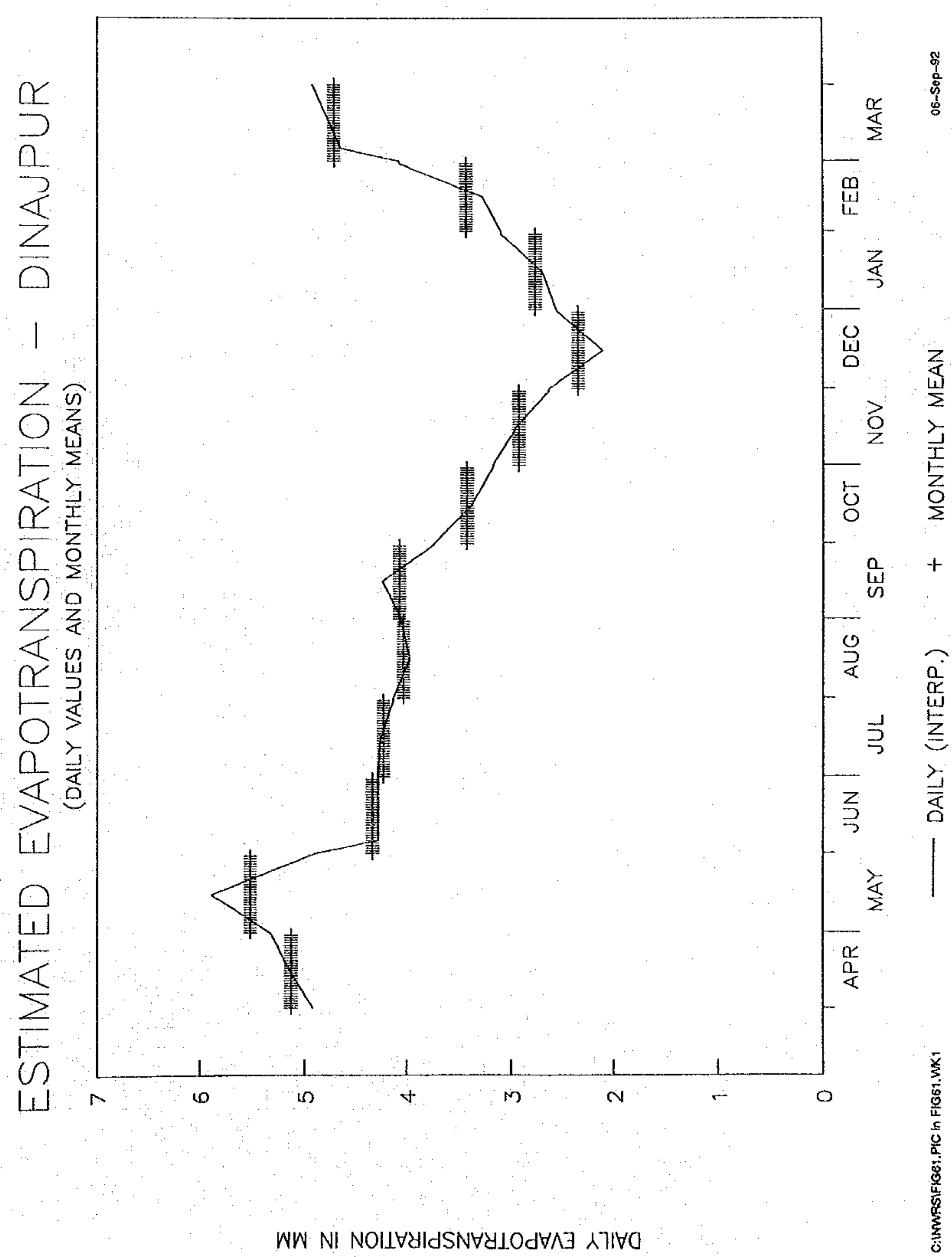


Figure 6.2

Average Evapotranspiration in the North West Region

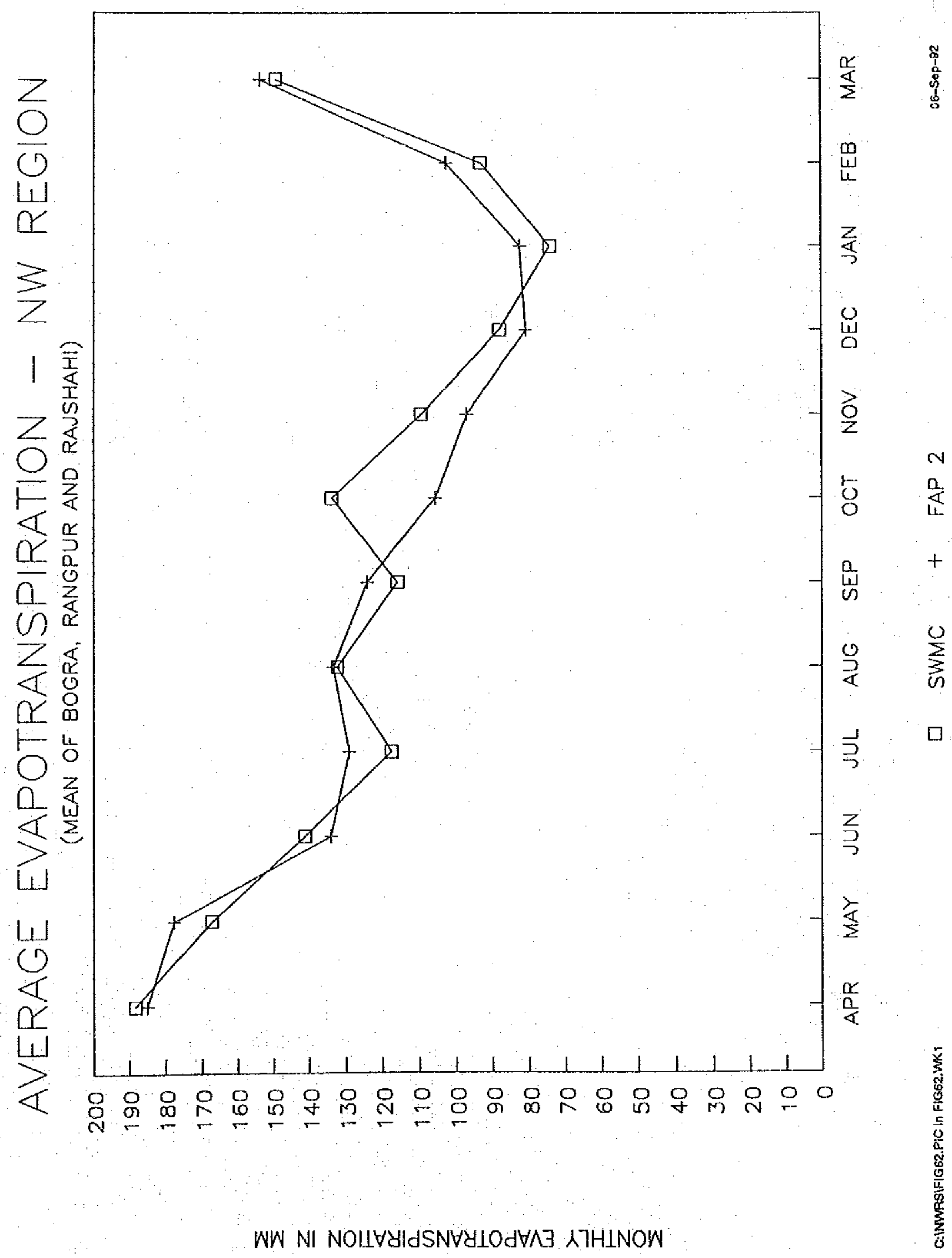
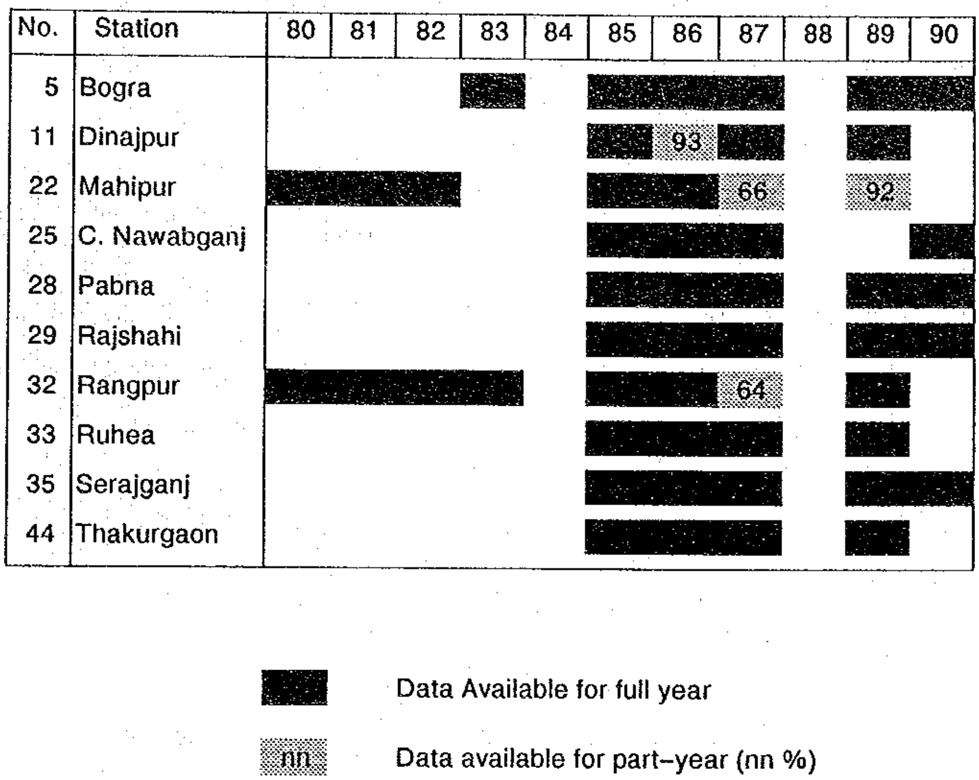


Figure 6.3

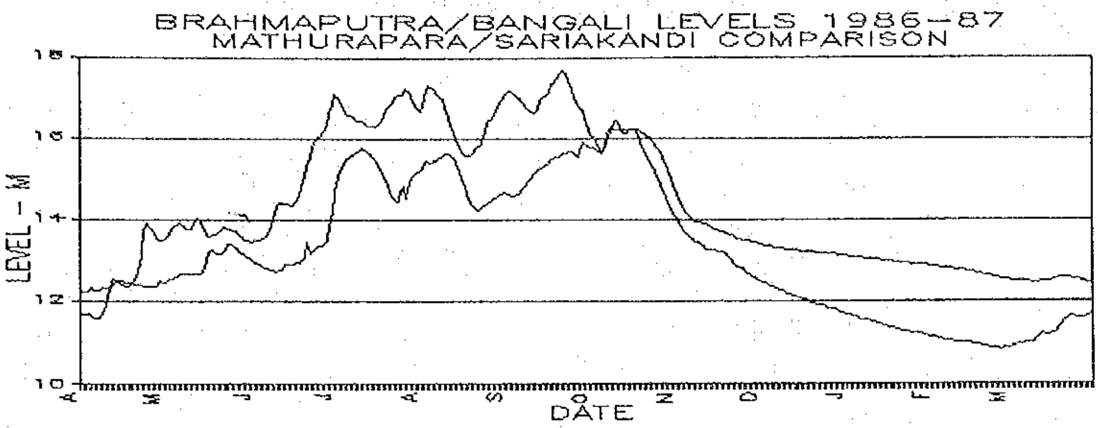
Availability of Evaporation Data from BWDB

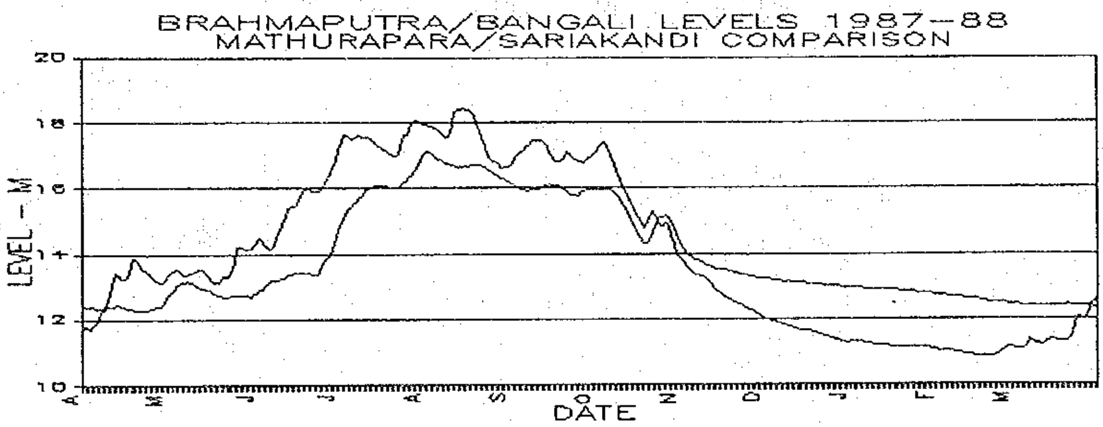


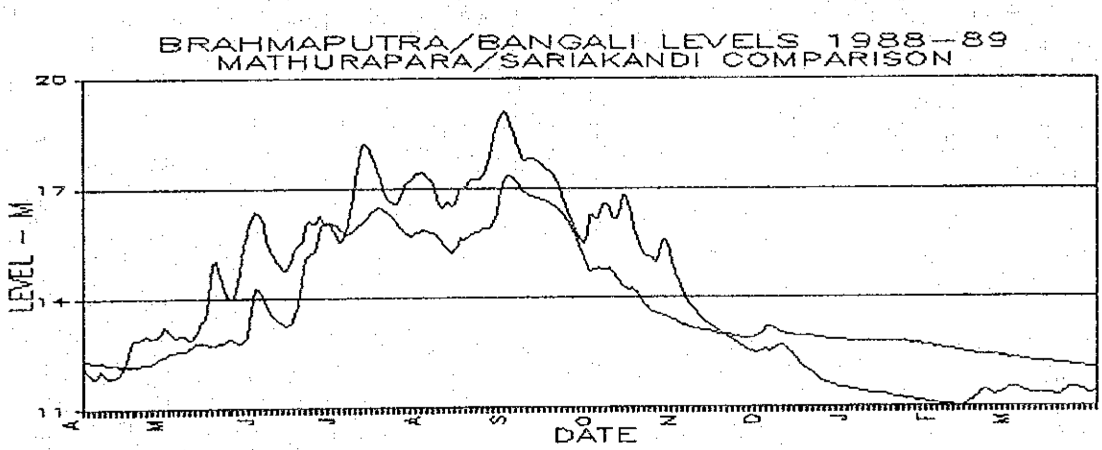
79

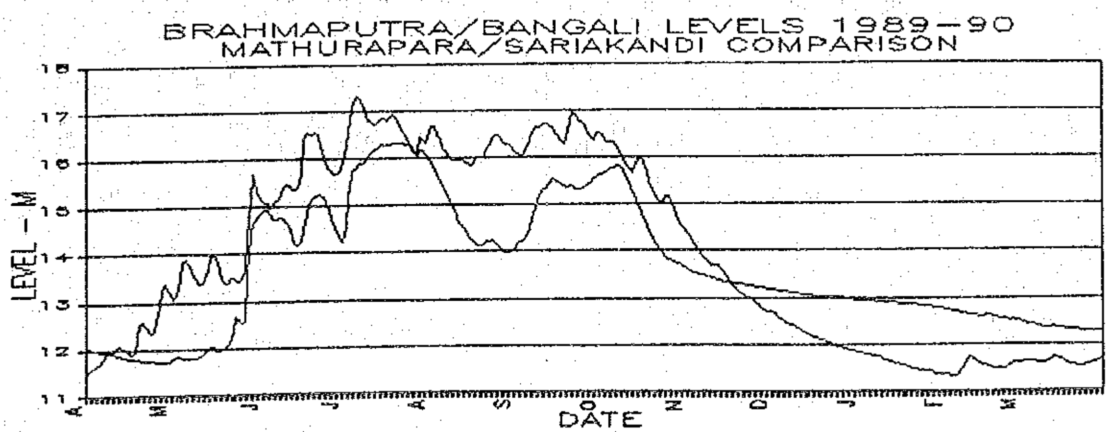
Figure 7.1

Comparison of River Levels – Jamuna and Bangali





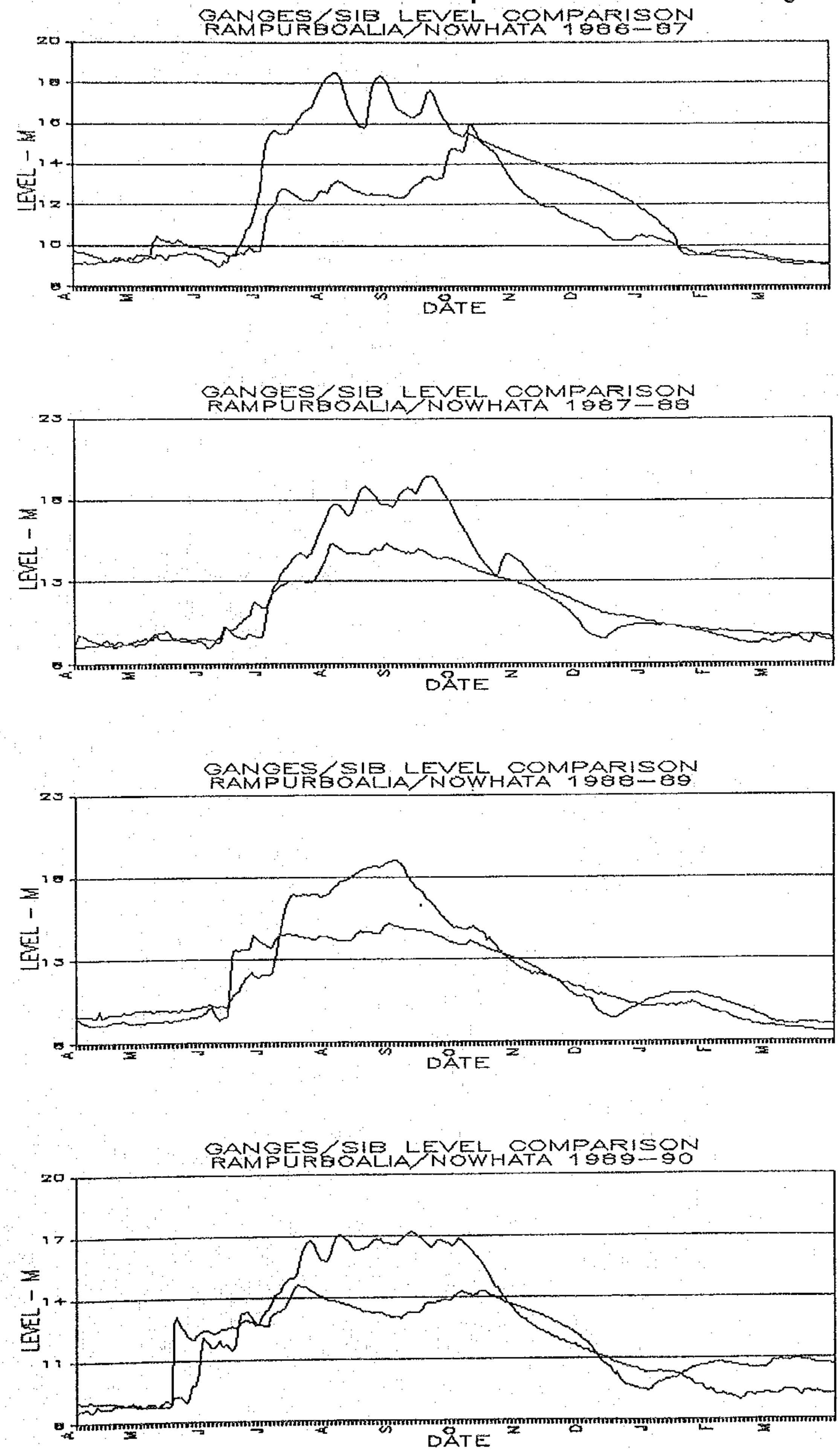




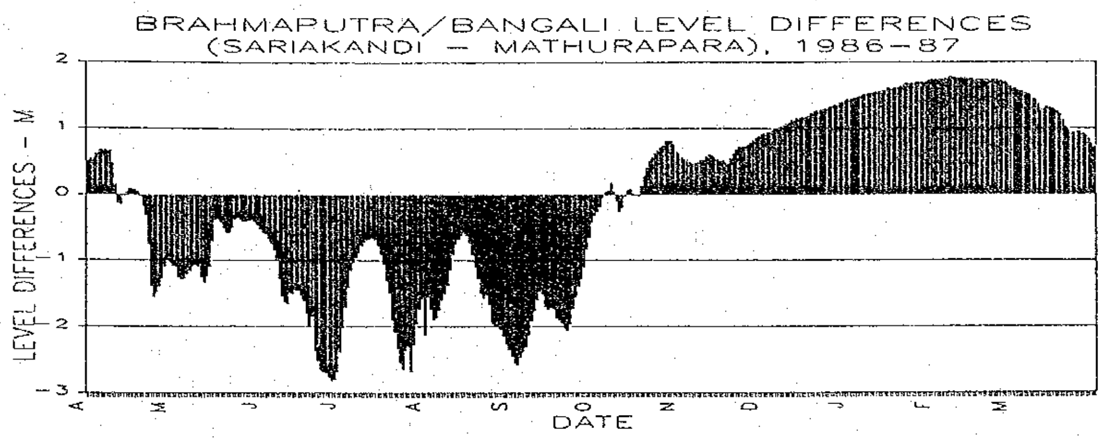
78

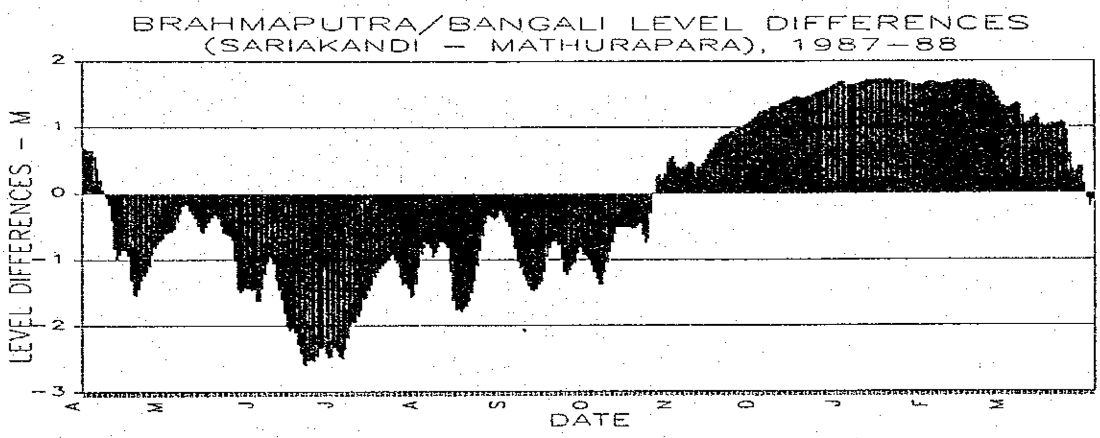
Figure 7.2

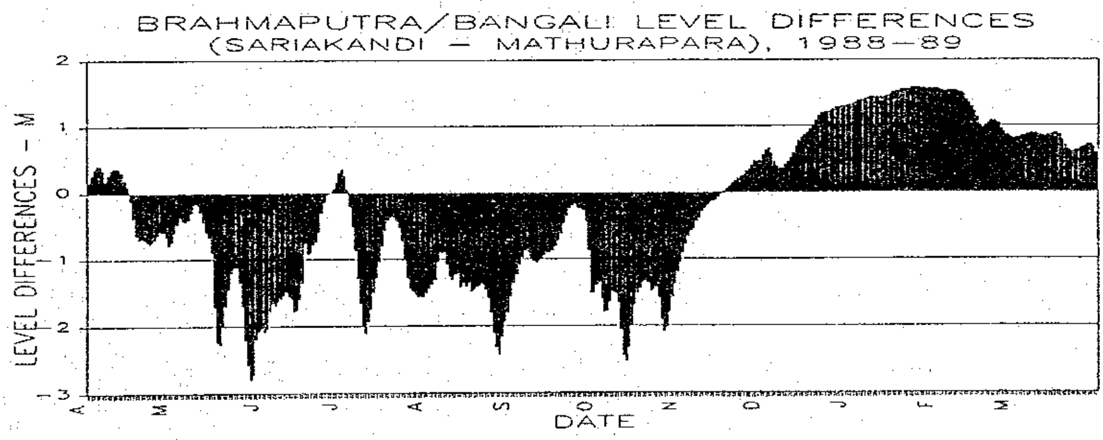
Comparison of River Levels – Ganges and Sib Barnai



Difference in River Levels – Jamuna and Bangali







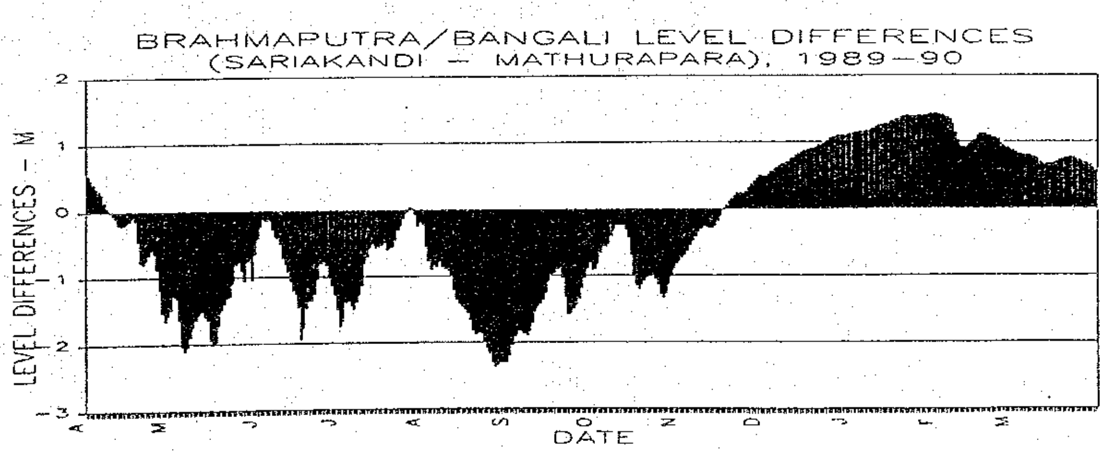


Figure 7.4

Difference in River Levels – Ganges and Sib Barnai

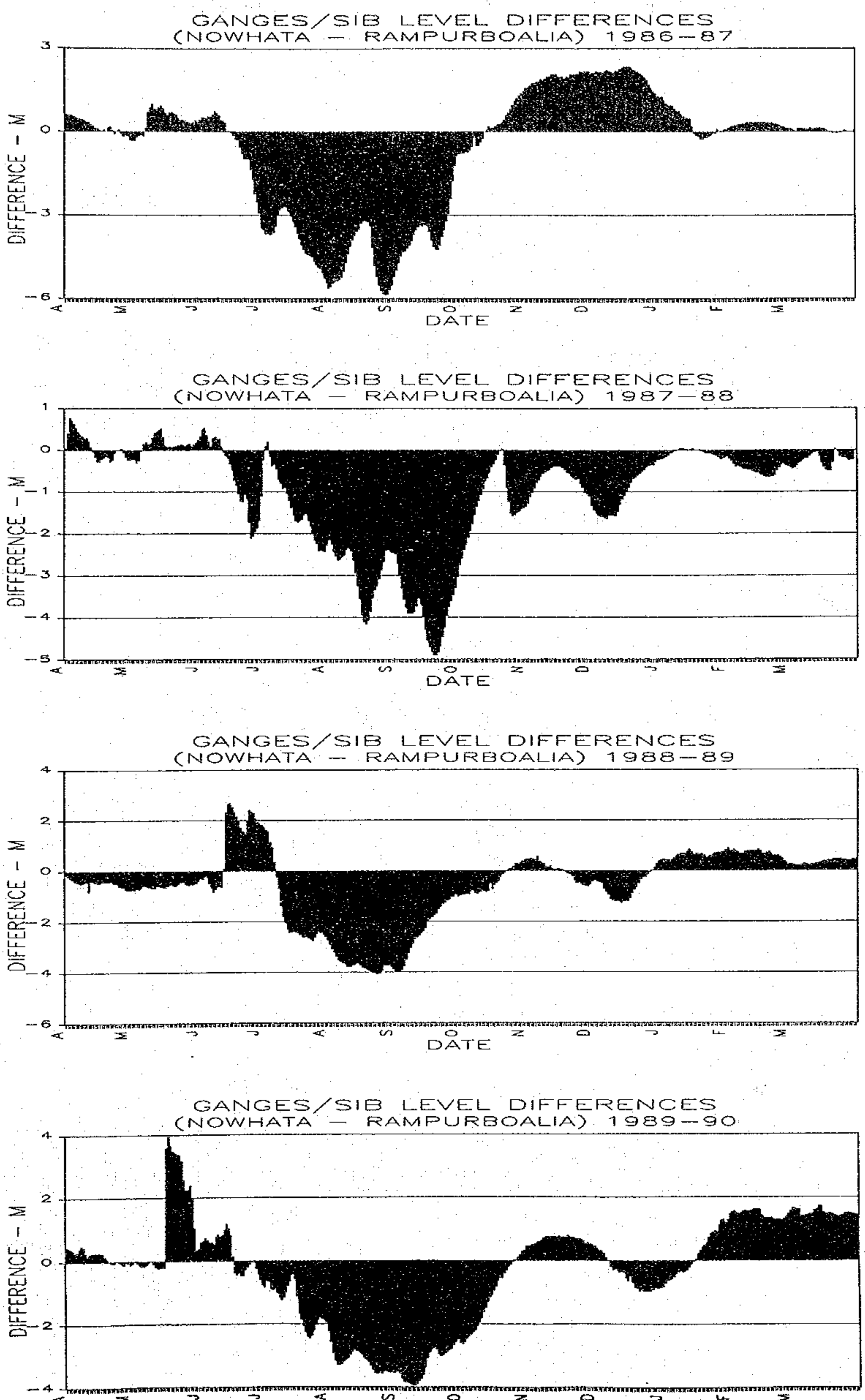
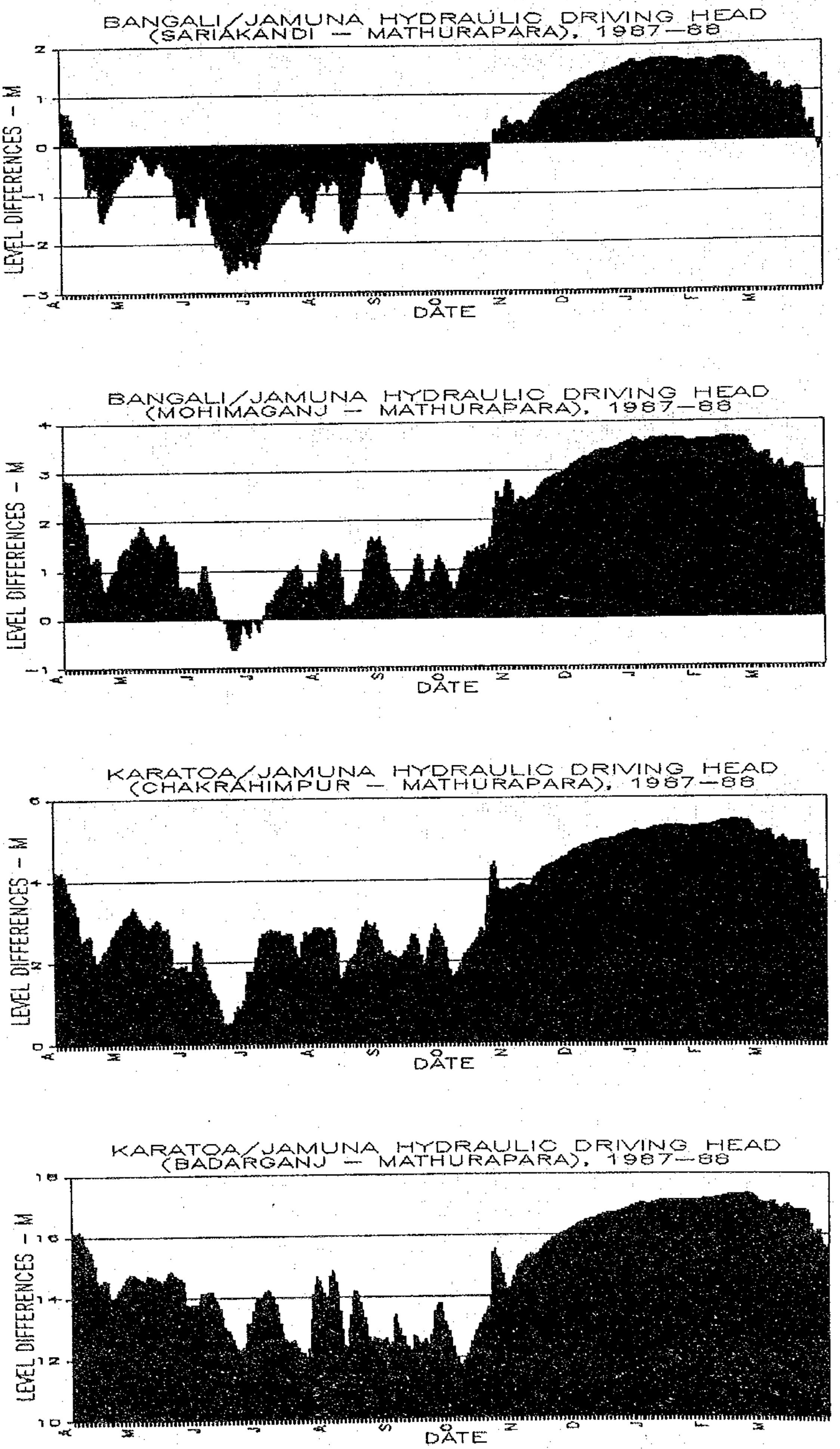
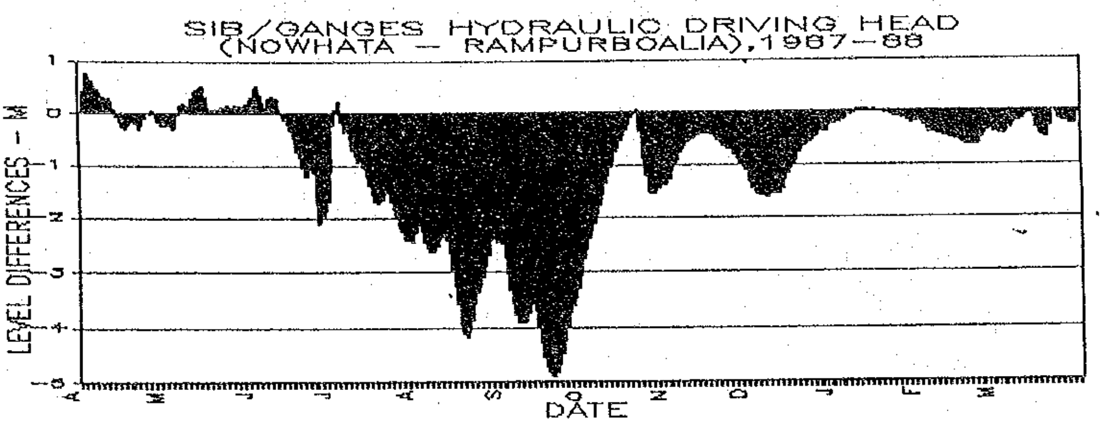


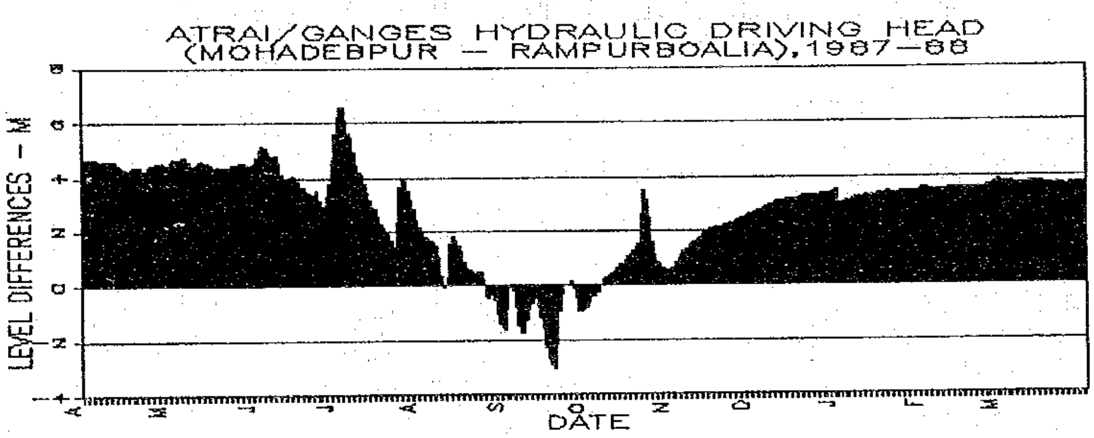
Figure 7.5

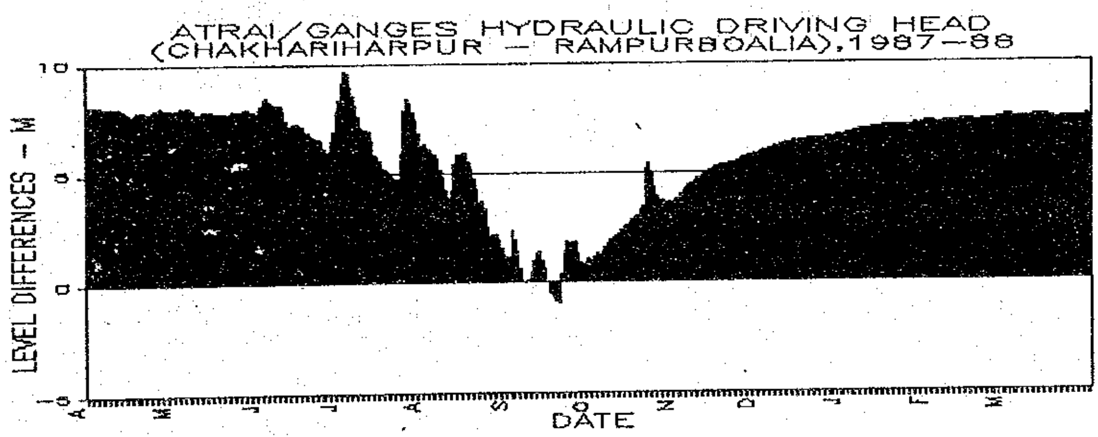
Potential Hydraulic Driving Head - Proposed Drain IC4



Potential Hydraulic Driving Head - Proposed Diversion Option D1







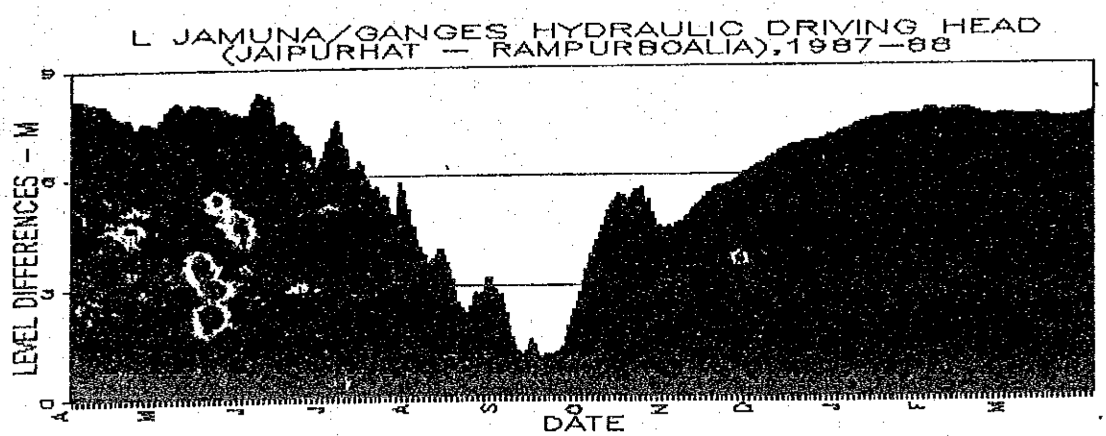


Figure 7.7

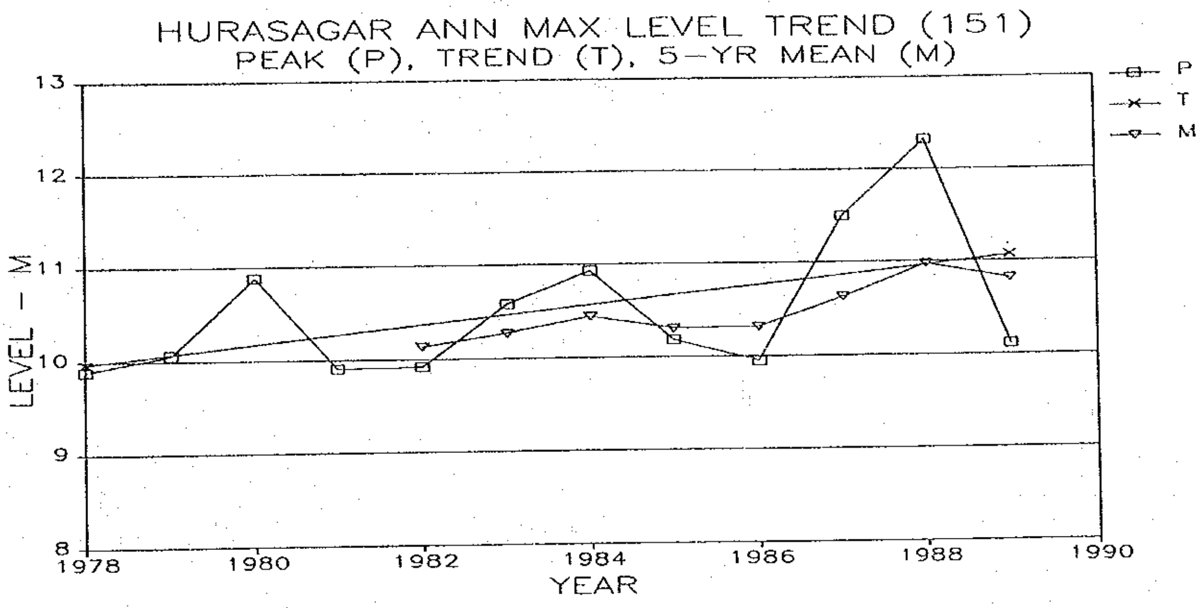


Figure 7.8

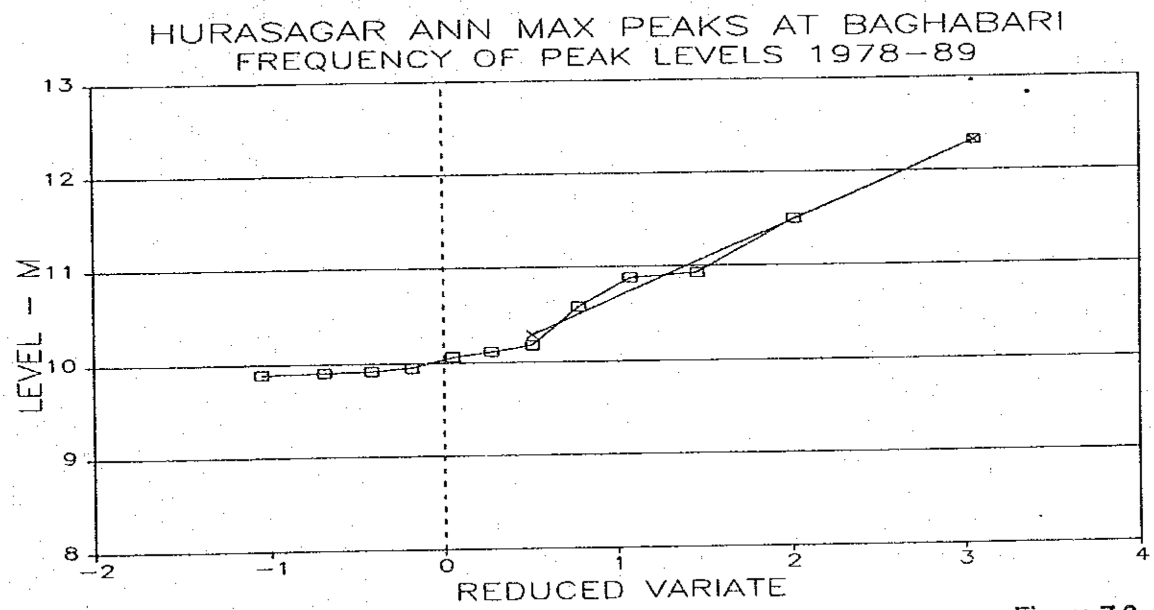


Figure 7.9

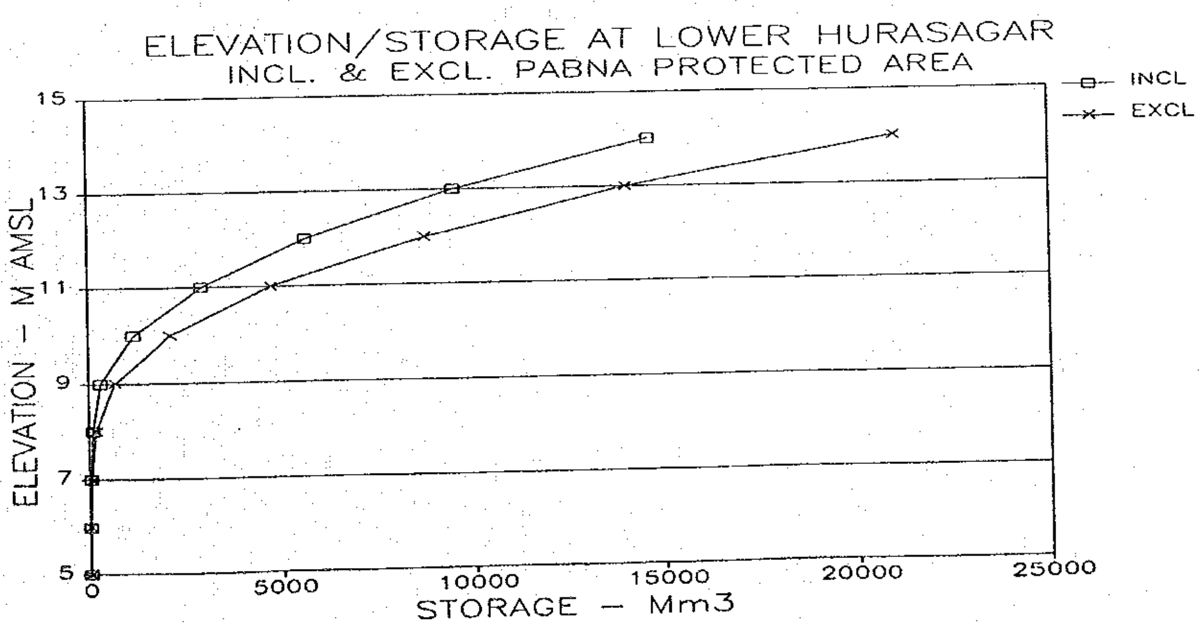
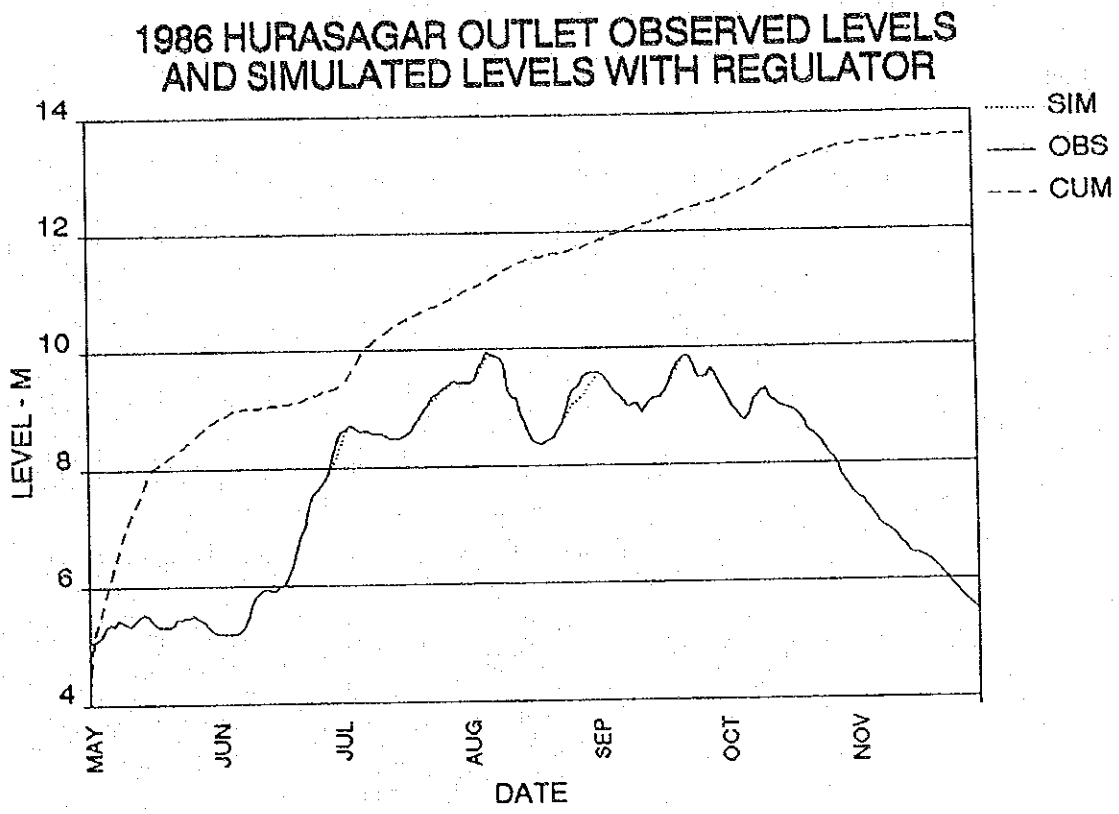


Figure 7.10

Observed and Simulated Hurasagar Water Levels, 1986 and 1987



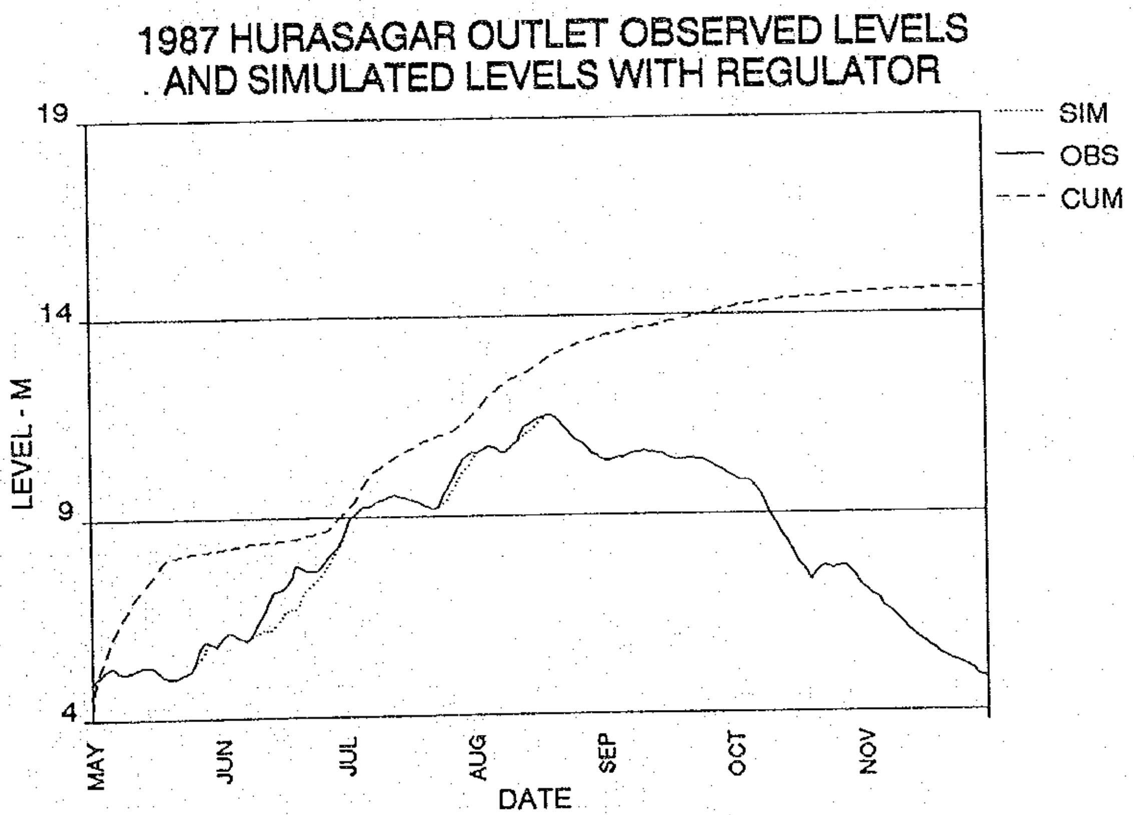
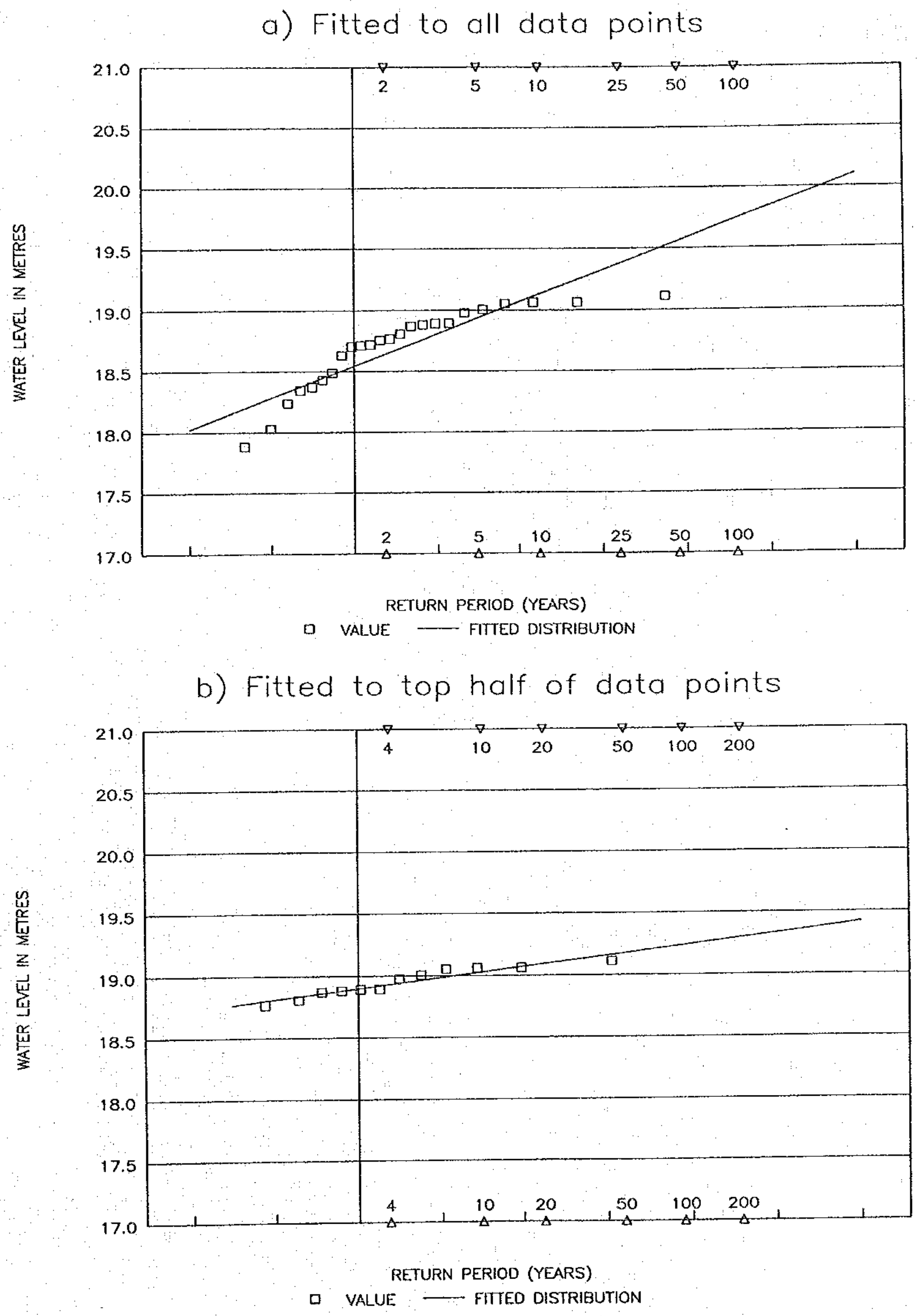


Figure 8.1

Gumbel Extreme Value Analysis of Annual Maximum Levels

(example for Atrai chainage 3.17)



C:\NWRS\FIG81.WK1 (FIG81A/B.PIC)

06-Sep-92

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APPENDIX A

SUPPORTING NOTES ON DATA INFILLING

Additional Modifications Subsequent to Working Paper Nr 6

R-012 Banwarinagar	1975 Apr until 1977 Mar	data factored by 0.58
R-015 Iswardi	1974 Jul until 1974 Sep	data set to missing (original implausibly low)
R-022 Nandigram	1990 Apr until 1991 Mar	data set to missing (original implausibly low)
R-024 Naokhila	1990 Jun until 1990 Jul	data factored by 10.0
	1990 Aug	data set to missing (original implausibly low; rainday distribution in June/July agrees with other stations, in August does not)
R-153 Bhurungamari	1966 Apr until 1971 Mar	data factored by 0.74
R-161 Boda	1991 Aug	data factored by 0.1
R-164 Ghoraghat	1991 Apr until 1991 Jul	data set to missing (original implausibly high)
R-173 Gomostapur	1972 Apr until 1979 Mar	data factored by 1.5
R-174 Hatibandha	1990 Apr until 1990 Aug	data set to missing (original implausibly low)
	1991 Aug until 1991 Sep	data factored by 10.0
R-190 Nachol	1990 Jun	value for "June 31st" omitted
R-203 Pirganj	1990 Apr until 1991 Oct	data factored by 0.5
R-210 Saidpur	1991 May until 1991 Oct	data set to missing (original implausibly low)
R-215 Shipganj (R)	1973 Apr until 1974 Mar	data factored by 0.5
	1975 Apr until 1976 Mar	data factored by 0.5
R-218 Sunderganj	1990 Sep	data set to missing (identical to October data)
	1991 Aug	data set to missing (data identical to July)

Secondary and Tertiary Infilling Stations
(1990/1 and 1991/2 Data)

Station Nr	Secondary Infilling			Tertiary Infilling	
155	161	197	213		
157	161	209	167		
160	221	166	210	168	
161	221	167	157		
162	179	193	197	167	154
165	157	220	221	167	154
175	181	201			
193	209	213			
197	209	221	167		
207	209	180			
209	193	166	197	167	154
213	179	168	154		
220	209	161	167		
221	209	179	167		

APPENDIX B

NAM MODEL OF THE NORTH WEST REGION

1. Introduction

The NAM hydrological model allows runoff (discharge) to be estimated from a knowledge of rainfall, evaporation and groundwater abstraction.

It is required to provide discharge hydrographs for input into the hydrodynamic model, MIKE11-HD. NAM is used to generate lateral inflows along different reaches of the main rivers, runoff in the flood storage areas and discharge hydrographs at discharge boundaries of the hydrodynamic model where discharge observations are not available. NAM is also required to give estimates of discharge in non-modelled areas.

NAM input is most important in areas where the flood regime depends on the river flows, rather than being as a result of backwater effects from the main rivers. As far as the North West region is concerned this is the upper catchments of the river basins which mainly occur in the North and North West of the region.

2. Model Set-up

For the purposes of the NAM modelling the North West region was divided into 33 catchments; the locations and identifiers for these catchments are shown in Figure 1. The catchments are based on the MPO catchments but, where appropriate, some have been modified by consulting contour maps, satellite images, looking at the drainage pattern of the area, and also from data obtained from field visits.

3. Model Data

3.1 Rainfall Data

Rainfall data for 94 stations have been used for the final calibration of the NAM model. The SWMC used 78 or 83 stations during their initial calibration of the NAM model.

Missing data at the 94 rainfall stations was filled by using the 'Normal Ratio' method (Ref 1). Data quality was initially checked by serial correlation of monthly values among the surrounding stations. Where the correlation was poor stations were checked by the Double Mass Method. Inconsistent data was made consistent and reviewed.

For each of the (NAM) catchments of the North West region weightings were calculated for the rainfall stations. This was carried out by using the method of Thiessen Polygons. The weightings for the rainfall stations are given in Table 1.

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3.2 Evaporation Data

The pan evaporation data available in the North West region is not reliable. Monthly evaporation data was calculated by using the Penman approach; this was done for five stations, Bogra, Dinajpur, Ishurdi, Rajshahi and Rangpur.

The 33 NAM catchments used this evaporation data; some catchments used an average of two evaporation stations. The weightings for the evaporation stations are given in Table 2.

Since the annual variation in evaporation is small the same set of evaporation data has been used for each year of NAM calibration.

The daily evaporation data which forms the NAM input was calculated from the monthly values.

3.3 Groundwater Abstractions

MPO and the SWMC have groundwater abstraction data available for two years, 1986 and 1989. During the calibration of the NAM model the 1986 abstraction data was used for 1986, 1987 and 1988, and the 1989 abstraction data was used for 1989, 1990 and 1991.

4. Model Calibration

The initial calibration of the NAM model for the North West region was carried out by the SWMC. The SWMC provided FAP-2 with an optimised parameter set to use as a basis for finer calibration and verification of the NAM model. The optimised set of NAM parameters, provided by the SWMC, is given in Table 3. Model calibration was carried out over the period from 1986 to 1991.

The NAM parameters were estimated to represent the characteristics of the whole catchment. Because of the varying nature of the North West region with respect to soil type it is difficult to work with large catchments; the catchments were kept small to facilitate the estimation of parameters.

The main method of model calibration was by comparing simulated groundwater depths with observed groundwater depths. This was done in each of the 33 catchments.

As part of the model calibration the North West region was divided into 14 discharge areas; these were delineated on the basis of the drainage pattern of the area. The simulated runoff was compared with the observed discharge and accumulated discharge for each of the 14 discharge areas.

5. Results

Figures 2 to 6 illustrate the results of the NAM calibration.

Badarganj (Figure 2)

Badarganj is on the Jamuneswari river. This river is the main tributary of the Karatoya upstream of Siraj.

In 1985, 1987 and 1988 the observed discharges are generally higher than those estimated by NAM. In 1986 and 1990 the agreement between the observed discharges and simulated runoff is more favourable.

The agreement between the observed and simulated accumulated runoff is good in both 1986 and 1990.

Naogaon (Figure 3)

Naogaon is on the Little Jamuna.

In all years except 1987 and 1988 agreement between the observed discharges and NAM simulated runoff is favourable. In 1987 and 1988 NAM over estimates the peak discharge and also under estimates the accumulated discharge.

Mohimaganj (Figure 4)

Mohimaganj is on the Bangali river.

Agreement between the observed discharges and simulated runoff is reasonable except in 1987 and for a single peak discharge in 1989. At these times NAM under estimates the peak discharge.

NAM over estimates the accumulated discharge in 1987 and under estimates the accumulated discharge in 1986. In other years, the comparison gives favourable agreement between the observed accumulated discharge and the simulated accumulated runoff.

Shimulbari (Figure 5)

Shimulbari is on the Bangali river a short distance downstream of Mohimaganj.

In general the agreement between the simulated runoff and observed discharge is good. In most years NAM slightly over estimates the peak discharge.

The agreement between the simulated and observed accumulated runoff is reasonable.

Mohadevpur (Figure 6)

Mohadevpur is on the Atrai river.

Both in terms of observed discharges and accumulated runoff the agreement between the NAM estimates and observations is reasonable.

The results show the NAM calibration to be satisfactory. Total volumes of discharge match well and the phasing of the discharge is adequate for the purposes of hydrodynamic modelling.

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6. 25 Year NAM Simulation

In order to provide discharges for the 25 year Without Project and With Project hydrodynamic model simulations a 25 year NAM simulation is required. This simulation was carried out for the period from 1965 to 1989.

The rainfall data at short term monitoring stations, which did not cover the entire 25 years of the NAM simulation, was extended.

Since the annual variation in evaporation is small the same set of evaporation data has been used for each year of NAM calculation.

For the purposes of the 25 year NAM simulation the most recent groundwater abstraction rate, 1989, was used for each year of NAM calculation.

In the 25 year NAM run the data was split into 5 equal blocks each of five years duration (1965-69, 1970-74, 1975-79, 1980-84 and 1985-89). Due to the liberation movement the rainfall data for 1971 was not collected properly; for this year a dummy set of data which was exactly the same as that in 1970 was used.

Due to the storage limitations of the DOS version of NAM, it is only possible to run the model for 21 catchments at one time. The 33 catchments of the North West region were divided into two groups one with 20 catchments (Group-I) and a second one with 13 catchments (Group-II). Group-I consisted of the catchments of the Lower Atrai, Middle Bangali, Lower Bangali and Gaibandha area. Group-II consists of the rest of the catchments of the North West region. Table 3 shows a list of the catchments in each group.

7. References

Mott MacDonald International

North West Regional Study (FAP-2), Working Paper No. 6, "Quality Control and infilling of rainfall data", February 1992.

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Table 1 Optimum set of parameter values for NAM module (Irrigation Module) for North West Region of Bangladesh.

Catchment No.	Area (km^2)	TG	Sy	GWLBF max	GWLBF min	K0-inf (mm/day)	CKIF (hours)	CKBF (hours)
15	374	0.8	0.04	1.0	1.0	4	75	200
02	1951	0.5	0.09	1.0	1.0	10	75	200
07	395	0.8	0.06	1.0	1.0	6	75	200
23	583	0.8	0.06	1.0	1.0	6	100	200
16	562	0.8	0.08	1.0	1.0	8	75	200
17	573	0.5	0.06	1.0	1.0	7	150	200
03	424	0.8	0.08	2.0	1.0	6	150	200
* 01	1186	0.8	0.08	1.0	1.0	7	100	200
04	836	0.5	0.06	2.5	1.0	6	600	300
10	1740	0.5	0.10	1.5	1.0	6	800	400
26	1337	0.5	0.05	2.0	1.0	5	300	200
27	1039	0.5	0.08	2.0	1.0	5	300	200
19	245	0.0	0.10	1.5	1.0	8	800	400
24	1479	0.8	0.07	1.0	1.0	1	400	200
32U	1176	0.8	0.04	2.0	1.0	3	400	200
40	1923	0.3	0.06	5.0	1.0	5	800	400
39	1668	0.5	0.05	3.0	1.0	3	800	400
13	528	0.8	0.10	2.5	1.0	7	600	300
14	428	0.5	0.12	2.5	1.0	8	700	350
21	1126	0.8	0.07	1.0	1.0	6	100	200
22	575	0.8	0.09	1.0	1.0	6	100	200
32L	2358	0.2	0.03	1.5	1.0	2.5	800	400
33	984	0.5	0.05	3.5	1.0	6	800	400
31	745	0.5	0.06	1.2	1.0	5	800	400
30	1323	0.8	0.04	5.0	1.0	3	800	400
35	410	0.2	0.035	2.0	1.0	4	600	300
38	2651	0.5	0.06	4.2	1.0	6	800	400
11	1159	0.0	0.12	0.5	0.5	5	500	250
12L	560	0.5	0.06	2.0	1.0	4	500	250
05	517	0.8	0.12	0.5	0.5	7	125	250
12U	852	0.8	0.15	0.5	0.5	8	125	250
28	379	0.5	0.05	3.0	1.0	6	600	300
34	575	0.2	0.06	3.0	1.0	6	600	300

* FOR CATCHMENT NW-01 A CAPILARY FLUX VALUE OF 1.0 IS USED INSTEAD OF STANDARD 1.65

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Table 2 **Rainfall and Evaporation Stations and their weightages for NAM model for North West Region.**

Catchment	Rainfall Station Number Percentage Weighting											Evapotranspiration Stations				
												BOG	DIN	RAN	RAJ	ISH
1	153 16	154 24	166 3	167 15	177 6	188 10	210 20	226 6						100		
2	157 45	161 22	162 2	166 13	167 4	179 2	197 11	200 1					100			
3	154 19	166 6	199 32	201 18	210 25								100			
4	153 30	186 15	196 22	201 19	203 10	206 2	210 2							100		
5	167 42	177 16	188 8	226 34										100		
7	160 20	161 7	162 24	166 12	179 32	221 5							100			
10	156 31	164 22	171 26	176 3	186 4	196 3	203 11					50		50		
11	156 24	163 2	178 6	186 11	188 5	202 17	206 15	218 20						100		
12U	174 10	177 44	178 10	183 19	188 10	226 7								100		
12L	163 5	178 15	182 19	183 15	202 12	218 25	222 9							100		
13	159 10	182 38	183 52											100		
14	159 100													100		
15	161 4	162 6	165 20	197 14	209 40	221 16							100			
16	160 7	168 43	180 26	213 10	221 14								100			
17	154 11	160 5	166 1	168 15	179 6	180 36	189 20	199 6					100			
19	164 2	171 25	176 30	216 43								100				
21	155 40	157 1	165 26	193 11	197 4	207 14	209 4						100			

Contd.....

Table 2 **Rainfall and Evaporation Stations and their weightages for NAM model for North West Region.** (Cont.)

Catchment	Rainfall Station Number Percentage Weighting											Evapotranspiration Stations				
												BOG	DIN	RAN	RAJ	ISH
22	155 4	193 30	207 59	209 3	213 1	221 3							100			
23	193 9	207 6	213 53	221 32									100			
24	158 6	168 5	194 41	208 6	211 42								50		50	
26	152 19	175 18	181 1	520 11	191 5	192 14	198 17	201 15				50	50			
27	152 4	164 28	169 1	175 18	181 23	196 5	201 3	520 18				50	50			
28	164 8	169 40	181 22	216 30								100				
30	158 11	172 6	173 14	190 12	195 20	208 13	215 24								100	
31	23 12	170 6	184 23	204 39	205 2	212 18									50	50
32U	168 2	187 5	189 29	192 14	194 3	198 4	211 43						100			
32L	3 7	170 14	172 7	185 21	187 4	190 12	194 3	205 8	219 24						100	
33	3 9	151 14	169 7	185 16	187 14	191 35	192 5					100				
34	3 18	22 40	36 9	151 25	169 8							100				
35	6 20	22 37	33 37	39 6								100				
38	6 24	11 6	24 8	29 21	33 5	34 9	35 9	40 18				100				
39	3 15	7 15	12 8	14 18	16 2	23 13	36 14	39 15				50				50
40	1 13	4 12	7 8	12 13	15 10	16 5	25 12	38 27								100

Legend: BOG- BOGRA
DIN- DINAJPUR
RAN- RANGPUR
RAJ- RAJSHAHI
ISH- ISHURDI

Table 3 List of the Catchments in Different Groups used for 25 year run in NWRS

Sr No.	Catchment	Group No	Sr.No.	Catchment No.	Group No.
1	01	I	1	02	II
2	04	I	2	03	II
3	05	I	3	07	II
4	10	I	4	13	II
5	11	I	5	14	II
6	12L	I	6	15	II
7	12U	I	7	16	II
8	19	I	8	17	II
9	26	I	9	21	II
10	27	I	10	22	II
11	28	I	11	23	II
12	31	I	12	24	II
13	32L	I	13	30	II
14	32U	I			
15	33	I			
16	34	I			
17	35	I			
18	38	I			
19	39	I			
20	40	I			

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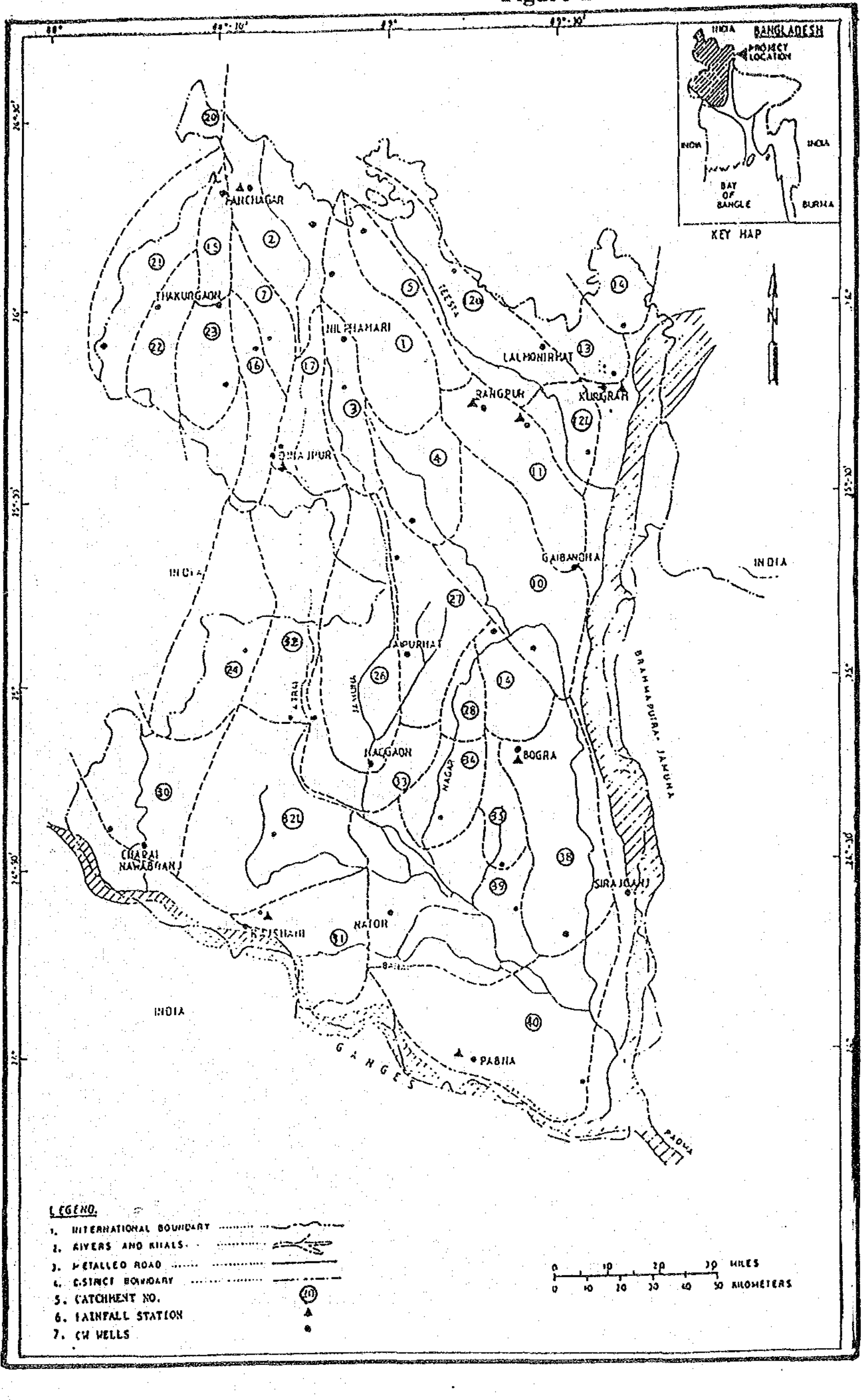
Figure 1 NAM Catchments



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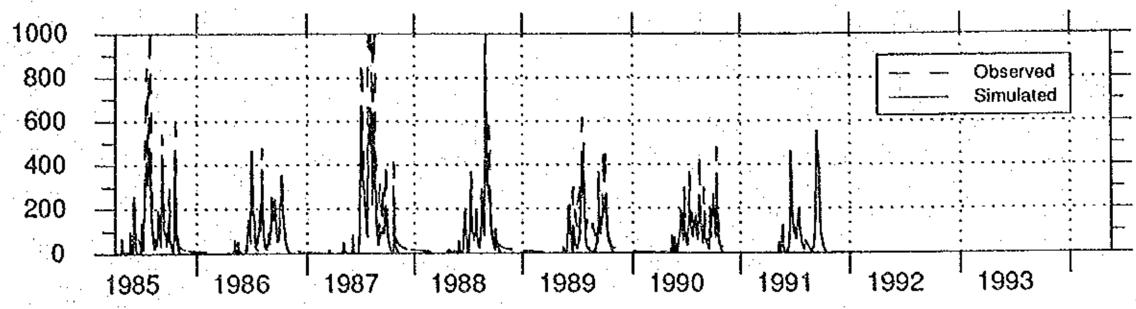

Figure 2a Badarganj - discharge

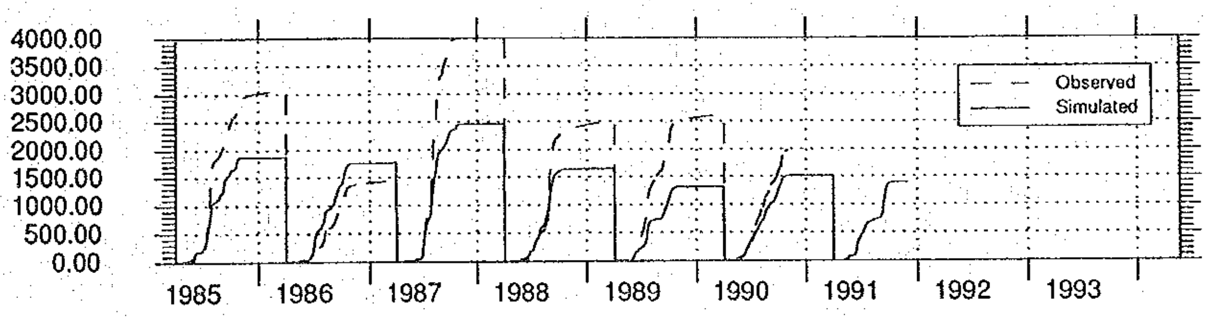

Figure 2b Badarganj - accumulated discharge.

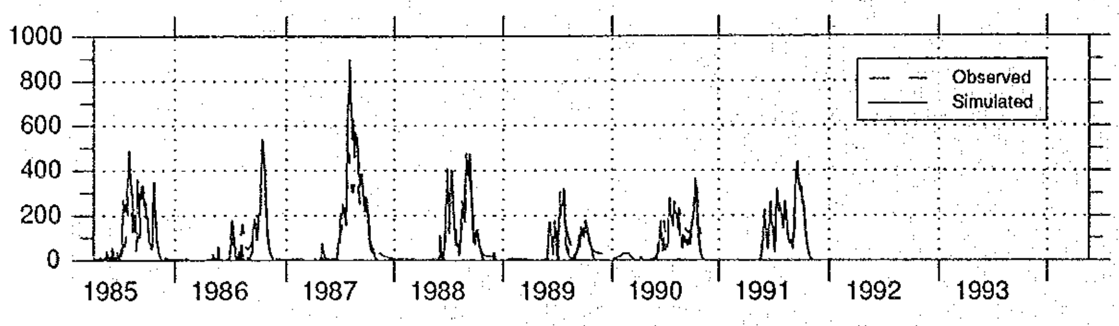

Figure 3a Naogaon - discharge

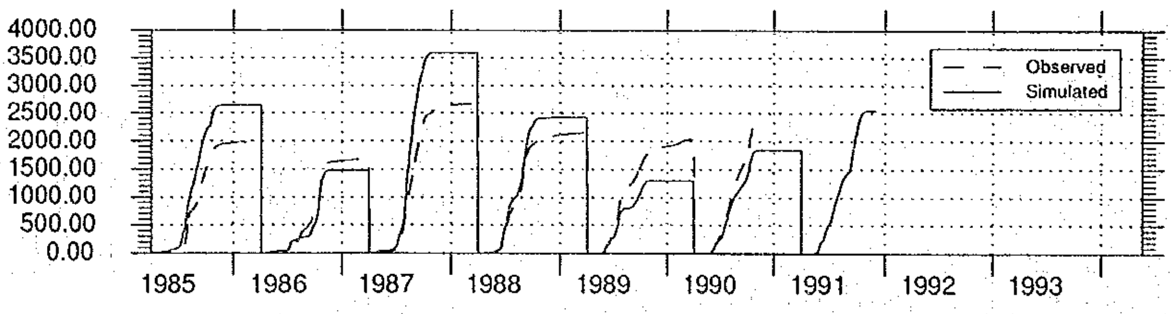

Figure 3b Naogaon - accumulated discharge

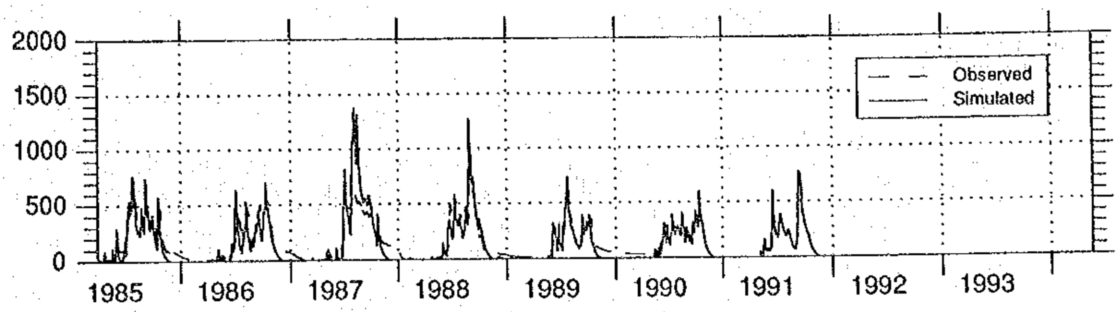

Figure 4a **Mohimaganj - discharge**

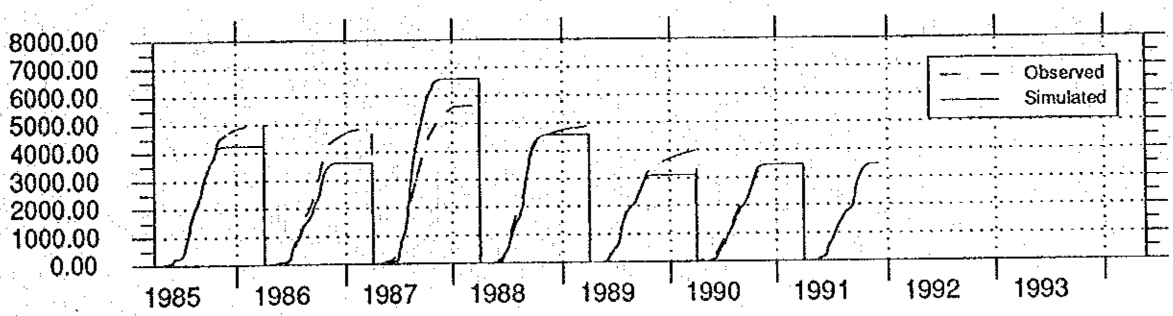

Figure 4b **Mohimaganj - accumulated discharge.**

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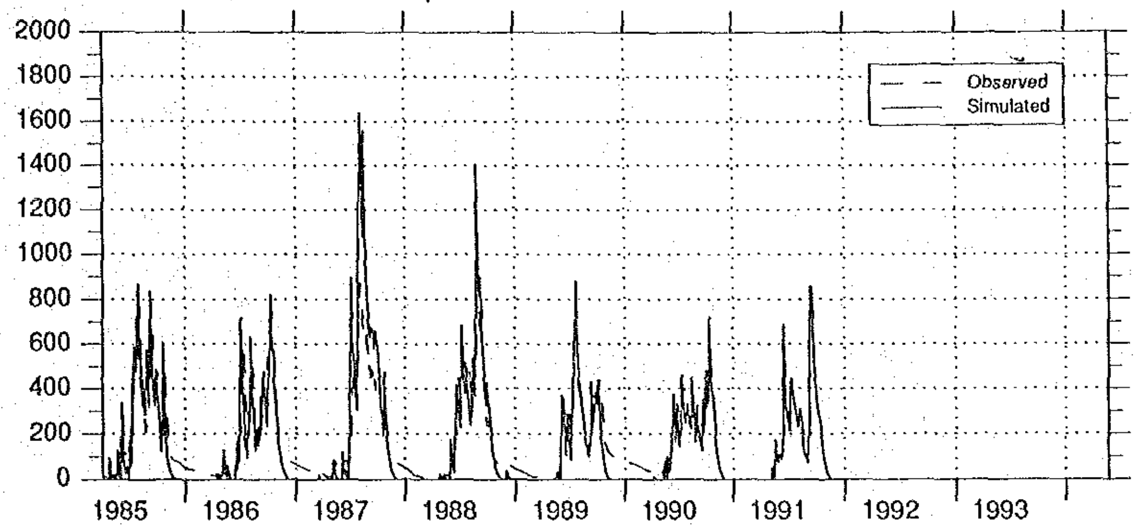

Figure 5a Shimulbari discharge

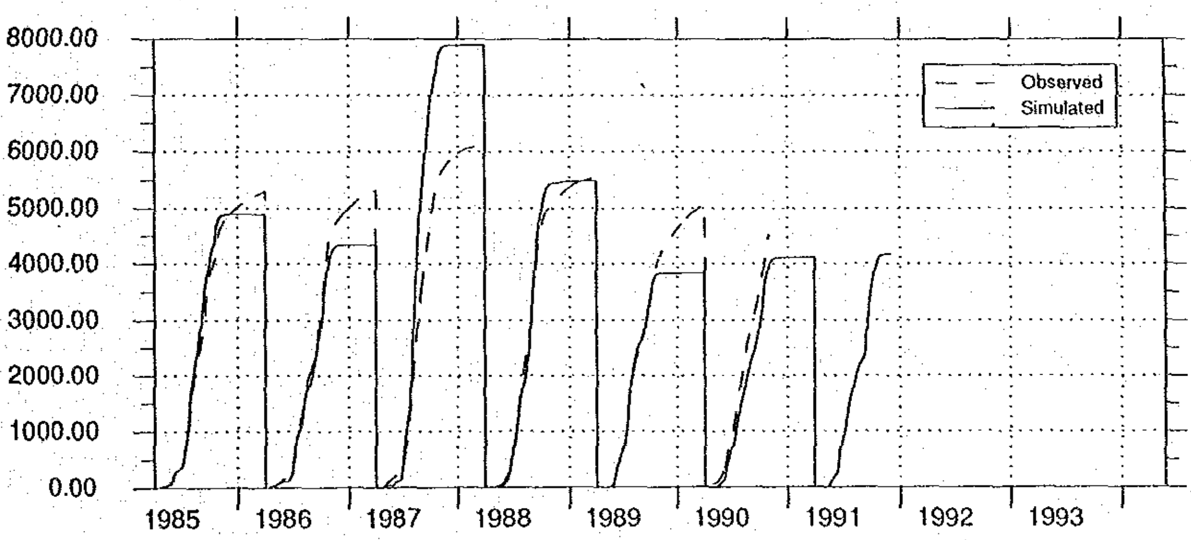

Figure 5b Shimulbari - accumulated discharge

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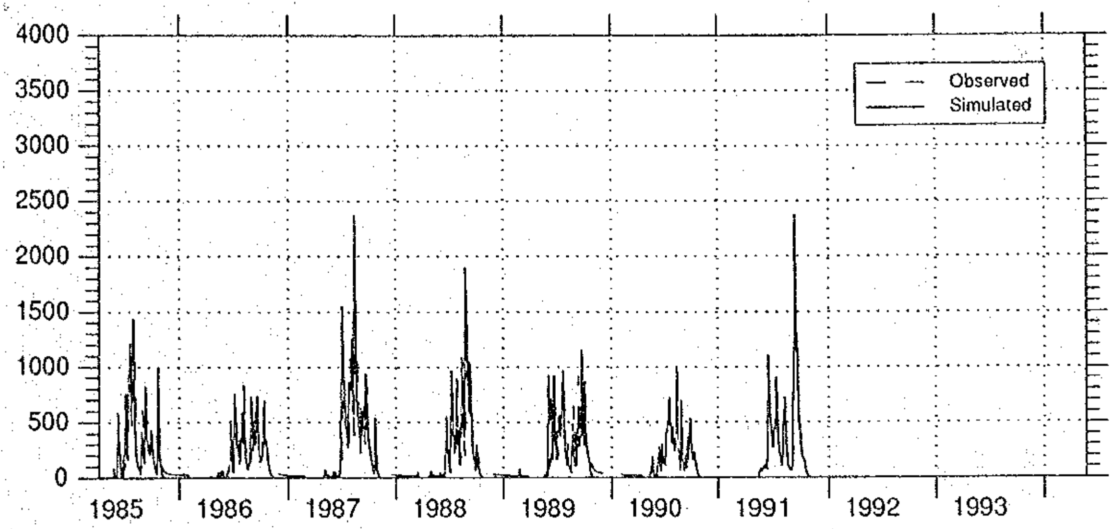

Figure 6a Mohadevpur - discharge

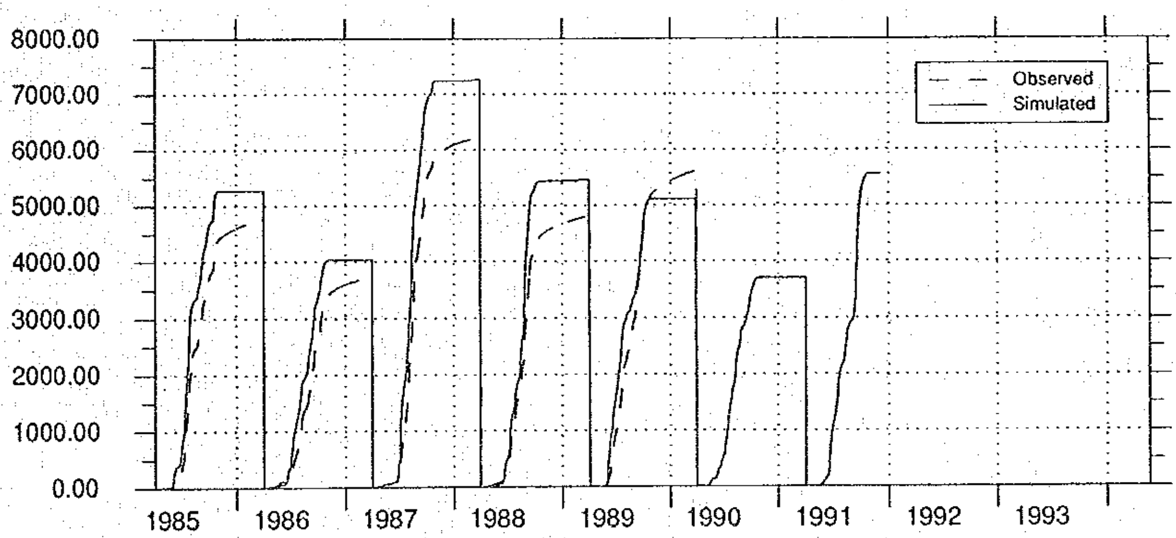

Figure 6b Mohadevpur - accumulated discharge

PART 2

GROUNDWATER

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PART 2

GROUNDWATER

1. Introduction

1.1 Study Objectives

The major objectives of the groundwater studies were the following:

- to assess the implication of flood control and drainage on the availability of groundwater for irrigation and potable water supply.

- to evaluate the historical development of minor irrigation and to forecast future development with and without FCD.

The MPO formed the major source of information on groundwater resource evaluation. Historical development of minor irrigation was obtained from thana statistics.

The groundwater resource development potential and the impact of flood control and drainage on resource availability for irrigation was assessed for 41 thanas associated with project options during September 1991. An additional 29 thanas have been further included in the resource assessment. The 70 thanas are shown in Figure 1.

The evaluation of resource potential has been based on existing information prepared during the second phase of the National Water Plan (NWP2), and on a re-evaluation of this information. Two models were used, a recharge model and a resource potential model, both conceptually similar to models used by the MPO. In the re-assessment account has been given of the extent of existing minor irrigation, which in many cases exceeds development potential limits evaluated by the MPO.

The minor irrigation statistics and the re-evaluated groundwater resource potential were used to derive forecast of minor irrigation development over a 15 year planning horizon in 21 project areas.

1.2 Background

The most complete description of the geology, hydrology and physiography of the North West Region is given in Volumes 3 and 5 of the National Water Master Plan, Phase 1. An earlier source includes the Northwest Bangladesh Groundwater Modelling Study (MMP/BADC, 1981). The following paragraphs provide only a summary of the groundwater resource characteristics.

The aquifer system in the northwest region comprises Quaternary to Recent sediments. The surface geology incudes Holocene Piedmont Deposits in the north western part of the region, Holocene Interstream Deposits, and the Madhupur Clays of the Barind areas in the central and south western part of the region.

The aquifer system has the following three main divisions :

- an upper layer, composed of silts and clays, which acts as a semi-confining layer. The thickness of this layer is variable but does not commonly exceed 10m in the majority of the region. Although the thickness is locally in excess of 50m in the southern part of Dinajpur district. A gradual thickening of the layer occurs towards the southern part of the region were maximum thickness ranges from 10 to 20m.

- a composite aquifer which is composed of very fine to fine sands, and which overlies the main aquifer. Its thickness varies from only a few metres in the northwest to over 30m in the Atrai basin. The composite aquifer is a major source of supply for village water supply wells and for hand tube wells.

- a main aquifer which is composed of medium to coarse sands and which has excellent water transmitting properties. The exploited thickness of the aquifer ranges from less than 10m in parts of Bogra district to over 60m in the northwest. Aquifer transmissivity is generally high to very high with values in a general range of 2000-4000 m^2/d. Values in excess of 4000 m^2/d are common along the Jamuna River.

Recharge to the aquifer is predominantly derived from deep percolation of rain and flood water. Lateral contribution from rivers comprise only a small percentage (0.04%, MPO, 1987) of total potential recharge. The MPO made a clear distinction between potential recharge and actual aquifer recharge. Actual recharge is generally much less than potential recharge due to so called 'aquifer full' conditions during the monsoon season, which occur when water tables have risen to ground surface. When this condition is reached, recharge is rejected from the groundwater reservoir.

The aquifer system, often referred to as the groundwater reservoir, has the capability to support large scale groundwater abstraction for irrigation. The rapid development of tubewell irrigation, particularly in the 1980's, clearly highlights this potential.

2. Development of Minor Irrigation

2.1 Minor Irrigation Technologies

An excellent account of minor irrigation technologies is given in Deep Tubewell II Project, Final Report, Supplement 2.2/4.1. Minor irrigation technologies can be can be divided into four major categories: manual methods, low lift pumps, suction mode tubewells (STW and deep set STW) and force mode tubewells (DTW).

Manual Methods

These include traditional methods, such as the swing basket and the dhoon, the counterpoise bucket lift, and manually operated shallow tubewells such as the No. 6 hand pump, the treadle pump and the rower pump. The use of treadle pumps is widespread in the northern part of the northwest region. Irrigated areas (rice) range from 0.04 to 0.08 ha for traditional methods, and up to 0.2 ha for treadle and rower pumps.

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Low Lift Pumps

Low lift pumps (LLP) were the major motorised means of minor irrigation prior to the large scale introduction of tubewells. The capacity of the LLP is variable and may range from less than 1 cusec (28l/s) to over 2 cusecs (56l/s) although the actual discharges are often less than these. The weighted mean command area for all LLP in the northwest region is 6.6 ha (AST/CIDA, 1991).

Shallow Tubewells

Shallow tubewells (STW) use suction mode technology i.e. centrifugal pumps for abstraction of groundwater. The depth of STW is variable in the range from 10 to 50m, depending on the thickness of the upper clays and silts, and the water transmitting properties of the aquifer. The average depth is about 25 m.

Shallow tubewells are constructed mainly with manual drilling techniques, including the donkey pump method (direct circulation) and the hand flush method (reverse circulation). Materials for STW include GI and PVC for the well casing, and GI Brass, PVC and sometimes bamboo for the well screen. Casing and screen materials are locally produced.

STW use centrifugal pumps driven by either diesel engines or electric motors and have a discharge capacity of about 0.5 cusec (14 l/s).

The major limitation of STW is the maximum suction lift (or depth to pumping level) of about 7m. To overcome this limitation in areas were pumping levels fall below 7m (particularly towards the end of the boro irrigation season), farmers dig pits to a depth of about 2 to 2.5 m and place the pump at the bottom of the pit. The pits are generally unlined, which restricts their depth. With brick or concrete lining, pit depths of 4 to 4.5m can be achieved. For deep set STW with pit depth exceeding 2.5m higher capacity pumps are required with increased power requirements.

Deep tubewells

Deep tubewells, which rely on force mode pumping technology (i.e submersible or turbine pumps) were first introduced on a large scale by BWDB in 1965 in Thakurgaon District. Since the early 1970's BADC became the main organisation for procurement and distribution of DTW. The DTW are either operated on a rental basis or are sold to farmers at a subsidised rate (subsidies will be stopped after 1992).

DTW's require advanced technology for installation and operation. Power rigs are used to construct the wells, which generally range in depth from 75 to 125m. Casing and screen materials include both GI and wirewound stainless steel respectively. GRP casing and screen have also been used extensively in the past.

Vertical turbine pumps with a capacity of about 2 cusecs (56 l/s) driven by either a diesel engine or an electric motor are most commonly used.

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